ABSTRACT

PATENTS AND HEADSTARTS: A STUDY OF THE POLYOLEFIN PLASTICS

By

William Anthony Lovett

A difficult problem in economics has been to determine how much patent protection is really necessary as an incentive for industrial innovation and efficiency. This study considers the problem theoretically, empirically, and reappraises the current compromise between the U.S. patent system and antitrust law. Particular emphasis is placed on the role of headstart advantages, i.e. reduced production costs or increased demand arising in favor of innovators, as a substitute for patent protection. 1/

Theoretically it would seem that long lasting, strong patent protection is unnecessary as an incentive for innovation and efficiency in at least the following conditions: 2/

(1) where a technology in an industry is maturing and substantial market risks are no longer involved in further innovation;

(2) where headstart advantages assure ample returns on innovative investments; or

(3) where well-established large firms with ample resources enjoy substantial headstart advantages.

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In such circumstances a lesser degree of patent protection for further innovations would seem to be sufficient.

On the other hand, where firms experience substantial market risks in innovating and enjoy no significant headstart advantages -- or perhaps suffer from the headstarts of large, well-established firms in their industries, strong patent protection may be appropriate. Such a patent subsidy may be especially important for small firms trying to establish themselves in a market or industry. If strong patent protection were confined to conditions where it is really needed to reinforce headstarts and encourage innovation a better compromise could be achieved with the needs of competition.

Experience in the polyolefin plastic resin markets tends to confirm this analysis. 3/ Compulsory, reasonable royalty licensing of patents and know-how was decreed in 1952 after most of the technical problems had been solved, and a large volume market potential was evident. Consequently, improvement patents could no longer serve to restrict entry, and the normal erosion of patent protection was greatly accelerated. As a result, strong patent protection and an absolute barrier to entry was followed by much reduced patent protection and only moderate entry barriers. However, large firm innovators still enjoyed substantial headstart advantages, which amply rewarded past innovation. In this situation, competitive

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rivalry was greatly enhanced, close-knit duopoly was transformed into a loose oligopoly, output increased more rapidly, further innovation resulted, efficiency was improved, and large price-cost margins were narrowed significantly.

The contrasting performance of aluminum, cellophane, rayon and synthetic rubber, also tends to confirm this analysis. 4/ These industries illustrate how strong patent protection may unduly reinforce the significant headstart advantages which often arise in favor of large innovating firms. While patent protection often erodes as a technology becomes better known and mature, the combination of improvement patents and headstart advantages may unduly extend a period of difficult entry, reduce longrun competition below optimal levels, and inhibit efficiency and further innovation. Hence, public policy action may be required to reduce excessive patent protection.

The polyolefins also indicate how a reduction in the strength of patent protection may encourage trading in complementary technology. Such exchanges are generally desirable, since they enable firms to improve efficiency and product quality. But when strong patent protection yields a close-knit monopoly, little benefit will flow to patent holders from dissipating their monopoly advantages and selling techn

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technology. Yet where moderate or weak patent protection is involved, much less monopoly profit will be sacrificed and it is more likely that trading in complementary technology will be advantageous. Before compulsory licensing was applied in the polyolefins, hardly any technology exchange occurred. But after compulsory licensing was applied, complementary R&D efforts, technology exchanges, and licenses flourished. A significant number of additional producers were encouraged to enter and continue in the polyolefin markets as a result of this technology exchange. Hence, a reduction in the strength of patent protection may encourage the interchange of technology, as well as increase the force of competition in affected product markets.

Finally, a number of public policy lessons are developed in this study about an improved compromise between the patent system and antitrust law. They include the following: (1) The very limited antitrust efforts thus far devoted to eliminating excess patent protection should be expanded. (2) Existing antitrust law is inadequate to correct situations of excess patent protection arising from accumulations of improvement patents. (3) A simple administrative remedy for this problem would be to create two classes of patents: (a) basic patents with a normal life of 17 years; and (b) improvement patents with a life of only 5 or 6 years. Such a change could make the natural erosion process work more effectively, and might reduce the need for patent "abuse" enforcement. Some other countries already have a two class patent system along these lines, including W. Germany, Japan, France and Italy. However, there is a danger that improvement patents might only add to the strength of existing patent protection -- unless the standard of invention for basic patents is changed and made much more selective, and far fewer basic patents issue.

1/ A variety of circumstances can lead to valuable headstarts, including secrecy as to superior processes, the difficulties of imitation, economies resulting from greater experience, scale economies enjoyed by earlier producers, and the benefits of an established reputation and goodwill with consumers. A few earlier economists, including Schumpeter and Machlup, noted the importance of headstarts, but they failed to analyze them systematically or consider their role as important substitutes for patent protection.

2/ Patents result in widely varying degrees of monopoly power and incentives to innovators: (i) "strong" patent protection may be defined as an absolute limitation on new entry; (ii) "moderate" patent protection as raising entry barriers for new competitors, but not enough to control market supply; (iii) "weak" patent protection as some defensive immunity against dominating claims, and some bargaining power for complementary exchanges or licenses of technology; and (iv) an "absence" of patent protection where no restraint on competition occurs, and no economic advantage accrues to patent holders.

3/ The polyolefins are a closely related family of thermoplastic polymers comprising: (i) low density polyethylene (LDPE), a light and flexible plastic originally developed in England during the 1930's; (ii) high density polyethylene (HDPE), a stronger and more rigid plastic which was developed almost simultaneously in the mid-1950's by

researchers in Germany and the U.S.; and (iii) polypropylene (PP), a still stronger and more rigid plastic which was also developed in the mid-1950's by researchers in the U.S., Germany and Italy. By the late 1960's these three resins accounted for nearly one-third of U.S. plastics production.

4/ These four other industries are among the few, well documented examples of strong patent protection over a long period of industrial development, where interindustry competition was also a significant factor. But strong patent protection and headstarts lasted longer in these cases, and their performance was less successful.

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Needless to say, none of the above are responsible for this analysis or any of its limitations.

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INTRODUCTION

Abraham Lincoln once observed that "patents add the fuel of interest to the fire of genius." Never has the function of patent monopolies been more succinctly expressed. Unfortunately, just how much fuel should be added, when, where and for whose benefit are questions that have still not been satisfactorily resolved. We know too little about the degree to which patent holdings actually influence technology and product markets, and the extra incentives for innovation which do, or should result. We need a better understanding of the extent to which headstart advantages arising naturally in favor of innovators may serve as a substitute for patent protection. We also need to better understand how competition within and among industries may complement, and yet conflict with patent and head-start advantages.

The polyolefin plastics provide a convenient opportunity to study these problems empirically.[1] Unusually

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[1]The polyolefins are a closely related family of thermoplastic polymers comprising: (i) low density polyethylene (LDPE), a light and flexible plastic originally

complete information is available on these markets, especially with respect to patent protection, technology licensing, and their effects on competition and performance.[2] Furthermore, the polyolefins are unusual in that compulsory,

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developed in England during the 1930's; (ii) high density polyethylene (HDPE), a stronger and more rigid plastic which was developed almost simultaneously in the mid-1950's by researchers in Germany and the U.S., and (iii) polypropylene (PP), a still stronger and more rigid plastic which was also developed in the mid-1950's by researchers in the U. S., Germany and Italy. By the late 1960's these three resins accounted for nearly one-third of U.S. plastics production. Polyolefins are employed in such diverse end uses as bread and meat wrappings, garment bags, construction insulation, coating for telephone and radar cable, pipe and hose, molded plastic flowers, unbreakable toys, garbage cans and laundry buckets, rope, carpet, backing and rugs.

[2]The Federal Trade Commission's Bureau of Economics obtained by compulsory process (Section 6b of the Federal Trade Commission Act) extensive data and documents from companies active in these markets. This information included all the patent and know-how licensing agreements in force between 1959 and late 1963, and a few key agreements implemented thereafter. These agreements revealed most of market activity in polyolefin technology which followed upon the compulsory licensing decree of 1952, a period of over 15 years. Licensing agreements before 1952 were largely revealed in an antitrust case brought against DuPont and Imperial Chemical Industries, Ltd. Polyolefin patents held up to 1963 were reported to the FTC by the polyolefin resin producers, and polyolefin patents held by other firms were obtained from the U.S. Patent Office. Royalty payments made on polyolefin resin patents and know how between 1959-63 were reported to the FTC by polyolefin resin producers. Some of the more important royalty flows in earlier years were revealed in published

reasonable royalty licensing of patents and know-how was applied in 1952 at the "take-off" stage in their industrial development. This means that the normal erosion of patent protection was greatly accelerated. As a result, strong patent protection and an absolute barrier to entry was followed by much reduced patent protection and only moderate entry barriers. However, large firm innovators still enjoyed substantial headstart advantages, which amply rewarded past innovation. In this situation, competitive rivalry was greatly enhanced, close-knit duopoly was transformed into a loose oligopoly, output increased more rapidly, further innovation resulted, efficiency was improved, and prices fell by more than two-thirds. (See Table 1). Therefore, the polyolefins provide an instructive case history on the performance impact of reduced levels of patent protection.

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sources. Early research and development efforts are described in other published sources, primarily by engineers. Cost, profit investment and market studies relating to the polyolefins were obtained by the FTC from nearly 20 major petrochemical producers for 1959-63, many of which included data from earlier years. Data on most of the joint arrangements, acquisitions and mergers within these markets were reported or available in the trade and financial press. Reasonably adequate production, capacity, sales and price data were available through survey and other published sources for the last 20 years. The result is an unusually complete record of technological and industrial development, from inception through rapid growth to relative maturity.

Table 1.--Historical evolution of the polyolefin plastic resin markets

1932-36

Imperial Chemical Industries, Ltd. (ICI) begins very high pressure experiments on various organic compounds, including ethylene.

In December 1935, a laboratory accident polymerizes the first low-density poyethylene (LDPE).

By mid 1936, the main elements of a commercial process for LDPE are worked out by ICI.

1936-40

In 1936-37, ICI makes applications for basic patents in the U.K., U.S. and other countries.

By the spring of 1939, ICI obtains basic patent protection in the U.K., U.S., and several other major industrial countries.

In September 1939, a small pilot plant for commercial production of LDPE is put on stream in the U.K. Coating for submarine cable is foreseen as the initial end use, but then radar cable preempts the entire supply for the British war effort.

1941-45

In late 1941, ICI informs DuPont of the strategic importance of LDPE as a coating for radar cable, and offers DuPont an exclusive license.

In 1942 the U.S. Navy Dept. insists upon a second U.S. producer, so Union Carbide also is licensed.

In 1943, Union Carbide's plant begins production; some months later DuPont's plant comes on stream.

Low-density polyethylene is priced at $1.00 lb. during the war, with almost all consumption in the form of coating for radar cable.

1946-52

In 1946 a new licensing arrangement is worked out, under which DuPont becomes the primary ICI licensee, and Union Carbide the sublicensee.

In the early postwar years ICI, DuPont and Union Carbide try to improve the properties of LDPE in collaboration with a few plastic product fabricators.

By 1949, significant commercial use begins for LDPE in a wide variety of products, and by 1952 annual output reaches 100 million lbs.

Prices for LDPE are reduced right after the war to $.52 lb. in 1946, and decline slightly to $.47 lb. by 1952.

1952-54

In 1952, Judge Ryan (S.D.N.Y.) rules that ICI and DuPont had violated Sections 1 and 2 of the Sherman Act by their long standing, exclusive cross-licensing of technology, which had begun in 1890. Compulsory, reasonable royalty licensing of patents and know how is decreed for these two firms on a large number of chemical products, including LDPE.

Six large firms--Eastman Kodak, Monsanto, Dow, Spencer, National Distillers and Koppers, obtain licenses on LDPE patents and know how, each agreeing to pay a minimum royalty of $2 million. U.S. market structure for LDPE is thereby transformed within 2 years from duopoly to an eight firm oligopoly.

By 1954 annual output of LDPE expands to 516 million lbs., which reflects an increase of 500 percent in production since 1952.

Prices for LDPE remain firm at $.47 lb., since the new producers still have only a modest share of industry output.

1954-63

Between 1954-63, consumption of LDPE increases at an average rate of 28 percent each year, and by 1963 annual output reaches 1.75 billion lbs., making it the largest selling plastic in use.

Two more producers enter the LDPE market, Allied Chemical and Rexall.

Prices for LDPE are dropped to $.41 lb. in 1955 as the new producers begin to have a significant impact on the market, and gradually decline under increased competitive pressure to $.18 lb. by 1963.

Meanwhile, in 1954-55, Karl Ziegler of the Max Planck Institute in W. Germany, and Phillips Petroleum Co. in the U.S., reveal processes by which high density polyethylene (HDPE) can be manufactured. Soon thereafter Gulio Natta of the Instituto Chimica Industrial del Politecnico in Italy reveals that such processes can also produce polypropylene (PP).

Patents, however, fail to protect the Ziegler process on HDPE, and Phillips decides to make a quick return on its process by licensing three other U.S. firms. As a result, patents are not an effective barrier to entry in the HDPE market. Patents also fail to restrict initial entry in PP, because claims for a basic patent are confused in a five-way patent interference proceding, which all potential entrants believe will take many year to resolve. (Actually, the first basic PP patents issue in 1963, and the interference is still not fully resolved by the end of 1968.)

Entry into HDPE proceeds rapidly, and by 1963 an eight firm oligopoly is established, with annual output of 516 million lbs. 1/ Annual increases in consumption average 54.4 percent between 1959-63. Prices decline from $.47 lb. in 1957 to $.23 lb. in 1963, reflecting considerable competitive pressure.

Entry into PP proceeds almost as rapidly, although its end use applications develop more slowly at first. By 1963 an eight firm oligopoly is established and output reaches 200 million lbs. 2/ Annual increases in consumption average 85 percent between 1959-63. Prices decline from $.65 lb. in 1957 to $.29 lb. by 1963. However, market concentration remains somewhat higher in PP than HDPE, because Hercules Powder, the initial PP producer, enjoys a significant headstart over other PP producers.

1963-68

The LDPE market continues to grow, but at a reduced average rate of 16 percent each year. Annual output increases to 3.1 billion lbs. by 1968, and LDPE is still the largest selling plastic in use.

Two more producers enter the LDPE market, Standard Oil (N.J.) and Chemplex (a joint venture of American Can and Skelly Oil).

Prices for LDPE reach a low of $.16 lb. in 1967, but appear to have increased slightly in 1968.

The HDPE market still grows very rapidly in this period, although at a somewhat reduced average rate of 37 percent each year. Output reaches 1.25 billion lbs. in 1968.

Three more producers enter the HDPE market. 3/

Prices for HDPE reach a low of $.18 lb. in 1966, but appear to have increased slightly in 1968.

The PP market continues rapid growth, but more slowly at an average rate of 42 percent annually. Output increases to .81 billion lbs. in 1968.

Although two PP producers drop out of the market, two others enter by 1965. 4/ But then entry conditions become significantly more difficult, as Montecatini begins to enforce its recently issued basic patent claims on polypropylene. No new entry occurs then despite a growth in PP consumption of 176 percent between 1965-68.

Prices for PP decline to $.22 lb. in 1965, rise the next year to $.23 lb., and may have risen slightly since then.

1/ Phillips, Hercules Powder, Union Carbide, Koppers, W.R. Grace, Celanese, DuPont and Dow.

2/ Hercules Powder, Avisun (a joint venture of Sun Oil and American Viscose), Eastman Kodak, Standard Oil (N.J.), Dow, Montecatini, Firestone, and Shell Oil.

3/ National Petrochemicals (a joint venture of National Distillers and Owens-Illinois), Monsanto, and Chemplex (a joint venture of American Can and Skelly Oil).

4/ Dow and Firestone drop out, but Rexall and Diamond-Shamrock enter. (Diamond-Shamrock is a joint venture of Diamond Alkali and Shamrock Oil, formed to purchase a plant constructed by Phillips, which divested itself of this plant in an FTC consent settlement.)

To help understand this polyolefin experience, the performance of four other comparable industries -- aluminum, cellophane, rayon and synthetic rubber, will be briefly reviewed. They are among the few, well documented examples of strong patent protection over a long period of industrial development, where inter-industry competition was also a significant factor. But strong patent protection lasted longer in these industries and their performance was less successful. Aluminum and cellophane provide the most extreme contrast, and these two industries behaved monopolistically for long period of time. Rayon and synthetic rubber are intermediate cases, with somewhat reduced patent dominance and moderate entry barriers. Their performance was more competitive, but less so than the polyolefins. This contrasting range of experience serves to highlight the success achieved in the polyolefins.

Theoretically it would seem that long lasting, strong patent protection will be unnecessary as an incentive for innovation and efficiency in at least the following

conditions:[3]

(i) where a technology in an industry is maturing and substantial market risks are no longer involved in further innovation;

(ii) where headstart advantages assure ample returns on innovative investments; or

(iii) where well-established large firms with ample resources enjoy substantial headstart advantages.

In such circumstances a lesser degree of patent protection for further innovations would seem to be sufficient.

On the other hand, where firms experience substantial costs or risks in innovating and enjoy no significant headstart advantages -- or perhaps suffer from the headstart of

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[3] One must distinguish sharply between different degrees of patent protection and the incentives which result: (i) "strong" patent protection may be defined as sufficient control over new entry to discipline market supply; (ii) "moderate" patent protection as raising entry barriers for new entrants, but not enough to control market supply; (iii) "weak" patent protection as some defensive immunity against dominating patent claims, and as bargaining power for complementary exchanges or licenses of technology; and (iv) an "absence" of patent protection where no restraint on competition occurs, and no economic advantage accrues to patent holders.

large, well-established firms in their industries, a good case can be made for strong patent protection, even if it may last a considerable number of years. Such a patent subsidy is especially important for small firms, when they are trying to establish themselves initially in a market or industry. If strong patent protection were confined to conditions where it is really needed to reinforce headstarts and encourage innovation, a better compromise could be achieved with the needs of competition.

The polyolefin experience, and the contrasting performance of aluminum, cellophane, rayon and synthetic rubber, tends to confirm this analysis. These industries illustrate how strong patent protection may unduly reinforce the significant headstart advantages which often arise in favor of innovating firms. Although strong patent protection may often be productive in the early phases of market development for a new product or industry, especially where the innovators are small businesses, a lesser degree of patent protection is likely to be sufficient in later stages. In other words, the appropriate balance of patent, headstart and competitive incentives for optimal industrial progress is likely to shift over the course of industrial development, such that patents play a stronger role in earlier years and competition a

stronger role in later years. While patent protection often erodes as a technology becomes better known and mature, the combination of improvement patents and headstart advantages may unduly extend a period of difficult entry, reduce long-run competition below desirable levels, and inhibit efficiency and further innovation. Hence, public policy action may be required to reduce excessive patent protection.

Another lesson is that patents and headstarts are likely to be more powerful as incentives and as restrictions upon competition in the hands of large, well-established firms, especially if such enterprises enjoy market power in some areas of their operation. For many of these firms headstart advantages and competition are likely to be sufficient incentives, although a modest degree of patent protection may encourage further improvements in processes and products. But for smaller enterprises without market power the role for strong patent protection may be much greater, since their potential for headstart advantages is reduced--and sometimes more than offset by the accumulated resources, talent, scale and integration economies of powerful rivals operating in their general area. Each of the early polyolefin innovators -- I.C.I., DuPont and Union Carbide, for example,

was a large, well-established chemical producer which enjoyed significant advantages over potential competitors. Since polyolefin technology was complex and difficult, and scale economies were substantial, important headstarts resulted in favor of these firms. This was sufficient to deter any other entry initially and to nurture early market developments.[4] The later innovators in the higher density polyolefins were also large, well-established firms, or research institutes supported by government or large enterprises. However, since the early 1950's a modest degree of patent protection has proved sufficient to encourage improvements, along with some headstart advantages. But had smaller firm innovators been involved, they would probably have needed a more substantial degree of patent protection for a longer period of time.[5]

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[4]Strong patent protection reinforced these headstarts, but the headstarts were probably substantial enough to preclude any outside competition until about 1952 -- the same time as compulsory licensing of patents and know-how were imposed.

[5]The same lesson can be drawn from aluminum, cellophane, rayon and synthetic rubber, where the successful innovators were initially -- or became in time, large and well-established firms with ample resources.

The polyolefins also indicate how a reduction in the strength of patent protection may encourage trading in complementary technology. Such exchanges are generally productive, since they enable firms to improve efficiency and product quality. When strong patent protection yields a close-knit monopoly, little benefit will flow to these patent holders from dissipating their monopoly advantages and selling their technology. But where moderate or weak patent protection is involved, much less monopoly profit will be sacrificed and it is more likely that trading in complementary technology will be advantageous. In the polyolefins there appears to have been only one exchange of technology during the period of strong patent protection, and this involved two outsiders. But after 1952 when compulsory licensing was applied, complementary R&D efforts, technology exchanges and licenses flourished. A significant number of additional producers were encouraged to enter and continue in the polyolefin markets as a result of this technology exchange.

Another lesson about technology circulation concerns limited cross-licensing and joint research arrangements, as

opposed to the joint venture subsidiaries, plant acquisitions and mergers. By and large the lesser and short-term arrangements in the polyolefins provided ample opportunity for desirable technology exchanges. Therefore, the need to exchange technology and achieve economies thereby does not really justify joint subsidiaries or mergers which significantly reduce competition. Most of the joint subsidiaries in the polyolefins illustrate relatively harmless joint entries or reinforcement of financially weaker entrants; but one joint subsidiary merged the polyolefin operations of two major producers, and involved a substantial threat to competition. The offending venture was divorced in a way which left intact the gains from shortrun technology exchange, but eliminated the longer run danger to competition from continued collaboration in production and marketing. Fortunately, only a few of the many mergers (largely vertical integration) occuring in the polyolefins involved a significant threat to competition, and their anticompetitive impact was restricted to the product markets. Merger activity began in this industry only after a loose oligopoly market structure had been established, and some producers began to suffer excess capacity and poor profits. However,

if significant mergers had occurred earlier in polyolefin development, the results might have been different. Mergers can substantially lessen the force of potential competition when the innovative contributions of smaller firms are pre-empted by large, well-established leaders in an industry, especially in a situation where strong patent protection or headstart advantages are operating.

Finally, the polyolefins reveal something about the effectiveness of rivalry among products and industries as a substitute for competition within industries.[6] The polyolefins (first LDPE, and then PP) became a major substitute for cellophane in the late 1950's, and far surpassed the latter in the 1960's. But without compulsory licensing in 1952, the polyolefin resins would probably have been less aggressively developed in competition with cellophane. In 1952, DuPont shared a close-knit duopoly over cellophane with its licensee, Sylvania, and DuPont shared a similar duopoly in low density polyethylene with its licensee, Union Carbide.

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[6]The celebrated controversy about the "cellophane case" among economists and lawyers centered on this issue. Unfortunately, the Supreme Court failed to resolve the problem. The decision and most of its analysis was confined to the threshold question of how broadly to define the relevant market. U.S. v. DuPont, 351 U.S. 377 (1956).

In the absence of the compulsory licensing decree low density polyethylene -- and perhaps also polypropylene, would have been much less aggressively priced and developed. Hence, a regime of strong patent protection or headstart advantages over substitutes is likely to inhibit competition among these products whenever a close-knit group of industry leaders dominates the relevant technology.

On the strength of this analysis and empirical evidence, at least, three public policy implications can be drawn. First, it would seem that a substantially increased antitrust effort is in order to police situations of patent abuse. Such efforts should be concentrated on markets in which strong patent protection still applies, and where significant market success has been achieved or could be anticipated, and either (i) headstarts are very strong, or (ii) large and well-established companies enjoy substantial headstart advantages. In recent years no more than a few of the 700 or so attorneys and economists employed by the Federal antitrust agencies have been working regularly on patent abuse matters. Considering both the special investigative difficulties that patents and technology markets present, and their fundamental importance in shaping industrial market structure and patterns of

concentration, this current antitrust investment in patent abuse enforcement is inadequate. This applies both to economic and legal staff allocations. A multiplied effort in the patent area could yield substantial benefits in improved competition, efficiency and perhaps even innovation, and would probably be more productive than some other types of current antitrust enforcement expenditure.

Second, it would also be helpful to create two classes of patents: (i) "basic" patents with full scope for 17 years, but much more selectively awarded; and (ii) "improvement" patents which last only 5 or 6 years. Such a change in the patent system could make the natural erosion process work more effectively and might reduce the need for patent abuse enforcement. In this connection it should be noted that some instructive precedent for such a two class patent system already exists in West Germany, Japan, France, Italy, Spain, Portugal, Brazil and the Philippines. Germany was the first to introduce 6-year "gebrauchsmusters" in 1936, which are literally translated as "utility models"; then other countries copied Germany in recent postwar years. However, the scope of "utility models" in all of these countries is narrower than "improvement patents," and they really only apply to improvements in certain mechanical devices or utensils, and not to all improved mechanical, chemical, electrical processes or products. Furthermore, there is the danger that improvement patents might only add to the existing strength of established patent protection -- unless the standard of invention for basic patents is changed and made much more selective, and far fewer basic patents issue. In other words, improvement patents would have to substitute in some substantial degree for basic patents if this reform is to achieve its intended result.

Third, it is important to correct a neglect of technology market considerations in antimerger enforcement. Although short-term cooperative R&D and technology trading are generally desirable and make the capital market function more efficiently, when such arrangements are made exclusive, long lasting, or enlarged in scope they may raise antitrust problems. There is a particular danger with joint subsidiaries, plant acquisitions or mergers that create or transfer market power over scarce technology or dominating patents. This applies especially to some conglomerate acquisitions, now the dominant type of merger activity, where large, well-established leaders in industries may be "picking-off" the smaller business innovators to sustain their leadership positions. Therefore, antitrust enforcement under Section 7

of the Clayton Act should include an alertness to substantially lessened competition involving patents and technology markets.

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CHAPTER I

PATENTS AS INCENTIVES FOR INDUSTRIAL INNOVATION

The Relevant Economic Literature on Patents

Although technological progress and economic growth have aroused great interest among economists in recent years, there are serious shortcomings in our analysis and knowledge of the patent system and its impact on industrial efficiency and progress. This study attempts to correct some analytical deficiencies and provide new empirical evidence on the problem. But in order to put this study in proper perspective, we must briefly review and appraise the relevant economic literature. This literature can be classified as follows: (i) comprehensive attempts at analyzing technological and industrial progress; (ii) a controversy over the need for large firms and market concentration in sustaining innovations; and (iii) appraisals of the patent system and its operation.

Few attempts have been made at a comprehensive economic theory explaining patents, technological innovation, and industrial progress because the topic is so

complex. Probably the most outstanding individual effort is still Joseph Schumpeter's Theory of Economic Development, published originally in 1911, revised in 1926, and further developed in 1944 with his Capitalism, Socialism and Democracy.[1] Schumpeter emphasized the possibility of conflict between healthy incentives for innovation and the requirements of competition. As he put it, profits stemming from patents and innovative headstarts, even though monopolistic in the short run, are nonetheless desirable as incentives to innovators. Furthermore, efforts to promote competition and reduce short-run monopoly profits could do more harm than good in weakening incentives for innovation. Some economists of the "Chicago School" carry this argument somewhat further, and contend that long run competition among industries and products is generally strong and sufficient to sustain industrial progress. Hence they conclude, competitive

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[1]See Schumpeter's Capitalism, Socialism and Democracy, Harper, 1944, and Theory of Economic Development, Third Edit., Harvard, 1934. A more recent effort along these lines was made by J. M. Clark in Competition as a Dynamic Process, Brookings, 1961, but although this contribution is more sophisticated on some points it is not nearly so comprehensive in scope. Unlike Clark, however, most modern economists have been content to refine and test certain aspects of economic theory applying to technological and industrial progress.

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rivalry within markets is not really so important, provided that capital is free in the long run to move among industries.[2]

Enthusiasts for a vigorous antitrust policy normally respond by denying that much conflict need really exist between innovation incentives and competition. In their view competitive rivalry within industries is a very important stimulus to innovation, and they typically favor a narrow construction of patent monopolies. To these economists it would be unwise to rely strongly upon the long run erosion of monopoly positions from interindustry or interproduct competition, because this process is slow and fails to maximize either efficiency or innovation.

At stake in this important controversy is the proper balance of incentives--patents, headstarts, and competition within or among industries. In other words,how important are patents, headstarts and competition as incentives for innovation and efficiency and in what market conditions?

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[2] While John Kenneth Galbraith's The New Industrial State, Houghton-Mifflin, 1967, also downgrades the importance of antitrust policy, he does so for different reasons. In contrast to Chicago school economists, Galbraith contends that market forces are weakening in much of the modern free enterprise economy, but antitrust policy in his view is too weak politically to restore strong competition. However, he seems to suggest that an increasing supply of able technocrats in modern business bureaucracies will be a sufficient substitute, with some appropriate government supervision.

Unfortunately, neither Schumpeter, nor those who style themselves as his followers, nor even his many critics have done an adequate job of analyzing the partial conflict between these incentives. What we need is a more precise breakdown of the proper roles for patents, headstarts and competition, and of the way in which various cost, demand and competitive circumstances influence these roles. We also need to know whether or not the balance between these incentives should change at different stages in technological and industrial development.

Most of the recent empirical literature on the relation between large firms, competition and innovation does not focus directly on the role for patents and headstarts.[3] But it does

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[3] The need for concentrated market structures and large firms in technological progress has been appraised by a number of economists recently, including: H. Villard, "Competition, Oligopoly and Research," JPE, Dec. 1958; J. Jewkes, D. Sawers, and R. Stillerman, The Sources of Invention, St. Martin's Press, 1958; M. J. Peck "Inventions in the Postwar American Aluminum Industry," in The Rate and Direction of Inventive Activity: Economic and Social Factors, NBER, 1962; J. L. Enos, "Invention and Innovation in the Petroleum Refining Industry," in Rate and Direction, ibid.; E. Mansfield, "Size of Firm, Market Structure and Innovation," AER, Dec. 1962; D. Hamberg, "Invention in the Industrial Research Laboratory," JPE, April 1963; D. Hamberg, "Size of Firm, Oligopoly and Research; The Evidence," QJE, 1964; J. W. Markham, "Market Structure, Business Conduct and Innovation," AER, May 1965; F. M. Scherer, "Firm Size, Market Structure, Opportunity and the Output of Patented Inventions," AER, Dec. 1965; A. Phillips, "Market Structure, Innovation and Investment," in Patents and Progress, Alderson, Terpstra; and Shapiro, Irwin, 1965; the

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bear on the related problem of how much competition may be desirable in fostering innovation. Unfortunately, only certain extreme contentions are ruled out by the available evidence. It is clear now that smaller firms have made a significant innovative contribution, and that some effective competition encourages innovation. But it is equally clear that large firms have made a significant innovative contribution, and that atomistic competition is not necessary for successful industrial progress. This leaves unresolved the problem of how much of a departure from competition, if any, may be desirable at various stages in the development of new or improved products and industries. In other words, the complementary role for headstarts and patents has not been adequately defined in this portion of the literature.

The patent literature itself is extensive, but is largely legal and concerned with fine points of interpretation and administration. Economic analysis of the patent

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testimony in Economic Concentration, Part 3, Senate Antitrust Subcommittee, 89th Cong., May-June 1965; W. Adams and J. B. Dirlam, "Big Steel Invention and Innovation," QJE, May 1966; and E. Mansfield, Industrial Research and Technological Innovation, Norton 1968, esp. Chapter 5.

system has been rather limited, especially in recent years.[4] Four of these contributions stand out as the most useful for our purposes. In 1958, Fritz Machlup wrote a comprehensive survey of the economic literature on patents existing at that time, in which he appraised the various arguments for and against patents, and some of the major suggestions for improvements. His general conclusion was agnostic:

> None of the empirical evidence at our disposal and none of the theoretical arguments presented either confirms or confutes the belief that the patent system has promoted the progress of the technical arts and the productivity of the economy. Machlup's Study No. 15 (1958), the "Bush" reports, cited below, at p. 79.

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[4] Important contributions to economic analysis of patents and licensing include: Floyd Vaughn, The Economics of Our Patent System, MacMillan, 1925; Walton Hamilton's TNEC Monograph No. 31, Patents, and Free Enterprise, 1941; several of the "Bush reports," a series of studies done for the Senate Judiciary Subcommittee on Patents, Trademarks and Copyrights in the late 1950's and early 1960's, especially Studies No. 1 by Vannevar Bush, and No. 15 by Fritz Machlup; Machlup's Chapter V in the Production and Distribution of Knowledge in the U.S., Princeton, 1962; the analysis of Carl Kaysen and Donald Turner in Antitrust Policy, Harvard, 1959, at pp. 160-79; Alfred E. Kahn's chapter on patents in Competition Cartels and Their Regulation, edit. J. P. Miller, North-Holland, 1962; Alderson, Terpstra and Shapiro, Patents and Progress, Irwin, 1965; John McGee, "Patent Exploitation: Some Economic and Legal Problems," Journal of Law and Economics, Oct. 1966; William Baxter, "Legal Restrictions on Exploitation of the Patent Monopoly: An Economic Analysis," Yale Law Journal, Dec. 1966; and George Frost, "Patent System Proposals: How Practical?" Harvard Business Review, Sept.-Oct. 1967, pp. 111-22.

Machlup insisted that more empirical study of patents and their role in specific markets was necessary, and he emphasized that such study must consider how much more or less patent protection is really desirable. He suggested that three variables deserved special consideration--altering the term of patents, introducing some degree of compulsory licensing, and limiting the restrictiveness of licensing agreements.[5] But although Machlup noted the importance of headstart advantages in recovering the costs of innovation, he did not give any emphasis to determining whether headstarts might serve in some situations as a substitute for patent protection. Furthermore, he did not indicate how the roles for competition within and mong product markets are influenced by patents or headstarts.

Almarin Phillips published in 1965 an interesting analysis of how variations in market structure influence innovative investments for cost reduction, improved products and new products.[6] He focused on three degrees of market

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[5] *Ibid.*, at pp. 66-76.

[6] Chapter 3 in *Patents and Progress*, cited *supra*, at pp. 37-60. This piece can also be classified as an example of market structure-innovation analysis.

imperfection: (i) monopoly or highly collusive oligopoly, (ii) loosely collusive oligopoly and (iii) high rivalry markets. While he did not consider the role of patents or headstarts in shaping these market structures, he does ask how changes in the degree of competition influence innovative efforts. Phillips suggests that the greatest departures from competition will inhibit investments for improved or substitute products, while a high degree of rivalry may inhibit innovation in new products. But so long as entry is left free a loosely collusive oligopoly may produce the greatest innovation. While this analysis bears on the problem of how much competition is desirable for innovation, it remains incomplete. It leaves unresolved the role for headstarts and patents and it fails to take into account varying cost and demand circumstances. It also does not allow for any significant changes in the need for patents, headstarts or competition over the course of industrial and technological development. But by extending this kind of analysis to include these extra variables, a reasonably adequate appraisal can be made of the proper role for patents and headstarts.

Alfred E. Kahn attempted in 1962 a comprehensive appraisal of the proper role for patents.[7] He reviewed the existing empirical literature on patents, largely from scattered industry studies, in terms of whether the patent system was really useful. He concluded:

> (1) The net effect of patents on competition will vary from one situation to another; no assessment is possible except in individual markets.
>
> (2) One cannot conclude that the patent system is so inherently monopolistic that its major effect is to suppress competition, or
>
> (3) That it is a major source of monopoly in the economy today.
>
> (4) Yet patents have had as one of their effects at one time or another in an exceedingly large number of markets the suppression or discouragement of competition beyond the scope of the individual inventive contributions they severally represented.
>
> (5) This effect has typically been felt where patents were controlled by firms with pre-existing monopoly power, or where several patents were subjected to unitary control -- and especially where several owners put their patents together. (at p. 328)[8]

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[7]Chapter 8, Competition, Cartels and Their Regulation, cited *supra*.

[8]Even though patents may not be a major source of monopoly in present industries, the contribution of patents has often been significant in shaping patterns of concentration in their formative years of industrial development. Hence, the cumulative contribution to present monopoly in the economy may be quite significant.

In other words, Kahn argued that patent protection has too often been excessive, even though it may not be a major source of present monopoly. Since Kahn contended the main problems of excess patent protection arise when individual patent monopolies are combined by one or more firms, he concludes that "a strong case can be made for the antitrust approach to the problem of patent-based monopoly."[9] Because Kahn feels it is difficult to engineer appropriate flexibility into individual patents, he thought it best to attack excessive patent protection on an industry-by-industry basis.[10] However, Kahn does not provide a sufficient guide or mode of analysis by which situations of excessive patent protection can be identified, or by which appropriate remedies can be selected. What is needed to carry his policy proposal forward is a more complete analysis of the proper roles for patents, headstarts and competition.

Finally, the comprehensive analysis of the patent system by Vannevar Bush should be mentioned.[11] His diagnosis

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[9] Ibid., p. 335.

[10] Ibid., see pp. 330-337.

[11] Study No. 1 (1958), The "Bush" reports, cited supra.

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of difficulties in the patent system includes excessive accumulations and combinations of patent protection, but it also emphasizes the problems of insufficient patent protection for individual and small business innovators. He explains how the Patent Office, inundated by an increasing flow of claims and a more complex technological literature, too often grants patents on the trivial and obvious. Consequently, the courts tend to view the validity of patents harshly, so that the reliability and probable value of individual patents have been diluted. This puts a greater premium on sheer numbers of patents and litigating strength, with the result that the present system tends to give more protection to large business innovators, with extensive patent portfolios.[12] Is this result consistent with the

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[12]Although most Commissioner's of the Patent Office in recent years have recognized this problem, the backlog pressures upon the patent examiner corps still remain intense. So long as this pressure remains it will be difficult to upgrade the standard of patentability, especially since private patent attorneys have responded to weakening standards by increasing the flow of marginal applications.

Within the Patent Office more careful review has generally been given to final rejections than applications approved for issuance. Therefore, the practical burden of proof in the examination process tends to be placed upon the examiner who desires to deny an application.

For a recent commentary on the backlog pressures upon the Patent Office, see the Address of Commissioner Edward J. Brenner, March 30, 1966, which is reprinted in the Official Gazette, U.S. Patent Office, April 19, 1966.

different costs, risks, and returns experienced by large and small innovating firms? To resolve this problem it will also be helpful to analyze more precisely the roles patents and headstarts play in different cost, demand, and competitive conditions.

In conclusion, then, there are some important shortcomings in the existing economic literature on the proper role for patents as an incentive for industrial efficiency and progress. We need to specify more precisely:

(1) how various cost, demand and competitive conditions influence the need for patents and headstart advantages at different stages in technological and industrial development;

(2) how headstart advantages may substitute for patent protection in various cost, demand and competitive conditions, and at different stages of technological and industrial development;

(3) how the needs of small and large business innovators for patent protection may differ in various cost, demand and competitive circumstances.

(4) how different levels of patent protection influence technology licensing and trading, competition and innovation; and

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(5) how compulsory, reasonable royalty licensing of patents and technology may affect technology trading, competition and innovation.

It is these issues that are the focus of the following analysis of the proper role for patent protection, and this empirical study of the polyolefin plastics.

Incentives for Technological and Industrial Development

Industrial activity in free enterprise economies requires three kinds of compensation to mobilize necessary resources: (i) payment of the market rate of interest on invested capital; (ii) provision of some appropriate insurance premium for risks on invested resources; (iii) some residual profit for entrepreneurs, which, when averaged over the long run, tends toward some normal level or "wage" for entrepreneurship.

Technological progress in such a system simply introduces new elements of risk and possibilities for gain.[13]

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[13]Technology determines cost and demand elasticities for the individual firms, and thereby is a major factor in explaining the supply and demand conditions for every industrial market. In conventional theory technology is usually assumed to be fixed in the short run. But where technology is changing fast enough to make a difference in the shortrun behavior of firms, as in markets like the polyolefins, the impact of such change needs to be analyzed.

For winners in the race for new technology, there is an opportunity for lower costs, and increased demand with new or improved products. For losers in the race for technology there is the risk of loss resulting from the impact of superior products and lower cost processes which are introduced by competitors. Those firms participating in markets where technological change has an influence are forced to adopt a strategy which optimizes their gains in light of this combination of risk and opportunity. Investments in established product lines are made more risky, and profitability estimates have to be altered. Meanwhile new investment opportunities arise with new or improved products. In other words, the impact of changing technology is fundamentally to alter the horizon of investment opportunities facing each firm, and their investment allocations will adjust accordingly.

Technical progress also encourages investments in innovation itself. But how are such innovative investments financed? Basically, these innovations often create profit opportunities, which normally attract substantial effort and resources into invention and innovation activity. If markets were entirely competitive, knowledge were perfect, ca

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capital completely mobile, and there were no externalities, then the rate of return on investments in technical innovation would also be competitive.[14] But since external costs and benefits are important, markets are frequently not competitive, capital is not completely mobile and knowledge is imperfectly distributed, the real world rate of return on specific investments in innovative activity is often much higher than competitive levels, though sometimes lower as well.

This means in practice that extra incentives beyond competitive norms often apply to research and development activity. These innovation incentives comprise both a "carrot" and a "stick."[15] One is positive, the prospect of additional profit from investments in technical progress.

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[14]Psychological drives and creative instincts are also important with inventors, and even some innovators. However, those who are significantly influenced by noneconomic incentives merely tend to offer their services at less than competitive money wages.

[15]To the extent the supply of invention and innovation is elastic to these extra incentives arising from market imperfections, technical progress will be increased. However, where imperfections in markets cause lower than competitive returns on innovative activity, technical progress will be reduced -- unless subsidies are provided to the degree justified by external social benefits.

The other is negative, the cost or penalty of failing to keep up with such progress, which takes the form of reduced profits for not maintaining an up-to-date technology.[16] Each form of incentive is desirable to the extent its presence increases net social welfare.

Positive Incentives

Three positive factors encourage research and development by private firms: (i) headstart advantages, (ii) patent protection, and (iii) direct subsidies and tax concessions. Each of these incentives makes investments in developing or otherwise acquiring technology more profitable for some firms, and thereby tends to stimulate technical progress.[17]

Headstart advantages comprise the reduced production costs or increased demand which arise in favor of firms

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[16] In this sense any given technology can be considered as a capital asset, one which experiences a kind of depreciation as technology is improved upon or superseded. Hence, firms must make investments to maintain technological parity with competitors, or else suffer an erosion of profits.

[17] Of course, investments by other firms may be discouraged by too much of any one of these incentives. Hence, net loss in innovation or efficiency may result from excessive patent protection, headstarts or competition.

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leading in the exploitation of a technological advance.[18] A variety of circumstances may lead to valuable headstarts. They include secrecy as to superior production processes, the difficulties of imitation, economies resulting from greater experience, scale economies already enjoyed by earlier producers, and the benefits of an established reputation and goodwill with customers. In effect, such headstart advantages constitute entry barriers to the extent that potential entrants may anticipate somewhat lower returns than the average expectation of the earlier, innovating producers.

One great advantage for these headstarts as an innovation incentive is that no government interventions or

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[18] The importance of lower costs and increased demand as incentives for innovation has been long recognized, for example, by Joseph Schumpeter and Fritz Machlup, respectively, in Capitalism, Socialism & Democracy, 3rd ed. Harper (1950), p. 89, and Study No. 15, "An Economic Review of the Patent System," Subcommittee on Patent Trademarks and Copyrights of the Committee on the Judiciary, 85th Cong., [the Bush reports], (1958), p. 60, respectively. However, no economist has yet ventured to estimate the relative importance of this kind of incentive as opposed to patents or other subsidies. Such an estimate would require more studies along the lines of this analysis of the polyolefins.

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decisions are involved. The natural interplay of market forces makes likely and normal some of these lead-time returns to innovators. However, such headstarts are often limited or transitory, and frequently evaporate under the impact of rival technological developments. This is particularly likely where continuing advances are being made in technology, or where substantial scale economies remain to be reaped in a market with rapidly growing demand. This is why headstarts alone may not be sufficient to induce many costly or risky innovations. Or, as many economists have put the matter, too much of the benefit from an innovation may be external to the innovator, leaving insufficient internal benefit to motivate the necessary innovative investment.[19] To the extent socially valuable innovations are not sufficiently encouraged, it is therefore desirable to supplement headstart advantages with some kind of subsidy -- either in the form of patent protection, direct

[19] Most analysts of the research and development process have emphasized the importance of such externalities. A good example is the recent study by R. R. Nelson, M. J. Peck and E. D. Kalachek, Technology, Economic Growth and Public Policy, Rand and Brookings, at pp. 159, 172, and 198. See also Nelson's earlier article, "The Simple Economics of Basic Research," JPE, June 1959, at p. 305.

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subsidies, contract research, or tax concessions.

The patent system is the most widely used subsidy for technological and market development; it can be considered as a reinforcement of headstart advantages, even though patents often serve as a substitute for headstarts. The fundamental rationale for patent protection as a subsidy is four-fold--that it encourages inventors, innovators, disclosure of patented inventions, and trading in patented technology. All of this benefit stems from the fact that, to some degree at least, technological innovations are converted into a form of marketable property.

The patent system as presently operating in the U.S. consists of a procedure for defining patent claims and a set of rules regulating the degree of monopoly power which can be asserted by a patent holder. Claims are defined by Patent Office examination of applications, in which novelty, priority, and susceptibility to invention are resolved. Once claims are defined in issued patents, the patent holder has a right to assert some degree of monopoly power over the use of invention. The claims may cover a product, a component of a product, or a process. Their market significance depends on the relative ease and certainty with which a patent infringement suit can be litigated, and upon whether a market is dominated, i.e., th

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the extent to which all firms can be forced to use the patent.

If patent claims dominate a market, or some portion of it, and are strong enough to seem reasonably capable of legal enforcement, then the patent holder can select some combination of four powers of "incidents" of a patent. The patent holder may (i) exclude competitors, (ii) select licensees, (iii) discipline their market behavior with respect to prices, output, products or territories, or (iv) require royalties from licensees in the form of lump sum and/or percentage payments on business covered by the patent.[20] The enforcement of one or more of these four incidents of a patent yields economic benefits to the holder in the form of reduced competition and presumably higher profits for his own business operations, or at least benefits in the form of royalty payments. These benefits give an extra compensation or subsidy to inventors and innovators exploiting patentable technological progress.

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[20] One of these powers--the right to discipline licensees, has been substantially reduced in a recent series of antitrust cases. See Chapter VII, infra.

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Then, finally, there are other forms of subsidy for technological development--direct subsidies, contract research and tax concessions. An increasing amount of research has been subsidized in educational institutions, especially for agriculture and medicine. Then in recent years--primarily in the defense sector, the "space" program, and in oceanography, government contracts for research and development have also become very important in financing invention and innovation. Whenever a great social premium is put on rapid and comprehensive innovation, the slower, happenstance character of R&D financed by private industry and educational institutions is unacceptable. To the extent special subsidies are successful, they may obviate some of the need for headstart advantages and patents, especially where an industry has reached a more mature stage of self-financing further development. As a result, procurement contracting for defense and space research has been preoccupied with reducing excess profits, and limiting the proprietary control of contractors over technology generated by government sponsored research. But in most specific industries private resources are still the dominant source of finance for industrial R&D.

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Tax concessions have become more important recently for inventors and innvoators in all industries. Inventors have had their income and capital gains taxes reduced somewhat, while investors in new plant and equipment have been granted some concessions on their tax burdens. In addition, small business has benefited for a long time from some tax concessions. These subsidies reduce somewhat the cost of pioneering, and encourage innovative efforts to some extent. But the major part of entry expenses still must be met privately in most industries. Consequently, where the need for subsidy is substantial, the moderate tax incentives thus far employed will not make much difference at the margin of decision making.

Competitive incentives

Operating in the opposite direction from positive subsidies are the penalites or costs of failing to keep up in the rivalry for improving technology. This incentive takes the form of reduced profits for not making proper investments in developing or acquiring technology.

Two types of competitive discipline need to be distinguished: (i) incentive resulting from rivalry within any given technology or product market, and (ii) incentive resulting from rivalry among different products or industries.

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While each tends to encourage process and product improvement and thus to lower the long run social cost of production, the determinants of each form of rivalry differ. Rivalry within markets requires a certain minimum of participation by different firms, or at least relatively easy entry. Rivalry among markets merely requires a certain interchangeability of use or a certain production flexibility, i.e., significant cross elasticity of demand or supply. The two kinds of competition may substitute for each other in terms of being a useful incentive to encourage technical progress or for product market efficiency.[21]

The natural interplay of market forces often makes either form of competitive rivalry important, just as important headstart advantages often arise naturally in the course of industrial development. But there is no guarantee that the optimal amount of competition will be forthcoming in any particular situation.

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[21]For example, limited competitive rivalry among firms within a market may be reinforced by enough rivalry between substitute products or processes of production so that the force of competition becomes strong. Of course, some economists might prefer then to redefine the relevant market more broadly, so that the competitive rivalry within the broader market is strong. But although some borderline situations may be hard to classify, the two types of competition can usually be isolated.

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To some degree these incentives and patents can operate harmoniously. The extra profits which flow to firms enjoying patent and headstart advantages may serve as the attractive force for new entry, and for innovation in rival products and processes. Hence, competitive rivalry tends to limit the monopolistic incentives while the latter tend to spur the efforts of many competitors. Unfortunately, however, a degree of conflict is unavoidable between these incentives. A high degree of competitive rivalry may crimp headstart and patent incentives, while strong patent and headstart protection may afford little opportunity for competitive rivalry.

The conflict between competitive, headstart and patent incentives

At stake in the conflict between monopolistic[22] and competitive incentives is a trade-off between social gains and losses. This trade-off can be conveniently illustrated

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[22] Monopolistic profits arising from patents or head-start advantages.

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with a simple welfare model.[23] See Fig. I-1. Given any downward sloping demand curve in the product market, a monopolistic profit involves a rise in price and a reduction in output relative to a competitive price - output equilibrium. This monopoly profit, SPQR, is a distribution effect; consumer surplus is transferred as extra profit or incentive to the monopolistically rewarded innovators.[24] The "deadweight" or net loss to society from such monopoly consists of a reduction in consumer welfare, PRT, resulting from reduced output and increased prices, which is not offset

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[23]This simple model owes its origin to Dupuit, but its modern use was revived by Abba Lerner, "The Concept of Monopoly and the Measurement of Monopoly Power," R. E. Studies, June 1934, and Harold Hotelling, "The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates," Econometrica, July 1938. More recent use of this analysis has been made by: Arnold Harberger, "Monopoly and Resource Allocation," AER May 1954; David Swartzman, "The Effects of Monopoly on Price," JPE, August 1959; Thomas Saving, "Concentration Ratios, the Degree of Monopoly and the Share of the 250 Largest Manufacturing Firms" (unpublished); and Oliver Williamson, "Economics as an Antitrust Defense," AER, March 1968.

[24]This transfer from consumers can be considered as part of a social investment, whose return comprises whatever cost savings (i.e., income increases) result from stimulated technical innovations.

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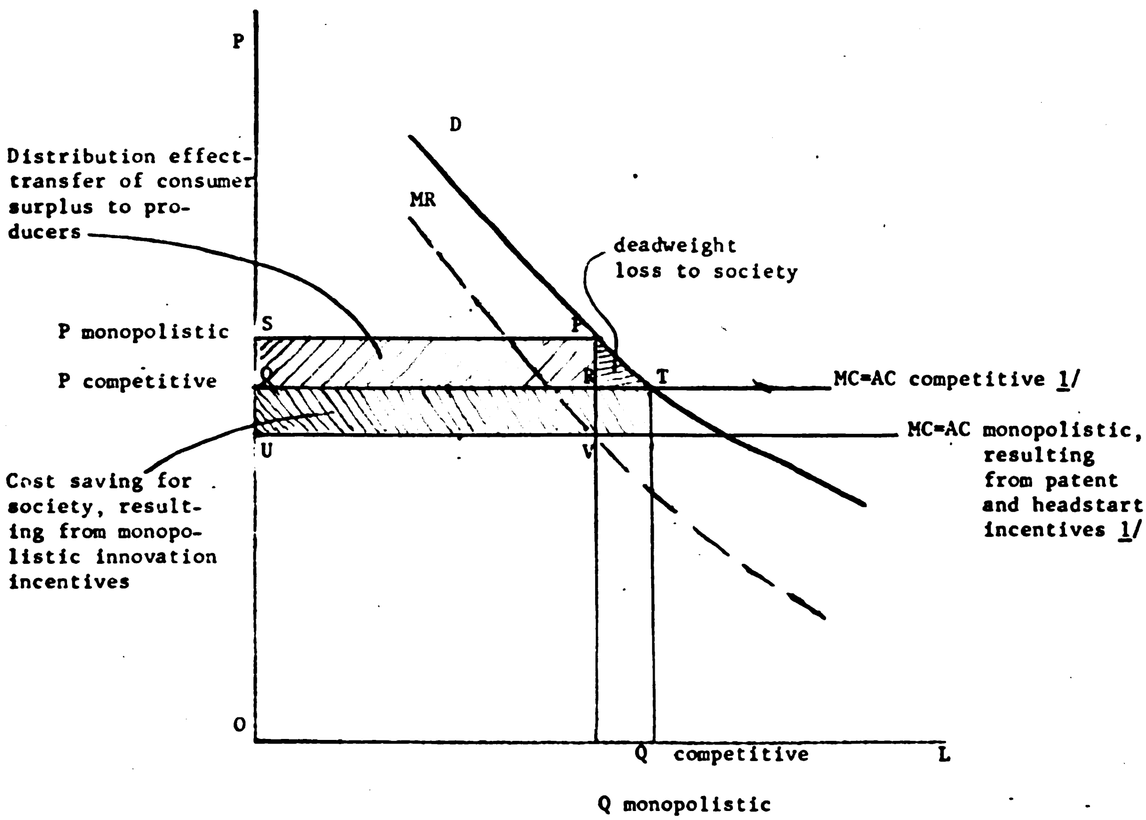

1/ Note--The net effect of monopolistic incentives may actually increase costs, i.e., raise the level of MC=AC resulting from patent and headstart advantages. In such a case, there would be no cost saving return on the social investment of deadweight loss and the transfer of consumer surplus to monopolistic producers.

For simplicity,costs were assumed to be constant in this diagram, hence MC=AC. If this assumption were dropped, this analysis of incentives would just become more complicated and more difficult to follow, but the analysis would remain an apt characterization of the relevant trade offs between conflicting innovation incentives.

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by the extra profits to producers. The net social gain from innovation can be represented as a cost saving, QRUV, relative to a competitive equilibrium. (Either a new product or a more efficient process can be represented by this cost saving effect, since the innovation allows more efficient use of existing resources, i.e., reduced costs for the same level of output.)

Whatever innovation arises from competitive rivalry is reflected in a reduction in the size of any net cost saving arising frmm monopoly, i.e., in the area QRUV. The monopolistic incentives may actually destroy more competitive innovation, i.e., cost saving, than is engendered in the first place by patents or headstart advantages. In such a case, costs would actually rise as compared with a competitive equilibrium. However, some degree of competitive pressure for innovation can easily coexist with moderate patent and headstart advantages. In practice, it is conceivable that the optimum combination will involve all three incentives in active operation to encourage technical innovation and market development.

What would be the optimal combination of these incentives? Clearly a long run horizon is essential to assess the ultimate balance of gains and losses.

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Innovations are often introduced only gradually. The social gains resulting from them usually accumulate somewhat later, even though an important invention may burst rapidly into widespread use once it catches on. Hence, a dynamic model is needed to reflect the relevant flows of social investment and its return to society.

The social investment in innovation can be considered as the accumulation over time of dead weight loss plus the transfers of consumer surplus (or income) as extra profits to supposed innovators. The social return from such investments can be considered as the accumulation of cost savings resulting from innovation. These flows of investment and return, of course, would have to be evaluated in terms of some period of time, with an appropriate discount rate for later returns. Then the present social value of these returns on investment could then be compared with other alternatives for social investment. The social optimum would involve an equilibrium investment allocation such that social welfare were maximized. In other words, we can express an innovation function,

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in which f(c) is cost of deadweight loss and consumer income transferred to innovators, f(i) is the income gain (or cost saving) which is traceable to this investment, and I is the discounted present social value of net innovation returns. The optimal situation would be where the I on nay given product is made equal to alternative social investments, for some relevant period of time, o to 6.

The problem of conflicting incentives arises in the f(i) and f(c) functions. Both f(i), innovation, and f(c), cost of innovation, depend upon the conflicting contribution of patents, headstart advantage and competitive rivalry. In other words: $f(i)=f_1$ (P,H C), and $f(c)=f_2$ (P,H C) where P,H and C are interrelated in both f_1 and f_2. What values of P,H and C will optimize the net return from innovation? This is an aspect of the longstanding problem of "workable competition," i.e., deciding what blend of monopolistic and competitive elements is desirable.[25]

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[25] "Workable competition" generally includes some blend of price competition and innovation for new products and processes, i.e., a "workable" degree of competition. This really implies two companion routes to increasing the quantity of goods, i.e., productivity, in particular industrial situations. We can either reduce imperfection in the market, i.e., reduce the degree of monopoly, lower prices and increase output, or we can increase the rate of technological

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Current opinion on this issue varies. While extremely large P,H values with a low C, or negligible P,H values with

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innovation and thereby increase output. To the extent these routes are complementary and reinforce each other, proper public policy becomes simply a matter of reducing market imperfection and providing for increased technical progress.

But many economists, especially the "Schumpeterians," deny that maximizing price competition yields a maximum of technological innovation. Schumpeterians typically contend that innovation is a more powerful force for long run efficiency than any regulatory efforts to promote competitiveness, and that therefore liberal incentives and freedom for innovation are the best public policy.

While most economists are still unwilling to abandon a reasonably vigorous antitrust policy, the problem then becomes one of deciding how much monopoly from either headstarts or patents is really desirable as an incentive for innovators.

However, even though some blend of monopoly and competition is unavoidable in the market place, this by no means implies that every antitrust case must wrestle with the compromise. Most rules of antitrust law are framed with this problem in mind, but their administrative application to particular cases requires only a limited inquiry to insure effective enforcement and fairness. See Walter Adams, "The Rule of Reason: Workable Competition or Workable Monopoly?," Yale Law Journal, January 1954.

"Workable monopoly" would be equally as good a label as workable competition, since the problem is to blend an appropriate degree of competitive and monopoly elements into real world market structures. See Edward S. Mason's review of these concepts in Chapter 18, "Workable Competition vs. Workable Monopoly," Economic Concentration and the Monopoly Problem, Harvard, 1957.

a large C, have few adherents, the proper values between these extremes remain controversial. The same also applies to the relative freedom with which large and small firms, variously, situated, should be able to strive for their P and H advantages. But framing the problem of conflicting incentives in this abstract form: (i) helps to jolt the mind out of any preconceptions in favor of competitive rivalry, patent or headstart incentives; (ii) suggests a need for some flexibility in adjusting incentives to different kinds of technological development, and the varying needs of innovation; and (iii) indicates that economic research should be directed at isolating the relative importance of P,H and C in technological and market development.

The Appropriate Role for Patent Incentives

The proper role for P as an incentive depends upon the costs and risks of innovation, cost and demand conditions in the relevant product markets, the strength of headstarts, competition within and among markets, and the degree of maturity reached by an industry or its technology. We must also consider how different levels of patent protection would affect the role of P in these different circ

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circumstances. Unfortunately, the existing industrial data simply does not allow any very precise or comprehensive testing of these interrelationships. But some analysis can be made which may help to narrow the zone of uncertainty as to proper levels of patent protection. The most convenient procedure is to consider in turn how each of the above factors will shape the need for patent protection.

Strong patent protection

Strong patent protection is characterized by the power to exclude competitors entirely from a market, either by a single firm or a close-knit small group of firms. This capability yields much of the potential profit to their patent holders; without it, firms only have a limited ability to charge royalties, raise entry barriers somewhat, or use patents as a basis for technology trading and exchanges.

Innovations that involve little cost or risk would not seem to require strong patent protection for very long to more than adequately compensate their innovators. While it is true that the prospect of extra profits for simple, inexpensive inventions may be some inducement to their production, it seems reasonable to restrict any long lastin

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lasting, strong patent protection to situations where substantial market risks are incurred.

Demand and cost conditions in the relevant product markets influence the need for patent protection through the net revenue that results from an innovation.[26] Where this potential profit is modest in scope and duration, patent protection may be more important as a motivating factor. But where the potential profit to an innovator is large and sustained the need for strong patent protection becomes minimal.

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[26]Four different cost situations may apply to product markets influenced by significant innovation: (i) substantial new scale economies may restrict participation in the market; (ii) substantial efficiency gains may apply to production processes, rendering old plants of any scale rapidly obsolete and inefficient; (iii) both (i) and (ii) may operate; or (iv) no significant scale economies or efficiency gains may operate. When significant headstart advantages are present, the first three situations will tend to reinforce headstarts and increase the profits accruing to innovators with an edge in leadtime. But if no headstart advantages operate, either new scale economies or improving efficiency may actually increase the relative cost of pioneering, and therefore impose a greater need for strong patent protection.

Two different demand situations may apply to markets influenced by significant innovation; (i) a substantial increase in demand may arise for some new or improved product, or at least for a product whose cost has been greatly reduced; or (ii) cost reduction may merely create a limited opportunity for replacing some portion of existing plant and equipment. Headstart advantages are likely to be more influential with limited demand opportunities, since later entrants will not have so much chance to share in the innovative profit potential.

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Headstart advantages serve a crucial role in extending the duration and scope of expected profits from an innovation. To the extent such headstarts can be relied upon as a protection of return from innovative investment, the need for strong patent protection will be greatly reduced. For example, a large cost saving on a product with large volume demand will generate great profit potential, provided that competitors do not immediately imitate and take away too much of the profit potential. Similarly, a new or improved product with great new demand potential will afford ample profit potential, provided that some headstart advantage prevents competitors from taking too large a share of the gains resulting from innovation. Hence, the more successful a new innovation proves to be, the less need there will be for long lasting, strong patent protection -- so long as the innovator can maintain a reasonable headstart advantage.

Large firms with superior competitive strength will generally have less need for strong patent protection than small firms with competitive weaknesses. The source of such differences in strength may be unrelated to innovative headstarts, but include superior R&D potential in related areas, liquid financial resources, and quickly available

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production and marketing capacity. Particularly where a new product or process is not too distant from the diverse activities of established industrial giants, such firms may be able to move much more powerfully and expeditiously in exploiting new market potentials. Therefore, the larger industrial firms may have some built in advantages -- really, a kind of headstart, which reduces their need for long lasting, strong patent protection.

The degree of maturity in technical and market development determines, in part, the risks, costs and profits which apply to innovative efforts. The early stages in the development of any new process or product typically involve greater risks, if not direct costs, than later stages. As a likely commercial success comes in view, the entrepreneurial risks normally decline, even though actual development costs may increase. When a substantial success is proven in the marketplace, such risks become still less important, even though rapid expansion to exploit an industrial opportunity may require very large investments of capital. Hence, the need for long lasting, strong patent protection decreases greatly as the technology in an industry or product market matures.[27]

Competition within or among industries provides a complementary, and yet partly conflicting incentive for innovative efforts. Strong patent protection is generally inconsistent with strong competition within an industry. One crucial attribute of strong patent protection is the ability to exclude competitors; if substantial competition is already established in an industry, it is not likely that newly issued patents would significantly reduce competition.[28]

Some significant interindustry or interproduct competition may not be inconsistent with strong patent protection, however, so long as the rival products or industries are

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[27]For a more complete analysis of the phasing of technological and industrial development, see R. A. Norman, "Industry Life Cycles and Patents," The Patent, Trademark and Copyright Journal of Research and Education, Winter 1961-62, pp. 303-309. Obviously, a smooth sequence from pioneering-to-refinement may not be the whole story of any one industry. Fairly often there have been successive breakthroughs in technological progress. But each major innovation will tend to follow the pioneering-to-refinement sequence, and so will normally experience a decreasing need for long lasting, strong patent protection.

[28]On the other hand, basic new inventions may create such major structural transformations that a new product market or industry is really involved, but then an entirely new competitive situation would have emerged.

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not dominated by the same group of close-knit firms. But if a few key firms dominate these rival products or industries, their rivalry may be ineffective in preventing a monopolistic outcome in those markets influenced by strong patent protection. Of course, if interindustry or interproduct competition becomes extremely strong, then the relevant industry or product market is really too narrowly defined, and the effective level of patent protection would not really be strong.

Reduced levels of patent protection and technology trading

Our attention so far has been concentrated on isolating the circumstances in which strong patent protection is desirable. For all practical purposes, we have really considered when patent holders should enjoy the power to exclude competitors -- generally the most powerful and profitable of all the incidents of patent protection. Without the power to exclude competitors, patent holders have much less restrictive influence upon competition.[29]

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[29]Compulsory, reasonable royalty licensing might be responsible for this lesser degree of patent protection; alternatively it might arise naturally through weak individual claims, inadequate litigating strength or through conflicting claims that leave no single firm, or close-knit group, in a position to exclude all competitors.

But what if, for one reason or another, strong patent protection no longer applies, and patent holders only enjoy an ability to raise entry barriers somewhat, to charge royalties, or to use patents as a basis for trading in technology? This reduced level of patent power is consistent with a high degree of competition within industries or product markets, and yet invention and innovation still receives extra reward and encouragement, and patented technology and its associated know-how becomes a more marketable commodity. Hence, reduced levels of patent protection -- even though far from complete patent "monopolies" in effect, are generally useful incentives for technological progress and efficiency.

The role of reduced levels of patent protection in stimulating technology trading deserves special emphasis for it is not widely appreciated by economists. Technology trading is significant in encouraging technological developmen and efficiency because it enables firms to achieve technical progress or entry into markets more quickly and cheaply than would be possible with their own resources. In other words, technology trading extends the attainable frontier of production in developing "new" technology, or in obtaining "established" technology, and makes the supply of industrial resources generally more mobile and elastic.[30] Such technology trading is especially important for smaller firms, which have less extensive endowments of technical talent, capital and marketing capability, and therefore, enjoy less headstart advantage.

Of course, strong patentprotection--involving the power to prevent competitors from using a technology, may discourage technology trading a great deal. The greater the monopolistic advantage and profit which results, the less likely it is that outsiders will be able to induce or compensate basic patent holders to dissipate their advantages and license the governed technology. Hence, a reduced level

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[30] Technology trading also enables complementarities in technological and industrial development to be more fully exploited. As E. I. Green, Vice President of Bell Telephone Laboratories recently observed:

> ". . ./T/he best way to obtain creativity /in industrial research/ . . .is to assemble a group of individuals whose talents are complementary, and train them for teamwork." J. R. Bright, Research, Development and Technological Progress, Irwin, 1964, at p. 118.

Since the specialized expertise of such teams is often complementary to that of other research teams, cooperation among firms can be extremely valuable, especially among those smaller and less diversified in their R&D experience.

of patent protection--providing some gains to technology holders, will generally stimulate technology circulation and will be generally desirable.

But does this mean that a reduced level of patent protection would be appropriate in all industrial circumstances? Not at all.[31] The proper lesson from this analysis is that a patent holders' power to exclude all competitors is a much more powerful and competitively dangerous incentive, which should not be employed in situations where such strong patent protection is excessive and undesirable. On the basis of the foregoing analysis, it would seem that long lasting, strong patent protection will be undesirable in at least the following circumstances:

(1) where a technology is maturing and substantial market risks are no longer involved in further innovation;

(2) where headstart advantages assure ample returns on innovative investments; and

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[31]Obviously, what would be most desirable is a compromise in which just enough, but not too much restriction on technology circulation is involved. A characteristic of ideally efficient markets for technology is that they would optimize the cooperation among complementary groups of talent and resource holders.

(3) where well-established large firms with ample resources enjoy substantial headstart advantages.

On the other hand, where firms expreience substantial costs or risks in innovating and enjoy no substantial headstart advantages--or perhps suffer from the headstarts of large, well-established rival firms in their industries, a good case can be made for strong patent protection, even if it may last a considerable number of years. Such a patent subsidy is especially appropriate for small firms which are not part of a close-knit group of industry leaders, when they are trying to establish themselves initially in a market or industry.

Strong patent protection established through restrictive agreements

Although patents held by an individual firm are often too weak to prevent entry by competitors, i.e., to achieve strong patent protection, it may still be possible to establish this degree of control over a market by restrictive technology trading. A close-knit group of patent holders may combine their limited litigating strength to prevent outside entry entirely, by agreeing to license only ea

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each other on an exclusive basis. Or, one or more firms may simply purchase sufficient complementary patent rights (or the companies owning them) to establish exclusive control over a technology. Either way, strong patent control over a technology and its related product markets will be established artificially, and not by virtue of an individual firm's innovative efforts. The patent dominance which results from such restrictive arrangements is not really a reward for innovation but a monopolistic profit arising from restrictive trade practices.

To be sure, technology trading generally promotes efficiency, and is therefore, desirable. But a pattern of technology licenses, exchanges or acquisitions which yields exclusive control over a market that would not otherwise be patent dominated, is a socially undesirable and perverted form of technology trading. Unfortunately, the reinforcement of weak patent claims by restrictive arrangements is profitable to the participating firms, and must be continually policed by antitrust law--or by self-enforcing limitations on the legitimate scope of patent protection.

The main problem to be avoided in exclusive technology sales, licenses or exchanges is the artificial creation of substantially greater patent dominance over a ma

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market than would arise in nonexclusive technology trading. This means that cross-licensing, joint R&D arrangements, sales of know-how, sales of plants, or mergers having this effect should be examined not only for exclusivity of language, but exclusionary effect. Unless patents and headstarts naturally create a complete barrier to entry, technology traders should not be allowed to create by agreement the effect of strong patent protection.

Compulsory, reasonable royalty licensing of technology

Compulsory licensing of patent regulated technology can arise in two ways: (i) the government can intervene in specific industrial situations to force licensing at some reasonable royalty; or (ii) circumstances can be defined in advance under which a patent holder can enforce no more than a claim to some reasonable royalty payment. Of course, the extreme case of compulsory licensing involves no royalty at all. But this extreme would be generally undesirable--for then patent holders would have very little incentive; they would have no motivation to market patented technology, and innovations would tend to b

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Whichever limitation on patent monopolies is applied should be a pragmatic decision. The optimal combination of these methods for achieving reasonable royalty licensing would depend on the frequency with which such licensing should be imposed, and the degree to which either government or private parties can determine the proper circumstances for its use. In other words, the ultimate prescription for public policy becomes a matter of administrative efficiency.

In the foregoing analysis we have seen how strong patent protection might be more carefully adjusted to the circumstances in which it is really desirable. In what follows we will try to apply this analysis to the polyolefin plastics. This industry is particularly appropriate for such an empirical study, because an unusual amount of data is available about the role of patents in these markets and their impact on technology trading, and because the polyolefins are a rare and successful example of compulsory, reasonable royalty licensing of patents and know-how.

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[32]Without any power to restrict entry or impose royalties, the only remaining incentive to a patent holder would be as a pyschic reward, in the form of publication, which would afford little inducement to innovative investments.

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CHAPTER II

POLYOLEFIN TECHNOLOGY, DEMAND AND COST CONDITIONS

The polyolefin resins are polymers formed from either ethylene or propylene. A very high pressure process yields low density polyethylene, a light, flexible and reasonably tough resin. Reduced pressure with different catalysts yields high density polyethylene, a slightly heavier, much tougher and more rigid resin. At least one of the reduced pressure processes with somewhat different polymerization conditions and equipment, yields polypropylene, a resin which is still stronger, tougher and with greater rigidity.

The current U.S. consumption pattern for the polyolefins is set forth in Table II-1 on the following page.[1] Film and sheet, coating and injection molding are the leading LDPE uses; blow molded containers and injection molding are the leading HDPE uses; and fiber and injection molding are the leading PP uses.

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[1] Modern Plastics, January, 1969. It must be emphasized in this connection that consumption in the same category does not imply functional substitutability.

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TABLE II-1.

POLYOLEFIN RESIN CONSUMPTION IN 1968
(millions of pounds)

	LDPE	HDPE	PP	Total
Film and sheet	1,250	55	80	1,385
Blow molded containers	50	530	12	592
Extrusion coating	375	15	5	355
Pipe and conduit	70	70	(a) 14	154
Injection molding	425	270	405	1,100
Wire and cable	350	45	6	401
Fiber	--	6	200	206
Rotomolding	35	15	--	50
Export	350	104	85	539
Miscellaneous	135	90	23	248
Total	3,000	1,200	830	5,030

(a) 4 million lbs. of this total is pipe; the remainder is profiles.

This divergent pattern of end use has resulted from the differences in polyolefin properties. There is actually little substitution between the polyolefin resins, although they may be blended to yield intermediate properties. Meanwhile, the supply of each polyolefin resin has been produced by different companies, albeit some firms are active in two or three of these markets. Production facilities have been specialized to each resin for maximum efficiency. Hence, al

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although know how in one polyolefin resin provides a significant headstart advantage for production of the other polyolefins, the three polyolefins can be considered as separate product markets for purposes of supply as well as demand.[2]

However, substitution in demand has operated between other materials and the polyolefins to a substantial degree. Much of the reason for the rapid growth of the polyolefins has been that they proved superior to cellophane and polystyrene plastics, paper, glass, rubber, wood and metals in a wide variety of applications. In addition, some polyolefin applications are novel, at least in the sense that a new functional capability resulted from the use of polyolefins which enlarged the demand for end products made from them.

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[2]Although each polyolefin product market is distinct in terms of supply and demand, from a technology market point of view these three resins are very closely interrelated. The know-how for any one resin yields a substantial headstart for the others, and the catalyst systems and pressure requirements for the two higher-density resins are quite similar. In other words, participants in one of these polyolefin technology markets automatically have a degree of participation in the other two polyolefin technology markets.

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Polyolefin Technology

Chemistry

The polyolefin polymers, like all plastics, are simply extended and interconnected chains of hydrocarbon molecules.[3] While some polymers, such as tree resins, horn, amber, or shellac are polymerized naturally in plants or animals, the bulk of modern plastics are synthesized artifically from cellulose, petroleum, natural gas, or coal derivatives.

While some of the natural plastics are ancient in their history, most of the modern plastics were not introduced commercially until after World War I. The polyolefins came relatively late in this sequence of commercial development because either very high pressures or at least exotic and unstable catalysts were necessary for their polymerization. The complexity and difficulty of engineering

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[3] Of the extensive technical literature concerning these plastics, the most complete and general accounts of polyolefin processes, properties, uses and their development are in Polyethylene, T.O.J. Kresser (Reinhold, 1957), Polypropylene, T.O.J. Kresser (Reinhold, 1960), and Polythene, 2nd Edition, A. Renfrew, Editor, Director of Plastics Division, ICI (Interscience, 1960). The more recent developments have been regularly discussed in Modern Plastics, a monthly trade journal published by McGraw-Hill.

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these special conditions for polymerization has required larger and more expensive plants than are employed for most other plastic resins.

However, the petroleum feedstocks employed in the polyolefins--ethylene or propylene, are simpler and cheaper than the hydrocarbon derivatives required for most other plastics. Furthermore, once a reasonably large batch size and rapid process speed were attained in polymer plants, the cost of polyolefin polymerization became relatively low as well. This relative cheapness and the inherent technical properties of the polyolefins have been responsible for their outstanding commercial success.

Low and high density polyethylene are both formed from chains of ethylene molecules.[4] The two resins are distinguished chemically by the degree of cross-branching among these chains. Low density resin has much more cross-branching between the chains, i.e., a lattice-like structure, while high density resin has a more nearly linear structure. Therefore, low density resin is light and

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[4]There is a limited degree of overlap between low and high density polyethylene in terms of production possibilities, but a density of .940 (as compared with water) is generally agreed upon in the plastics industry as a convenient boundary between the two resins.

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flexible, while high density resin is slightly heavier, relatively rigid, and much stronger.

Polypropylene is formed from chains of propylene molecules. Because these propylene molecules are slightly heavier and more complex than ethylene molecules, polypropylene is somewhat less prone to cross-branching and is stronger in its linkages. Consequently, polypropylene is relatively rigid, is slightly stiffer, heavier and stronger, and has greater tensile strength, chemical and heat resistance than high density polyethylene.

Properties and end uses

These differences in chemical structure are responsible for variations in the properties and therefore, end uses of the polyolein resins. The impact of this difference in properties upon end use patterns is best indicated by a detailed review of important end uses and the reasons why each polyolefin resin is employed therein.

In its initial end use, the coating of wire and cable, low density polyethylene had advantages in combining flexibility, high dielectric strength, a low power factor, low water absorption, high tensile strength, lightness, and resistance to low temperatures. This made it

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ideal for flexible cables employed in outdoor radar installations (particularly those in high-flying aircraft), and appropriate for the coating of telephone cables.[5] Another important advantage for polyethylene was its easy adaptability to extrusion equipment already in use with the production of vinyl insulation material. On the other hand, polyethylene had some weaknesses in limited resistance to heat, vulnerability to insects, vulnerability to some corrosive agents, and a liability to electrical failure under combined mechanical and electrical stress.

The largest end use for low density polyethylene has come to be as a film and sheet, primarily employed in packaging. Polyethylene is as effective as most thermoplastic films in general use and yet has some significant extra advantages. Perhaps most important is its great yield (area of coverage per pound), for example, because of its greater yield polyethylene would be one-third less expensive than cellophane, even if the two resins had similar prices per

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[5]Polyethylene replaced lead to a substantial degree for jacketing telephone cables because of its lightness and superior chemical resistance.

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pound.[6] Polyethylene has great practical durability, a substantial asset compared to other films, because of its superior tear strength, resistance to elongation, and folding endurance. Its ease of heat sealing is not unique but is a necessity for widespread use in packaging, ranging from "baggies" to garment bags. Its low permeability to water is also a major advantage in keeping foods fresher for longer periods, or in protecting contents of packages, drums, or other containers from moisture. On the other hand, what could be a weakness in some uses, a high permeability of polyethylene to gases, particularly oxygen and carbon dioxide, is useful in packaging some fresh foods, especially meats, which need oxygen to maintain an attractive red "bloom." The weather resistance of polyethylene combined with its lightness makes it useful for building insulation, and in mulching. Some high density polyethylene is also used in film and sheet manufacture, to make stiffer, stronger films.

Another large volume end use for polyethylene is in

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[6]Actually, since the mid-1950's cellophane has been more expensive per pound than polyethylene.

blow molded containers. In this form polyethylene is light, highly resistant to breakage, easy to form and therefore amenable to eye-catching shapes on store shelves, and cheaper than most materials for smaller containers. Some low density polyethylene is employed for the more flexible squeeze bottles, while high density polyethylene is used in much greater volume for stronger, more rigid containers. The capability of polyethylene containers has been further enhanced by coating the inside of bottles with various materials and by special blends to improve stress cracking properties. Such containers now account for nearly one eighth of all usage and include milk bottles, detergent, pharmaceutical, cosmetic, motor oil, and shipping containers.

Another important polyolefin end use in packaging is for the coating of paper and other substrates. Low density polyethylene adds water resistance to Kraft paper, while the Kraft provides strength lacking in polyethylene alone. When used as a coating for multi-wall bags polyethylene also prevents contamination and wear on the contents during handling. Polyethylene bags are more flexible, offer better protection, and lengthen the service record of bags. Another large volume use for polyethylene and paper co

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coating has been the coating of paper milk cartons, for which parafin wax was replaced due to its inferior ability to prevent leakages. Some polyethylene has also been employed with a variety of other substrates, such as aluminum foil or cellophane, to give a high degree of impermeability to these materials.

Polyethylene is also used widely for pipe and hose. Its water and chemical resistance combined with lightness, sufficient strength, and resistance to low temperatures, made it widely useful for carrying water and some liquid chemicals. Compared to other materials for smaller diameter pipe, it has been the cheapest available, particularly in view of its ease of handling and the very low cost of laying polyethylene pipe.

In injection molding all three polyolefin resins found wide use, based upon their toughness, lightness, relative flexibility, easy colorability and resistance to cooler temperatures. Typical examples are ice cube trays, toys, artificial flowers, juice containers, and salt shakers. While polyethylene is somewhat more expensive than certain competitive plastics, particularly general purpose polystyrene, in many uses this handicap is more than offset

by unbreakability.

The difference in properties between low and high density polyethylene is largely a matter of reduced flexibility and increased strength with increased density. Polypropylene is more akin to high density polyethylene, but has a somewhat distinct envelope of properties. In film applications polypropylene has superior clarity, even exceeding that of cellophane. Polypropylene is now cheaper than cellophane, superior in tear resistance, in aging, as a barrier to moisture, and yet like polyethylene allows for the passage of gases. Polypropylene may have its most important potential in film as a substitute for cellophane, although its uses also extend beyond this area.

Polypropylene has somewhat greater resilience than high density polyethylene, which makes it somewhat better as a heavy-duty bottle. This superior strength also makes it an efficient thin walled container, some contending that it would be the cheapest plastic material available for such uses. Polypropylene is also superior as a material for bottle closures. Still another area of superiority is in vacuum formed trays, boxes, skin and blistered packs where a combination of clarity, strength, and some flexibility is ap

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appropriate. Polypropylene properties make it appropriate for a variety of durable goods components to a much greater extent than either polyethylene. Examples are tanks, valves, pipe fittings, or grids in air conditioners and refrigerators, hair dryers, and vacuum cleaners. Its main advantages in these uses are its combination of strength, a degree of flexibility, lightness and relative cheapness. Polypropylene has greater tensile strength than high-density polyethylene and accordingly has a substantial extra use as a fiber material. Polypropylene fiber has replaced saran in webbing for outdoor furniture with superior weather resistance qualities. It has also replaced nylon and natural fibers to some extent in rope with its combination of lightness, strength, and weather resistance. It also is employed as a strong, heavy-duty rug and carpetbacking fiber.

Production processes

Production processes also differ significantly and plants are specialized among the three polyolefin resins, although know-how is closely related, especially between the higher density resins. The stages of production for polyolefin resins include purification of the olefin monomer (ethylene or propylene), the reaction process in which polymerization occurs, purification and recovery of the polymer, and then extrusion of the polymer into a form convenient for storage and shipping. Since some catalysts are highly unstable, and are prepared by resin makes shortly before polymerization, catalyst preparation can also be considered as a stage of production.

Production of polyolefin resins requires a high degree of purity in the ethylene or propylene monomer. Inert impurities are removed to facilitate reaction speed and the presence of active impurities, such as water or oxygen, must be carefully controlled, because even small amounts could have significant effects on the resulting polymer. Conventional distillation techniques with pressure towers are generally employed for this stage and it involves no great difficulty.

For low density polyethylene the very high pressure process (over 500 atmospheres and more) presents great mechanical problems, requires large power inputs, and represents a large portion of the cost of polymer production.[7] After ethylene gas is compressed it is led through a reactor, either of the autoclave or tubular type. Catalysts (such as oxygen and oxides of nitrogen) are then introduced, together with initiators designed to speed the reaction process. A percentage of the ethylene is polymerized at each pass; the remainder is merely recycled to keep the reaction temperature down. The polymer drops out and is purified until all ethylene gas has been removed. The polymer at this stage is in a molten state, and is extruded into strips or rods, which are then chopped into "pellets." These pellets are the most convenient and common form in which to store and ship thermoplastic resins. The end product fabricators later remelt these pellets,which are then either extruded or molded into desired applications--film, fiber, coatings, tubing, containers or other shapes and objects.

The production processes for higher density polyolefin resins involves substantially reduced pressures, different catalysts, and yet somewhat greater difficulties in

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[7]The original high pressures employed by ICI for polyethylene were similar to those involved in firing a 16" naval gun, or nearly 35,000 pounds per square inch.

purification and recovery of the polymer. There are three catalyst systems and processes which can be employed for high density polyethylene, at least one of which is widely used for polypropylene.[8]

The dual purpose process involves the Zeigler catalysts. This reaction is usually carried out in an inert hydrocarbon solvent with transition metal salts and organometallic compounds as catalysts. (A typical example would be a titanium halide and an aluminum alkyl.) After polymerization the catalyst remains must be eliminated and a dry or semi-dry flake results. Then a molten plastic is formed and pelletized for storage and shipment.

The Phillips process typically involves chromium oxides supported upon high surface area silica alumina. A solvent is employed in the reaction and is removed by centrifuge or filtration of the hot polymer solution. Thereafter the molten polymer is extruded and pelletized.

The Standard Oil (Indiana) process involves the use

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[8]Theoretically all three catalyst systems and processes can be employed for polypropylene production, but according to survey information obtained by the FTC, only the Ziegler process has been used for polypropylene commercially.

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of molybdenum oxides on a variety of refractory bases. This reaction also involves a solvent. The catalyst is filtered out in a series of stages and finally removed with superheated steam. Then the molten polymer is extruded and pelletized.

Hence, production processes for the three different polyolefin resins are distinct, requiring somewhat different reactors, purification, and recovery[9] even though the Ziegler catalysts (theoretically also the Phillips and Indiana processes) are employed in producing both high density polyethylene and polypropylene. Specialized plants and processes have been found most efficient for each of the three polyolefin resins.

The Polyolefins as Separate Product Markets

The conventional economic criteria for the separateness of markets are the relevant cross-elasticities of

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[9] One firm does manufacture both resins in the same plant, but only some of its reactors were designed to yield both resins and these required different operating conditions to produce each resin.

supply and demand, i.e., the degree of substitutability in production facilities and the degree of substitutability of products in demand.[10] When these criteria are applied to the polyolefins it becomes clear that (i) production flexibility is low among the polyolefins, and almost non-existent between each polyolefin resin and other related

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[10]In order for any commodity market to be considered as distinct from other markets, it must be reasonably separate in terms of both supply and demand. Cross-elasticity of supply is generally defined as the percentage change in quantity supplied of a given commodity associated with a percentage change in the price of some other, substitute commodity, i.e.,

$$\frac{\Delta q_x}{q_x} \Big/ \frac{\Delta P_y}{P_y} = \frac{P_y \Delta q_x}{q_x \Delta P_y}$$

When the cross-elasticities of supply with all conceivable substitutes in supply are small fractions or zero, the given commodity can be considered a separate market in terms of supply.

Cross-elasticity of demand is generally defined as the percentage change in quantity demanded of a given commodity associated with a percentage price change in the price of some other, substitute commodity, i.e.,

$$\frac{\Delta q_x}{q_x} \Big/ \frac{\Delta P_y}{P_y} = \frac{P_y \Delta q_x}{q_x \Delta P_y}$$

When the cross-elasticities of demand with all conceivable substitutes in usage are small fractions or zero, the given commodity can be considered as a separate market in terms of demand.

chemical process industries, and (ii) although the cross-elasticity of demand between each polyolefin is low, it is significant with respect to some other plastics and materials. In other words, one can say that each polyolefin resin is properly classified as a separate commodity market, but each polyolefin resin is subject to some significant interproduct rivalry with respect to other plastics and materials.

The relevant cross-elasticities of supply are conditioned by the fact that plants for each polyolefin resin are specialized to that market. No other plastic or chemical plants can be converted efficiently to use as a polyolefin plant; such plants are designed from the outset simply to be polyolefin plants. In other words, there is no flexibility of production facilities between other industries and the polyolefins. While some know-how advantage applies to a polyolefin producer in entering the other polyolefin markets, especially between the higher density resins, only a slight know-how advantage applies in favor of firms experienced in operating other chemical process plants as entrants into any of the polyolefin resin markets. This means that in the short run there is little

cross-elasticity of supply among the polyolefin resins, and next to no cross-elasticity of supply between the polyolefins and other plastics or chemical industries.

To be sure, once the patent barriers entry into the polyolefin resin markets were broken down, significant new entry flowed into each polyolefin market. But although the companies making such investments came from a wide variety of other industries, they all entered simply as polyolefin resin producers. Each was required to obtain specialized polyolefin technology for at least several million dollars, and to construct specialized plants costing from $20 to $30 million.[11] This flow of new entry does indicate long run elasticity of supply within each polyolefin market, i.e., a sensitivity of the capital market generally to the profit prospects in the polyolefins as compared to other investment alternatives.[12] Butthis long run capital

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[11]Costs of constructing polyolefin plants are discussed more fully, <u>infra</u>, at pp.87-100.

[12]Furthermore, it must be emphasized that even the large companies familiar with operating other kinds of chemical process plants have not been able to enter at will. Their participation in the polyolefins has depended on access to technology allowed by the polyolefin technology markets. Such access has ranged from difficult to relatively easy.

mobility does not produce as competitive a pattern of industrial behavior as short run production flexibility; it is the absence of short run production flexibility from other industries that enables each polyolefin resin to behave as a separate market in terms of supply.[13]

More competitive rivalry among products and industires is evident when we consider cross-elasticity of demand. Although very little substitution is possible between LDPE and the two higher density polyolefins, and only limited substitution between HDPE and PP, there has been significant substitution between each polyolefin resin and some other plastics and materials. The evolution of polyolefin end uses is replete with examples of such substitution, as was indicated in the foregoing review. The relative cheapness of the polyolefins has combined with its technological properties to carve out a large volume usage at the expense of other materials.

How substantial is this cross-elasticity of demand? Although data on price and consumption shifts is too skimpy

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[13]If long run capital mobility had to be taken into account in defining markets for purposes of industrial analysis, there would be very few separate industries or markets.

for much precision, the available evidence indicates no great cross-elasticity of demand with respect to moderate price changes.[14] But with respect to large price changes, the cross-elasticity of demand between each polyolefin resin and its rival materials is probably much greater.[15]

What does this differing degree of demand cross-elasticity mean? The relatively low elasticity with respect to moderate changes in relative prices means that interproduct rivalry is not strong enough to prevent a monopolistic price level from persisting in any of the three polyolefin resin markets. Price competition in the static sense could only operate to the extent that rivalry was effective within the polyolefins, or to the extent

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[14]If polyolefin substitutes were decreased in price by 15-25 percent, for example, it is very doubtful that much change in polyolefin consumption would result. The reason is simply that the chemical properties of the polyolefins have been predominant in making them superior in performance and efficiency to other materials within this range of relative prices. The relative advantage of the polyolefins in most end uses is so great that 15-25 percent price declines in polyolefin substitutes would not make enough difference for polyolefin consumers.

[15]If, the prices of polyolefin substitutes were decreased by 200-300 percent, for example, it is likely that polyolefin consumption would decline by as much or more. In other words, the qualitative superiority of the polyolefins in many uses is not so great as to prevent reaction to large changes in relative prices.

that new entry was relatively easy. But even though inter-product rivalry is not strong enough to insure perfect price competition in the polyolefins, it was strong enough to constitute a substantial pressure for innovations in the polyolefins and their substitutes. Hence, cross-elasticity of demand was high enough to bring some of the benefits from competition, even though it could bring all of the benefits from perfect competition.

Demand growth and demand elasticity

One striking and important structural characteristic of the polyolefin resin markets has been a very rapid and sustained growth in consumer demand.[16] In 1952 U.S. polyolefin resin consumption was about 100 million pounds; in 1968 consumption was about 5 billion pounds. Annual increases in polyolefin resin consumption averaged (geometrically) nearly 28 percent in the polyolefins as a whole during this entire period.[17] In these 16 years, the number of

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[16]See Chapter III, *infra,* for more details on growth in market demand.

[17]The yearly average increases in consumption for each polyolefin resin were also very substantial; LDPE averaged 24.1 percent between 1953-68; HDPE 38.4 percent between 1959-68; and PP 61.3 percent between 1959-68.

polyolefin plants increased from 2 to 40, and the number of polyolefin resin producers from 2 to 18. This growth in demand, therefore, enabled a great increase in competition within the polyolefin resin markets.

Price reductions, product improvement and shifts in consumer tastes combined to cause this growth in demand. Average prices declined from more than 42¢ lb. to a range of 15-21¢ lb. currently.[18] Resin properties were greatly improved, which enabled a many-fold increase in polyolefin consumption. And then, consumer awareness of these properties increased greatly. Although available data does not allow precise estimates of the contribution from each factor, it seems reasonably clear that improving polyolefin properties were the dominant influence at work. In other words, demand shifts were large and sustained over this period, and price elasticity of demand can hardly explain the major part of this massive growth in consumption.

Costs and Risks of Polyolefin Innovation and Production

Costs and risks of early innovation in the polyolefin

[18]Actually only LDPE was produced in 1952. The first HDPE and PP was produced in 1957.

plastics were large as compared to most industries, and help explain, along with strong patent protection, the very limited participation in these markets before the early 1950's.[19] Although data on early R&D budgets for ICI are not available, it seems clear that the very high pressures being employed (more than 20,000 p.s.i.--well above what were then used in industry) made any LDPE pilot plants quite risky from a technical point of view, as well as relatively expensive. In addition, the very limited initial prospects for use of this resin made market potential unattractive for any firm that could not afford a long, patient period of further research designed to develop broader market applications.

When ICI informed DuPont in late 1941 of the strategic significance of LDPE for coating radar cable and offered an exclusive license, it greatly reduced the cost and risk of innovation that DuPont would otherwise have experienced. ICI shared its headstart with DuPont because the U.S. market

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[19]The early research and development efforts are described more fully in Chapter III, <u>infra</u>.

could not, under World War II conditions, be efficiently served by ICI alone. In other words, DuPont was really brought into the early exploitation of LDPE because it had complementary resources which were needed to fully exploit the U.S. economic opportunity. A similar reduction in the cost and risk of innovation applied to Union Carbide in 1942, when the U.S. Navy Department insisted that a second domestic producer be licensed to provide an alternate source of supply.

But substantial innovative investments with some risk were still required from all three firms for the further development work of the early postwar years. Some refinements in the resin process were undertaken, but most important, the properties of LDPE were improved substantially, which created a much greater demand potential. By the late 1940's most of the present end uses had been opened up in rudimentary form. Further innovative effort on LDPE in the 1950's was largely a matter of refinement, and market risks were much reduced, even though more LDPE patents were actually issued between 1953-63 than in all the preceding years.

Then in the mid-1950's the higher density polyolefins w

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were developed. Costs and risks were greater in HDPE and PP than in the contemporary refinements of LDPE. But the degree of technical pioneering required was significantly less than that needed for LDPE in the 30's and 40's. Some of the process chemistry had been revealed, and work on LDPE properties and end uses pointed the way to a much larger market potential for higher density polyolefins than was evident in the early years of LDPE. By the early 1960's the higher density technology had matured to a considerable degree. Although further refinements were being made in process efficiency and new product applications, a very large demand potential was then evident and the risks in further innovation were greatly reduced.

In other words, as polyolefin technology matured, the risks of innovative effort in this industry declined very substantially. This was a significant factor in helping to reduce the costs and risks of entry. But this change also indicates that the need for strong patent protection or headstart advantages only really applied to the early innovative investments in the industry. Later innovative investments in refining polyolefin technology could be self-financed, by a modest R&D charge on expanding polyolefin resin sales. Such R&D expenses could be considered

much like ordinary maintenance costs, insofar as their limited risk and ease of payment were concerned. Therefore, the need for some kind of innovation subsidy applied only to the early years of development for each polyolefin resin, and mainly with respect to LDPE, for which early innovative risks were quite substantial.

Production costs

Production costs within the polyolefins have reflected substantial scale economies and progress in process efficiency. Fortunately, for the sake of a simple exposition, the costs for the three polyolefin resins are very similar. The investment required for plant and equipment in each resin is about the same, crew sizes are the same, and raw material costs are much alike. Therefore, we can summarize cost experience in this industry merely in terms of typical polyolefin costs.

Costs for polyolefin resin operations comprise fixed costs for plant and equipment, a crew of operatives, and some overhead costs for technology. Variable costs comprise feedstock (ethylene or propylene), catalysts and other chemicals, utilities (water, steam, or electricity), and selling expenses. In recent years the fixed costs averaged from

4-11¢ lb., while the variable costs averaged from 6.5-11¢ lb. (Table II-2).[20] The highest costs were for smaller plants (25-40 million pounds capacity) lacking the most efficient processes; the lowest costs were for large plants (140 million pounds or larger) with the most efficient processes.

Although less is known about early polyolefin cost experience, it is clear that average costs for resin manufacture have declined substantially at least since the

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[20] Six resin makers submitted comprehensive studies concerning estimated costs and rates of return for polyolefin plants to the FTC. All six were prospective entrants at the time, and their studies were prepared either by independent consulting firms or by their own engineering and planning staffs. The studies prepared in the late 1950's reflected average costs of 15-22¢ lb. for fully utilized plants of 25-60 million pounds of annual capacity. While some over-optimism may be present in these estimates, it is probably more than offset by lack of access to the most efficient process know-how.

Operating data submitted to the FTC by the leading resin makers also revealed that by 1963 the most efficient plants with annual capacities over 150 million pounds had average costs as low as 10-11 cents per pound.

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TABLE II-2.

AVERAGE FIXED AND VARIABLE COSTS FOR POLYOLEFIN PRODUCTION IN CENTS PER POUND

	Fixed costs		Variable costs
Plant[21]	1.5-5¢ lb.	Feedstock	2.5-5¢ lb.
Labor	2.5-5¢ lb.	Catalysts and chemicals	1-2¢ lb.
Royalties for technology	0-1¢ lb.	Utilities	1¢ lb.
		Selling expenses	2-3¢ lb.
	4-11¢ lb.		6.5-11¢ lb.

Source: Cost estimates on new plants proposed during 1959-63, and operating data on established resin plants for 1959-63, both submitted to the FTC by polyolefin resin makers.

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[21]Actually, data provided for 1959-63 would only indicate plant costs as low as 2.5¢ lb. when amortized over a 10-year period by a straight line depreciation method. But the recent investment outlays revealed for several new large scale polyolefin plants were $25-30 million for 150-200 million pounds of annual capacity. When similarly amortized, this would imply an average fixed cost for plant and equipment of only 1.5¢ lb.

Note: Shipping costs are not significant in the polyolefins, and average in most cases no more than one-third to one cent per pound. See Appendix Table A-1 on shipping costs. Since most polyolefin plants are in Texas and Louisiana, it seems that location near raw materials is generally considered to be most efficient. See Appendix Tables B-1, 2 and 3, which list the polyolefin plants and their capacities.

mid-1950's. Minimum average costs in recent years have declined from about 15 - 22 cents per pound for new entrants with small scale plants, to about 10 - 15 cents per pound for established producers with large scale plants. Just what the two industry leaders, DuPont and Union Carbide, may have been experiencing in the way of average costs in the 1940's has not been disclosed. But it seems reasonable to assume that they had neared the 15 - 22 cents per pound level at least by the late 1940's when their plants were in the 50 million pound capacity range. Similar technology was made available by ICI a few years later in patent and know-how licensing arrangements, and would be the basis for the polyolefin cost estimates quoted to new entrants in the later 1950's.[22]

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[22] By the late 1940's the LDPE process had been under development for 15 years by ICI, DuPont and Carbide. When compulsory licensing was decreed for patents and know-how in 1952, it covered the state of the art as of that time. ICI was not obliged to license subsequent developments, though in a few cases it did license updated know-how for additional royalties.

Three factors have been responsible for declining costs in recent years. First, greatly increasing sales volume allowed most firms to take advantage of scale economies. Second, process efficiency was improved substantially and the later entrants tended also to catch up with the leaders. Finally, the severe excess capacity which characterized the late 1950's and early 1960's was substantially reduced by the mid-1960's.

The magnitude of polyolefin scale economies is suggested by resin maker estimates of the cost differentials associated with increasing the scale of their plants. Savings on labor cost seem to be most important, while savings in capital cost are still considerable (Table II-3). In four of the six cases for which data is available the saving in labor cost--1.4 to 4.8¢ lb., was more than twice as great as the saving in capital cost--.6 to 1.9¢ lb. In the other two cases labor and capital cost savings were roughly the same, at about 1.7¢ lb. Since technology costs are less significant to begin with, savings associated with increases in scale would be less important for technology--no more than .5¢ lb. on most lump sum royalties; and no saving at all would be involved on a percentage of

TABLE II-3

AVERAGE COST DIFFERENTIALS PER POUND ASSOCIATED WITH INCREASING SCALE OF PLANT

(Annual capacity in millions of pounds)

	Labor	Deprecia-tion	Overhead	Feedstock and raw materials
Estimate A (LDPE)				
30 M, lb.	4.7¢ lb.	2.7¢ lb.	--	--
60 M. lb.	3.3	2.1	--	--
Differentials	1.4	.6		
Total Differential	2.0			
Estimate B (LDPE)				
30 M. lb.	15.5	2.9	2.3	--
60 M. lb.	13.2	2.1	1.3	--
Differentials	2.3	.8	1.0	--
Total Differential	4.1			
Estimate C (HDPE)[1]				
30 M. lb.	5.7	3.4	.34	--
60 M. lb.	3.9	2.7	.27	--
Differentials	1.8	1.7	.07	--
Total Differential	3.6			
Estimate D (HDPE)[2]				
30 M. lb.	5.1	3.0	1.68	--
60 M. lb.	3.5	2.4	1.44	--
Differentials	1.6	1.6	.24	--
Total Differential	3.4			
Estimate E (PP)[1]				
30 M. lb.	6.1	2.8	.48	--
60 M. lb.	3.5	2.3	.23	--
Differentials	2.6	.5	.25	--
Total Differential	3.4			
Estimate F (PP)[3]				
36 M. lb.	8.5	3.7	---	8.4
112 M. lb.	3.7	1.8	---	5.9
Differentials	4.8¢ lb.	1.9¢ lb.	---	2.5¢ lb.
Total Differential	8.2¢ lb.			

[1]Overhead differential consists only of insurance in these two instances.

[2]Overhead differential comprises royalties and insurance in this case.

[3]This feedstock cost differential is probably due to a higher price quotation from the feedstock supplied for a relatively small volume usage.

Source: Cost estimates prepared by six prospective entrants into the polyolefin resin markets.

sales royalty.[23]

Resin makers have definitely taken advantage of scale economies. Over the years, most polyolefin producers expanded their initial plants up to the 100-150 million pound annual capacity level before building a second plant.[24] In 1959 16 LDPE plants (for 9 producers) averaged 76 million lb. annual capacity, whereas by mid-1968 there were 20 plants (for 12 producers) with an average of 183 million lb. capacity.[25] The first 8 HDPE plants

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[23]Royalty costs were not a very important factor for polyolefin resin producers until Montecatini began to assert its dominating patent claims against recent entrants into polypropylene production. Up to this point, royalty costs had generally been less than one cent a pound, even when large lump sum know-how payments were amortized. But if Montecatini imposed its current asking price for its polypropylene patent licenses, royalties could amount to 7¢ lb. or 25-30 percent of the current price of polypropylene. Such a royalty cost would probably be prohibitive to further entry, and might even force out of the market some of theless efficient or small producers. However, it is doubtful that Montecatini could ever impose such a royalty burden on established producers; this level of royalty demands is significant mainly as a litigating threat against any new entrants.

[24]More recently, the 200-250 million pound range seems to be the limit most firms accept before building another plant.

[25]<u>Chemical & Engineering News</u>, August 17, 1959; Appendix Table B-1.

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(for 8 producers) each averaged 39 m.lb. capacity in 1959, whereas in mid-1968 12 plants (for 11 producers) averaged 96 m. lb. capacity.[26] When the PP market first filled out with 8 producers in 1962 each firm averaged 53 m. lb. capacity; by mid-1968 there were still only 8 active plants, but average capacity had increased to 78 m. lb.[27]

For resin makers operating other kinds of chemical plants or oil refineries in the nearby area, another type of scale economy is also available in feedstock costs.[28] The minimum price for feedstock (whether ethylene or propylene) in recent years seems to have been about 2.5¢ lb. But to achieve this level of feedstock costs, one needs feedstock plants with annual capacities of 300-500 million lbs. Since the normal polyolefin plant will not by itself justify such a large scale feedstock plant,

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[26] Chemical & Engineering News, August 17, 1959; Appendix Table B-2.

[27] Oil Paint Drug Reporter, September 3, 1962; Appendix Table B-3.

[28] Transport costs require that polyolefin plants be located near, i.e., within a few miles or less, petroleum refineries or natural gas lines. However, feedstock technology is not difficult and it is easy for a polyolefin resin maker to produce its own feedstock, so long as it can make efficient use of the output.

some integration with other petrochemical operations is needed for the lowest feedstock costs. For small feedstock plants, costs have ranged up to 5-6¢ lb. However, polyolefin producers have frequently been charged the higher price for feedstock even though their feedstock supplier could conveniently sell or use the extra feedstock from a large scale plant. The basis for such pricing has been the opportunity cost of the polyolefin resin producer. Obviously, this kind of pricing and potential economy has tended to encourage some integration between petroleum refining, on the one hand, and the production of polyolefin resins and other chemicals using ethylene or propylene on the other.[29]

Economies achieved through improvements in process speed or cost reduction have also been very important in the polyolefins. For example, one higher density polyolefin producer recently tripled its "through-put" rate with only a modest increase in its investment cost. Another

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[29]Such integration has taken several forms: (i) construction by resin producers of their own feedstock plants; (ii) entry of oil and petrochemical producers into polyolefin production, and (iii) contract integration or joint ventures between polyolefin and feedstock producers. By 1968 almost all polyolefin producers were integrated with feedstock production in one way or another.

indication of process speed economies comes from the reduction in typical investment costs for plant and equipment per pound of annual capacity. In the late 1950's new plants of 50-60 million lbs. in size required about $15-20 million, or 30-35¢ lb. in capital outlay (3-3.5¢ lb. when amortized over 10 years). By the mid-1960's new plants of 150-200 million lbs. in size required only about $25-30 million, or about 15¢ lb. in capital outlay (1.5¢ lb. when amortized over 10 years).[30]

Still another indication of process efficiency improvements are the recent changes in depreciated investment of resin makers relative to units of production. Such data was available for six of the larger low density polyethylene resin producers and five of the larger higher density polyolefin resin producers. Most producers greatly reduced their depreciated fixed investment relative to annual production between 1959 and 1963. (Table II-4). Seven of 11 reporting firms achieved more than 50 per cent reductions in plant and equipment costs per pound, and three others reduced such costs substantially. While scale economies and

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[30] Source same as Table II-2, <u>supra</u>.

TABLE II-4

AVERAGE DEPRECIATED INVESTMENT PER POUND OF PRODUCTION [1]

Low density polyethylene[2]	1959	1963[3]
Company A	18.2¢ lb.	10.3¢ lb.
Company B	42.5	10.3
Company C	18.1	15.2
Company D	15.8	6.6
Company E	17.4	6.3
Company F	23.9	19.7

Higher density olefin resins	1959	1963[3]
Company G	67.3¢ lb.	16.1¢ lb.
Company H	78.4	24.3
Company I	58.1	16.6
Company J	43.3	35.3
Company K	94.0	36.2

[1]These ratios are based on six low density polyethylene producers that made about 75 percent of all shipments, and five higher density resin producers that made nearly 90 percent of all higher density polyolefin shipments.

[2]One of these companies included a modest portion of high density resin investment with their low density investment for year 1963, hence the stated average in this case overstates slightly the average investment per pound of LDPE production.

[3]In several instances 1962 figures are given.

improved utilization rates are reflected to some extent in these reductions in costs, a major factor in explaining the large reductions would have to be improved process efficiency.

The fact that the later entrants were able to catch up in process efficiency reflects the impact of polyolefin technology trading. The diffusion of know-how resulting from compulsory licensing in 1952 with respect to LDPE, and the absence of strong patent dominance on HDPE and PP, led to a situation where technology trading among firms was encouraged.[31] The swift entry of an oligopoly of producers in each market also prevented any effective restraints on the flow of polyolefin personnel among these polyolefin producers.

Another source of cost reduction in recent years has been an improvement in the utilization rate for plant capacity. Other than building a plant with optimum scale and process efficiency, the most important thing a resin maker can do to lower costs and maximize profits is to operate the polymer plant as nearly as possible to its rated

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[31]These technology trading developments are discussed more fully in Chapter V, <u>infra</u>.

capacity. As shown in Table II-2, the average fixed costs for resin makers vary from 4-11¢ lb. If the utilization rate were cut in half, average fixed costs would increase from 4-11¢ lb. to 8-22¢ lb. Because many firms felt optimistic about polyolefin prospects and entered in advance of demand, the result was general excess capacity in each polyolefin resin market for most producers until the last few years. Utilization rates in low density polyethylene suffered somewhat less, however, because its sales volume and annual increases in sales have been much larger. On the other hand, recent demand for high density polyethylene and polypropylene has grown at a slower rate than some producers had hoped, and excess capacity has been somewhat greater in these markets.

Thus polyolefin technology, costs of innovation and production, and demand conditions shaped what proved to be a great market opportunity for the polyolefin resins. Headstarts and strong patent protection enforced limited

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[32] The role of headstarts in yielding extra profits to the earlier innovators is explained more fully in Chapter VI, <u>infra</u>, in connection with polyolefin profit performance.

participation in these markets for many years. But then compulsory, reasonable royalty licensing of patents and know-how combined with a very rapidly growing demand opportunity to induce substantial new entry. A period of vigorous competition , rapid expansion of production facilities and aggressive development of new markets followed. Although headstart advantages were still significant in yielding extra profits to the earliest producers, they were no longer capable of preventing new entry into the polyolefin markets. Thereby, a maturing technology, increased demand, more efficient and larger scale plants, combined with a shifting balance among patents, headstarts, and competition to produce the current market situation in the polyolefin plastics. The course of this industrial evolution is set forth with more detail in the following chapter.

CHAPTER III

DEVELOPMENT OF THE POLYOLEFIN PLASTIC RESIN MARKETS

Low Density Polyethylene

The early development of the first commercial polyolefin resin, low density polyethylene, illustrates the role of headstarts and patent incentives in encouraging technical progress. The innovating firm, Imperial Chemical Industries, Ltd., enjoyed a significant lead-time advantage in a complex, difficult, and--when ultimately developed--a costly technology. As the dominant chemical producer in Britain, ICI also enjoyed financial, production and marketing capabilities which were superior to any conceivable rivals--in that country, at least. Then, in addition, ICI obtained control of this new market through dominating patents in Britain, the U.S and some other industrial nations.

The history of polyethylene as a plastic began in 1932 with a recommendation by the Dyestuffs Division of ICI to the effect that useful and interesting results could be

achieved with very high pressure reactions (greater than 20,000 p.s.i.)--well above what were then employed in industry.[1] Earlier scholarly work, particularly that of P. W. Bridgman and James B. Conant at Harvard, indicated that polymerization reactions, among others, would be strongly assisted by such pressures. Some 50 reactions were tried and results were disappointing in all cases. One of these "disappointments" was recognized as a polymer of ethylene. In the spring of 1935 the series of experiments was reviewed and a research investment decision was made to go on with the attempt to polymerize ethylene. In December another trial was made and a laboratory accident brought about the creation of eight grams of polyethylene. A leak in the apparatus had steadily introduced oxygen, which proved to be a necessary catalyst to sustain a rapid reaction.

Thus, low density, high pressure process polyethylene was invented as a result of basic, long-range research investments, financed by the dominant chemical company of Great Britain. It was a classic example of serendipity.

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[1] A full description of this research is available in Polythene, edited by A. Renfrew and Phillip Morgan, Chapter 1, "History of Polythene." J. C. Swallow, Second Edition (Iliffe & Sons, Ltd., London, 1960). [In Great Britain polyethylene is known by the ICI trade name, polythene].

The marginal cost of the polyethylene research itself was modest, but only firms willing to undertake substantial basic research with little prospect of immediate returns could have made this effort. Notably, even ICI found it desirable to employ complementary R&D assistance, in the form of equipment and researchers previously employed at Amsterdam University,

The next phase of research effort by ICI was directed toward developing an efficient, large scale production process and commercial end uses. It became apparent that the manufacturing problem could be solved any one of three ways: (i) by forcing ethylene rapidly through tubular reactors, and extracting the heat through the walls of the tubes, (ii) by introducing a liquid or diluent to absorb heat and carry away the polymer, or (iii) by introducing ethylene at a cool temperature while the heated polymer and resin gas continuously left the reactor chamber. The end use problem was solved almost immediately when producers of submarine cables expressed great interest in the new resin because of its excellent insulating and water resistant properties. On the basis of submarine cable demand a plant was erected with capacity to produce several hundred tons of polyethylene a year. The plant was put on stream about September 1939, the beginning of the war.

Meanwhile, ICI's patent people took care to claim property rights to the discovery of this process for polymerizing polyethylene. Applications were filed in many countries and patents were obtained. The basic patent in the U.S. on a process for producing low density polyethylene with pressures ranging from 500 to 3,000 atmospheres was obtained in April 1939 as a result of an application filed in February 1937.[2] This gave ICI both a product and process monopoly in the U.S. (The first application anywhere had been filed in the United Kingdom in August 1936, about 8 months after the main elements of the basic process were discovered. A patent monopoly was obtained there and in a number of other important industrial countries.)

Technological progress up to this point clearly involved some kind of subsidy; costs were substantial and benefits were much too uncertain for this effort to be financed as an independent venture by the capital market. Government

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[2]U.S. patent No. 2,153,553. The Patent Office segregated the oxygen catalyst claims from the basic patent, and issued a patent covering this catalyst in January 1940, U.S. patent No. 2,188,465. This pair of patents then became the dominating basic claims on low density popyethylene.

funds, monopoly profits, or at least ordinary profits pooled from operations in many markets were needed to compensate the extra costs and risks of innovation. In this case, ICI, as the dominant chemical company of Great Britain had ample extra financial strength to carry on the costly development work needed to develop a workable, high pressure process for polyethylene, provided there was sufficient possibility of significant rewards. Patent protection was a significant incentive, but with ICI's technical lead, and its financial and marketing resources as the dominant British chemical firm, it also had substantial headstart advantages over other potential producers.[3]

Then a need arose for electrical insulation material for high power and high frequency cables in radar equipment. Polyethylene was found to be the best insulation material available.

> The availability of polythene transformed the design, production, installation, and maintenance problems of airborne radar from the almost insoluble to the comfortably manageable.

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[3]ICI's necessity for patent protection in this particular case is doubtful because its dominance and headstart gave ample prospect of leading the British polyethylene market for years. However, if the inventor of polyethylene had been a much smaller U.S. or British company, patent protection would almost certainly have been necessary at this stage to mobilize capital and engineering talent on a sufficient scale.

> Polythene was an essential element in that 'single technical device' to which the Fuhrer as ascribed the 'temporary', but as it proved, enduring, set-back experienced by the U-boats.[4]

A larger production plant was soon erected and almost all polyethylene produced during the war was used in radar.

The fall of 1941 was the beginning of U. S. polyethylene development. ICI granted DuPont a straight, royalty-free license under their long standing, exclusive cross licensing arrangement, which covered most products produced by both companies.[5] The license operated throughout the war effort. When it was learned DuPont was experiencing delays and difficulties in production, Union Carbide requested and was encouraged to engage in the manufacture of polyethylene for the war effort. The U.S. Government extended immunity from the ICI patents during the war period, and a pilot plant was constructed for the Navy.[6] Later, in December 1942, the Navy Department, realizing that the available facilities would be inadequate for

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[4]Sir Robert Watson Watt. Polythene, p. 7, cited supra.

[5]"The Polyethylene Gamble," Marshall Sittig, Fortune, February 1954.

[6]Testimony of C. M. Blair, in The Matter of Union Carbide, FTC Docket No. 6826.

urgent wartime demand for polyethylene, signed a contract with Union Carbide, and financed a commercial scale installation at South Charleston, West Virginia. By the spring of 1943 this facility was producing polyethylene, some months ahead of the DuPont plant.[7] Toward the end of the war production of the two firms reached a peak of 8 million pounds per year or about 1 percent of U.S. plastics production.[8]

Government intervention and subsidy thus combined with the shortrun market opportunity to encourage two U.S. polyolefin producers. No other volunteers for polyethylene resin development appeared in the U.S. during the war. This duopoly reflects a double inhibition on other entrants, (i) ICI's patent monopoly and (ii) the inherent technical difficulties of working with very high pressures, with only limited prospects for shortrun demand. Most likely each of these two factors was sufficient to deter any other participants at this stage in market development. In other words,

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[7]Part of the reason for Carbide's superior performance was its Linde Division's prior research into very high pressure in connection with gases and synthetic gems. William T. Cruse, testimony before Senate Antitrust Subcommittee, September 20, 1967.

[8]This is a War Production Board estimate.

once ICI was induced to license its technology, headstarts would probably have been a sufficient incentive for either DuPont or Carbide.[9]

Postwar development until 1952

The next phase of development effort focused on finding other end uses, since at the end of World War II the demand for radar cable coating contracted greatly. One of the first new markets was in replacing lead jacketing for many telephone cables. This required new stabilizers to improve stress cracking and weather resistance. Another new market was as a packaging film. This had appeared already during the war for mepacrine (anti-malaria) pouches, and then after the war for sausage cases, frozen food wrappings, tablecloths, drapes, baloons, and garment bags. These applications required stabilizers and treatments to prevent slippage, to eliminate excess stickiness, to improve uniformity and clarity, and to reduce deterioration from oxidation. As a molding material, polyethylene soon found

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[9]While ICI might have preferred to exploit the U.S. market on its own in peace time, its long-term technology exchanges with DuPont implied respect for each others home market, and made a license more likely. In any event, wartime restrictions on British capital investment abroad made any direct ICI investment in the U.S. impossible in the early 1940's.

use in blown squeeze bottles, buckets, toys, containers for juice and other foods to be kept in refrigerators, and dividers for ice cube trays. Extruded pipe and hose was developed as an end use in this period and also a beginning in coating paper was made.[10]

During the period 1945-52 all of the present end uses for the polyolefins had been developed to some degree, except as a fiber, and even in this form experiments with fishing line had been carried out.[11] The main contributors to this development were Union Carbide, DuPont, ICI, and at least several of the larger plastic product fabricators--Visking, Plax, Injection Molding Company, and Dewey & Almy.[12]

All of these companies were actively engaged in resin production or fabrication of end products during this period, and to a great extent financed their developments out of growing sales revenues. These companies enjoyed incentives

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[10]This listing of end use applications up to 1952 is based on the new product commentaries regularly appearing in Modern Plastics in the period 1945-52.

[11]The tensile strength of low density polyethylene was insufficient for use as a fiber, and this end use was only exploited by a polyolefin when polypropylene became available in the late 1950's.

[12]The four smaller firms had between $5-25 million annual sales in the late 1940's, but grew significantly, and all were acquired by resin makers between 1951-61.

for further investments flowing from headstart advantages. Such advantages provied to be important in succeeding years, consisting of both lower costs and superior quality of products. This led to greater profits than those of later entrants, or what might be considered a rent on superior ability.[13]

The security of patent protection also operated as an incentive for Carbide and DuPont during these years, but probably did not become a significant source of extra profitability until the early 1950's, when other potential entrants could have entered. But for compulsory licensing in 1952, patent sheltered profits undoubtedly would have been greater on resin manufacture in succeeding years. However, despite the issuance of many patents on polyethylene fabricating, patents proved to be an ineffective barrier to new entry in fabricating.[14]

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[13] See Chapter VI, _infra_, at pp. 254-258.

[14] The main reason was that plastic fabricating machinery had largely been developed already and little patent dominance existed. Only minor refinements were needed to process polyethylene. Consequently, little additional opportunity for market dominance existed, and inventing around was relatively easy. Another factor was that Carbide and DuPont held many of these fabricating patents, and being only resin suppliers interested in maximizing resin sales, they had little desire to restrict new entry of fabricators.

By 1948, output was still only about 17 million pounds.[15] But then production and usage began to grow more substantially, with output reaching about 100 million pounds in 1952, or about 4 per cent of U.S. plastics output.[16] Throughout this period, Union Carbide and DuPont were the only polyethylene resin producers.

As process "bugs" were eliminated, resin properties were improved and end use market applications were developed, polyethylene became increasingly attractive as an investment opportunity for new entrants. The costs and risks of entry became more predictable and the new evident growth prospects made it clear there was room for more producers of polyethylene and polyethylene end products. By the early 1950's polyethylene was increasingly recognized by chemists as a valuable, widely useful resin:

> It would be very easy to say that polyethylene 'had everything,' and indeed such claims were made. Polyethylene certainly had serious limitations, but it also had a number of properties that made it extremely attractive. To the polystyrene molder beset by complaints about the brittleness of his products

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[15] The Chemical Industry: Viewpoints and Perspectives, edit. by Conrad Berenson, John Wiley & Sons, Inc., (1963), p.92.

[16] Francis Bello, "The New Breed of Plastics," Fortune, Nov. 1957, p. 172, and Synthetic Organic Chemicals, 1952, U.S. Tariff Commission. Annual production capacity for LDPE was 125 million pounds in early 1953. Oil & Gas Journal, May 18, 1953, p. 218.

> it offered a material almost indestructible in everyday use, at a price not too much above that of his own material. To the vinyl extruder, fighting corrosion problems and encountering troubles due to plasticizer odor, or plasticizer migration, polyethylene was a material which contained no troublesome chloride to corrode equipment, and which was permanently flexible without the use of a plasticizer. Limited experience had indicated that it molded at least fairly well, extruded quite easily and once you got the hang of it, it could even be calendered to a reasonably good sheet.[17]

Polyethylene had by then, and perhaps several years earlier, passed the initial phase of invention and innovation when an extra subsidy was needed to sustain progress in technology and market development. Ordinary market forces and profit incentives could now take over in stimulating further development.

Profits from polyethylene resin production in the early 1950's appear to have been substantial, and further prospects were excellent. Average resin costs were probably not much above $.20 per pound, even allowing for reasonable amortization of capital investment and further research and development efforts.[18] Resin prices had been dropped substantially

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[17]Polyethylene, T.O.J. Kresser, Spencer Chemical Company (Reinhold, 1957), pp. 5-6.

[18]These cost estimates are based on the experience of new entrants in the late 1950's, who did not then have access to the most efficient and up-to-date processes. By the late 1950's average costs for Carbide and DuPont with large scale plants were being reduced to not much above $.10 per pound. See Chapter II, pp.87-100 for further discussion.

soon after the war from $1 per pound, and ranged around $.45-.50 per pound through 1954.[19] Demand growth potential was correctly foreseen as rapid and as many times that of the current production volume. Minimum efficient scale at this stage allowed room for a number of additional producers in the next few years. Hence, profit prospects invited substantial new entry.

But patents remained an absolute barrier to entry in resin production. ICI's basic product and process claims were reinforced by a considerable number of improvement patents. Some of these patents were ICI's but others had been obtained by its licensees, DuPont or Carbide.[20] The effect was to limit ICI's freedom to license additional U.S. producers, and to protect the exclusive duopoly position

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[19] Polyethylene sold at $1 per pound list price during World War II. List prices were dropped by Carbide and DuPont to $.52 in 1946, $.47 in 1947 and $.43 in 1948, in an obvious attempt to stimulate peacetime consumption. List price was moved up slightly during the Korean War to $.45 in 1950, and $.48 a pound in 1951, but dropped to $.47 in 1952. <u>Modern Plastics</u> published this series of list prices on base grade plastics through 1961. This series is reasonably accurate for polyethylene until 1958-59, when off-list discounting became prevalent in polyethylene. See Chapter VI, pp. 254-58 , for further discussion.

[20] By the end of 1952, DuPont obtained 45 such improvement patents on low density resin making, Carbide 8, and ICI 6.

Table III-1.--Polyolefin resin producers in the U.S.
(Years of entry and exit indicated)

LDPE	HDPE	PP
Union Carbide (1942)		
DuPont (1942)		
Eastman Kodak (1953)		
Monsanto (1954)		
Dow (1954)		
Spencer (1954) 1/		
National Distillers (1954) 2/		
Koppers (1954) 3/		
	Phillips (1957)	
	Hercules (1957)	Hercules (1957)
	Union Carbide (1957)	
	Koppers (1957) 3/	
	Grace (1958) (sold to Allied in 1965)	Avisun (1958) (sold to Standard Oil (Ind.) in 1967)
	Celanese (1958)	
Allied (1959) (narrow spectrum wax)		
Rexall (1960) 4/	DuPont (1960)	Eastman Kodak (1960)
	Dow (1960) 7/	Standard Oil (N.J.) (1960)
Foster-Grant (1961) (dropped out in 1962)	Goodrich Gulf (1961) (dropped out in 1963)	Dow (1961) (dropped out in 1968)
		Montecatini (1961)
		Firestone (1961) (dropped out in 1964)
		Shell Oil (1962)
	National Petrochemicals (1964) 6/	Rexall (1964) 4/
		Phillips (1965) 6/ (sold to Diamond-Shamrock in 1967)
Standard Oil (N.J.) (1967)	Monsanto (1967)	
Chemplex (1968) 5/	Chemplex (1968) 5/	
	Gulf (1969) 8/	
Phillips (1972) 6/	Standard Oil (Ind.) (1970) 9/	

1/ Spencer was acquired by Gulf in 1963.

(Footnotes continued on next page.)

2/ National Distillers constructed in 1968 a plant for Cities Service under an agreement by which National Distillers agreed to operate the plant for Cities Service.

3/ Sinclair reinforced Koppers in a joint venture agreement in 1965.

4/ El Paso Natural Gas reinforced Rexall in a joint venture agreement in 1964.

5/ Joint venture of American Can and Skelly Oil.

6/ The entries of Phillips and National Distillers were made initially in the form of a joindre of their respective polyolefin operations. After the Federal Trade Commission challenged this arrangement under Section 7 of the Clayton Act, the two companies agreed in a series of consent settlements to the following disposition: (i) a newly constructed polypropylene plant was sold to Diamond-Shamrock, a joint venture of Diamond Alkali and Shamrock Oil; (ii) Phillips agreed to continue its license to National Distillers in high density polyethylene; (iii) National Distillers agreed to license Phillips in a newly constructed plant for low density polyethylene, which Phillips agreed to put into operation by 1972. Thus, net new entry resulted in each of the polyolefin resin markets.

Owens-Illinois has been involved from the outset as part owner in the National Distillers' high-density polyethylene plant, operated as National Petrochemicals, a joint venture.

7/ Dow has announced that it is closing its two small scale high-density polyethylene plants, but will build a larger scale plant in the future using a new process of its own.

8/ Gulf has obtained a Phillips license for high-density polyethylene, and its plant is scheduled for operation in 1969.

9/ Standard Oil (Ind.) is constructing a high-density polyethylene plant, scheduled for completion in mid-1970.

Source: Directory of Chemical Producers, Standard Research Insitute, Menlo Park, Calif., July and October entries, 1968. For the polyolefin plants in operation at mid-1968, see Appendix Tables III- 1, 2 and 3, infra.

of DuPont and Union Carbide.

Low density polyethylene after compulsory licensing in 1952

Then in 1952 an important external factor greatly increased the growth in use of polyethylene and enhanced its development. This was the compulsory licensing decree arrived at in the "International Chemical Cartel" case, which found DuPont and ICI guilty of monopolizing many chemical products by a longstanding, exclusive cross licensing arrangement, covering both patents and know-how.[21]

Judge Ryan's final decision, holding that ICI and DuPont had restrained trade by their exclusive cross-licensing of technology, required both companies to license immediately all "bona fide" applicants, at a reasonable royalty, under all patents and know-how held by the two defendants. A large number of chemical products were covered by the decree; polyethylene was just one of the many. Post-decision activity with respect to polyethylene took the form of direct negotiations with the London firm.

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[21] U.S. v. Imperial Chemical Industries, 105 F. Supp. 215 (S.D.N.Y.; decision in 1952, final judgment settled in 1953). The Justice Department's complaint against this licensing arrangement, which had originated in complementary research and patent cooperation back in 1890, was brought in 1944 under the Sherman Act.

To expedite matters, ICI sent a group of representatives to their subsidiary at New York in September 1952. Within four months, over two dozen U.S. firms had made contact with ICI about possible licenses on polyethylene.[22]

These American companies were bargaining for a package containing a "manual," which described the technique of any process covered by the ICI patents, the patents themselves, and associated technical help. The price for the package was a $500,000 down payment on a cumulative series of royalties which specified at least $2 million as minimum cost for access to polyethylene know-how and a patent license.[23]

Six companies promptly took licenses: Monsanto, Dow, Eastman Kodak, Spencer, National Distillers and Koppers (Table III-1). What had been a duopoly in 1952 with about 100 million pounds of production, quickly became in 1954 an 8-firm oligopoly with 516 million pounds of production (Table III-2). Growth in output temporarily outstripped consumption and slumped in 1955, but from 1956

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[22]Marshall Sittig, "The Polyethylene Gamble," Fortune, Feb. 1954, pp. 136 and 166.

[23]Sittig, ibid., p. 133.

TABLE III-2

LOW DENSITY POLYETHYLENE PRODUCTION AND CONSUMPTION, 1952-68[24]

Year	Production (in m.lb.)	Percent change	Consumption (in m.lb.)	Percent change	Dollar sales	Percent change
1952	100					
		+516.0				
1953	N.A.		137			
				+51.1		
1954	516		207			
		-22.1		+69.1		
1955	402		350			
		+40.8		+44.9		
1956	566		507			
		+ .9		+24.3		
1957	571		630			
		+34.9		+34.1		
1958	770		845			
		+40.3		+20.8		
1959	1,080		1,021		248.0	
		+ 4.0		+ .3		-12.7
1960	1,123		1,024		216.6	
		+17.3		+28.8		+ 5.7
1961	1,317		1,319		229.0	
		+22.0		+19.9		+13.3
1962	1,607		1,581		259.4	
		+ 9.1		+ 9.4		+ 6.1
1963	1,754		1,730		275.3	
		+11.5		+11.6		+16.5
1964	1,955		1,930		320.8	
		+15.8		+ 6.0		+ 7.5
1965	2,263		2,046		344.4	
		+17.0		+13.4		+16.7
1966	2,268		2,321		402.0	
		+23.5		+12.0		
1967	2,800		2,600			
		+10.7		+15.4		
1968	3,100		3,000			

onward growth has been, for the most part, rapid and sustained. By 1959 industry production was 1.08 billion pounds, and a decade later in 1968 it reached 3.1 billion pounds.[24]

Since the six firm burst of entry in 1953-54, two other firms entered successfully in 1959-60, and two more entered in 1967-68. Allied began producing a limited spectrum wax resin in 1959, while Rexall came on stream with an ICI license in 1960. (Foster-Grant entered briefly in 1961-62 with a small plant, but abandoned this effort when it decided the projected 12 million pounds of annual capacity was too small to be efficient, and that it preferred not to expand its investment beyond a $3.5 million level.)[25] In 1965 National Distillers sold one of its two plants to Phillips as part of their polyolefin joint venture. Under the consent decree divesting this joint venture, this plant

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[24]Production, Consumption and sales 1954-66 from Synthetic Organic Chemicals, U.S. Tariff Commission; production for 1952 from Francis Bello, supra, p. 7; and consumption and production estimates for other years from Modern Plastics.

[25]Even the small scale effort which Foster-Grant did make was financed to a substantial degree by Socony-Mobil, its ethylene feed-stock supplier, with a $2.5 million loan.

was returned to Distillers,but Distillers agreed to license Phillips for a new plant to be constructed by 1972. Then in 1967-69 Chemplex (a joint venture of American Can and Skelly Oil), and Standard Oil (N.J.) came on stream.[26] Consequently, in 1968 there were 12 active producers of low density polyethylene in the U.S., and another was in prospect by 1972. (For current plant locations and capacity estimates, see Appendix Table B -1).

Concentration declined fairly steadily over recent years as new producers came on stream, although it remains relatively high. The share in production of the four largest firms was 87.6 percent in 1955, 75.9 in 1959, 70.2 in 1962, and 61.3 in 1966.[27] Market concentration to this degree often results in conscious oligopoly interdependence, and either collusive or tacit understandings as to price levels. However, the continued rapid growth of LDPE demand tended to encourage further entry, produced recurrent excess capacity, and led to sustained competitive pressures on price levels.

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[26] Chemplex obtained process licenses from DuPont and National Distillers, while Standard Oil (N.J.) purchased process know-how from Rexall.

[27] FTC survey data for 1955-62, and Tariff Commission tabulation for 1966.

As a result competitive rivalry drove prices down from \$.47 lb. in 1952 to about \$.16 lb. currently. A major factor in causing this decline in price level has been recurrent excess capacity, which was especially severe in the late 1950's and early 1960's, when the most rapid decline in prices occurred.[28] List price for base grade, low density polyethylene remained at \$.47 lb. until 1955, the year when the six new producers actually entered production. Then list prices went down to \$.41 lb. That level was maintained until 1957, when a \$.35 lb. price was established. In 1959, a more rapid downtrend began in price, with an increasing use of off-list discounts by all suppliers. (From this point the average prices on shipments as recorded

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[28]The mechanism by which excess capacity reduced prices involved the newer entrants, usually with the greatest degree of excess plant capacity, experiencing low marginal costs. Such firms "dumped" their resin, sometimes also of inferior quality, at sacrifice prices. The industry list price "leaders" like Carbide and duPont, were forced to follow downward the price shading of their weaker rivals. But with their greater efficiency, the leaders were still able to make a profit.

One might interpret this strategy of the price leaders as a conscious policy to forestall entry but the facts are ambiguous. It is not clear whether the list price leaders merely followed prices down, or helped to drive them down. But it is clear that further entry was discouraged somewhat by price reductions and losses for later entrants. This discouragement applied especially between 1962-65, in the aftermath of the most rapid price reductions. No new entry occurred between 1962-65.

by the Tariff Commission are the best index of price levels.)[29]

By 1963 average prices had reached $.18 per pound. For several years the price level stabilized at $.17 lb. and some producers made attempts to increase prices as excess capacity was gradually reduced. But along with the new entrants of 1967-68 significant excess capacity again became evident, and average prices fell slightly by late 1967 to a level of roughly $.16 per pound.[30] Further efforts to raise the price level were made in 1968, and with the help of stronger inflationary pressure in the economy as a whole, prices may finally be rising slightly.[31]

Profits were squeezed for all producers when prices declined most rapidly, but Carbide and DuPont were still able to make a substantial return on their investment.

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[29] Synthetic Organic Chemicals, U.S. Tariff Commission, reports average prices per pound as follows: 1958, $.32; 1959, $.32; 1960, $.28; 1961, $.23; 1962, $.21; 1963, $.18; 1964, $.17; 1965, $.17; 1966, $.17. Modern Plastics reports the 1968 market price as $.16.

[30] Modern Plastics, January 1968.

[31] Most of the LDPE producers announced 1¢ lb. price increases which were reported in the Journal of Commerce on various days in the last three months of 1968. According to subsequent reports from some polyethylene film makers who purchase a large volume of LDPE, this price increase, unlike some other attempts in recent years, has been effective.

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The leaders were enjoying this profitability because of their headstart advantages. Some of the less successful LDPE entrants, however, suffered annual losses for 4 or 5 years running. The causes of such losses were typically process inefficiency, inferior resin quality and lower selling prices, and either too small a plant or an efficient plant operated substantially below capacity. As most resin makers caught up in process efficiency and expanded their sales, they tended to catch up in profitability with the leaders.[32]

The dual causes of recurrent excess capacity in the low density polyethylene market were the continued rapid increase in demand, and the loose oligopoly structure achieved as a result of compulsory licensing. The demand increases encouraged new entry. Then compulsory licensing allowed this entry to take place. Without this reduction of patent barriers to entry it is likely that only 4-5 firms could have entered production.[33] Once an oligopoly market structure had been established, it became very difficult to coordinate output and prices among 8-12 firms

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[32] See Chapter VI, pp. 254-58.

[33] See Chapter IV, where this effect is discussed at more length, at pp. 196-201.

in the face of rapid demand growth. A strong rivalry in capacity expansion led to recurrent excess capacity, which in turn led to softening of the price level, discounting and a tendency for prices to follow costs downward. Hence, compulsory licensing led to greater output and lower prices than would have been the case without it.

In addition, the energies devoted to further research and development were substantially increased as a result of compulsory licensing. Certainly the R&D budgets devoted to polyolefins increased because of the extra participation in the market.[34] This R&D effort took the form of enhanced rivalry to develop additional end uses, improve resin properties, and lower cost of production. The effectiveness of this effort was reflected in improved properties and reduced costs of production, both which reinforced the rapidly increasing demand and the decline in prices.

The greater diffusion of R&D effort as a result of compulsory licensing is also reflected in a shift in the

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[34] Limited information was reported to the FTC on their polyolefin R&D outlays by a few of the polyolefin resin makers for the period 1959-62. Annual budget allocations ranged from several hundred thousands of dollars up to $3.8 million for individual years. If this data is representative, at the very least several million dollars of extra R&D effort each year was contributed by these new entrants.

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distribution of successful U.S.patent applications on low density polyethylene resin manufacture.[35] Through 1952, when the ICI and DuPont-Carbide group ceased to have patent dominance, DuPont made 45 such applications, Carbide made 8 and ICI 6. Meanwhile, all other companies and individuals made 65 successful applications in this period, the majority of which concerned narrow spectrum waxes and related copolymers which were not really plastic materials. After 1952, when compulsory licensing gave equal access to technology for all producers of low density polyethylene, the distribution of successful patent applications relating to low density polyethylene was altered significantly. In the decade 1953-63, Carbide received 41 such patents, DuPont 8, the new resin makers (traceable to compulsory licensing) a total of 54,and all

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[35]These tabulations are based on a nearly exhaustive set of the polyolefin resin patents issued through August 31, 1963, as reported both (i) by the polyolefin resin makers to the FTC, and (ii) by the Patent Office with respect to the polyolefin category among chemical polymer patents. Most popyolefin fabricating patents issued to resin firms in this period were also reported, but those issued to smaller firms and individuals were reported only to a lesser extent.

other firms a total of 31.[36]

The development and growth of high density polyethylene

Until about 1940 it was assumed by the British researchers who developed polyethylene that their polymer was a linear, long chain hydrocarbon. But infrared studies of polyethylene molecules revealed that there were also side-branches among the chains. Then it was realized that if the chains could be formed with less side-branching, a higher density and stronger resin could be expected.[37] This aroused some research interest with ICI, DuPont, Standard Oil (Ind.), and perhaps elsewhere, but no commercial process resulted.

Then in early 1954 rumors circulated in the chemical industry that linear, high density polyethylene was a

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[36] In contrast, the pattern of successful fabricating patent applications concerning low density polyethylene reflects a lack of domination by ICI, DuPont, or Carbide. In fabricating, of course, the ICI-DuPont-Carbide group had no effective patent dominance. Through 1952 DuPont received only 16 and Carbide 4, while other firms received 76 of these patents. Between 1953-63 Carbide received a somewhat larger share with 36, DuPont 16, there were 61 for the next 6 entrants, and a substantial additional number for other firms and individuals.

[37] _Polythene_, _op. cit._, pp. 8-9.

commercial possibility.[38] In June Phillips Petroleum Company revealed in an Australian patent application that they had a low pressure process for polymerizing a high density polyethylene.[39] * Eleven months later Professor Karl Ziegler of the Max Planck Institute at Manheim disclosed elements of his low pressure process for high density polyethylene in a Belgian patent.[40] * Then, new and major significance was attached among major firms in the chemical industry to a laboratory process and a series of

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[38] "The German Bombshell--Early in 1954 the plastics industry began hearing rumors that a German professor, Karl Ziegler, had devised a simple low pressure polyethylene process that might obsolete the original process. Whether the new German product exactly duplicated the standard material or had improved properties was not clear from first reports. The rumors seemed almost unbelievable, for some of the world's finest industrial chemists had been trying for years to devise a new process." Francis Bello, "The New Breed of Plastics," Fortune, November 1957.

[39] Australian Patent Application 764/54 (June 8, 1954), Phillips Petroleum Company.

[40] Belgian Patent 533,632 (May 5, 1955, Karl Ziegler).

* Both Belgian and Australian patents are obtained by a declaration which is publicly disclosed at the outset. Then any challenge to the novelty of an invention is litigated. The U.S. patent system, on the other hand, is based on a secret application which is prosecuted as a confidential legal proceeding by patent attorneys before the U.S.Patent office, which appraises the evidence on "invention" and "reduction to practice," and then either grants or denies the application. A granted patent is then published, whereas a denied application is not published and merely becomes a dead file in the Patent Office.

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patents on high density polyethylene which had been developed since 1943 at the Battelle Memorial Institute in Columbus, Ohio, under the sponsorship of the Standard Oil (Ind.)[41]

Therefore, by mid-1955 three alternative processes for high density polyethylene were generally believed to be available -- the Phillips, the Ziegler, and the Standard Oil of Indiana. Although it was likely that each of these might receive some degree of patent protection for their own processes, it was not at all clear who, if anyone, might receive any product patent rights to high density polyethylene.[42] Then it soon became apparent that Ziegler's U.S. patent attorney had failed to fully describe his catalysts, leaving one process unprotected by patent claims, so far as the U.S. market was concerned. Ziegler was then only able to sell process know-how, not a patent

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[41]The first patent was applied for in December 1946 and was issued in July 1949. A pilot plant was erected at Whiting, Indiana, and a small amount of polymer was tested with a fabricator. The product was found suitable for waxes and some molding, but not extrusion, because of excessive cross-branching among chains of molecules. Little interest had been aroused by this Standard Oil of Indiana process and its patents, however, until the summer of 1954. "Standard Oil Company (Indiana) Polymerization," Edmond L. D'Ouville, Polythene, op. cit., pp. 35-41.

[42]It is common in chemical industry patents for there to be many independent processes for a product, whereas each product normally has only one, if any, dominating patent claim.

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protected license to use his process.

Consequently, the strength of patents as a barrier to entry into high density polyethylene was greatly reduced at the outset, as compared to the early development of low density polyethylene. Furthermore, the recent extension of LDPE technique to six new producers made for a considerably larger number of likely potential entrants. This was because LDPE producers had useful know-how which would greatly assist them in making an entry into HDPE. The effect of reduced entry barriers and an enlarged circle of likely entrants was quickly made evident in rapid new entry.

Phillips began a plant of its own and licensed Union Carbide and two newcomers, W. R. Grace and Celanese. All four began production in 1957-58 on this process. The Ziegler process know-how was licensed directly or indirectly to Union Carbide, Dow, Monsanto, Koppers, plus two newcomers, Hercules and Goodrich-Gulf.[43]

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[43]The Ziegler process was never sold as a fully developed package of patent rights and manufacturing know-how, as was the Phillips process. Ziegler licenses only received limited patent protection and partial process know-how, and they had to provide much of their own manufacturing technique. As a result, some Ziegler licensees were slower in coming into production. All that Ziegler offered were "recipes for catalysts." Bello, Fortune, February 1957, p. 172.

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All six of them eventually entered, four of them before 1960.[44] During the 1955-57 period, the Standard Oil of Indiana process also was licensed to Spencer and Eastman Kodak, both already producers of low density polyethylene. But neither company ever got into production; so far the only companies employing the Indiana process are in other countries--Furukawa of Japan in 1963, and Rumianca of Italy several years later.

Hence, seven of the eight LDPE producers active in 1955-57 took some immediate action toward producing the complementary product, high density polyethylene, as soon as it became commercially practicable for them to do so.[45] Meanwhile, four entirely new polyolefin firms--Phillips, W. R. Grace, Celanese, and Hercules--were constructing plants for high density polyethylene.

> By the summer of 1956, before a single commercial plant was in production, a low pressure polyethylene capacity had been planned to produce no less than 395 million pounds a year--a production twice as large as that which had been attained by cellulose acetate in

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[44]Union Carbide built two high density plants, one for each process.

[45]The only exception was National Distillers, which did eventually enter in 1964 by joint venture with Owens-Illinois, the leading fabricator of high density polyethylene blow-molded containers, the most important end use. Later Allied made its decision to produce a medium density polyethylene for limited wax and coating purposes.

> 1955 after 20 years of steady growth, and greater than the total 1955 production /actually, sales/ of polyethylene. This tremendous capacity was planned for a material that had only been tested in pilot plant quantities; it had never been tested to determine its true position in the market.[46]

This remarkable entry performance indicates how the patent situation and demand potential had combined to make new entry relatively easy and attractive.

The pioneering phase with respect to high density polyethylene had evidently been completed by the time all this new entry took place. Market forces were clearly able to undertake further development without any special subsidy.[47] An absence of dominating patents allowed market forces to carry forward a speedy industrial development when this invention and innovation had been completed. Development was unusually rapid even for the plastics industry, which has generally been distinguished by rapid technical progress. Output of high density polyethylene

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[46] Polyethylene, T.O.J. Kresser, op. cit., p. 6.

[47] However, just what special incentives were needed to bring high density polyethylene to this stage is not so easy to unravel. As was the case with low density polyethylene and ICI's research, some subsidy was evident in the basic research of Ziegler's Max Planck Institute, the Battelle Institute, or Phillips, and in the parallel research conducted by duPont. All of these research organizations enjoyed funding from substantial operations in many markets, while the hope of

moved up more rapidly than consumption for a considerable period, and great excess capacity ensued through the early 1960's. (Table III-3). For a while HDPE producers ceased to expand their plants, as consumption caught up with capacity.

But in 1964-68 three more firms entered high density polyethylene production.[48] Two of these were already involved to some degree in fabricating high density polyethylene containers, the dominant end use. Some economies of integration were involved, including at least a know-how, or marketing advantage relative to firms with no prior polyolefin experience. In 1964, National Distillers and Owens-Illinois jointly entered high density resin production, based on know-how obtained by Distillers in a joint venture relationship with Phillips. Owens-Illinois was then one of the leading consumers of high density polyethylene as a bottle producer, and Distillers

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profitable patents contributed somewhat to the total of incentives for such basic research. Small firms would have been most unlikely to carry on this early speculative research.

[48] Goodrich-Gulf (a joint venture originally set up in the early 1950's to purchase government rubber plants) also entered in 1961, but dropped out in 1964, being unsuccessful in attempting to develop a largely independent and patent-protected process of its own.

TABLE III-3

HIGH DENSITY POLYETHYLENE PRODUCTION
AND CONSUMPTION, 1959-68

Year	Production (in m. lbs.)	Percent change	Consumption (in m lb.)	Percent change	Millions of dollars sales	Percent change
1959	111.9		72.2		24.2	
		+87.2		+74.1		+79.3
1960	209.5		125.7		43.4	
		+32.4		+78.3		+61.1
1961	277.4		224.1		69.9	
		+52.1		+44.9		+36.9
1962	422.0		324.8		95.7	
		+22.3		+20.8		- 3.9
1963	515.9		392.5		92.0	
		+27.6		+40.3		+23.8
1964	658.3		550.5		113.9	
		+18.5		+34.4		+ 5.3
1965	780.0		740.0		119.9	
		+16.7		+12.2		+21.8
1966	910.3		830.6		146.0	
		+20.8		+24.3		
1967	1,100.0		1,032.0			
		+13.6		+16.3		
1968	1,250.0		1,200.0			

Source: Same as Table III-2.

was a leading low density polyethylene producer. Monsanto finally began its production in 1967, although it had been fabricating containers since it acquired Plax in 1957 and was a major low density polyethylene producer. Another joint venture, Chemplex (American Can-Skelly Oil), entered in 1968--American Can was already one of the leading plastic container fabricators. In 1969 Gulf is scheduled to come on stream with its new plant, and Standard Oil (Ind.) is also constructing a plant using its own process. This made a total of 12 high density polyethylene producers scheduled for production in 1969.[49]

Concentration declined somewhat over recent years along with this new entry, but remains relatively high. The share in production of the four largest producers was 75.4 percent in 1959, 65.1 in 1962, and 55.1 in 1966. The lower level of cencentration in high density as opposed to low density resin reflects the reduced importance of headstart advantages. Most of the high density polyethylene producers entered soon after each other, and there was less opportunity for

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[49]Meanwhile Dow announced plans to close its two plants -- one a Ziegler process and one a Phillips process, but indicated it would re-enter later with a plant using its own independent process.

obtaining a headstart for the leaders.

Prices for high density polyethylene experienced a rapid decline similar to that in the low density market, although the downslide lasted slightly longer with high density polyethylene.[50] List price for base grade was set initially at $.47 lb. by Phillips, the first producer in 1957. In early 1958 this was dropped to $.43 lb. and a year later to $.38 lb. and 8 months later to $.35 lb. Meanwhile, substantial off-list discounting had begun already in 1958. Average prices ranged as follows:

1958	$.33 lb.
1959	.33 lb.
1960	.33 lb.
1961	.32 lb.
1962	.31 lb.
1963	.23 lb.
1964	.21 lb.
1965	.18 lb.
1966	.18 lb.

Thereafter, prices do not appear to have changed much until the latter part of 1968, when a slight rise may have occurred.[51]

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[50] Modern Plastics and Synthetic Organic Chemicals.

[51] Journal of Commerce reports price increases by some producers in the last three months of 1968. This indicates attempts to raise the HDPE price level, but their success is not yet clear.

Profits were generally poor during the period 1959-63, but some improvement was evident toward the end of those years as scale increased, as process bugs were eliminated, and as excess capacity became somewhat less pronounced.[52] Profits for large scale producers have probably been moderate in the last few years.

The forces which drove prices down until recently on high density polyethylene were similar to those at work in LDPE. Rapid growth in demand attracted and made room for new producers, and the lack of a patent barrier on high density polyethylene then enabled this new entry. The lack of a strong barrier to entry on HDPE is traceable to a number of circumstances. The first factor was that the earlier, dominating patents on conventional polyethylene were subjected to compulsory licensing in 1952. This altered significantly the setting in which new investments into high density polyethylene had to be appraised, not only for new plants, but also for R&D development. Entry was now easy into the closely related, and much larger low density market, where most of the major technical problems had already been solved. This made research and entry into high density

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[52] See Chapter VI, pp. 258-262.

polyethylene more attractive, and added substantially to the number of firms which would be interested in it. This is illustrated by the fact that seven of the first eight producers of low density resin (all of which were producing in 1954-55), made at least a rpompt R&D investment into the new prospects for high density production. Eventually, all but one of these eight firms did enter high density polyethylene production.[53]

Other circumstances leading to an absence of dominating patents were that three independent processes were revealed almost simultaneously. Then when the U.S. patent attorney for one of them blundered and left it unprotected, this encouraged each of the process holders to license freely at the outset, knowing that no effective close-knit cross licensing pool could be arranged to limit entry.

Still another factor was that no basic product claim was awarded to any of the three apparently successful process holders. Instead, three years later in 1958, and after seven firmshad committed substantial investments

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[53] See Table III-1. The only LDPE producer which has not yet entered the HDPE market is Eastman Kodak.

toward high density production, duPont was awarded a weak composition of matter product claim. This was issued on the basis of DuPont's earlier lab work with very high pressures directed toward a higher density polyethylene. Since the other companies in the industry were well aware that DuPont did not have a workable, commercial process for high density polyethylene, this patent proved to be ineffective in disciplining the established producers, and proved in time to be a weak barrier to further new entry.[54] Therefore, even though process know-how remained scarce and actually became more valuable as headstart advantages for early producers lengthened, patents were not an important barrier to entry in HDPE when its present oligopoly structure was taking shape. Consequently, its relatively competitive market behavior at the outset was similar to the post-1952 pattern in LDPE.

The development and growth of polypropylene

In 1954, the year that high density polyethylene was announced as a practical possibility, Professor Gulio Natta of the Instituto di Chimica Industriale del Politecnico

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[54] See Chapter IV, *infra*, at pp. 173-175.

in Italy also made known his discovery of "isotactic" polypropylene to the world.[55] This basic research work was similar in financing and character to that which yielded the HDPE processes, but his contribution was more theoretical. His discovery increased understanding of

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[55]The significance of isotacticity in polypropylene is that such regular, but unsymmetrical spiral chains can interlock closely to form a crystalline structure, whereas an atactic polypropylene will not be regular or crystalline. Crystalline polymers are stiff, strong, impermeable to solvents, and highly resistant to heat. On the other hand, amorphous or largely atactic polymers are soft, weak, vulnerable to solvents, and rapidly softened by heating. A polymer which is a mixture of the two has intermediate properties.

Another feature of polymers which Natta revealed with polypropylene is "steroblocking" or ordered blocking. If a polypropylene chain starts off as one spiral variety of "isotactic" polypropylene, and then after maintaining this condition for awhile, reverses to become another spiral variety of polypropylene, we have a steroblock polymer. Steroblock polymers differ from each other greatly, because the length of the blocks can vary from very short to very long. Depending on how often the order of a steroblock polymer is reversed, the polymer shows more or less rubber-like properties. Generally, infrequent inversion in a long chain causes only a slight tendency to elasticity. When partial crystallization is combined with some inversion, a high tensile strength, yet elastic substance results which is stronger than vulcanized rubber. Yet this combination material can be handled with the flexibility inherent in a thermoplastic.

how hydrocarbon molecules generally could be linked in an ordered fashion.[56]

The commercial implications of this were that propylene, a more plentiful and potentially cheaper feedstock than ethylene, could be made into a strong, elastic polymer, with resistance to chemicals and heat resistance, high tensile strength and high surface hardness.

On the strength of its promise as a plastic, and the tempting possibility that Ziegler catalysts and polymerization equipment for HDPE could be modified fairly easily to

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[56]"Subsequent events, however, have shown that the most exuberant enthusiasts were conservative. Natta's work sparked a volume of research on polymerization never before approached. Within a short time the scientific literature was full of endless examples of stereospecific polymerization. The patent literature all over the world also soon showed the effect of this tremendous growth of scientific effort."

"Curiously enough, some of the most startling and perhaps, in the long-run, most valuable consequences of this work resulted not in polypropylene but in improved synthetic rubbers. The use of synthetic rubber had always been limited because the molecules produced in the factory had a random, irregular structure. This fact had been known for a great many years, and there had been much speculation as to the means whereby the living cell was able to direct the growth of the rubber molecule into this regular pattern.

"Professor Natta's work included some sterically ordered dienes. Thousands of researchers all over the world immediately saw that this might be the clue to the long-sought synthetic rubber that would really duplicate natural rubber." Polypropylene, T.O.J. Kresser, p. 1-2. (Natta and Ziegler received the Nobel Prize in chemistry for 1963 for their researches.)

produce polypropylene, an enthusiasm equal to that for HDPE quickly resulted in polypropylene plant investment. Seven major U.S. petrochemical companies and Montecatini of Italy built U.S. pölypropylene plants by 1962. Hercules and Avisun began production in 1957-58, and were followed in 1960-62 by Eastman Kodak, Standard Oil (N.J.), Dow, Shell, Firestone and the Montecatini subsidiary, Novamont. Although one of these, Firestone, quickly dropped out of production after several years, two more firms entered in 1964-65 -- the joint ventures, Phillips-National Distillers and Rexall-El Paso. Then Dow dropped out in 1968. This left the present oligopoly of eight firms in 1968.

Patents were no effective barrier to entry at first because polyolefin know-how had become fairly widespread, and because it was generally recognized that no important product patents were likely to be issued until the early 1960's. Ziegler failed to describe the relevant catalysts sufficiently to get a U.S. patent. This meant no dominating patent was likely to issue on the production process. With respect to any possible product claims, all prospective producers were aware that a complex, 5-party patent interference proceeding (Interference No. 89,634), involving DuPont, Hercules, Phillips, Standard Oil (Inc.), and Montecatini would take years to be resolved.[57]

TABLE III-4

POLYPROPYLENE PRODUCTION AND CONSUMPTION, 1959-68

Year	Production (in m.lb.)	Percent change	Consumption (in m.lb.)	Percent change	Dollar shipments	Percent change
1959	16.8		13.4		5.7	
		+194.4		+130.6		+126.3
1960	41.9		30.9		12.9	
		+161.1		+ 95.6		+ 80.6
1961	109.4		60.5		23.3	
		+ 30.6		+ 71.2		+ 49.4
1962	142.9		103.6		34.8	
		+ 37.8		+ 41.4		+ 22.4
1963	196.9		146.5		42.6	
		+ 37.2		+ 54.0		+ 33.8
1964	270.2		225.7		54.8	
		+ 38.5		+ 33.3		+ 18.2
1965	374.1		300.9		64.8	
		+ 48.0		+ 23.8		+ 29.9
1966	553.5		372.5		84.2	
		+ 17.6		+ 72.1		
1967	645.0		641.0			
		+ 24.0		+ 29.5		
1968	810.0		830.0			

Source: Same as Table III-2.

[57] Chemical Week, Nov. 7, 1959, pp. 23-24. As of May 1969, this interference proceeding is still partially unresolved, more than a decade after it was initiated. Only two basic patents have issued so far--both in favor of Natta's assignee, Montecatini. These claims are being challenged by Avisun, Standard Oil (N.J.), and Rexall in various infringement litigations.

Polypropylene, like high density polyethylene, saw considerable excess capacity, but it materialized somewhat later, as the pace of development and entry lagged several years behind in polypropylene. But the rate of demand growth has been very rapid. By 1968, production was 810 million pounds, while consumption reached 830 million pounds (Table III-4).

As a result of its loose oligopoly market structure and considerable excess capacity, prices declined steadily in the polypropylene market, until entry barriers increased again in the last few years. Hercules, the first successful producer of polypropylene in 1957, initially set base grade list price near that of nylon, which was initially believed to be the closest chemical substitute, at $.65 lb. This price level was dropped rapidly, however, by a series of cuts to $.42 lb. in early 1960.[58] These cuts coincided with the entry of its first rival, Avisun. Then in 1961, as the next entrants were entering production, prices were cut by off-list discounts to an average price of $.38 lb., and then more rapidly to $.24 lb. by 1964.[59] In 1965 the

[58] Intermediate steps were $.56 lb. in May 1958 and $.49 lb. in August 1958.

[59] Yearly average prices in between were $.41 lb. in 1960, $.38 lb. in 1961, $.133 lb. in 1962 and $.29 lb. in 1963.

average price decline slowed substantially to \$.22 lb., and then a slight rise occurred in 1966 to \$.23 lb. More recent data indicates that there may have been a slight decline in the polypropylene price level until the fall of 1968, when another slight increase may have been established.[60]

Although substantial shortrun excess capacity has characterized polypropylene until recently, in July 1965 Montecatini signaled a major new risk and cost for further potential entrants by suing both Rexall and Standard Oil (N.J.) for infringement of its recently issued basic product patents. (These patents were issued in November 1963, and months of unsuccessful negotiation preceded these litigations.) Up to this point, only Hercules and DuPont have formally conceded the validity of the Montecatini claims in cross-licensing agreements. Since some excess capacity continues, it is probably this significant change in entry

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[60] R. L. Van Boskirk, Senior Editor of Modern Plastics, writes in the October 1968, issue (at p. 43), that the polypropylene price situation "is still somewhat confusing . . . . The most often-quoted price now heard for that resin is 21¢ lb., which is 1/2¢ over the former so-called list price. But there is no guarantee that it is final--not all companies announced their acceptance. In general, the adjustment on prices has been slightly upward all along the line...."

conditions which explains the failure of polypropylene prices to come as far down as polyethylene.[61]

Average costs for most polypropylene producers have almost certainly declined in the interim, as a result of scale and process speed economies.[62] Profits for most producers have therefore been improving also. Since average cost levels for polypropylene are not much, if at all, above polyethylene cost levels, these circumstances suggest that a consensus of some sort on a noncompetitive price level might be presently operating. Average prices have been substantially higher in polypropylene than in either LDPE or HDPE for some years.

Profits in polypropylene appear to have been much the same as in high density polyethylene until recently.[63] Costs are very similar, and significant excess capacity was present in both cases. However, Hercules--the leader in polypropylene, enjoyed a greater headstart advantage and was more profitable between 1959-63 than any high density polyethylene producer. Recently though, the cessation of new entry and its higher prices suggest that polypropylene

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[61]The significance of these licensing arrangements is discussed at greater length in Chapter IV, <u>infra</u>.

[62]Chapter II, pp. 87-100.

[63]Chapter VI, <u>infra</u>, at pp. 258-262.

profits will improve somewhat more than profits in high density polyethylene.

Concentration in polypropylene has declined steadily as the new entrants began large scale production, but remain significantly higher than the other polyolefin markets. The share in production of the four largest firms was 100 percent in 1959, 85.1 in 1962,and 72.7 in 1966. Whether this higher level of concentration and more limited rivalry will continue should depend upon the patent situation.

If demand growth continues to be rapid, some new entrants would be expected, just as occurred in the other polyolefin resin markets. But whether or not this entry actually occurs will be influenced by the threat of patent infringement litigation by Montecatini. Since the average production for each producer in polypropylene is still considerably less than average production for each poly-ethylene producer, and significantly below optimum scale of efficient operation, several years might elapse before any new entry materialized--even if the Montecatini patents were to prove ineffective as a barrier to entry. Therefore, it may be until 1970-71 before the ultimate effectiveness

of the Montecatini patents as an important barrier to entry is established.[64]

[64] However, some doubts emerged recently as to the validity of the Montecatini claims, when Canada resolved a similar polypropylene patent interference proceeding in favor of Standard Oil (Ind.) and denied any Montecatini claims.

CHAPTER IV

POLYOLEFIN PATENTS AND TECHNOLOGY LICENSING

We have seen generally how patent and headstart advantages combined to nurture early innovations in the polyolefins. Then, just as market demand began a "take-off" to large volume and rapid growth, the strength of patent protection was substantially reduced. This greatly increased the force of competition in the polyolefins, market growth was accellerated, and prices declined very substantially. But now we need to understand in more detail how different levels of patent dominance actually evolved, the changes in licensing strategies that resulted, and to consider whether the degree of patent protection that emerged at each stage in market development was sufficient or excessive.

Different Levels of Patent Protection

The influence of patents upon technology and product markets may range through four levels of intensity: (i) "strong" patent protection--the power to exclude entirely, and to select and regulate any licensees; (ii) "moderate" patent protection--the ability to raise entry barriers and restrict entrants, but not to control market supply; (iii) "weak" patent protection--the defensive capability to withstand infringement, and some bargaining power for complementary exchanges of technology; or (iv) an absence of patent protection, i.e., generally, no influence at all upon competitors. The profitability of such protection to patent holders will reflect the degree of market dominance; the greater the strength, the more valuable would be the patent protection.

A number of factors will then determine the level of patent protection in any given market. To begin with, there can be no significant influence from patents in any industry unless its technology--and especially the more recent development, can be expressed in market dominating patents.[1]

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[1] Furthermore, quite apart from patent dominance, the degree to which the technology is actually revealed in patents will also influence entry conditions. When patents reveal enough to enable use and production without any great know-how cost, technological barriers to entry will be reduced. On the other hand, when the engineering art is so complex or difficult that patents themselves do not disclose enough to enable production, as in the polyolefins--substantial know-how barriers to entry are likely to operate even though patent dominance may not be very strong or effective by itself.

This will depend largely upon institutional quirks and habits in the patent granting process. In some branches of engineering, the standard of invention applied by the Patent Office is extremely demanding; in others, the standard of invention allows market dominance with relative ease.[2] In the polyolefins each major resin development could be expressed in basic or comprehensive claims covering either the resin product or alternative catalyst systems. But although many minor improvements were expressed in patents, their scope was typically narrow and alternate solutions were easy, hence improvement patents could only reinforce the headstarts achieved by basic patent holders. Once basic patent claims ceased to be an effective barrier to entry, polyolefin improvement patents merely served as a defense against later, possible dominating claims, and as a basis for bargaining in complementary exchanges of technology.

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[2]Relatively easy patent dominance is illustrated in the drug industry, where separate compounds are often subject to a high degree of patent control, even though many compounds compete to some extent with each other. Rare patent dominance is illustrated with some types of machinery, where the mechanical art is so obvious and novelties so narrow and easy to invent around that market dominance hardly ever results.

The distribution of dominating patents among firms in technological or product markets will also be significant in determining the litigating power and cohesiveness of the patent holders. Where a basic product or process patent, or its equivalent in accumulated improvement patents, is held by a single firm with sufficient financial resources, the patent barrier to entry will usually be the strongest. On the other hand, where a relatively large number of firms hold dominating patents, effective dominance can only be enforced by a licensing pool, which is more likely to break down in time, to suffer antitrust attack, and will usually be a weaker barrier to entry.[1]

Finally, the pre-existing competitiveness of technology and product markets when dominating patents are issued will be significant. This influences the litigating strength of patent holders, the bargaining power and resistance of likely infringers, and the distribution of dominating patents. Where

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[1]However, in some situations a small group of firms holding interlocking patents will actually impose a stronger barrier to entry than a single dominating patent holder. This would arise because a small group may find it possible to agree only upon excluding other competitors from the market, whereas a single dominant patent holder might find a limited selection of licensees to be the profit maximizing exploitation strategy.

only one or a few producers are active in a technology market when dominating patents issue, such firms usually have enough relative strength to maintain their market power as against new entrants. On the other hand, where the pre-existing participants in the relevant market are relatively numerous, even if dominating patents issued to one or a few firms, effective dominance in the market is much less likely. Then the established rivals in an industry can rarely be eliminated, will tend to be licensed, and are soon likely to develop some independence through improvement patents. The way in which all of these various circumstances influence the patent and know-how licensing policies of firms is conveniently illustrated by six different phases of patent dominance in the polyolefin plastic resin markets.

Strong patent dominance

Low density polyethylene, 1940-52

The strongest phase of patent dominance in the polyolefins was during its early market development. For a dozen years after its commercial introduction in 1940, conventional, low density polyethylene in the U.S. was a patent monopoly regulated by ICI, the basic product and process patent holder.[3] Improvement patents issued to ICI and its two U.S. licensees served merely to strengthen and extend this monopoly. The licensing policy adopted by these firms in this period illustrates joint monopoly profit maximizing. The power to exclude competitors, select and discipline licensees, and impose royalties were logically employed to this end. Particularly interesting in this regard is the constraint on licensing policy which resulted from a gradual shift in the distribution of the dominating patents, as DuPont and Carbide began to share significantly in the ownership of improvement patents, and began to limit ICI's licensing freedom.

The initial licensing policy of ICI on polyethylene was made in the context of the 1929 Patents and Processes Agreement between ICI and DuPont. This agreement formalized a prior practice of exclusive, royalty-free, cross-licensing on the development of most chemical commodities produced by both companies. This arrangement helped to reinforce the

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[3]The initial technology for low density polyethylene was described in the two basic patents with just enough completeness to provide strong patent dominance but--since the art was complex and difficult, not enough completeness to make entry and production easy. Hence, scarcity of know-how reinforced the patent barrier to entry.

leading role each firm played in its respective home market, and particularly its leadership in chemical research and development.

The ICI-DuPont arrangement was entirely understandable from the point of view of profit maximizing. It was simply a complementary R&D exchange relationship between relative equals. There was no need for net royalty flow from one to the other; the mutual grant back of the other's research achievements provided ample consideration. ICI and DuPont thereby greatly enhanced and protected the market power they enjoyed as a result of patent accumulations, headstart advantages and monopolistic leadership in many chemical markets. Under present U.S. antitrust law, such an arrangement between leaders of their respective industries would be vulnerable under Sections 1 or 2 of the Sherman Act as a monopolization or a restraint of trade, as in fact it proved to be in 1952.

The addition of Union Carbide to this arrangement was a wartime measure, imposed externally. The U.S. government, desiring maximum production volume in a short time, extended patent immunity from the ICI patents on the Carbide polyethylene plant it helped to finance. After the war, the question arose as to what commercial patent agreement might govern polyethylene licensing rights.

In January, 1946, even though a Department of Justice suit had been brought 18 months before charging that ICI and DuPont were monopolizing a great many chemical products through their exclusive cross-licensing, an agreement was negotiated between ICI and DuPont to regulate the civilian manufacture and sale of polyethylene.[4] The license from ICI to DuPont was dated January 17, 1946; 3 weeks later on February 8, 1946, DuPont granted to Carbide a sublicense under certain ICI basic patents only, for Union Carbide inteded to continue using its own process.[5] Thus, Carbide held its license under the United States polyethylene patents granted to ICI as a sublicensee of DuPont. The sublicense provided for payment by Carbide to DuPont of $500,000 and royalties of 5 percent on the net selling price of polymerized ethylene.[6]

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[4]Sittig, ibid., p. 233.

[5]Already Union Carbide felt confident enough about its improvement patents to claim process independence from ICI, a sign of defensive patent power.

[6]U.S. vs. Imperial Chemical Industries, 105 F. Supp. 215, 233 (SDNY, 1952).

Judge Ryan's opinion in 1952 illuminates the manner in which DuPont retained an advantage via the terms of the sublicense:

> "Although DuPont is required to pay over to ICI the excess in royalties it receives from Carbide, it was permitted to retain the cash payment of $500,000. DuPont also paid royalties to ICI for use of its polyethylene patent, but they were set at a rate graduated according to the amount of poundage produced under its license. The rate began at 5 percent of the net selling price of polyethylene polymers sold, and gradually was reduced to a royalty of only 2 percent. Whereas, Carbide paid a straight 5 percent royalty irrespective of the total amount of sales throughout the period of the license--requiring Carbide to operate at a [slight] cost disadvantage. DuPont also kept close tabs on Carbide production for Carbide was required to keep a separate record of polymerized ethylene manufactured, used, or sold by themselves and to permit DuPont accountants to examine these books and records from time to time." . . .[7]

"DuPont thus was able to keep a watch and check on the activities of its competitor in the polyethylene field." In Judge Ryan's view, "This [did] not present a very pretty picture of competitive conditions when established by the joint action of ICI and DuPont . . ." [8]

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[7] Ibid., pp. 233.

[8] Ibid., pp. 233-234.

As improvement patents were issued to ICI, DuPont and Union Carbide, the patent barrier to entry was strengthened and its duration extended. Through 1952, 42 such resin patents had issued to DuPont, 6 to ICI and 8 to Union Carbide. (More fabricating patents were issued, but these had little effect on entry conditions.) While not all of these improvements were really important or essential for production of polyethylene, the collective deterrent of this accumulation of patents did strengthen the patent barrier to entry.

No formal cross-licensing pool was necessary in this evolving situation, because DuPont had been made the primary licensee under the basic patents. Since Carbide respected DuPont's derivative dominance in the U.S. market, and shared in the exploitation of the duopoly, there was no real likelihood of rival patent licensing between the U.S. producers. Furthermore, the independent entry of ICI into the U.S. market was unlikely, or any licensing of other U.S. companies, for two reasons: (i) ICI and DuPont tended to respect their respective spheres of influence under the 1929 Patents and Processes Agreement, and (ii) the shifting ownership of the improvement patents in this informal patent pool gave an increasing veto power to DuPont and

Carbide, with which they could prevent any further licensing by ICI of competitors in the U.S. market.[9] Therefore, the shifting distribution of patent holdings actually transmuted what was originally a single firm patent monopoly into a somewhat more close-knit, cross-licensing pool. The effect upon entry barriers of this transmutation was to reduce the chance that ICI would someday select additional U.S. licensees to increase its royalty income.

Since all three of these firms were very strong in terms of financial, marketing and chemical process know-how, there was little need for any of them to offer licenses to any other holders of complementary resources. However, if the basic patent holders had been a small firm, or in some way incompletely endowed with the necessary resources to carry on production or marketing, the holders of complementary resources would probably have been extended licenses in order to enable the maximum of profits for these patent holders. But, it is important to emphasize, such concessions would really be no more than the substitution of contractual resources for resources already owned by the firms.

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[9] Even if ICI desired to break the pattern of its relationship with DuPont on one commodity, the DuPont and Carbide improvement patents served as a deterrent, since ICI's basic patents would expire in late 1956, leaving DuPont in control of most of the governing improvement patents.

In other words, any holder of dominating patents normally has the option to acquire some portion of the needed technology as well as developing the whole technology entirely within its own organization. Dominating patent holders simply choose the most efficient and profit maximizing way to exploit their patent--unless public policy for some reason restricts their control of the relevant market for technology.

Moderate patent dominance

Polypropylene after 1963

A somewhat lesser degree of patent dominance is illustrated in the polypropylene market after November 1963. In that month Montecatini, the assignee of Gulio Natta, was issued patents which, on their face, were claims on all polypropylene resin manufacture.[10] These claims issued as a result of an application filed in June 1955, nearly a decade beforehand, when a number of rival firms began their research and development, and were soon to decide upon new plant investments for polypropylene production.

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[10] The expressability of polypropylene technology in patents was like that of low density polyethylene; plausible dominance resulted, but the complexity and difficulty of the process made know-how scarcity a substantial barrier to entry. However, the validity of these patents is now being challenged by Rexall and Standard Oil (N.J.) in infringement litigations brought against them by Montecatini. Avisun has made similar challenges in several other countries, including Japan.

By the time these dominating patents were issued there were already, pre-existing in late 1963, eight U.S. producers of polypropylene resins actually in production. Some of these firms had by then obtained improvement patents, which gave at least a defensive bargaining strength as against the Montecatini claims. Such color of immunity was enjoyed to some degree by the following producing companies: Eastman Kodak, Dow, Hercules, Shell, Standard Oil (N.J.) and Avisun, together with potential entrants including DuPont, Standard Oil (Ind.) and possibly even Monsanto and National Distillers. The number of improvement patents held as of August 31, 1963, by these firms varied from 65 down to 8.[11] The improvement patents held by rivals of Montecatini were the natural consequence of entry into production at an early stage in development. Ample opportunities existed to successfully obtain patents at least colorably useful in bargaining, or as a screen for the actual process used in production.

Therefore, the degree of dominance actually enjoyed by Montecatini when its "dominating" patents finally issued in 1963 was not nearly as great as that enjoyed by ICI in 1939-40. At

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[11] Eastman Kodak had 58 such patents on polypropylene resin making, Dow 12, Hercules 44, Shell 19, Standard Oil (N.J.) 65, Avisun 63, Standard Oil (Ind.) 59, Monsanto 10, and National Distillers 8.

this stage Montecatini was not able to select the producers in the market, or to regulate their behavior. The best Montecatini could hope for was to prevent any further entry, and perhaps to obtain a royalty from the other already established producers.

The bargaining tactics employed by Montecatini in this period reveal its awareness of the limitations on its bargaining power. The initial Montecatini cross-licensing arrangement was actually signed with DuPont years beforehand in September 1959. The apparent basis for this agreement was the early conviction of both firms that they were the leading contenders in the basic patent interference proceeding (Interference No. 89,634.)[12] It provided that DuPont and Montecatini should grant to each other, and their respective licensees if the other party so requested, a nonexclusive license on polypropylene for 1 percent on net sales. This insured to the two most likely winners of the interference proceeding that no great barrier to entry would be imposed on the other. This agreement covered not only the patents

[12] This belief was based (i) upon DuPont's successful receipt of the basic product claim on high-density polyethylene in December 1957, wherein it had also claimed higher olefin polymers, including polypropylene, and (ii) upon Natta's breakthrough in theoretical analysis of polypropylene polymerization.

issuing from pending interference proceeding, but also "any future interference" proceeding involving polypropylene between the two parties.

The defensive character of this first agreement was also indicated by the reservation of the right to challenge any patent issuing to either party. Hence, the first agreement merely reduced for these two firms a risk of patent barriers to entry in polypropylene. This defensive agreement was not a mutual disposition of expected dominance in polypropylene; it was merely a hedge or insurance against the possibility of dominance by the other. As such this arrangement reflects relatively weak patent power at work.

But in May 1963, as the likelihood of dominating patent claims increased, a second agreement between DuPont and Montecatini was signed. The essence of this agreement was to mutually determine a major part of the entry barrier into polypropylene for other firms; it set royalty schedules or prices for licenses on dominating polypropylene patents. It was evidently based on the belief that each firm had a good chance for dominating patent rights. Minimum royalties of generally 2.5-3 percent on net sales were established for either firm, so that if both firms received the contemplated claims any outsider would have to pay at least 5-6 percent on net sales for polypropylene.[13] A defensive character remained to this agreement in that royalties between these two firms and selected licensees should be no more than 80 percent of the levels imposed on outsiders. Furthermore, the agreement contemplated mutual royalties, so that net cost to DuPont and Montecatini would be greatly reduced. Hence, the other established polypropylene producers, and any new entrants would be faced with a significant royalty charge on their operations, while DuPont and Montecatini could enjoy much lower royalty costs.

Once Montecatini actually received its share of the contemplated dominating patent rights in November 1963, it began to enforce its claims. Within about a year it signed a pair of licensing agreements with Hercules, in which Montecatini agreed

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[13]Actually, this was broken down such that 1.5 percent minimum royalty was set on resin sales, 1.5 percent in fiber, and 1.0 percent on film. A complicated formula for individual claims and counts was etablished, with royalties ranging between .3 percent to 1.7 percent, depending on the scope of rights awarded, i.e., the degree of market dominance obtained over U.S. sales.

to pay .7 percent on net sales to Hercules, and Hercules an unspecified royalty to Montecatini.[14] Becuse Hercules enjoyed the strongest bargaining power of any established producer, with larger production and sales and reputation for a superior process, it is likely that Hercules received generous treatment from Montecatini. By obtaining formal adherence from Hercules, Montecatini increased the litigating value of its claims as against outsiders and other producers, which was also in the best interest of Hercules in reducing the threat of new competition in the polypropylene market.

Montecatini, having reached an accomodation with what it considered its strongest rivals in a patent sense, then chose to sue the weakest firm in the polypropylene market for infringement in order to have the best chance of obtaining a victory. Rexall was the producer at this stage which had the least polypropylene patent protection. It was the only poly-

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[14] The first of these agreements was exhibited to the FTC, and provided .7 percent on net sales from Montecatini to Hercules. However, Hercules refused to produce the reciprocal agreement, insisting, in effect, that FTC formally subpoena the document. The general counsel of Hercules explained in a letter of May 25, 1965, to the FTC's Division of Industry Analysis that "...[W]e have construed our agreement with Montecatini as not permitting its disclosure even to public authorities unless such disclosure is required by proper formal process issued from a public agency."

propylene producer which had obtained no resin patents of its own, as of August 1963. Furthermore, Rexall had been the most aggressive new entrant in raiding personnel from other firms. Montecatini insisted on very high royalties in bargaining with Rexall, amounting to 25 percent on net sales, and precluded Rexall from any polypropylene fiber production--perhaps the most important potential end use. The negotiations broke down and an infringement suit was begun by Montecatini in July 1965.[15] This litigation was still bogged down in extended discovery as of May, 1969--nearly four years later, with no apparent urgency in prosecution by Montecatini, or in defense by Rexall.

Thus it would seem the primary goal of Montecatini is to inhibit entry, and not to tax the other established polypropylene producers. Taxing the other producers to any significant degree will be difficult, since the other polypropylene producers have significant numbers of improvement patents. Hence, the fact

[15] As collateral suit was later brought against a polypropylene fiber subsidiary of Standard Oil (N.J.), and eventually Avisun was added as a defendant, but only the Rexall suit appears to have been prosecuted to any real extent.

that dominating patents issued late in the course of technological and market development has weakened their effective dominance. Montecatini now enjoys only the power to impose a cost and risk of litigation upon infringers, and cannot select or discipline licensees.

The long run effectiveness of Montecatini's entry limiting use of its patents is not yet resolved. But so far, despite a rapid rate of growth in demand, no new firms have decided to enter since 1963, and two firms, Dow and Firestone, have dropped out of the market. Patents may not have been a factor in these withdrawals, since the plants involved were small and evidently not efficient. But patents are much more likely to be a factor in the halt of new entry. The continued effectiveness of patents as a barrier to entry, of course, will depend on the infringement litigation with Rexall, et al.[16]

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[16] Recently the bargaining position of Montecatini was weakened somewhat when Canada resolved its polypropylene patent interference proceeding in favor of Standard Oil (Ind.), and denied the Montecatini claims. However, Montecatini is still the beneficiary of the two apparently dominating U.S. patents on polypropylene issued in November, 1963. Even though the U.S. interference proceeding (No. 89,634) is not resolved, it is very doubtful that the U.S. Patent Office would issue any further claims which would be directly inconsistent with these issued patents. Hence, the effect of the Canadian decision is to add persuasive authority to the "infringers" argument that the Montecatini patents were really invalid and never should have issued.

Weak Patent Dominance

High density polyethylene

The degree of patent dominace operating in the high density polyethylene market illustrates a still weaker influence. As a result, patents could not be employed as a substantial barrier to entry, and were employed primarily as a basis for bargaining in sales and exchanges of know-how. However, since the engineering art was difficult and complex, know-how scarcity remained a significant barrier to entry. Hence, the patents protecting such know-how provided significant advantages to their holders, even though the patents themselves proved ineffective in preventing new entry into the market.

The relative weakness of patent dominance in high density polyethylene is traceable to several factors: (1) The initial distribution of important patents involved only process patents, divided among the three independent commercial process developers, Phillips, Ziegler, and Standard Oil (Indiana). (2) Ziegler's U.S. patent attorney failed to state his claims broadly enough to protect the process, which made the patent application worthless. This allowed other producers to claim they were using the Ziegler process, which became for patent purposes, a free good. (3) The DuPont product claim which issued several years later in December 1957, when seven producers were either in production or had begun construction of expensive polymer plants, was very weak from a litigating point of view. The impact of these three factors can be seen with the licensing strategies employed by Phillips, Standard of Indiana, Ziegler, and then DuPont.

Phillips was in the strongest position, since it had an efficient commercial process with complete patent dominance over its use. Phillips began licensing less than a year after it first revealed its process in an Australian patent application. The first license agreements were signed between July--September 1955, with Union Carbide, W.R. Grace and Celanese in that order.[17] The sequence is significant because Carbide, as the leading producer of low density polyethylene, had the greatest bargaining power, and evidently terms set for the others were significantly affected by this initial bargain.

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[17]By the spring of 1956, a series of licenses with foreign producers had also been arranged, one each in France, Germany, Britain, Japan, Belgium and Brazil, with Rhone-Poulenc, BASF, Distillers Co., Ltd., Showa Denko, Ltd., Solvay et Cie, and Industrias Quimicas Electro Cloro, respectively.

The Phillips license was sold to each of the domestic licensees for: (i) down payments of $250,000; (ii) 7 percent on net sales, with a minimum of $300,000 if substantial production was not undertaken; and (iii) mutual grant-backs of future process know-how.[18] Six foreign licensees were similarly treated, except that the cash guarantees were larger, ranging from $1,326,000 to $2,475,000. The result was to provide Phillips with a substantial profit on its research and development effort, and to pool future know-how to the mutual benefit of all participants in the group. Although the Phillips patents were not strong enough to limit entry into the high density polyethylene market, they did yield substantial extra returns to Phillips.

Standard of Indiana also began promptly to license its process, to Eastman Kodak in May 1956, and to Spencer in July 1956. But since the Standard process was not yet fully developed, the return to Standard was less substantial. The licenses took the form of joint development effort carried on in joint research and development contracts, although a net consideration flowed to Standard in each case. Eastman guaranteed

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[18] Later, in the 1960's, National Distillers and Chemplex were added as licensees.

a 3 percent royalty to Standard and agreed to invest $350,000 in a pilot plant, while Spencer guaranteed 6 percent on net sales.[19] These arrangements involved a use by Standard of its patented process and limited headstart advantage to bring together complementary resources. However, these efforts were evidently not completely successful, for none of these firms has yet employed the processes commercially in the United States.[20]

Meanwhile the Ziegler process was not sufficiently claimed by its U.S. patent attorney, so it early became apparent that Ziegler could only offer process know-how. However, since the art was complex and difficult, even this know-how proved valuable. This Ziegler know-how was further developed than the Standard catalysts, but Ziegler himself had not developed it to the stage of being a proven commercial process. As a result Ziegler's know-how was widely licensed to a number of U.S. and foreign

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[19] A subsequent agreement of October, 1957 with Eastman indicates this firm went further with the joint research than Spencer.

[20] The Standard process was subsequently licensed to Furukawa in Japan in 1958, and to Rumianca of Italy in 1961. But it is not entirely clear whether it is the standard process with these firms are employing. Conceivably, the Standard license may be employed by these two firms as a screen against infringement suits on use of another process. Some progress in the process is evident, however, as Rumianca contracted to pay at least $1.6 million in royalties, while Furukawa guaranteed to pay only a $550,000 minimum.

Standard is planning to enter the HDPE market currently, however, with its own process.

firms, but Ziegler was unable to control future development of his process in the U.S.[21] Some of the subsequent licensing of Ziegler technology in the U.S. occurred independently of Ziegler.[22] Hence, his returns on R&D investment were less than what they might have been with U.S. patent control over his process.

It must be emphasized at this point that the licensing strategies of all three process developers, Phillips and Standard of Indiana as well as Ziegler, were strongly influenced by the failure of Ziegler to get effective patent dominance over his U.S. process. If his process had been patent protected, then

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[21] The Ziegler process was licensed directly to Hercules, Monsanto, and Koppers, and indirectly through Farbwerke Hoechst to Hercules, through BASF to Dow, and through Ruhrchemie to Goodrich-Gulf. Cash consideration to Ziegler directly was generally $350,000, together with royalty promises of 2 percent on net sales if the Ziegler process was actually employed. There were no such royalty payments in the years 1959-63, except for $1,400,000 paid by Hercules to Ziegler in 1961-63. This indicates the Hercules license on know-how continued much longer than the others.

Among the foreign firms having Ziegler licenses or know-how are BASF, Farbwerke Hoechst, Ruhrchemie and Montecatini. Other licenses in Britain, France and Japan are likely, but no information was available to the FTC on these arrangements.

[22] Such subsequent know-how trading in Ziegler "chemistry" included the licensing of Dow by BASF, Goodrich-Gulf by Ruhrchemie, Hercules by Farbwerke Hoechst, know-how exchanges between Dow-Monsanto, Dow-Asahi, and joint R&D between Koppers and Avisun. See Chapter V, <u>infra</u>.

all the available routes to high density polyethylene production could have been regulated by a close-knit cross-licensing pool among these three firms. In such circumstances, it might well have been more profitable for these firms to license far fewer outsiders than they actually did license, and to allow much less participation and competition in the market. But when Ziegler's catalysts were not sufficiently claimed, entry could no longer be limited by agreement among themselves. Then the three developers each found it profitable to license more widely in the U.S. market, a total of the 12 different firms receiving licenses directly or indirectly. The licensing strategy adopted was one of making the most of a fragile, depreciating asset while its value lasted; but this involved lower profits, more competition, and a faster rate of technological and market development.

After these licensing strategies had been implemented and an oligopoly market structure had taken shape, in December 1957, to the surprise of industry participants, DuPont was awarded an apparently dominating product patent on high density polyethylene. DuPont had filed a patent application way back in April 1947, claiming a very high pressure process for polymerizing a high density polyethylene. The prosecution of this applicant went slowly, however, and was eventually abandoned in favor of a substituted application in August 1951. This substitute was the well-known Larchar composition of matter patent claim, finally granted and published as U.S. Patent No. 2,816,833. Larchar claimed for DuPont a very high pressure process (5,000-20,000 atmospheres) by which higher density linear polyethylene could be polymerized. However, the Larchar claim was in no credible sense an efficient commercial process. Pressures involved were many times higher than the other already successful processes. The Larchar application was merely a stated area of laboratory results, which were reduced to practice in research and which were never before claimed in a patent or otherwise revealed.[23] Hence, the Larchar patent was not strong from a litigating point of view.

DuPont chose to make its patent most credible and valuable by suing Phillips for infringement, the strongest

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[23]No showing of commercial efficiency is required to successfully obtain a composition of matter patent. In a sense, such patent claims (commonly allowed by the Patent Office) are allocations of free or unclaimed "technical space," and patent application rushes for technical space are as common today in chemicals as land claims used to be with open land space. But there must be some kind of possession or a "reduction to practice." Mere speculation or wishful thinking will never serve as the basis for a patent claim.

process developer in terms of patent strength, and then settling on generous terms to save the apparent validity of the Larchar claim. A cross-license was agreed upon in early 1959, but the terms revealed the small worth of the Larchar claim. Phillips and its licensees received a DuPont license, but DuPont's license from Phillips was unlike all the other Phillips licenses. No know-how was provided, and only a vague option to purchase know-how at an unspecified royalty was mentioned. Since Phillips could not preclude entry into the market anyway, it conceded very little. But this concession did prove of some value to DuPont, for in the next year and a half most of the non-Phillips producers in the market took a DuPont license on 2,816,833. However, in the period 1959-63 DuPont was only able to get total royalties of $360,000 on this patent, and these from only four of its licensees.[24] These royalties provided a return on R & D investment, but were trivial when compared to costs of production, and constituted no effective barrier to entry in high density polyethylene.

Finally, it should be pointed out that patents held by other firms on high density polyethylene did have some

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[24]Koppers paid $149,000; Carbide, $119,000; Hercules, $57,000; and Dow $52,000.

market value in providing a stronger bargaining power in trading for complementary technology, and helped provide some degree of defensive immunity from rival process claims.[25] This was particularly true of Union Carbide, Monsanto, which entered some years later, and Dow, which eventually claimed complete process independence with its own technology. But these defensive immunities were even more important in the case of polypropylene.

Polypropylene until 1963

The early years of polypropylene patent licensing, already indicated to some extent, reveal similarly weak dominance. No effective patent barrier to entry operated, but the difficulty and scarcity of know-how did inhibit entry. Patents merely served to increase the bargaining strength of some participants in know-how trading and to provide an increasing defensive bargaining strength against any eventual winners in the five-way, basic product patent interference proceeding. (Interference No. 89,634, involving Montecatini, DuPont, Phillips, Standard of Indiana, and Hercules.)

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[25]This complementary trading in know-how is explained more fully in Chapter V.

While in theory all three of the commercial processes for high-density polyethylene would be applicable, only the Ziegler catalysts appear to have been successful through mid-1968. This means that the one process least influenced by patent control was the only practical method of making polypropylene. This weakened patent dominance in the early years of polypropylene, but the threat of a possible winner in the basic patent interference proceeding created some risk for new entrants. It behooved all entrants into polypropylene to build up an independent patent portfolio to obtain bargaining independence.

Those with some degree of patent independence in polypropylene by late 1963 actually included most of the active producers, Hercules with 44 patents, Avisun with 63, Eastman Kodak with 58, Standard Oil (N.J.) with 65, Dow with 12, and Shell with 19, plus two strong potential entrants, Phillips with 80 and Standard Oil (Ind.) with 57.[26] The trading in complementary technology which resulted in this situation was extensive, and helped to reduce costs and risks of entry for the majority of these firms. This trading is described more fully in the next chapter.

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[26]The other polypropylene participants were Montecatini, which became a basic patent holder in November 1963, Firestone, which had only 2 patents by late 1963, and dropped out of the market the next year, and Rexall which was just entering and had no patents by late 1963. Rexall became the principal target of Montecatini's infringement litigation.

Absence of effective patent dominance

Low density polyethylene after 1952

The impact of compulsory licensing in low-density polyethylene has already been described in some detail, but the impact on subsequent licensing arrangements should be pointed out. For some years afterwards patents ceased to be a substantial barrier to entry in this rapidly growing, and profitable market. Six new entrants took licenses at the outset under the terms of the licensing decrees. They paid at least $2,000,000 each, largely in the form of minimum royalty guarantees. By 1957 both basic patents had expired, and no further royalty claims could be made by ICI.

Rexall did not bother to obtain an ICI license in the early 1960's for its entry, evidently putting together enough technology by hiring men from other companies. Foster-Grant took a know-how license from an independent group of engineers, the Scientific Design Co. (through its Leichstenstein affiliate), for several hundred thousand dollars. Chemplex, however, in 1968 chose to purchase know-how for $6,000,000 from DuPont. These varying experiences indicate the know-how barrier still existed, but with 10 producers active and without strong patents to restrict entry, this residual know-how barrier was not enough to prevent successful new entry.

Polyolefin fabrication

The polyolefin resins have been sold through seven major end use channels: film, fiber, blow molding, injection molding, pipe and tubing, the coating of wire and cable, and the coating of paper and other packaging materials. Each has many polyolefin end product applications. In only one market does it appear that patents held by resin makers, or any fabricator, were significant as a barrier to entry. The one exception was the polyethylene coated paper milk carton. In this case four different seal designs did obtain effective dominance. But only fabricators held these patents, the degree of dominance was intermediate, and an oligopoly of milk carton makers was the result. There were also some licenses granted among some resin makers on fabricating machinery, and modest considerations (generally well below $100,000) were transferred among a minority of the resin makers. But most of the fabricators, and the majority of resin makers in each instance did not bother to take licenses.

There was a brief attempt by Union Carbide to impose licenses on film makers with a group of film processing patents in the late 1950's, after Carbide entered this market by acquisition. But the effort was abandoned, and those film makers which had signed up and were paying modest royalties had their money refunded. In informing its licenses of the refund, Carbide's representative wrote, somewhat grumpily, that this action "should not be taken as a precedent." Nonetheless, the fabrication of polyolefin end products remained free of effective patent dominance.

Some know-how trading and cooperation seems to have taken place, but was of a much less important and extensive character than that undertaken in resin manufacture. The reason was simply that the art of fabricating polyolefin resins was much less complex, less difficult, and more obvious than the art of resin making. Hence, know-how was not really scarce in polyolefin fabricating.

Patents as an Incentive for Technological and Industrial Development

One important lesson of the foregoing range of licensing experience is that patent incentives are really a very flexible instrument, reflecting various technological, market and litigating circumstances. Some degree of advantage to patent holders results from weak as well as strong influence over the market. Hence, the concept of incentives from patents must be broadened to include all levels of patent influence.

Strong patent dominance

The greatest profit opportunities with patents apply to single holders of a strongly dominant patent; such firms can limit entry, select licensees and regulate price and output behavior with the greatest freedom to maximize return on their technological property. A somewhat reduced profit opportunity applies to close knit groups holding complementary parts of strongly dominant patent protection; their individual share in a patent monopoly is diluted to begin with, and group cohesiveness does not often allow an equivalent freedom in exploiting the patent monopoly for maximum profits. Such a group would normally just restrict entry, and would be less able to take advantage of opportunities for allying the complementary resources of outsiders.

The degree of competitive rivalry which would emerge from these two situations would vary somewhat, depending mainly on how few the licensees or participants in the dominant group might be. In terms of market output and prices, there might well be little difference in performance. But in terms of technological rivalry, even a few competitors are likely to produce superior performance over a single firm monopoly. Hence, strong patent dominance does not entirely preclude the presence of significant competitive incentives within an industry.

These distinctions are certainly borne out by the polyolefin experience. The initial phase of ICI dominance over low density polyethylene illustrates the greatest advantage for the dominant patent holder and its licensee, DuPont. But just one more competitor, Union Carbide, yielded faster and larger U.S. market growth, and nearly doubled the number of improvement patents in the years before 1952.

Moderate patent dominance

A lesser degree of advantage accrues to patent holders with moderate dominance, but nonetheless, it may be significant. Entry by outsiders is likely to be greatly inhibited and price competition will be reduced, royalties may flow to the stronger patent holders, and yet the holders of significant patent portfolios attain a defensive independence to reduce their own costs and risks of entry and a better bargaining basis for trading in complementary technology. All these effects yield significant advantages to patent holders and their licensees in the form of somewhat higher profits than would apply in a competitive market situation.

Meanwhile, however, competitive rivalry is likely to be greater than situations where strong patent dominance applies. The number of rivals in technical progress is greater, while the attainable degree of monopolistic price-output restriction is likely to be reduced. Rivalry will be particularly strong if the demand growth for the products involved is rapid and substantial, a frequent occurrence with important new technical innovations.

Such circumstances are illustrated in the polypropylene market after 1963, and to a somewhat lesser degree in the early years of high density polyethylene development. More firms were participating in technical development, and their positive contribution was reflected in a substantial increase in the number of improvement patents. Extensive trading in technology also occurred, aided partly by patent protection for some of the individual traders. Output was increased, and due to rapid demand growth, excess capacity resulted, and a period of vigorous price competition.

<u>Weak patent dominance</u>

A further reduced advantage to patent holders operates with weak patent dominance. But even without any significant ability to inhibit new entry, the holders of significant patents may obtain some royalty revenues, better bargains for complementary technology, and at least some defensive protection against possibly dominating claims, to reduce costs and risks of entry. On the other hand, competitive rivalry is even stronger in situations of weak dominance.

The early development of polypropylene growth, and most of the later years with high density polyethylene, illustrate this kind of situation. Market demand growth and potential was great enough to stimulate many firms to invest in the polyolefins, and since the basic innovations had already occurred, technological and market development was rapid. Excess capacity through much of this period caused considerable price competition as well, and brought prices near costs for most producers--in some cases producing short-run losses.

Absence of patent dominance

With an abuse of effective patent dominance there is not likely to be much significant return to patent holders. The power to influence one's competitors is negligible and therefore the value of patents is small, both in a monopolistic sense and also in a defensive sense. Nonetheless, the effort to obtain patents is not very expensive; on the average, taking into account the strongly contested patent situations, according to prevailing fees, it merely comes to several thousand dollars apiece.[27] Considering that efforts to obtain patents may conceivably result in a higher degree of patent dominance at some point, this prospect, together with habit, seems to explain continued, albeit reduced, patenting activity in areas where no effective dominance was operating.

This is illustrated in the polyolefins after 1952 with respect to low density polyethylene resin patents. More LDPE resin patents actually issued after compulsory licensing than before.[28] The same was true of polyolefin fabricating

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[27]Filing of an ordinary uncontested application will cost no more than a few hundred dollars, with no more than several hundred for each subsequent amendment. The expenses of contested applications (involving appeals of rejections and interferences) are much higher. But relatively few applications are contested.

[28]Up through 1952, a total of 124 low density resin patents issued. After 1952, 140 such patents had issued up to the latter part of 1963. To be sure, however, research and applications had in some instances begun before compulsory licensing.

patents. However, the intensity of inventive effort in higher density polyolefin resin making (as measured by numbers of patents), was substantially greater than for low density processes after 1952. More than three times as many resin patents issued on higher density polyolefins than on low density polyethylene, even though the latter was a 350 percent larger market in consumption dollar volume.[29] This larger number reflects the greater incentives for defensive patenting in higher density resins. In low density polyethylene after 1952 there was much less incentive for defensive patent portfolios, since compulsory licensing made patents relatively unimportant.

Sufficiency of Patent Incentives

To analyze the sufficiency of patent incentives after a long period of technological and market development involves some guesswork about "might have beens," but is nonetheless worthwhile and illuminating with the polyolefins. On the whole, the polyolefins have to be conceded as an unusually rapid and successful example of technical progress and market growth. This is particularly true since 1953, for annual

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[29]By the latter part of 1963, 606 higher density polyolefin patents had issued, almost all of which issued after 1952. This larger number also reflects the fact that higher density processes were hardly developed in 1952, whereas the low density process was largely perfected. But even so, the ultimate number of resin patents issued on the higher densities was twice as large as the number issued on low density resins. Defensive patenting explains much of the difference.

growth in production over this 15-year period has averaged 24 percent each year, with greatly improved products and aggressive market exploitation. Prices were originally $1 lb. and now range between $.16 lb. to $.21 lb. Average costs in the most efficient, large scale plants are about $.10 lb. (This price-cost margin, at the current stage in market development, still reflects some headstart advantages in favor of the market leaders.)

One can fairly conclude that, up to the present at least, patent incentives, along with headstart and competitive incentives, were probably sufficient to stimulate successful performance. To be sure, if polyolefin resins had been of greater strategic interest and priority for defense uses after 1945, a still more rapid development might have been called for with direct subsidies. But polyolefin usage has been overwhelmingly civilian in the postwar years, and no such urgent need developed.

This successful evolution occurred in spite of public policy interventions which significantly reduced patent dominance and caused a substantial increase in competitiveness. In 1942, as the first commercial polyolefin was introduced into the U.S., the Navy Department's procurement policy forced the licensing of two producers rather than just one. This increased somewhat the pace of technical and market development. In 1952, the Department of Justice obtained a compulsory, reasonable royalty, licensing decree on patents and know-how. This decree came at a time when most of the major technical problems had been resolved and market growth was entering a "take off" stage. As a result, market structure was transforced from duopoly to oligopoly, innovative rivalry was intensified, and competition reduced prices by more than half.

Then a second wave of technological change provided an additional market opportunity for higher density polyolefin resins. At this stage, the earlier loosening of the market structure through compulsory licensing contributed substantially to a reduced degree of patent dominance, and created more potential entrants into these newly opened markets. In a few years of rapid adjustment to this opportunity, a considerable number of joint technology arrangements and sales of know-how and plants were engaged in which facilitated further technical and market development for their participants.[30] Fortunately, most of these transactions and joint arrangements presented no threat of market dominance. The few that did involve such threats were greatly diluted to eliminate competitive dangers in a series of consent settlements arranged by the Federal Trade Commission. Hence there was no interference with rapid and reasonably competitive

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[30]These technology exchange arrangements are discussed more fully in chapter V, _infra_.

progress. Most of these technology transactions served instead to reduce the costs and risks of entry for new producers.

Therefore, although the profitability of patents was considerably reduced by government intervention, patent incentives generally proved sufficient. To appreciate more fully the implications of this experience, we must appraise patent incentives as they operated at each stage in polyolefin development.

Basic research

Basic research is not really an end in itself for profit making enterprises. Ultimately, it only makes sense as a way of reducing costs or making improvements in established product lines, or of opening up promising new product opportunities. Nonetheless, valuable prestige and attractiveness to technical talent may result from sponsoring basic scientific inquiry.[31] Hence, one must be careful to include all the indirect benefits of basic research as part of the relevant incentives.

The stage of basic research for low density polyethylene involved the period up to about August 1936, when the first basic patent application was filed. ICI's research effort was the only activity in polyethylene at this point. For

[31] Although scientific prestige is valuable as a method of attracting technical talent, if a firm is maximizing profits, the value of such services should ultimately be expressed in the profitability of product line activities.

high density polyethylene and polypropylene the postwar years up to mid-1954 were the period of basic research. This research involved primarily DuPont, Standard Oil (Ind.), Phillips, Ziegler's Max Planck Institute in West Germany, Natta's Institute in Italy, to a lesser degree, some research by Monsanto, and ICI as well.

Resources for ICI's initial technical effort came from the accumulation of headstart, patent and monopolistic profits enjoyed by ICI in many markets as the dominant British chemical producer. Its very size also enabled basic research of this character. The hope of strong patent dominance on polyethylene may have been an important incentive, but the costs were not large, and such basic research may not have needed this degree of temptation. Headstart advantages and prestige incentives might have been sufficient.

Somewhat the same is true of the later basic research on higher density polyolefins. The resources of size were combined with advantages enjoyed in other markets, together with government and industry subsidies in the cases of Ziegler and Natta. Patent prospects were less strong, however, since the seven firms could not be so sure of the priority and novelty of their work as was ICI 15-20 years before. Nonetheless, these basic research costs were not substantial and even these somewhat reduced patent incentives were probably sufficient.[32] But likewise, the other non-patent incentives may have also been sufficient, especially since there was some proven market success in the substantial postwar sales of low density polyethylene.

Hence, in the basic research phase, one might conclude that either patents, or a combination of headstarts and prestige, were sufficient incentives. This means that a chance of substantial patent dominance on the one hand, or headstart and prestige incentives on the other, were substitute, alternative incentives for basic research. However, had these basic researchers been smaller firms, without size and diversification advantages, strong patent protection would have been essential for the work actually carried out in the polyolefins. While the direct costs of basic research were not large, they were much too risky for small firms without more assurance that they could capture major benefits from these innovations.

Development research for initial production

With development research, costs increase greatly, and this was undoubtedly true in the polyolefins where high pressures, exotic and highly explosive catalysts created serious engineering complications. Pilot plants generally

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[32]The market risks were also much less with the higher density polyolefins, since the market success of LDPE suggested substantial demand potential for HDPE and PP could be developed.

amounted to $300,000-$400,000 at least, and a significant portion of the total cost of one's first substantial plant--$15-20 million, was probably development expense. Uncertainties and risks were important as well, especially in the earlier years of polyolefin development.

Fortunately, however, the fact that ICI could rely on headstarts and strong patent protection to secure most of the initial market opportunities from LDPE to itself and its two U.S. licensees, DuPont and Union Carbide, meant that these costs could be recovered in early operations. For the first small plant designed to meet submarine cable demand in 1939, and the war-time plants for radar cable coating, it is likely that headstart advantage alone was sufficient to guarantee this result. Prices were certainly held very high at $1 lb. relative to what because the average cost of production in the later postwar years, i.e., about $.20 lb. and eventually as low as $.10 lb. for the largest scale plants.

The postwar plant expansion proceeded slowly and in pace with civilian market development. It was probably at this stage that strong patent dominance had its greatest influence as an additional incentive. The fact that five outside research organizations: Monsanto, Phillips, Standard Oil of Indiana, Ziegler and Natta were doing research on the complementary, but closely related higher density polyolefins, reveals the presence of some potential competition. Standard Oil (Ind.) actually obtained 17 low-density polyethylene resin patents in this period, and there were 6 for Monsanto, 2 for Hercules, 2 for Phillips, 5 for Sun Oil, 4 for Universal Oil, 2 for Shell, 2 for Olin Mathieson and 1 for Pittsburgh Plate Glass. Without strong patent protection on LDPE some of these firms might have spoiled its early profitability for the initial innovators, ICI, DuPont and Union Carbide.

Nonetheless, due to the complexity of the process, the slowness and difficulties experienced by most new entrants, the leaders in this period, ICI, DuPont and Union Carbide, still enjoyed substantial headstart advantages. Headstarts might have been sufficient incentive for the pioneering development investments made in low density polyethylene up through compulsory licensing in 1952. Hence, even in this postwar, civilian development phase, headstart incentives were conceivably a sufficient substitute for patent incentives.

So far as the pioneering development expenses on higher density polyolefins were concerned in the mid-1950's, the costs were similar, but the market risks were much reduced. By this time the market prospects for all the polyolefins were generally known to be much greater, hence ordinary profit prospects were larger. But this fact, and the evident readiness of nearly 15 firms to enter, indicated the headstart advantages were much less substantial in the mid-1950's. Furthermore, it quickly became apparent that only moderate to weak patent dominance would result in both high density polyethylene and polypropylene.

However, while events proved that strong patent protection was probably not necessary, it is fair to say that lesser levels of patent protection still helped to encourage the early development of higher density resin plants. Profits traceable to patent protection proved substantial for several of the leaders in the high density polyolefins. (Patent profits were quite substantial for Phillips, Ziegler still made a net profit on know-how licenses, and Standard Oil [Ind.] eventually covered its early R&D costs.) And most of the other entrants into the higher density polyolefins gained a valuable defensive immunity from their patent portfolios, which in most cases more than paid for their patenting expenses. Furthermore, the still significant barriers to entry in terms of know-how (a headstart advantage for established producers) indicated that long run profits of the eventually participating oligopoly would be substantial. Consequently, although strong patent dominance clearly proved unnecessary beyond 1952, a lesser degree of dominance was still significant as a reward to innovation.

However, it must be emphasized again that, if the initial developers of either low or higher density polyolefin resins had been much smaller firms, strong patent protection would have been essential from the outset to mobilize the needed large sums from the capital market, and any other complementary resources. Smaller firms would not have had anywhere near as strong a combination of headstart incentives.

Further development effort

As more than a few firms began to participate in each of the polyolefin resin markets, it is clear that patents became much less important as an incentive for further innovation. The hopes of cost reduction and sales advantages were stimulated by competitive incentives, which also forced those with headstart advantages to be on their toes technically to maintain better than average profitability. Patent incentives ceased to be very significant in stimulating further development at this stage, except as they helped to encourage technology exchanges and trading. This in turn helped to improve the efficiency of participating firms, and to encourage some new entry into the polyolefin resin markets.

The decreasing need for patent incentives

The polyolefins illustrate a technological development which may be the most common in general phasing. An initial major breakthrough in R&D was followed by others of decreasing relative importance over the course of technical and market development. Polyolefin progress deviated only in that a second wave of breakthroughs crested in the mid-1950's with higher density resins, but this was of decidedly less novelty than the original breakthrough.

The most critical need for special incentives to finance innovation came after basic research had been completed, and when expensive pilot plants and early commercial plants for LDPE had to be financed. But by the early 1950's in LDPE, market growth potential was unusually large. Thereafter, the need for patent incentives was greatly reduced in this industry. In other markets with less dramatic growth opportunities, the need for patent incentives might have been greater, unless strong headstarts gave ample incentive and protection to the leaders in development.

But as the polyolefin technology was perfected, and innovation took increasingly the form of cost reduction and product improvement, the need for incentives other than the normal hopes and fears of competitive rivalry greatly receded. To be sure, further new products might still be encouraged by hopes of patent dominance, or major differentiation in the original product. But firms producing established products do not need patent dominance to continue cost reduction and minor improvements. Competitive incentives are then an adequate incentive to sustain more refinement in technology.

Hence, the need for patents as an incentive seems to decline in the normal course of a product market's evolution.

Excessive Patent Protection

Strong patent dominance applied to the polyolefins in their first 14 years of market growth, between 1939-52. Market structure comprised a monopoly in Britain and a duopoly in the United States, and the patent barrier to entry was practically absolute. Two basic patents were the original source of this dominance, but their strength was reinforced and extended in duration by improvement patents shared among three firms.[33]

Was this accumulation and growing interlock of patents an excessive degree of dominance? The answer is that this particular patent dominance probably did not make a great deal of difference before 1952. Headstart advantages were so strong as to preclude much entry before then. But if such strong patent dominance had continued without some dilution, such as compulsory licensing imposed in that year, performance in the polyolefins would have been significantly less successful, at least in terms of prices and outputs, and to a lesser extent in terms of innovation. The market impact of compulsory licensing was described at length in Chapter III. Here it is sufficient to note that, without compulsory licensing, perhaps only half as many firms would have participated in

[33]In this period, some 59 U.S. improvement patents issued on low density polyethylene resin manufacture--45 to DuPont, 8 to Union Carbide and 6 to ICI.

these markets by now, i.e., oligopolies of 4-6 would have resulted instead of 8-12.[34] All the extra output, sales

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[34]How can this estimate of the impact for the 1952 compulsory licensing decree in LDPE be justified? We need to reconstruct the likely evolution of U.S. polyolefin markets in its absence: (1) The duopoly of Union Carbide and DuPont in LDPE would have continued through 1957 (the expiration of the basic ICI patents) at least, and have lasted some years thereafter as a result of improvement patents. Considering the strength of headstarts in LDPE, and the many improvement patents, it is doubtful that any later new LDPE producers would have entered except for several of the leading, independent innovators in HDPE and PP, such as Phillips or Hercules. (2) Without the six new entrants into LDPE which resulted from compulsory licensing in 1953-54, the roster of eager potential entrants into HDPE and PP in 1955-57 would have been greatly reduced. (Participation in LDPE greatly strengthened technological capability to enter either HDPE or PP. Furthermore, the much larger sales value available in LDPE meant that this market's evident potential helped finance more experimenting with HDPE and PP). All eight of the next entrants into LDPE after 1952 made some effort at entering the higher density polyolefin markets, and every one (or at least its successor) eventually did enter either HDPE or PP. These eight firms (or their successors) formed much of the subsequent participation in these two markets--6 of the 12 HDPE producers in 1968, and 2 of the 8 PP producers in 1968. (3) If there had been significantly less early entry into HDPE and PP, it is conceivable that patents might have been a stronger barrier to entry in either HDPE or PP. With fewer early participants, a close-knit cross-licensing pool might have emerged in either HDPE or PP. (4) Certainly the lack of U.S. patent protection on the Ziegler HDPE and PP process, and the confused 5-way patent interference in PP, were important independent factors in enabling entry into HDPE and PP. Nonetheless, the much larger growth in LDPE consumption resulting from compulsory licensing led to much greater confidence in the market potential for HDPE and PP. Hence, the success of compulsory licensing in LDPE helped encourage the success of HDPE and PP, and probably led to more entrants into these latter markets.

price, and innovative rivalry which these extra entrants entailed would probably have been lost. Hence, by the happenstance of compulsory licensing, strong patent protection was reduced when its perpetuation would clearly have been harmful to industry performance.

Would this excessive patent protection have eroded anyway, through (i) efforts to invent around existing patents and (ii) increasing obviousness of the technology? The answer is somewhat different for the two main waves of technical change. Patent dominance and interlock was so strong in low density polyethylene that, in view of the complexity and difficulty of the high pressure process, little opportunity existed for inventing around the dominant accumulation of patents. Furthermore, the scarcity of know-how enforced by continued patent dominance would have delayed the impact of eventual obviousness in this technology. Consequently there would have been in all likelihood only a slow erosion of strong patent protection over the low density polyethylene market.

In contrast, the moderate degree of patent dominance which later developed in the higher density polyolefins was much more subject to this kind of erosion. The barriers to entry from patents were not strong enough to offset the attractiveness of their demand growth potential. Most of the firms which followed the pacesetters into these markets invested considerable effort in building patent portfolios for defensive purposes, i.e., for inventing around the possibility of dominant patent claims. Increasing obviousness in these markets was combined with entry by 15 different firms to make any close-knit control of know-how much more difficult. Therefore, once LDPE had been opened up, patents were not the main barriers to entry in the higher density polyolefins for the first decade of their development.[35]

Finally, even though there was a danger of continued strong patent protection in the low density market, would competitive rivalry have been sufficient in any event to ensure desirable technological and market development? The answer here differs in terms of technological performance,

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[35]More important factors in deterring higher density polyolefin entry in this period were the costs and risks associated with developing an efficient process, and in securing a large enough market. Had low density polyethylene been foreclosed from entry by continued, strong patent dominance, the attractiveness of entry into the higher density resins would have been further reduced. As it was, the majority of the latter entrants were originally, or became later, low density resin producers. Since the low density resin was always, and still is, the much larger market, participation in one or both of the higher density resins alone would have been less attractive. Hence, continued patent dominance in the low density market would have inhibited entry and rivalry in the higher density markets as well.

as opposed to price-output performance. Technologically, even though the marginal entrants made a real contribution to the pace of rivalry and received a significant share of the later improvement patents, one must concede that most of the technical developments would probably have been made without the 1952 decree. The degree of technical rivalry existing then, comprising at least ICI, duPont, ICI Phillips, Standard Oil of Ind., Ziegler, Natta, Monsanto and Hercules, was sufficient to provide the greater part of technical development which actually occurred.

But price-output performance would probably have been considerably less successful. The presence in these markets of roughly half of the present 10-12 participants, and probably a larger proportion in low density polyethylene, is traceable to compulsory licensing. With a much smaller number of producers, mutual dependence is greater, and likelihood of consensus or collusion on price levels and market shares is considerably greater. Prices would probably not have declined so far or so fast, and output would probably have grown less dramatically. Therefore, the main burden of continued strong patent protection in the original, larger LDPE market, would have been suffered in reduced output and higher prices, together with larger profits for the few producers.

This result would have provided a greater patent incentive to the few participants in these markets, but an unnecessary, and hence excessive reward. The main polyolefin innovations had already been amply encouraged and rewarded. Consequently, it was desirable public policy, albeit fortuitous in this instance, for compulsory licensing to be applied.

Chapter V

POLYOLEFIN TECHNOLOGY TRADING AND JOINT ARRANGEMENTS

As strong patent protection is reduced to lesser levels in an industry, technology trading and joint R&D arrangements are likely to be encouraged. Such transactions may take many forms, including--patent and know-how licenses, cross-licenses, joint R&D efforts, joint venture subsidiaries, acquisitions of plants, or complete mergers of companies. Although this kind of market activity may be generally desirable in improving the efficiency of firms and in reducing entry barriers, some of these arrangements may actually restrict entry or competition in a market or industry. When restrictive agreements significantly enlarge entry barriers or limit competition beyond what patents or headstarts would yield, a problem of conflict arises.

The polyolefins illustrate nicely the effect of reduced patent protection in stimulating technology trading and R&D cooperation. The first section of this chapter reviews that experience. The subsequent sections consider the degree to which competition was restricted by the more substantial R&D cooperation, joint venture subsidiaries, plant acquisitions and mergers. Fortunately, once compulsory licensing was applied, not much restriction was placed on the flow of technology in this industry. Nonetheless, it is instructive to review the licensing, cooperative R&D, joint venture, plant acquisition and merger activity in the polyolefins to see how excessive restraints on technology trading can be avoided.

Reduced levels of patent protection, technology trading and R&D cooperation

In extreme situations of perfect knowledge, mobility and competition, there would be little basis for technology trading; one could always assemble technological inputs at their marginal cost. But in the real world, where technology is often scarce and valuable, at least a demand for technology often exists, as a shortcut or aid to participating in a product market. Whether sales of technology actually take place will then depend on the interests of technology holders. As technology is more closely held, its scarcity value tends to increase. This means the compensating price to technology holders will have to increase, whether in the form of complementary technology, cash, or other consideration. As this price becomes higher, there are fewer firms likely to be willing or able to pay it.

The competitiveness or technology and product markets, and particularly the degree of patent dominance, will influence the kind of technology trading and joint research efforts that occur. With strong headstarts or patent dominance, technology sales by the technology holders are not likely unless complementary resources are provided in return. The reason is simply that the value of their monopolistic position is greater to those enjoying it than to those outsiders who might benefit from its dissolution. 1/

However, cooperation among outsiders to develop technology and the capability to participate in a monopolistic market is another matter. So long as such firms were in reasonably equal positions, each receives sufficient benefit in mutual assistance toward entry into a more profitable new market. But if one were substantially ahead of the other it is less likely to confer this valuable advantage upon its weaker rival; the leader will tend to reason as a prospective participant in the higher profit, monopolistic market. Hence, outsider cooperation would normally be restricted to relatively equal contributors.

As patent dominance is reduced to a moderate level, involving just a substantial cost differential for new entrants, the scarcity value of technology is reduced. If the number of participants is

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1/ Competitive returns on investment are normally lower than monopolistic returns. Therefore, it is unlikely that the outsiders benefiting from a breakdown of strong patent and headstart dominance would be able to gain enough to compensate the losers. Hence, once strong patent and headstart dominance is established it is not likely to be dissipated by technology sales from those enjoying this protection from competition.

still few in the product market, however, this premium is not likely to be much reduced. But as the number of oligopolists in production increases, the reduction in scarcity value will become substantial. Hence, as competition increases, the inhibitions on selling technology will be reduced greatly.

Nonetheless, even moderate or weak patent protection will assist sellers of know-how in making sure they can capture some return in technology trading. If patent protection were to disappear completely, the holders of scarce and valuable know-how would have less motivation to sell it. Technological know-how, once circulated beyond a very limited circle, tends to lose its market value. Furthermore, buyers would have less confidence in technology purchases, unless some degree of patent protection precluded free imitation by competitors.

Polyolefin Technology Trading

Polyolefin technology trading up through 1952

Apart from ICI's initial license to DuPont and the early instruction of Union Carbide in the process during the war, there is no significant evidence of know-how cooperation among these firms, or between them and any outsiders. In fact, despite their collaboration in maintaining strong patent dominance and a near absolute barrier to entry, Carbide revealed technological rivalry in pushing ahead of DuPont in early developments.

One pair of outsiders, however, did cooperate to a limited extent as relative equals during this period. This involved Standard Oil of Indiana and Monsanto in a complementary relationship. Between December 1949 and June 1953, an arrangement operated whereby Monsanto tested the plastic properties of the higher density polyethylene being worked on by Standard. Monsanto contributed plastics expertise gained in many other plastic resin markets, and Standard contributed its research headstart toward a higher density resin. A nonexclusive license to Monsanto for 4 percent on net sales was worked out and the possibility of joint production was contemplated in the agreement. However, the quality of Standard's plastic was insufficient at this stage, and the collaboration never went beyond the testing phase.

Polyolefin technology trading after 1952

Compulsory licensing in 1952 greatly altered the competitive setting within which technology trading took place. The up-to-date and complete process know-how held by ICI suddenly become available at reasonable royalties. The price for know-how was roughly 10-15 percent of the initial cost of constructing an efficient, large-scale plant, which was no great barrier to entry. And most important, ICI's obligation to furnish know-how meant that much of the learning risk ordinarily applying to new entrants was eliminated. Therefore, insofar as low density polyethylene was concerned, relatively easy access to know-how abruptly ensued for new entrants, and six firms immediately took advantage of it. 1/ Hence, there was little need for R&D collaboration among these new entrants.

Two years later, however, with the almost simultaneous success of the Ziegler and Phillips processes for higher density polyolefins, new market and investment opportunities arose in which technology trading played a much more important role. The primary reasons were that (i) these two processes, and the rival Standard process, were

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1/ It is interesting, however, that two of these licensees, Monsanto and Koppers, still found it worthwhile to take a supplementary know-how license from Badische Analin und Soda Fabrik (BASF). These investments can be interpreted as a hedge against process inefficiency.

less completely developed and needed refinement, and (ii) a reduced degree of patent dominance combined with large demand potential to encourage widespread interest, and many investments in both R&D and production. In this relatively competitive but stimulated environment, know-how collaboration and trading was extensive.

Each of the six initial entrants into the LDPE market after compulsory licensing made such arrangements in connection with their investments in, or at least R&D investigations of, the higher density olefin markets. Eastman Kodak strengthened its own R&D effort into higher density resins by (i) making an arrangement in 1956 with Standard Oil (Ind.) for a pilot plant, financed by Eastman with Standard process know-how; (ii) taking a know-how license in 1958 from ICI; and (iii) exchanging know-how in 1959 by conferences and reports with Rhone-Poulenc. By 1961, when Eastman had developed its own "404" process, this was licensed to Showa Denko for cash and further R&D cooperation.[1]

Spencer took a Standard license also in 1956, and in the next year exchanged technology with Staatsmijnen (the State Mines of the Nether-

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[1] A similar arrangement was worked out on an option basis with Diamond Alkali in 1961, but was evidently not carried further. Diamond Alkali later joined with Shamrock Oil in 1967 to purchase the Alamo Polymer (Phillips Petroleum) polypropylene plant.

lands, a diversified coal, chemicals and plastics producer). Then in 1961 it exchanged know-how with Standard Oil (N.J.) on polypropylene, in an agreement which contemplated a joint venture low density polyethylene plant; this later part of the arrangement never materialized, however.

Monsanto resumed its interest in higher density olefins with a Ziegler license in 1955, know-how exchange arrangements with Dow and Chemische Werke Hüls in 1959, and then also BASF in 1962. Dow, meanwhile, began its own independent research, exchanged know-how with Monsanto in 1959, and then in 1960 entered into a 10-year joint R&D development contract with Asahi of Japan, together with a partial investment in a production joint venture in Japan, Asahi-Dow.

Koppers took a Ziegler license in 1954, and in 1959 entered into a 3-year R&D cooperation with Avisun. This arrangement involved converting parts of the Koppers high density polyethylene plant to pilot polypropylene production.

National Distillers was the only one of the six new entrants into low density polyethylene not to make a prompt effort at entering high density olefin markets. But it took a Phillips high density polyethylene license in 1961 (jointly with Owens Illinois), and in 1962 it worked out a joindre of its polyolefin operations in the other two markets with Phillips in two separate joint venture subsidiaries, A.B. Chemicals (for low density polyethylene), and Alamo Polymer (for polypropylene). Meanwhile in 1962 it also exchanged know-how on low density polyethylene with the French firm, Ethylene Plastique, and in 1963 provided such know-how to Toya Soda, and worked out a tentative arrangement on these lines with a government financed company in the United Arab Republic.

Among the original eight producers of low density polyethylene only DuPont and Carbide failed to enter into any major joint research efforts. They were much stronger technologically than the other firms, and evidently felt it unnecessary--except that Carbide took a Phillips license on high density polyethylene in addition to its own R&D work using Ziegler catalysts, and later exchanged technology with the Phillips group on that process as a licensee.

Most of the other entrants into higher density polyolefin resins extensively employed joint R&D and technology exchange arrangements. The most important in this category was Hercules. It took a Ziegler license in 1954, and reinforced it with an 8-year joint research and development arrangement with Farbwerke Hoechst. This relationship was probably the most successful of all the R&D collaborations in the olefins, for it made Hercules the first and most successful polypropylene producer, and one of the earliest high density polyethylene producers. In 1959 this success was recognized in a technology and patent exchange with ICI on polypropylene resins, fibers, and films. This ICI arrangement was broadened somewhat in 1962.

Meanwhile, all of the Phillips licensees on high density polyethylene were committed to exchanging further process know-how with Phillips, and indirectly to each other. The group included Celanese, Grace, and later on Union Carbide.[1] This joint R&D relationship was operating by 1957 and proved to be quite important. In time it gave the Phillips group a significant technical edge over several firms attempting to use the Ziegler catalysts commercially.

Somewhat less successful was Goodrich-Gulf, which took a Ruhrchemie license on Ziegler catalyst know-how in 1957 and exchanged technical information until early 1959. Its small scale plant was abandoned after several years. Much later, in

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[1]Much later Gulf Oil, National Petrochemicals, and Chemplex also took Phillips licenses on HDPE.

1968, Gulf Oil itself entered high density polyethylene production with a Phillips license. Another relatively unsuccessful firm was Firestone, which merely took a license from a German engineering company, Hans J. Zimmer Vefahrenstechnik. Compared to the successful entrants, these two firms illustrate more modest commitments to R&D development.

It is interesting in contrast that the two Phillips licenses which were new to the olefins reinforced their positions in high density polyethylene with additional technology exchanges. Grace entered into a joint R&D program with El-Rex (Rexall and El Paso Natural Gas) in early 1961. This was extended in 1963, and Allied continued the relationship when it acquired the Grace plant in 1965. Celanese reinforced itself in an exchange of know-how in 1962 with BASF on high density polyethylene. Incidentally, a Phillips representative was explicitly provided for in the conferences.

Avisun, already mentioned as a collaborator with Koppers, reinforced its efforts further in license and technology exchange agreements with Shin Nippon Hiryu in 1961, and with Standard Oil (Calif.) in 1962.

Standard Oil (N.J.) took a Ziegler license in 1955, then entered into brief "look see" exchange agreements with DuPont and Eastman in 1959-60, followed by a joint research contracts on polypropylene fiber and yarns, with J. P. Stevens in 1960 and National Plastic Products Co. in 1962, together with a fiber process license from Hans J. Zimmer Verfahrenstechnik of W. Germany. This was supplemented by a limited technology exchange with Spencer in 1961, and a more extensive one with El-Rex in 1966.

Shell also employed a Ziegler license, and may also have added Montecatini know-how during the mid-1960's when Royal Dutch Shell became part owner of Montecatini. Shell also obtained exclusive patent rights and technology from Reeves Brothers, Inc. on polypropylene fiber processing.

The net of all this complementary trading in polyolefin technology was a total of more than 20 relationships among actual or potential polyolefin resin producers, plus the 13-firm technology exchange provided for by the Phillips licenses. 1/ By 1968, the only producing firms which had not participated in and benefited

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1/ This total of 13 firms includes 6 foreign licensees.

from such arrangements were DuPont, the unsuccessful entrants--Firestone and Foster-Grant, and the newest entrant, Chemplex, itself a joint venture of American Can-Skelly Oil. Chemplex simply took a $6 million know-how license from DuPont.

Impact of technology trading and joint-R&D efforts

Both technology trading and joint arrangements for research and development are aimed at reducing the costs of acquiring technology and entry into a product market. As such, their direct effect is to make innovative investments less costly, more profitable, and to increase competitive rivalry. So long as technology transactions occur within limited periods of time and leave their participants free for rivalry with their enhanced technological capabilities, their effect is unambiguously to increase the efficiency of the capital market and the effectiveness of competition. As patent and headstart advantages weaken, technology trading is part of the process by which competitive rivalry tends to limit the advantages of past innovators. This role for technology trading is socially desirable and not at all controversial.

Such controversy as does arise with technology trading and joint research and development concerns the effect of exclusive and longer lasting alliances between firms, which inhibit rivalry between them and restrict competition in the marketplace. In other words, some of these transactions may do harm to competition even though the participating firms gain significant advantages. Therefore, we need to consider the anticompetitive effects of joint technology trading and R&D efforts.

The initial close-knit patent licensing arrangement of ICI, DuPont, and Union Carbide illustrates a long lasting, and completely market dominating technology exchange. From 1942-52, these firms reinforced the basic protection afforded by ICI's initial patents with 58 improvement patents. In the absence of compulsory licensing on LDPE patents and know-how in 1952, these improvement patents would have ensured strong patent protection well beyond the expiration dates (1957) of ICI's two original basic LDPE patents.

But since compulsory licensing was applied in 1952, technology trading and joint R&D efforts among polyolefin resin makers have been largely in aid of new entry. Although such arrangements could have been a serious competitive problem if the result had been to restrict technique to a close-knit group of dominant firms in these markets, their use in the polyolefins has generally encouraged new or marginal firms to make an entry into these markets, or to continue in production. Consequently, technology exchanges since 1952 in the polyolefins have been largely procompetitive.

Almost all of the subsequent R&D cooperation has involved the newer resins, polypropylene or high density polyethylene. The reason is simple enough; low density polyethylene know-how became widely available for reasonable royalties by court decree, whereas firms desiring technique for high density polyethylene have either had to develop it themselves, pay a high price for it from an established producer, or develop it jointly with others.

Five of the nine successful entrants into polypropylene were aided in some significant degree in their entry by R&D joint ventures. These five producers are Hercules, Avisun, Dow, Phillips, and El-Rex. Only one of these research relationships, Phillips-National Distillers, was broadened into a production joint venture.

Each of the other relationships left its partners free to enter independently. (Avisun-Koppers and El Rex-Grace also fit this general rule, although Avisun and El Rex were themselves joint ventures for production before they participated in a R&D joint venture with third parties.) Furthermore, several potential entrants into polypropylene also obtained some know-how by R&D efforts. These firms included Koppers, Standard Oil (Calif.) and W. R. Grace.

In high density polyethylene no entry is clearly traceable to an R&D venture beyond Hercules. But all the current producers except DuPont were aided to some degree by joint arrangements, and several potential entrants resulted -- the latter included Monsanto, Eastman Kodak and Standard Oil (Ind.). Like the polypropylene R&D ventures, the effect of these arrangements was generally to help firms compete more effectively.

Competitively speaking, the impact of these R&D ventures was clearly beneficial and in aid of entry. No foreclosure of technique for others has resulted, and technical progress was further encouraged. While several of the production joint ventures, including the Phillips-National Distillers relationship, involved some lessening of potential competition, it was the more permanent tie involved in continued production that involved a danger to competition, not any short-term cooperation for research and development.

There is only one polyolefin technology exchange since 1952 which could conceivably involve dangers to competition. This is an aspect of the cross-licensing pool for the Phillips HDPE process. When Phillips began to license its process in the mid-1950's, it had just one of three competing HDPE processes. The technology was still far from fully refined, and a mutual grant-back on future patents and know-how developments was included to assist all participants in the Phillips group. 1/ Over the years, however, the Standard Oil (Ind.) HDPE process proved less successful--and it is still not being used commercially in the U.S. 2/ Even though Union Carbide, Dow, Koppers, Hercules, Monsanto and Goodrich-Gulf at one time were in production on the Ziegler HDPE process, only Koppers, Monsanto and Hercules survive as Ziegler process users. Meanwhile Dow and DuPont claim independent

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1/ Current U.S. participants in the Phillips group include: Phillips itself, Union Carbide, Celanese, Allied, National Petrochemicals, Gulf, and Chemplex. (See Table III-1, supra.)

2/ Standard Oil (Ind.) will be the first U.S. producer to use the process, in a new plant scheduled for operation in 1970.

HDPE processes of their own. This means 7 of the 13 present and prospective HDPE producers have benefited from the mutual exchange of improved technology in the Phillips group. But although cooperation in the Phillips group has been somewhat more successful than some of the smaller groups and bilateral relationships, the Phillips group still lacks market dominance or control over entry into the HDPE market. Therefore, the mutual grant-back of future technological development has not--up to this point, restrained competition in the development of high-density polyethylene.

In this connection it should be emphasized that, although the Montecatini product claims on polypropylene seem to have inhibited new entry into PP since 1965, thus far no restrictive cross-licensing arrangement has evolved. The reason is that the Montecatini patents, on their face at least, dominate the PP market. Consequently, as Montecatini enforces its claims to assert very substantial royalties, it inhibits entry into the market for the benefit of all other established PP producers.[1] No joint agreement or patent licensing pool is needed in these

[1] These claims are not likely to be enforced very strongly, i.e., for any large royalties, against the established PP producers, with significant defensive patent portfolios in polypropylene.

circumstances to maintain an entry barrier. Montecatini's own independent efforts, are not sufficient to restrict entry into the PP market.

Resin Making Joint Subsidiaries

Joint subsidiaries are typically more substantial in scope and duration than either short-term trading in technology or joint R&D cooperation. This certainly is illustrated with the eight joint venture subsidiaries which have been active in the polyolefins. The parties to these ventures no longer remained free to enter and compete in the polyolefins as independent firms. But, on the other hand, joint subsidiaries are normally less permanent and binding than a complete merger of joint venture partners. Hence, their competitive impact ranges somewhere between short-term technology exchanges and mergers.

Anti-competitive effects from joint venture subsidiaries fall into three categories: (i) the impact in markets in which the venture is operating; (ii) the impact in markets where the parents compete; and (iii) the cumulative effects of many joint ventures in a group of industries, such as petrochemicals, in linking the leading firms together and in altering the present and potential competition among these firms and their smaller rivals. 1/

Competition may be reduced in the market in which the joint venture is active when the joint venture itself, or its partners, are significant participants or potential participants. The joint venture itself may be so powerful as to foreclose or limit entry or to dominate already participating firms in such a way as to substanitally lessen competition. The venture partners might already be such substantial factors that joint venture between them amounts to a competitively dangerous horizontal consolidation. Or, one or more of the partners might otherwise have entered independently, and the loss of this potential entrant might be a significant reduction in competition. If entry remains easy into affected lines of commerce, the danger from joint arrangements will not be significant. But if entry is difficult, and the market has

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1/ U.S. v. Penn-Olin, 378 U.S. 158 (1964); Kaysen and Turner, Antitrust Policy, op. cit., pp. 136-141. See also, Robert Pitofsky, "Joint Ventures Under the Antitrust Laws," 82 Harv. L. Rev. 1007 (March, 1969).

relatively high concentration and interdependence, the elimination of just one of a relatively few potential entrants by joint venture might substantially lessen competition.

In addition to the direct elimination of potential competitors and competition in the market where the joint arrangement is operating, there may be a reduction of competition in the other markets where the partners participate. Competition in other markets may be reduced when the partners are significant factors in these markets, because partnership in one field may be inconsistent with rivalry in others. In these other markets competition and entry conditions may also be affected adversely by a network of large firm alliances, putting the remaining independents and potential entrants at a disadvantage.

The cumulative effect of many joint ventures in a group of closely related industries such as petrochemicals may be injurious to competition. Intermediate product marketing patterns already require a great deal of reciprocal purchasing and selling among major firms. There is also considerable exchange and cross-licensing of petrochemical technology among the larger firms, even though such firms are often strong rivals in research. If to these already established patterns of reciprocal dealing are added a substantial number of joint ventures among major firms, a network of interrelationships and alliances could result which is cumulatively inhibitive to competition in these industries. The larger companies could reduce their competition substantially, or the smaller companies or potential entrants might find their competitive role substantially reduced.

Fortunately, the polyolefin joint venture subsidiaries have not had a significant restrictive effect on competition--with one exception. This venture was promptly divested after a Federal Trade Commission challenge under Section 7 of the Clayton Act. Altogether, eight joint venture subsidiaries have been active in polyolefin resin production. A significant portion of the current producers have been joint subsidiaries--3 of the 12 low-density polyethylene producers, 3 of 12 high-density polyethylene producers, and 3 of the 8 polypropylene producers **(Table V-1)**.

Table V-1

Resin making joint venture subsidiaries

LDPE	HDPE	PP
A. B. Chemical (1) (National Distillers-Phillips)	National Petrochemicals (4) (National Distillers-Owens-Illinois)	Alamo Polymer (6) (National Distillers-Phillips)
El-Rex (Rexall-El Paso) (2)		
Sinclair-Koppers Co. (3) (Koppers-Sinclair)		
	Sinclair-Koppers Co. (Koppers-Sinclair)	El-Rex (Rexall-El Paso)
	Goodrich-Gulf (5) [dropped out of production in 1964]	Avisun (7) (Avisco-Sun)
American Can-Skelly Oil (8)	American Can-Skelly Oil (8)	

Ventures among substantial producers

The National Distillers-Phillips petroleum joint ventures were unique among the polyolefin resin making ventures in that they linked already well established polyolefin producers; all the other joint ventures have been either new entrants or simply reinforcement by a new firm of an established resin maker. Distillers and Phillips joined forces in 1962 to produce polypropylene. This was a new market for both; up to that point Distillers produced only low density polyethylene, and Phillips only high density polyethylene. Their polypropylene joint venture firm, Alamo Polymer Corp., then began a program of vertical integration acquisitions into polypropylene fiber (they are described *infra*, at pp. 242-248.) If the venture had stopped here, it would be somewhat like the other resin making joint venture subsidiaries in that a new entry was involved; yet this venture would still be unique because each firm was already one of the strongest and most likely potential entrants into polypropylene. Phillips had been the leading high density producer from the beginning, with nearly 25 percent of the market, and Distillers was the third ranking low density producer with about a 15 percent market share.

But then the relationship was enlarged. Distillers subsequently sold one of its two low density resin plants to Phillips, operating it on a joint venture basis a A.B. Chemical Corp. In return Phillips licensed Distillers as a high density polyethylene producer. Distillers next went into production of high density polyethylene in a joint venture with Owens-Illinois. Owens was in 1961 the leading blow-molder, with nearly 40 percent of the market, and was also one of the leading glass bottle makers. (Blow-molding is the dominant end use for high density polyethylene.) In effect, Phillips and Distillers came close to merging their polyolefin resin operations by joint venture, and Distillers (and perhaps also Phillips) made a major vertical integration forward with the Distillers-Owens partnership for high density polyethylene.

Since there are only 12 LDPE producers, 11 HDPE producers and 8 PP producers (a total of 19 companies, with some firms producing several resins), a combination of two of the leading firms in these markets threatened a significant lessening of potential competition. Since both firms were among the few strong and most likely entrants into the other olefin markets, by acting jointly this eliminated one of them as a potential competitor. Furthermore, even though the joint market shares in each resin were not at the outset much larger than their independent market shares, this collaboration encouraged other combinations among the leading producers, and tended to inhibit entry by other companies. Hence, the force of potential competition was significantly reduced by this arrangement. 1/

1/ Apart from reducing the strength of potential competition in the polyolefins, there was little impact in other markets. Both Phillips and Distillers manufactured nitrogen and nitrogen compounds, together with a number of petroleum feedstocks for plastics. But there are many more producers of nitrogen and nitrogen compounds than there are polyolefin producers, and neither Phillips nor Distillers has the competitive strength in the nitrogen area that each had in the polyolefins. In petroleum feedstocks--including ethylene, propylene, butylene and butadiene, the relative importance of Phillips and Distillers is no more significant than their combined standing in nitrogen, since any major refiner of petroleum or natural gas can easily produce such feedstocks and, in addition, a considerable number of the large chemical and rubber companies in the nation have integrated backward into the production of feedstocks. Hence, neither Phillips nor Distillers were significant enough in these other markets to make any lessened rivalry between the two firms a substantial lessening of competition.

In addition, the Phillips-Distillers venture was unique in that these two firms together made the largest number of vertical integration mergers in the polyolefins, a total of 11--including the National Distillers arrangement with Owens-Illinois. Such a major campaign of vertical integration by already well established resin producers tended to encourage still more vertical integration. Too much of this integration would tend to raise entry barriers, by foreclosing new resin producers from markets, and subjecting independent fabricators to the threat of a collusive price squeeze.

Insofar as a cumulative lessening of competition in the broader category of petrochemicals is concerned, it is clear that the Phillips-Distillers-Owens combination has been one of the most important joint venture combinations in this field. Its size and scope, if allowed to stand, might have given too much impetus to the recent trend. If such a combination were imitated very often, competition might be endangered in many markets.

Because the Federal Trade Commission found these competitive effects amounted to a probable substantial lessening of competition, it notified the parties that a complaint would issue. After some negotiation, the parties agreed in a consent settlement to separate their operations and partially divest the vertical integration acquisitions.[1]

Reinforcement ventures

The Rexall-El Paso and Koppers-Sinclair ventures both involved a reinforcement of established polyolefin producers by a major petroleum or natural gas producer. Neither venture nor the parent companies involved had sufficient market power to threaten competition in the polyolefins, but both ventures did contribute somewhat to a trend of joint relationships between major oil and chemical companies.[2]

Insofar as the Rexall reinforcement is concerned, it is clear that the decision to expand from low density polyethylene into polypropylene was to some degree made in reliance on the financial support of El Paso, and perhaps with reliance on its

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[1]For the final results of this litigation see Table III-1, and the appropriate footnotes.

[2]Both reinforcement ventures would, of course, aid entry if El Paso and Sinclair later entered polyolefin resin production independently as a result of joint cooperation, and then terminated these partnerships.

R&D cooperation. 1/ Whether Rexall would have entered polypropylene independently is conjectural without detailed inquiry into the planning and resin process available to Rexall. But Rexall could have entered alone, even though its financial risk would have been greater, and it would have been in a better know-how position than all petrochemical producers but those few firms which were better established polyolefin producers. El Paso would have been much less likely to enter independently, particularly as entry barriers had been substantially increased. However, with a rapidly growing market, an entry by El Paso was still conceivable, as it was earlier by Phillips and Standard Oil (N.J.).

In contrast, the Koppers reinforcement came after both of its plants were established. And although Koppers suffered some process difficulties with its higher density plant, the reinforcement probably had little effect on the continued presence of Koppers in the market. However, future expansion plans may be bolder after reinforcement than they were before.

1/ Feedstock supply does not appear to have been a significant factor, since many alternative sources of feedstock could have been arranged with little or no extra cost to Rexall.

Sinclair Oil, like El Paso, was clearly less likely to enter independently; but it has similar size and strength, and its own feedstock, to justify independent participation.

However, in neither venture was the reinforcing firm a likely independent entrant into polyolefin resin manufacture. Neither Sinclair nor El Paso has ever produced plastics of any kind before and both were faced with scale and know-how barriers to entry. Both are more likely to enter independently now after having had some joint experience. Furthermore, Rexall and Koppers were the smallest of the surviving polyolefin producers; with about $200 million in assets when reinforced, and might justifiably desire financial aid to reduce the risk of their large polyolefin investment. Therefore, these two ventures involve only modest shortrun costs for competition, which may well be offset by modest gains to competition.

New entry ventures

The remaining joint ventures in polyolefin resin making--Avisun, Goodrich-Gulf, and the recent American Can-Skelly Oil, have all been joint entries into new fields for both partners. None of these ventures or their parents have had sufficient market power in the polyolefins to threaten competition. Each venture added a new producer, although it did eliminate a possible competitor which might have entered independently, and added to a cumulative trend of joint ventures in oil, rubber and chemicals. At least five of the parent companies had sufficient financial resources to enter polyolefins independently, but none were as strong potential entrants as the major producers of other plastics, such as Monsanto, Dow, Allied or American Cyanamid.

Avisco was the smallest of the joint venture parents, with about $100 million in assets when it joined with Sun to enter polypropylene in 1957 and may well have needed external financial support in its entry. 1/ Skelly Oil was larger, with $380 million

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1/ However, Avisco as a synthetic fiber producer was closer in a production know-how sense to polypropylene, which is also a synthetic fiber.

in assets, but six years later entry was considerably more costly, risky and difficult. Sun Oil and American Can, on the other hand, had approximately $1 billion in assets, respectively. Hence, Sun Oil and American Can had no financial problem in entering, although each was a stronger entrant with support than they would have been independently. In each of these cases, however, independent entry by both pairs of firms was not likely. Hence, the actual entry of a stronger joint competitor was probably more of a gain to competition than the doubtful loss of another potential entrant.

In the case of Goodrich-Gulf, however, joint venture was clearly unnecessary for either firm's entry. Despite this lack of redeeming necessity, Goodrich-Gulf as such had no significant market share in the polyolefins, and any challenge as to its impact on potential competition in the polyolefins became moot when Goodrich-Gulf ceased production of high density polyethylene. Shortly before production terminated, Gulf entered low density production by acquisition of Spencer.

Goodrich now remains a potential independent entrant into polyolefin resin manufacture.

Hence, in these three situations of new entry into resin making by joint venture subsidiaries, the loss to potential competition was modest or offset by the immediate gain of a new entrant. Although the trend of increased joint venture activity may have been encouraged by these ventures, the significance of this trend must be appraised in the light of competitive conditions in the chemical industry as a whole.

Polyolefin Plant Acquisitions

There have been two important plant acquisitions in the polyolefin resin markets. Each involved a seller that had been active in one of the polyolefin resin markets, but preferred to commit new investment resources in other fields, and hence was willing to sell off its plant. Each involved a buyer that was a strong potential entrant into one or more of the polyolefin resin markets, and took this opportunity to reduce its costs of entry. Both acquisitions were

investigated as possible violations of Section 7 of the Clayton Act by the Federal Trade Commission, and so considerable information is available on each transaction.

The first to be resolved in terms of legality was the acquisition by Standard Oil (Ind.) of Avisun's polypropylene plant in 1967. Standard, although one of the three developers of catalysts for higher density polyolefins in the mid-1950's, had not made any direct investment in the U.S. toward actual production. Apart from furnishing technology and helping to finance the Furukawa and Rumianca HDPE plants in Japan and Italy, Standard was merely a strong potential entrant into the polyolefins.

This transaction substituted a somewhat larger oil company, Standard (Ind.), for Sun (Sun had acquired its joint venture partner's share in 1963) as the owner of Avisun's polypropylene plant. The problem facing the Commission was whether there had been a substantial lessening of potential competition. In the short run it could be reasonably argued that no entry at all was likely in the face of substantial excess capacity in the market, and the apparently dominating patent claims received by Montecatini in late 1963. In the long run, however, there was a considerable number of other potential entrants into polypropylene of roughly equivalent strength and size. DuPont, Union Carbide, Monsanto, Allied, Celanese, Gulf, Koppers, and Chemplex had already entered one or more of the other polyolefins, and at least some other large oil companies, including Standard Oil (Calif.), Mobil, Texaco, Continental, Sinclair, Cities Service, and Atlantic-Richfield, several of which were already producing polyvinyl or polystyrene plastics, were also strong potential entrants. Hence, from any time perspective, it could be plausibly argued that Standard's entry by acquisition of the Avisun plant would not be a substantial reduction in the force of potential competition.

And yet if Standard Oil (Ind.) were an eventual winner in the basic patent interference proceeding on polypropylene (Interference No. 89,634, which is still pending), and received a dominating patent claim, then its acquisition of Avisun would take on a new significance. Standard (Ind.) would then be a much stronger potential entrant into polypropylene. Not to have challenged its purchase of the second largest polypropylene plant (Avisun), would be, in retrospect, a serious failure to prevent a significant lessening of likely and potential competition in this market. In this situation a consent settlement was worked out under which Standard accepted reasonable royalty, compulsory licensing of any basic patent rights on polypropylene that it might receive in Interference No. 89,634. Thus Standard, at least, was prevented from unreasonably restricting entry into polypropylene with its patent rights. In these circumstances, the Commission allowed Standard to keep the Avisun plant.

The facts in the Allied acquisition of the Grace high density polyethylene plant were somewhat alike. Allied was one of the strong potential entrants into the market, but had only been involved in the polyolefins thus far as producer of a narrow spectrum, medium density polyethylene wax resin in two small plants. This second transaction subsituted one chemical company, Allied, for another of about the same size and strength, Grace, which had simply decided to pull out of these markets. The problem for the Commission was similar. Had there been a substantial lessening of potential competition? However, entry conditions were considerably easier in HDPE, as was evidenced by four new entries since 1964--National Petrochemicals (National Distillers-Owens Illinois), Gulf, Monsanto and Chemplex (American Can-Skelly Oil). Allied could have entered independently, and arguably did not need to acquire the Grace plant, but the removal of Allied as a potential entrant was less significant. A number of other potential entrants into HDPE also existed, who were already polyolefin producers, including Eastman Kodak, Shell, Rexall, and Standard Oil (N.J.), together with some major oil companies, Standard Oil (Ind.), Standard Oil (Calif.), Mobil, Texaco, Continental, Sinclair, Cities Service, and Atlantic-Richfield.

But even though these two plant acquisitions may have involved a marginally substantial lessening of potential competition in terms of their respective product markets, it

seems clear that nether transaction had nearly as much competitive impact in the relevant technology markets. By the time these two mergers occurred, participation in higher density polyolefin technology had become so extensive that some 20 firms could be reasonably counted as potential participants. 1/ In this context, the residual patent protection applying to the Phillips and Standard of Indiana processes, and the Montecantini claims on polypropylene, were much more significant restrictions on the circulation of technology. This illustrates the likelihood that, except where mergers occur in a more close-knit, smaller group market--such as might be involved when strong patent and headstart advantages are operating, patents are more apt to restrict technology trading than mergers.

Complete Mergers in the Polyolefins

In the polyolefin markets there has been one complete merger involving a resin maker, and about 40 vertical integration acquisitions by resin makers of independent fabricators. The one resin maker was Spencer, which was

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1/ This includes all of the active polyolefin producers, plus Standard Oil (Ind.) and Standard Oil (Calif.).

acquired by Gulf Oil in 1963, and this transaction is somewhat similar to the Avisun and Grace plant acquisitions just discussed. Spencer was operating a large, efficient low density polyethylene plant, although it also had capital assets spread through many other chemical markets. Spencer had about $100 million assets and the same in annual sales when acquired, of which 15-20 percent were involved in the LDPE plant.

Gulf was in a better position to enter low density polyethylene than some other large oil or chemical companies. Gulf had already attempted a small scale, tentative entry into HDPE with its Goodrich-Gulf joint venture. Hence, this merger posed the same kind of potential entry problems. Was the elimination of Gulf as an independent entrant a substantial lessening of potential competition in LDPE?

Entry conditions into LDPE in 1963 were probably the most favorable of the polyolefins. Demand growth each year in LDPE was by far the largest in terms of minimum efficient scale of plant. Patents had ceased to operate as a significant barrier to entry, although know-how remained scarce and expensive.

There were many potential entrants, including at least Hercules, Celanese, Standard Oil (Ind.), Standard Oil (Calif.), Shell, Sun, Mobil, Texaco, Sinclair, Cities Service, Atlantic-Richfield, and less obvious joint venture partners, such as American Can-Skelly Oil. Gulf's elimination from this list would not be significant, unless perhaps it became a precedent enabling a significant number of large oil-chemical marriages. Therefore, this acquisition was at most only a marginally important reduction in the force of potential entry; it is not surprising that this merger was not challenged by either of the antitrust agencies. From a technological point of view, the Gulf-Spencer merger again illustrates the lesson that--absent a close-knit control over patents or know-how, a merger which does not significantly affect product markets will not ordinarily restrict technology circulation.

Only one of the 40 vertical integration mergers occurring in the polyolefins was important enough to be challenged under Section 7 of the Clayton Act, and there, the significant effects were in the resin and film product markets.

This case involved Union Carbide's acquisition of Visking in 1957. Carbide then had 40 percent of the low density polyethylene market and Visking accounted for one-third of the polyethylene film production, or about 15 percent of low density polyethylene consumption. This merger was ultimately found illegal, as tending to encourage a threat of vertical foreclosure to both resin makers and independent fabricators, the latter also being threatened with a price squeeze. Complete divestiture of the acquired assets was ordered in 1963, although Carbide was allowed to keep a large film plant it constructed thereafter. 1/

All of the other forward vertical acquisitions in the involved much smaller market shares at both ends, resin supply and resin consumption. No individual acquisition appeared to involve more than 2-3 percent of resin consumption, and there was no significant market impact individually (Table V-2). However, one group of these vertical acquisitions was challenged.

1/ Most of Carbide's LDPE competitors later acquired film makers, but with much smaller market shares. The resin and film markets had meanwhile grown substantially, so that Carbide's retained captive consumption only amounted to some 10 percent of the film market, and 3 percent of LDPE consumption.

This involved the 11 vertical acquisitions engaged in by Phillips-National Distillers; they were collaterally attacked along with their joint venture, and two plants were divested in one form or another. 1/

In none of the fabricating markets affected by these vertical mergers was there any significant restriction on technology access or circulation. The competitive effects considered and objected to were entirely in the product markets. Hence, in the absence of close-knit control of patents or know-how, vertical mergers did not raise technology market problems.

1/ In the Matter of Phillips Petroleum Co., FTC Docket No. C-1088 (1966), Wall Industries (a polypropylene rope manufacturer) and a National Distillers film plant at Stratford, Conn. were divested.

Table V-2

Vertical Integration by Polyolefin Resin Makers

Resin Makers (entry years)	Resin Market Share 1962 (Millions of pounds produced)	Direct Investment and End Product Fabricator Acquisitions (year acquired)	End Product Market Share When Acquired 1/
1. Union Carbide (LDPE in 1943)	27.0% (433.1)	Film - Visking (1956) 2/	Large (33.0%)
(HDPE in 1958)	8.6% (36.3)	Bottles - Direct investment and acquisition of Engineered Plastic Containers	Modest
2. Du Pont (LDPE in 1943)	17.0% (273.2)	Film - Direct Entry	
(HDPE in 1960)	12.3% (52.3)		
3. Monsanto (LDPE in 1955)	6.4% (102.9)	Film - Plax (1957)	Modest
		Gering (1961)	Substantial
		Bottles - Plax	Substantial
		Pipe - Gering	Modest
4. Dow (LDPE in 1955)	11.0% (177.2)	Film - Dobeckmun (1957)	Substantial
		Extruders, Inc. (1958)	Modest
		Joint venture with Pacific Chem. & Fert. in Hawaii	Negligible
(HDPE in 1960)	4.9% (20.9)	Bottles - Joint Venture with Hoover Ball & Bearing and subsequent direct investment	Modest
(PP in 1961)	2.8% (4.0)	Injection Molding - Quinn Berry Corp. (1964)	Modest

Resin Makers (entry years)	Resin Market Share 1962 (Millions of pounds produced)	Direct Investment and End Product Fabricator Acquisitions (year acquired)	End Product Market Share When Acquired 1/
5. National Distillers			
(LDPE in 1955)	15.2% (24.4)	Film - Kordite (1958) 3/	Substantial
(HDPE in 1964)		Bottles - JV with Owens-Illinois (1964)	Large
(PP in 1964)		Fiber - G.F. Chemical (1964) Reeves Bros. yarn plant (1964) Beacon Mfg. Co. (1964) Wall Industries (1963)	(Modest (as a (group
		Color Concentrates - Polymer Dispersions, Inc. (1964) 4/	
6. Eastman Kodak			
(LDPE in 1954)	7.1% (115.1)		
(PP in 1961)	6.5% (9.3)		
7. Koppers			
(LDPE in 1955)	3.0% (48.4)	Film - Durethene (1955)	Substantial
(HDPE in 1958)	3.6% (15.2)	Bottles-Nat'l. Platics Div. Pacific Industries Inc. (1955)	Modest
8. Rexall-El Paso			
(LDPE in 1961)	4.2% (67.6)	Film - Chippewa (1959)	Substantial
		Injection Molding - IMCO (1961)	N.A.
(PP in 1964)		Bottles - IMCO (1961)	Substantial
		Hose - Colorite (1964)	Negligible
		Color Concentrates-Wilson Products (1965)	

Resin Makers (entry years)	Resin Market Share 1962 (millions of pounds produced)	Direct Investment and End Product Fabricator Acquisitions (year acquired)	End Product Market Share When Acquired 1/
9. Gulf (Spencer)			
(LDPE in 1955)	7.2%	Film - Crown Zellerbach supply contract (1958)	Substantial
(Gulf acquired	(115.1)	Flexicraft (1961)	Negl.
Spencer in 1963)		Crystal Tube (1961)	Negl.
		Rafco (1964)	Negl.
10. Allied			
(LDPE in 1959)	1.5%		
	(24.3)		
(HDPE in 1959)	1.2%		
	(4.1)	Pipe Mennesman, Inc. (1964	Modest
11. Hercules			
(HDPE in 1957)	13.1%	Bottles - JV with Amer. Seal-Kap (Haskon, Inc.)5/ (1963)	Negl.
		Haveg	
(PP in 1957)	36.2%	Injection Molding - Haveg (1963)	
	(51.7)		
		Film - Direct investment	Modest
		Fiber - Direct investment and acquisition of Columbian Rope (1965)	

Resin Makers (entry years)	Resin Market Share 1962 (millions of pounds produced)	Direct Investment and End Product Fabricator Acquisitions (year acquired)	End Product Market Share When Acquired 1/
12. Phillips			
(LDPE in 1962)		Film - Sidney Thomas (1962)	Substantial
		Extrusion Coating - H.P. Smith (1962)	Substantial
		Sealright (1963)	
(HDPE in 1957)	23.3%	Bottles - Purex (12% interest)	Substantial
		Brown Machine (1964)	in bottle usage
		Pipe - Skyline Industries (1963)	A leader, with 10%
(PP in 1964)		Fiber - Wall Industries (1963)	(Substantial
		Reeves Bros. yarn plant (1964)	(as a
		G. 7. Chemical (1964)	(group
		Beacon Mfg. Co. (1964)	
13. Celanese			
(HDPE in 1958)	12.1%	Film - Plastic Horizons (1959)	Modest
	(51.3)		
		Bottles - Royal (1959)	Substantial
		Polybottle (1960)	
		Pipe - Yardley (1963)	Substantial
		Injection Molding - Fed'l. Enameling	Substantial
14. W.R. Grace			
(HDPE in 1958)	16.4%	Film - Howard Plastics (195?)	Negl.
	(69.4)	Molding - Southbridge Plastic Products (1965)	N.A.
		Dewey & Almy (1951)	Modest
		Fiber - Dawbarn (1963)	Substantial

Resin Makers (entry years)	Resin Market Share 1962 (Millions of pounds produced)	Direct Investment and End Product Fabricator Acquisitions (year acquired)	End Product Market Share When Acquired 1/
15. Standard Oil (N.J.)			
(LDPE in 1963)		Film - Extrudo (196)	Substantial
(PP in 1961)	17.4%	Fiber - National Plastic Products (acquired	Modest
	(24.8)	jointly with J.P. Stevens)	
16. Shell Oil			
(PP in 1961)	1.4%		
	(3.4)		
17. Avisun			
(FMC - Sun Oil)	21.4%	Film - Direct investment	
(PP in 1958)	(30.5)	Strapping - Direct investment	
		Carpet backing -Plymont Packague joint venture investiment	
18. Montecatini			
(PP in 1961)	10.1%		
	(14.5)	None	

1/ Market shares in end use markets are rated as follows: large, over 10%; substantial, 3-10%; modest, .5-3% negligible, under .5%. Since no end product market has accounted for more than 25-30 percent of resin consumption, only the "large" market share acqusitions in any given product market could account for as much as 2-3 percent of total resin consumption.

2/ Half of expanded assets divested to Ethyl Corporation in 1963.

3/ Half of assets sold to Socony Mobil in 1962.

4/ Color concentrates are used in fabricating many plastic resins, including polyolefins.

5/ Later acquired the share of American Seal-Kap.

Source: Federal Trade Commission, Bureau of Economics Survey Data.

Chapter VI

PERFORMANCE LESSONS

An interesting performance lesson emerges from the polyolefin experience.[1] At least three circumstances can be identified in which strong patent protection seems to be unnecessary and excessive: (i) where the pioneering stage of technological and market development is completed and substantial market risks are no longer involved in further development; (ii) where substantial headstart incentives provide ample returns on investments in innovation; and (iii) where well-established large firms enjoy substantial headstart incentives. Polyolefin performance confirms the hypothesis that strong patent protection would not be needed in such conditions.

From a performance standpoint the most striking feature of polyolefin development is an abrupt shift in the balance of patent, headstart, and competitive incentives. From its discovery until 1952, low density polyethylene was nurtured through research and into the

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[1]Industrial performance comprises the results or achievements of an industry's operations. Efficiency results are reflected in the trend of costs within an industry, its cost-price margins, and profit rates. Progressiveness results are reflected in the rate of innovation, the spread of new processes and products, and the rate of growth in new product use. These results must then be evaluated in terms of potential achievements, or at least by comparison with similar industries. (Footnote continued on next page.)

market with the help of strong headstart and patent incentives. While significant interproduct rivalry applied, only limited duopoly rivalry between DuPont and Union Carbide was effective within the U.S. market. In this situation the quality of resin product was improved very greatly, consumption increased substantially, and costs were probably reduced considerably. But although prices were dropped somewhat to promote sales, profit rates were very great in the latter years of this period for the two duopolists.

Then a decade of oligopoly rivalry began in the early 1950's. Patent barriers to entry were broken down in low density polyethylene by compulsory licensing, and proved weak at the outset in the higher density polyolefins. Because demand potential was evidently large and inviting to new entrants, market structure was transformed quickly into an oligopoly of 8 to 10 large, diversified firms in each resin market. Competitive rivalry within these markets increased. Product quality was further improved, consumption mushroomed, costs were lowered substantially, and profit margins greatly narrowed.

Unfortunately, many aspects of potential performance are very hard to identify, especially those relating to innovations in cost reduction or with new and improved products. For this reason economists have generally contented themselves with asking--Could performance have been improved in some way by structural change, altered conduct, or perhaps some government intervention? The object is to find some means by which a net improvement in performance could be achieved without offsetting costs. As Jesse Markham once observed, "[A]n industry may be said to be workably competitive if public policy measures can produce no changes that would obviously make society better off." Competition in The Rayon Industry, Harvard, 1952, at p. vii of the preface. Incidentally, Markham credits Schumpeter with suggesting this performance standard.

But although patents were reduced in importance, they remained important enough to stimulate a flourishing trade in technology, which facilitated both new entry and further innovation. Meanwhile, head-starts--in the form of scale, know-how and marketing advantages remained substantial in favor of the leaders, and also forced the new entrants to emphasize R&D efforts and innovation to catch up. Thereby product improvement and cost reduction were rewarded and encouraged.

Since 1963 there has been a somewhat slower rate of growth in demand and a leveling off in prices. Much of the innovative potential seems to have been reaped, but some developments with copolymers and blending are being carried on currently. Further cost reduction may be in prospect as well, but most of the recent cost reduction has probably been by the later entrants, which were catching up with process know-how and scale economies. Headstart incentives have weakened substantially as know-how became more widely available, but large amounts still have to be paid to acquire such know-how. The two polyethylene markets are still growing enough in absolute volume to invite new entry. But in polypropylene some excess capacity and recently issued patents have combined to inhibit any new entry for the time being. Hence, prices for the two polyethylene resins remained soft until very recently, when general inflationary pressures seem to have caused an increase. Meanwhile polypropylene prices have remained somewhat higher, even though its cost of production is not much different than polyethylene. Profit margins have generally been improving in all of the polyolefins, however, as the more recent producers caught up in process know-how and achieved substantial scale economies. Most producers would now be earning modest to substantial returns on their polyolefin investments.

By conventional performance standards, industrial development so far would probably meet the tests of workable competition, i.e., no public policy measures were missed which obviously could make society better off. Given the importance of scale economies and the difficulty of its technology, the polyolefins could not have been made much more competitive or progressive. And yet, compulsory, reasonable royalty licensing of LDPE technology combined with an initial weakness of patent protection on HDPE and PP to greatly weaken patent barriers to entry. Competition increased greatly at just about the right stage in polyolefin development. Headstart advantages were sufficient then to sustain further technical progress and market growth.

Cost reduction

Substantial cost reductions were achieved over the years in the polyolefins.[2] By the early 1950's average costs of production in 50-75 m. lb. plants (annual capacity) were somewhere in the range of 17-25¢ lb. By the mid-1960's average costs in the most efficient 150-200 m. lb. plants (annual capacity) were as low as 10¢ lb. This cost reduction reflects both scale economies and improvements in process efficiency. Competition helped to enlarge demand more rapidly and may have helped to increase the average size of plants in the polyolefins. But the main effect of competition was in pressing producers to reach the most efficient scale and process for production. With a high profit duopoly there was much less pressure for cost reduction. But once market structure in each polyolefin resin was transformed into a loose oligopoly with no strong entry barriers, new entrants kept threatening, recurrent excess capacity developed, and the price level fell substantially. This competitive discipline put a much greater profit premium on achieving optimal plant size and process efficiency.

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[2] Cost experience is set forth more fully in Chapter II, supra, at pp. 85-100.

Cost-price margins and profits

Not much is known about cost-price margins or profits on low density polyethylene before about 1948. Prices were kept at $1 lb. during the war, were dropped to 52¢ lb. in 1946, and to 43¢ lb. by 1948. However, costs were probably covered, and then some, under the target rate of return pricing policy followed by Union Carbide and Dupont in this period.[3] Since patents precluded any competition in polyethylene except among these duopolists, it is very doubtful that their rivalry reduced profit margins below at least moderate levels.

But for the late 1940's somewhat better estimates can be made about margins and profits. By this time the conventional, LDPE process had been under development for 15 years and probably was near the level of process efficiency reflected in the mid-1950's licenses. If this assumption is correct, and it seems reasonable, average costs would be about 17-25¢ lb. for the scale of plants used in the late 1940's by Carbide and Dupont. With prices ranging from 43-48¢ lb. between 1948-54, this means the two duopolists were obtaining at least 20-25¢ lb. in profits, or roughly 50 percent rate of return on sales.

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[3] Dupont and Carbide traditionally sought generous rates of return on their investments. Pricing over their entire portfolio of activities was designed, insofar as they enjoyed market power in specific markets, to yield this result. These policies are described in Pricing in Big Business, Dirlam, Kahn and Lanzillotti, Brookings, 1958. One of the planning studies prepared by Dupont for HDPE in 1959 also referred explicitly to this policy, and indicated that their target rate of return on investment had been recently lowered from 20 to 15 percent. Increased competition in chemicals generally had been responsible for this reduced expectation. See Jules Backman, Studies in Chemical Economics, Mfg. Chemists Assn., 1965, for an analysis of this increased competition in many chemical markets.

The aggregate profits, on roughly $190-250 million worth of resin sales by these two firms in these 6 years, would then be $85-125 million. Since polyolefin investments of the two firms probably averaged about $20-25 million in these years, this would mean the annual rate of return on investment averaged somewhere between 45-80 percent.[4]

Such returns would be well above normal for competitive industries, and reflect the subsidy being returned by the patent monopoly. Since ICI was getting royalties of 1-2 percent on sales in this entire period, its direct share of these innovator rewards would have been $2.5-4 million.[5] Of course, ICI also obtained many other advantages from its long term, complementary tehcnology exchanges with Dupont.

But in the mid-1950's this profit picture began to change as market structure and behavior became more competitive. Prices for LDPE were dropped by Carbide and Dupont in 1954 from 47¢ lb. to 41¢ lb. as the six new entrants began to build their plants. In 1956, as these plants began to produce significant amounts of resin, prices were dropped

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[4] This estimate assumes the process efficiency attained by Dupont and Carbide in the late 1940's was not much lower than that available in licenses to new entrants in the mid-1950's. The LDPE process had been under development for 15 years by ICI, Dupont and Carbide. Furthermore, ICI was forced to license only the 1952 level of process know-how and not later developments. Hence, the mid-1950's licenses would only reflect the 1952 level of process know-how.

[5] This assumes cumulative LDPE sales by 1954 (subject to royalty) were 500 million lbs., at an average sales price of 45-50¢ lb. This estimate could be in error by 10-20 percent or so.

to 35¢ lb. Another drop to 32¢ lb. occurred in 1958, and in 1959 a more substantial and sustained decline set in. By 1966 prices were stabilized at 16¢ lb., and in 1968 it seemed prices may have been increasing slightly along with general inflationary pressure in the economy.

Meanwhile the profits of most LDPE producers sagged, reaching a trough in 1960-61, when excess capacity was at its peak. (Figure VI-1.) Median rates of return on depreciated fixed investment declined from 43 percent in 1959 to an average of 5 percent in 1960-61. However, even in these 2 years, three of the seven firms reporting profits enjoyed rates of return greater than 15 percent on depreciated fixed investment. Furthermore, the two original producers--Union Carbide and Dupont--were generally the most profitable of the LDPE producers. They earned an average of at least 18 percent on depreciated fixed investment in the entire period 1958-63. These superior performances for some firms, in the face of unprofitability for others, reflect head-start advantages at work--(i) more efficient processes, and (ii) a volume of production adjusted more closely to maximum scale economies.[6]

Meanwhile in the higher density polyolefins similar excess capacity developed, once the later entrants got into full production. Prices for

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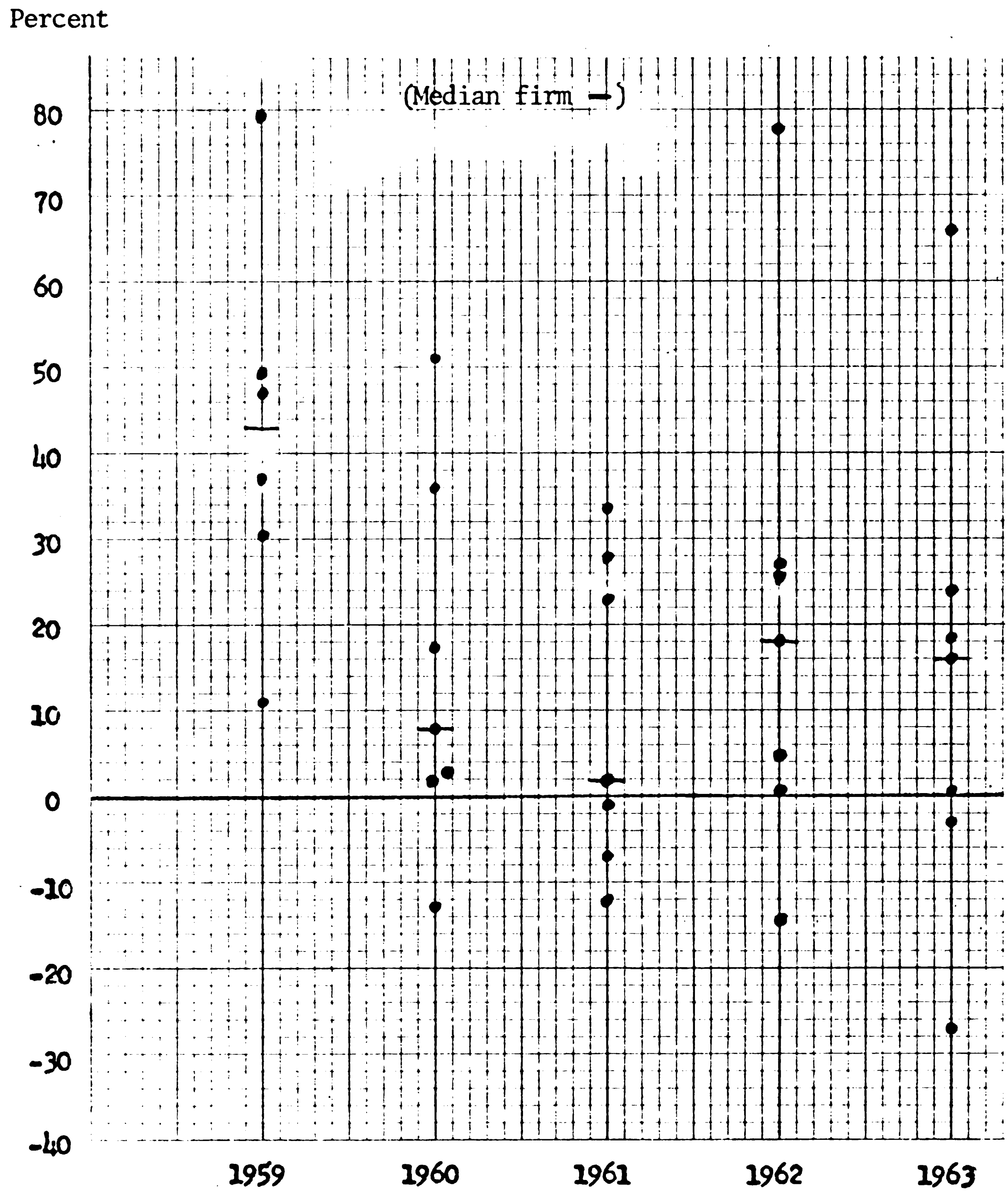
[6] Headstart advantages were also reflected in higher average prices on resins sold by the leading producers. See <u>infra</u>, pp. 262-264.

Figure VI-1.--Rate of return on LDPE resin manufacture

(Profit before taxes/depreciated fixed investment)



Source: Operating data submitted to the FTC by seven LDPE producers. (Ten-year straight line depreciation applied to data from each company.) Since depreciated fixed investment forms the great bulk of polyolefin resin investment, the above ratio is a reasonable proxy for rate of return in resin making.

HDPE started lower to begin with at 33¢ lb. between 1958-60, sagged to 31¢ lb. by 1962, and broke sharply to 23¢ lb. in 1963. Thereafter prices stabilized in 1966-67 at about 17¢ lb. In PP Hercules developed a long headstart over other entrants and kept prices above 40¢ lb. until 1961, when a similar slide began to 18¢ lb. in 1965. Then as the Montecatini patent litigation made clear that any new entry was very risky, prices began to rise again slightly.[7]

Since excess capacity was generally more pronounced in the higher density polyolefins, their costs were higher and profitability suffered. In HDPE the median profitability was negative in all years between 1959-63, with losses on depreciated fixed investment ranging between 1-20 percent. (Figure VI-2.) In only 3 years did any firms report profitable operations, and in each instance only one of the three or four reporting firms was profitable. These profits were not impressive, ranging from only 3.5 to 10 percent. Although only four companies reported profit data reflecting their high density polyethylene experience, they were in most years the leading four producers. They made more than 80 percent of the sales and shipments of high density polyethylene in all these years. Hence, even the most substantial high density producers with larger scale plants were generally unsuccessful profit-wise throughout the years 1959-63.

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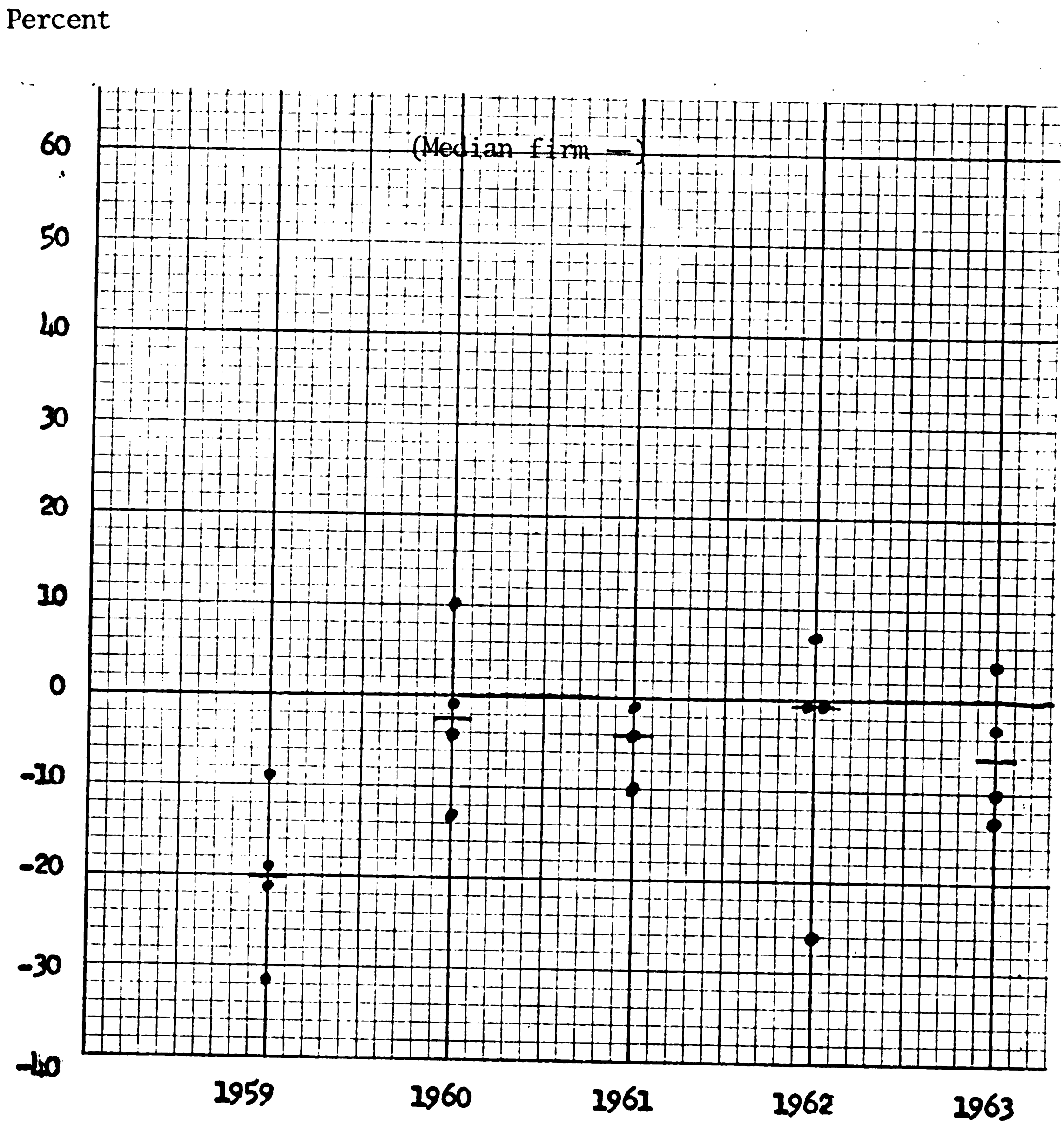
[7]See Chapter III, at pp. 145-146.

Figure VI-2.--Rate of return on HDPE resin manufacture

(Profit before taxes/depreciated fixed investment)



Source: Operating data submitted to the FTC by four HDPE producers. (Ten-year straight line depreciation applied to data from each company.) Since depreciated fixed investment forms the great bulk of polyolefin resin investment, the above ratio is a reasonable proxy for rate of return in resin making.

Although less information was provided by resin makers about polypropylene profitability than the other olefin resins, the available data suggests a situation similar to that of high density polyethylene--in that many producers must have lost money during the years up through 1963.[8] On the other hand, the lack of profitability is not so general in polypropylene. Whereas the median and average performance of the reporting high density polyethylene producers was a loss in every year up through 1963, the average performance in polypropylene involved a loss in only 3 years, and a modest profit in 2 years. The leading firm, Hercules, appears to have done somewhat better than other producers and to have made a profit on the whole. Like Dupont and Carbide in LDPE, Hercules enjoyed substantial headstart advantages in process, scale economies, and in reputation for superior product.[9]

From an efficiency point of view one must conclude that polyolefin performance was reasonably competitive--at least since 1952 when compulsory licensing was imposed. Competitive rivalry was an important factor in causing costs to decline substantially, and was even more important in forcing prices down rapidly. The very generous price-

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[8] Polypropylene profit data were provided for over 90 percent of 1959 sales and shipments, but only for 60 percent of 1963 sales and shipments. Because only one producer was active in 1959, and only two in 1960, polypropylene profit data has not been disclosed in detail.

[9] See <u>infra</u>, at pp. 262-264.

cost margins of the 1948-54 period were squeezed substantially in later years. Although the leading firms with headstarts still enjoyed above "normal" profits, by comparison with other industries, many later entrants lost money for years on their polyolefin operations. On balance, profits for the polyolefins as an industry were not abnormal or excessive after compulsory licensing was imposed. Since 1952, with the possible exception of the last several years in polypropylene, the polyolefin resin markets seem to have been examples of workable competition. In other words, no basis for improvement on efficiency grounds is evident.[10]

So far as the period before 1952 is concerned, an efficiency assessment is somewhat more difficult, and really depends upon the effect of strong patent protection in the early years of polyolefin development. But even if patent protection had been substantially weaker in these

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[10]In the future, as the polyolefin resin markets become more mature, it is likely that performance would be less competitive. The market structure in each polyolefin resin remains relatively concentrated, and their producers are quite aware of their mutual interdependence. When growth in demand for these resins ceases to be substantial, further entry would probably not be attractive. Scale economies are substantial and require major investments. If demand stopped growing, new entrants would have to cut into the existing market of established producers. New entry would then become much more risky. Hence, a pattern of "administered pricing" reached by consensus, if not collusion, might well emerge. But the limitations on long-run competition in the polyolefins are really enforced by substantial scale economies; these markets could be characterized as "natural oligopolies."

Of course, if the recent Montecatini patent claims on polypropylene were successfully imposed, new entry there could be precluded entirely. In that event, the threat of potential competition would cease to discipline the PP market. But such a situation could probably be challenged as a restraint of trade.

early years, the strong headstart advantages of ICI, Dupont and Carbide, and a limited early demand potential, would have prevented much additional competition before 1952. Of course, if these pioneering firms had been smaller businesses, then strong patent protection would have been a necessary incentive to mobilize the essential resources for LDPE development.[11]

Headstarts and rents on ability

Both types of headstart advantage for innovators are well illustrated in the polyolefins--reduced costs of production, and superior demand for their products. Each reflects a rent on superior ability for the more successful firms.

In terms of reduced costs, the most successful polyolefin producers enjoyed average costs in their largest and most efficient plants of about 10¢ lb. by 1963. At that time some of the most recent entrants with smaller plants, less success with their processes, and substantial excess capacity, were experiencing up to 20-30¢ lb. in average costs. Average polyolefin prices in 1963 were 18¢ lb., 23¢ lb. and 29¢ lb. in LDPE, HDPE and PP, respectively. Therefore, it is not surprising that some of the leading innovators with headstarts were considerably more profitable in the early 1960's than some of the recent entrants.

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[11] See Chapter IV, supra, at pp. 189-196.

In addition, the leading innovators were enjoying also substantially higher average prices for their resins (see Table VI-1). For example, in 1962 the four most successful firms in LDPE averaged 25.8¢ lb. in selling prices, while the four least successful averaged 16.8¢ lb. In HDPE the four most successful averaged 32.5¢ lb. while the four least successful averaged 18.7¢ lb. In PP the same differential was 36.8¢ lb. and 23.4¢ lb., respectively. These price differentials reflect superior resin product quality and reputation at work. Although average selling prices for individual companies cannot be disclosed for reasons of confidentiality, there was a strong correlation between experience in the market and selling price success. Hence, differences in the demand experienced by each polyolefin producer also reveal substantial headstart advantages.

Certainly in the years since 1963 these headstart advantages have been reduced, at least insofar as the well-established producers are concerned. The recent entrants of the late 1950's and early 1960's now have large scale plants in operation, and have generally learned how to produce a better quality of resin more efficiently. But the fact that such substantial headstart advantages did operate in the polyolefins helps explain why strong patent protection was not needed since the early 1950's. Headstarts were strong enough to ensure substantial extra returns to innovators and early entrants.

Table VI-1.--Average price received by polyolefin resin makers (Value of shipments/pounds shipments, expressed in cents per pound)

	1959			1960			1961			1962		
	LDPE	HDPE	PP	LDPE	HDPE	PP	LDPE	HDPE	PP	LDPE	HDPE	PP
	37.3	36.8	43.9	31.6	37.3	43.8	28.8	35.6	42.7	29.6	35.6	39.7
	35.6	36.6	20.0	31.1	35.4	39.3	27.5	33.9	40.6	25.6	31.3	37.5
	35.3	35.3		30.7	34.8	36.8	26.5	33.0	35.7	24.3	31.2	37.2
	32.6	33.3		29.8	34.5	30.4	26.4	31.4	33.3	23.9	30.1	32.7
	31.6	32.2		28.8	33.8		25.6	30.3	33.1	19.5	30.0	31.3
	30.6	32.0		25.4	33.3		21.5	29.7	05.0	18.7	29.7	30.6
	30.6	27.5		24.7	32.5		20.6	28.6		18.6	27.7	28.2
	28.5			24.4	32.4		18.4	27.0		18.5	26.8	03.4
	26.8			20.3			16.6	23.8		17.5	22.3	
										14.9	17.5	
										14.6	10.0	
Average unit value for all producers shipments (cents per pound)	33.5	33.6	42.5	28.7	34.5	41.8	24.1	31.1	38.5	21.7	29.5	33.6

Progressiveness

The polyolefins achieved a rapid rise to pre-eminence among the plastics. By comparison with other major plastics their sustained growth performance has been exceptional. Considering the extremely high pressures involved in their initial polymerization, and the dangerous and unstable organometallic catalysts employed, their development was no small accomplishment. A great deal of process and product innovation by resin producers and fabricators was unquestionably required. But the important issue is the degree to which the polyolefins reached their potential.

No significant inhibition is evident in the earlier years, including the period when ICI was doing all of the innovating by itself. The initial, waxy LDPE polymer--polymerized in a very high pressure, laboratory "bomb" had little evident use and was very hard to handle.[12] Although some disclosure to the world was made in 1937-39 when patents were published, no one appeared to seek a license. Dupont had to be told by ICI how important this resin really was in one narrow application, making insulation for radar apparatus. When the U.S. Navy and Union Carbide learned of its significance for the war effort, they

[12] Polythene, cited supra in Chapter III, at p. 102.

joined in building a second plant. But this response met wartime needs with no difficulty. On the whole it is hard to imagine how technical progress up to 1945 could have been much faster. Polyethylene prospects at this stage probably did not justify any greater R&D effort.

Much the same is true for the next several years. The headstart advantages of ICI, Dupont and Carbide deterred all other chemical producers from any direct interest. Only Standard Oil (Ind.) was aroused, perhaps by the earlier patent disclosures, to search for a low pressure process for a higher density polyethylene. Fabricators had interest in using the new resin, of course, and were encouraged by these resin producers. But none of these small fabricators could seriously consider resin production themselves.[13]

But by the late 1940's the polyolefins were becoming attractive to other potential resin producers. The pioneering work of ICI, Dupont, Carbide and several fabricators had proven that a major market opportunity existed for these resins. Fortunately, the compulsory licensing decree of 1952 came just at the stage when more firms were eager to participate in polyolefin development. As the new entrants fostered by

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[13]These fabricators were firms with $5-25 million in annual sales and assets during these years. Resin plants alone would cost $25 million, and were prohibitively risky at this stage for such small firms. The smallest company to invest independently in a polyolefin resin plant was Spencer, with $70 million in assets during the early 1950's, and this occurred (i) when entry barriers were greatly reduced by compulsory licensing in 1952, and (ii) when market potential was further developed.

competitive licensing came into production, they also contributed to innovations. The newcomers helped to improve processes, reduce costs, improve properties for many applications, and expand product markets. Between 1952-63 these new entrants received 500 patents on LDPE resins and end products, almost as many as the original producers, Dupont and Union Carbide.[14] While a desire for technological independence may have been a motivation in some of these patent applications, nonetheless the fact that the Patent Office awarded so many patents is testimony to the significance of their research contributions. Without the accident of compulsory licensing in 1952, it is clear that LDPE development would have been less vigorous technically, as well as less competitive in price-output performance.

Much the same is true for the next major developments, the low pressure processes for HDPE and PP, which were revealed in 1954-55. Although most of the early innovations in HDPE and PP came from outsiders, none of these new innovators had sufficient priority to obtain strong patent dominance over either HDPE or PP.[15] No effective limitation could

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[14]See Chapter IV, supra, at pp. 168-177.

[15]The three main innovators were two European chemists, Karl Ziegler of the Max Planck Institute in West Germany, and Gulio Natta of the Instituto di Chimica Industriale del Politicnica in Italy, and a research group headed by Thomas Hogan of the Phillips Petroleum Company in the U.S. The earlier work at the Battelle Institute which was sponsored by Standard Oil (Ind.) may also have been important, but Dupont's as yet undisclosed experiments with a very high pressure process proved to be a blind alley, and of no significance to the main innovators.

be placed on entry from patents. In addition, the earlier diffusion of LDPE technology from compulsory licensing had a significant secondary impact in increasing the number of potential entrants in both HDPE and PP. As was noted in chapters III and IV, only about half as many higher density polyolefin producers would have entered in the absence of compulsory licensing on LDPE.[16] The rate of innovation was also speeded up by the flourishing technology market, which developed in the absence of suffocating patent and headstart incentives. Hence, the technical development of these new resins was also speeded up by compulsory licensing and by an absence of dominating patent protection.

On the whole, it would be hard to expect any faster innovative performance in the polyolefins after 1952. After patent and headstart incentives had served to foster the basic process and product innovations, these incentives were reduced--enough so that substantial new competition was allowed within each of the polyolefin resin markets. This adjustment in the balance of patent, headstart and competitive incentives happened to occur just about at the right time. This industrial evolution is unusual, and traceable in considerable degree to (i) compulsory patent and know-how licensing on LDPE in 1952, and (ii) the absence of strong patent dominance early in the development of HDPE and PP.

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[16] In the absence of these extra entrants, the number of patents issued on the higher density olefins might well have been reduced by 15-20 percent.

Industrial development frequently involves a much slower erosion of patent and headstart incentives. Too often this leads to a restriction on new entry when it would be most attractive--in the formative years when demand is growing most rapidly. Then when demand growth slows, substantial headstarts tend to become entrenched, and new entry becomes much less attractive. A highly concentrated market structure may be frozen into a permanent limitation on competition. In other words, initially strong patent and headstart incentives may often have a momentum of their own which outlives their usefulness. What was appropriate nurturing to begin with may become unreasonably swollen and excessive rewards, as well as an inhibition on efficiency and further innovation.

Performance in Comparable Industries

The significance of this polyolefin performance is best appreciated in comparison with the performance of some similar industries. For this purpose aluminum, cellophane, rayon and synthetic rubber are particularly convenient. Interindustry competition was more or less substantial in each case; but these industries differed in one important respect--the degree to which patents and headstarts operated to limit competition within each industry. In the polyolefins, except for the initial 14-year phase of patent monopoly, a substantial reduction in patent and headstart advantages combined with a large and evident growth potential to encourage nearly 20 large firms to enter production within 8 years. Each firm invested $25 million or more in their polyolefin plants and operations. Patents and headstart advantages were too weak in this second stage to frustrate a very rapid and competitive market development, characterized also by an excellent innovative performance.

Aluminum

Aluminum represents the most extreme contrast--for 55 years only one producer found it appropriate to participate in the U.S. market.[17] Aluminum was discovered independently in 1886 by the American, Hall, and a Frenchman, Héroult, with the former obtaining a dominant U.S. patent in 1888. At that point several entrepreneurs joined Hall in forming what eventually became the Aluminum Company of America (Alcoa). Although one other group, the Cowles brothers, also attempted production between 1893-1903 with the rival Bradley process, they were bought off by Alcoa.[18] Alcoa paid the Cowles brothers a lump sum payment and royalties, and received in return an exclusive license under the Bradley process patent. This left only Alcoa as a producer, since the Cowles brothers then abandoned their efforts at production.

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[17] This account is based upon D. H. Wallace, Market Control in the Aluminum Industry, Harvard, 1937.

[18] The Bradley process patent had been issued in 1892. In 1903 the U.S. Court of Appeals decided both patents were essential to production of aluminum. This decision precipitated the settlement.

This license under the Bradley patent extended Alcoa's ability to exclude any entrants to a total of 21 years. In subsequent years improvement patents operated also as a deterrent to new entry. As a result, patents served to give Alcoa a considerably longer headstart than applied to ICI, Dupont and Union Carbide in the polyolefins. Furthermore, Alcoa did not have to share aluminum development with anyone, whereas ICI had to share LDPE with Dupont and Carbide.

From this point on other headstart incentives helped to maintain Alcoa's monopoly position. During the period 1905-09 Alcoa tied up many of the most attractive bauxite sites by purchase or long-term contract.[19] Just before World War I a French-owned firm with its own bauxite and know-how was about to enter the U.S. market with a $10 million plant. But the war dried up its financing.[20] The war then greatly expanded Alcoa's market, and it grew even larger and obtained a more substantial headstart over competitors in scale economies.

Problems in coordinating technology, sufficient bauxite, a suitable hydroelectric power site, and financial capital proved to be "too much

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[19]One unresolved controversy about early aluminum development concerns the degree to which Alcoa pre-empted raw material sources by this policy. Alcoa denied it, but critics pressed the charge in hearings before the Tariff Commission and in an unsuccessful antitrust action. D. H. Wallace concluded such pre-emption was important after 1909, and that some divestiture of bauxite sites could have been achieved at this stage which would have led to viable competitors.

[20]One other joint effort by French and U.S. investors never really got off the ground, although an agreement involving an untested process was signed in 1913. Wallace, ibid., p. 113.

work" for one potential entrant after World War I. In all probability the prospective rate of growth in aluminum demand was not sufficient to warrant assuming the differential entry costs which were involved. A second near entrant was bought off for $16 million by Alcoa, after power and bauxite had been arranged, but before any plant had been constructed.[21] In this second case entry might have occurred, but for Alcoa's very generous offer. Later the depression also deterred entry. Ultimately, it was not until government investments were made for World War II aluminum plants that it became practical to introduce viable competitors within the aluminum industry. After the war some plants financed by the government were divested from Alcoa's control, and sold to new aluminum producers.[22] Thus a major monopoly, which persisted for 55 years after the basic patent issued, was finally broken up.

In contrast to the polyolefins, the long-term balance of patent and headstart incentives in aluminum seems clearly unsatisfactory. The patent incentive was stronger and longer lasting and this helped Alcoa to gain such a massive headstart that no effective competitor emerged until the government divested some plants after World War II. While

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[21]The first near entrant was the Uihlein family, which owned the Schlitz Brewing Company; the second involved J. B. Duke of the American Tobacco Company and several Boston entrepreneurs. Wallace, ibid., pp. 102-18.

[22]This result was precipitated by Learned Hand's famous decision under Section 2 of the Sherman Act, which held that Alcoa's more than 90 percent control for so long a time was presumptively monopolistic and illegal.

considerable innovation and market development were stimulated by Alcoa's profit incentives and the rivalry of aluminum with other materials, few modern economists would doubt that more competition within the aluminum industry could have improved performance. By at least 1913 there was enough room for more producers. Prices could have been further reduced, sales and output increased, and innovation and industrial development speeded up. Many aluminum applications were not particularly difficult from an engineering point of view, and could have been developed earlier. Certainly aluminum proved to have massive innovative and market potential for many civilian uses in the years after 1945.[23]

Cellophane

Cellophane was less monopolistic than aluminum, but was a considerably less competitive industry than the polyolefins.[24] Basic and dominating patents in the U.S. and Europe were issued to a Frenchman named Brandenburger in 1912. He assigned his rights to a French firm, La Cellophane. Then in 1923 the U.S. rights on Brandenburger's patents were assigned to Dupont, which gained thereby an exclusive patent

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[23] Merton, J. Peck, Competition in the Aluminum Industry, Harvard, 1961.

[24] The cellophane experience is revealed in U.S. vs. Dupont, 118 F. Supp. 41 (1953), and 351 U.S. 377 (1955), together with G. W. Stocking and W. F. Mueller, "The Cellophane Case and the 'New' Competition," AER (March 1955), and J. B. Dirlam and I. M. Stelzer, "The Cellophane Labyrinth," A. T. Bull. (April 1956).

monopoly over cellophane in this country. A U.S. joint venture for cellophane production was then established between the two firms, with Dupont providing about 85 percent of the financial capital, and La Cellophane providing most of the technology and about 15 percent of the financial capital.[25]

Although the basic patents expired in 1929, Dupont was able to continue effective patent dominance for another full 17 years and more, by virtue of a comprehensive set of improvement patents on moisture proofing.[26] Since most cellophane applications required this property, these improvement patents continued to dominate the market. However, one competitor, Sylvania, did manage to enter in 1930. Sylvania had been begun in France 5 years earlier by two former employees of La Cellophane, from which they carried away the necessary know-how. Dupont sued Sylvania for infringement under its moisture-proofing patents but a settlement was reached in 1933.

Dupont feared the infringement action might end in its improvement patents being declared invalid, while Sylvania feared it could be forced out of the market. The agreement guaranteed that Sylvania would follow

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[25]Dupont received a 52 percent interest, while La Cellophane received a 48 percent interest.

[26]The first of these patents on moisture proofing issued in 1929.

Dupont's lead in price-output policy.[27] Strong patent dominance thus combined with significant headstart advantage to prevent any significant price competition within the cellophane market. However, there was still some interproduct rivalry between cellophane and wax paper, glassine, sulphite paper, and later on, other plastics--including LDPE, PP and polyvinyl chloride.

In this situation considerable innovation was stimulated to improve cellophane properties. But price-output behavior remained monopolistic, with sustained high profits for Dupont and Sylvania.

> Although [Dupont's] annual rate of earnings before taxes declined somewhat from a high of 62.4 percent in 1928, in only 2 years between 1925 and 1950 inclusive did the rate fall below 20 percent.[28]

Between 1925-50 the average rate of earnings was 34.2 percent and 24.2 percent after taxes.[29] The prospects of this monopolistic reward were also so large and certain for Dupont, that in 1929 it was able to buy out La Cellophane's interest in the U.S. joint venture for $90 million in Dupont stock, even though Dupont's cellophane investment was only valued $5.1 million in 1929.

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[27]Sylvania agreed to pay Dupont a 2 percent royalty on its sales, and to limit its sales to a fixed percentage of Dupont sales--20 percent in 1933, and increasing to 29 percent in 1942. Thereby one can see that Dupont retained effective patent dominance and was able to discipline the behavior of its only competitor.

[28]Stocking and Mueller, cited _supra_, p. 145.

[29]_Ibid._, p. 146.

Finally, one other competitor, Olin Industries, entered the cellophane market in 1951.[30] But by this time most of the growth potential had panned out, and the two polyolefin resins--LDPE and PP, together with polyvinyl chloride, took over most of cellophane's market potential. These newer resins with superior properties expanded their markets greatly in the late 1950's and early 1960's--in considerable part at the expense of cellophane.

Meanwhile, between 1953-56 the courts ruled on the Justice Department's complaint under Section 2 of the Sherman Act that Dupont had monopolized the cellophane market. The courts accepted the defense argument that intermaterial competition was so strong that flexible packaging materials had to be the relevant market, and not cellophane itself. Since Dupont had no dominance in flexible packaging as a whole, the courts did not consider whether Dupont's long-term patent dominance for nearly 30 years was monopolization. Many economists sharply criticized these decisions. Some critics noted that the evidence on intermaterial competition consisted largely of sales in broad functional categories, without any careful appraisal of the

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[30]Dupont's motivation in granting Olin a license at this stage was largely to undercut the basis for the Justice Department's monopolization complaint, which had been filed in December 1947.

relevant cross elasticities of demand.[31] Other economists challenged the courts for failing to consider the degree to which interproduct competition and innovation could be a substitute for price competition within a product market.[32]

This study of the polyolefins, however, has attempted to resolve the conflict between patent and headstart incentives and the competitive incentives arising within and among industries. By comparing the cellophane and polyolefin experiences it seems likely that strong patent and headstart incentives lasted for a longer period than was really necessary in cellophane. Cellophane enjoyed such incentives for at least 34 years, the life spans of two full patent terms. In the polyolefins, the period of strong patent dominance lasted only 14 years. Meanwhile, the cellophane process was less complex and challenging than the polyolefin processes, although it must be noted that industrial chemistry was less sophisticated between 1912-46 than between 1939-52. Therefore, it seems likely that patent and headstart incentives for cellophane were excessive. Improved performance in the U.S. market, especially with respect to price-output efficiency, could have been attained with either compulsory technology licensing or divestiture, probably in the early 1930's. The eventual growth of the

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[31]See Mueller and Stocking, ibid., for example, pp. 132-44.

[32]Stelzer and Dirlam, cited supra.

cellophane markets suggests there was enough room in the market for at least several more producers. At the very least price-output performance could have been improved by allowing the threat of new entry in these years, or by eliminating Dupont's control over Sylvania's production.

Rayon

Rayon is a cellulosic plastic material like cellophane, but its main use has been as a fiber.[33] Four processes were discovered for its production, and this led to a lower level of patent dominance and a more competitive market structure and behavior than cellophane. This sequence bears some similarity to the HDPE evolution, except that the four rival processes for rayon were unequal and were discovered over a 15-year period while the three rival HDPE processes were more equal and were discovered almost simultaneously. Hence, the competitive evolution of rayon was less rapid than that of high density polyethylene.

Chardonnet invented the nitrocellulose process in the early 1880's and obtained his first French patent in 1884. Under its protection the Tubize Company entered into production. Tubize used this process in France, Belgium and the U.S., but it was abandoned in the 1920's in France and Belgium and in 1934 in the U.S. when the viscose process

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[33]Jesse Markham, Competition in the Rayon Industry, Harvard, 1952, is the main source for this account of rayon development. See also, Markham's, "An Alternative Approach to the Concept of Workable Competition," AER (September 1950).

proved to be more efficient. Meanwhile the cupromonium process had been invented in 1890, but was abandoned until 1918. Then a German firm began production of some higher cost, finer yarns with it, and set up a U.S. subsidiary in 1928.

But the major process proved to be the viscose process. It was discovered in the early 1890's by Cross and Bevan in Britain, who obtained patents in 1892. These patents were later taken over by Courtaulds, Ltd. which set up plants in Britain, Germany, France, Belgium and the U.S. The American branch, which was begun in 1910, prospered greatly and became in 1937 the American Viscose Corp. For many years this was the dominant U.S. rayon producer.

Cellulose acetate was patented in 1899, but its first significant use was for World War I airplane dope. A Swiss firm was invited by the British government to produce it and shortly thereafter a plant was established in the U.S. The yarn version of cellulose acetate was then developed, and what led to the modern Celanese Corp. was first formed in 1918 to take over the British plants.

In the 1920's, after the basic Cross and Bevan patents on the viscose process had expired, a considerable amount of new entry into rayon production occurred in the U.S. The then market "took off," competing successfully against a $20 lb. price for silk. An oligopoly market structure took shape in the late 1920's. Although strong patent dominance had applied in the U.S. between 1910-18, this broke down rapidly in the 1920's. While American Viscose had enough headstart advantage to outdistance its new rivals, their entry could not be prevented. As the new competition was established, prices broke, particularly in the 1930-32 depression years. Off-list selling and "chiseling" was widespread. However, as demand for rayon was re-established prices were increased somewhat and stabilized. Since demand did not grow very rapidly a pattern of price leadership could be established. Viscose, as the leading firm, took the role of price leader. But scale economies and process improvements were generally passed on to consumers, and prices tended to follow costs downward. Rates of return on investment, although high in the period 1915-29, declined to low and moderate levels thereafter up to 1940.[34]

On the whole, this performance was characterized by Markham as "workably competitive," meaning that he could conceive of no way by which public policy might have improved it. This appraisal was based on the assumption that the initial nurturing period with complete patent protection was reasonable and appropriate to foster the early innovations. But since the late 1920's, in any event, when strong patent and headstart incentives ceased to operate, it seems that rayon performance was as close to competitive as scale economies and a much slower growth in demand would allow.

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[34]For example, rates of return on rayon investment for Dupont, a rayon producer since 1921 averaged 40.7 percent between 1921-29 and 7.9 percent between 1929-38. Mueller and Stocking, cited _supra_, at p. 148.

Synthetic rubber

Synthetic rubber began its commercial development in the late 1920's with a joint R&D effort by the German chemical combine, I. G. Farben, and Standard Oil (N.J.).[35] These two firms led the way in improving the early butadiene process then known to chemists. By 1938, the two firms were ready to market a synthetic rubber tire in the U.S., which although more expensive than natural rubber, had some superior qualities. In the summer of 1939 these two also decided to widen their research collaboration, and formed the Catalytic Research Association. This group comprised I. G. Farben and Esso, together with four other U.S. companies prominent in the oil business--Standard Oil (Ind.), Texaco, Universal Oil and M. W. Kellogg, plus Royal Dutch Shell and Anglo-Iranian Oil. But the outbreak of World War II forced the group's dissolution. Esso then received the patent and technology rights in the U.S., Britain and France, while I. G. Farben received such rights for the rest of the world. Up to this point strong patent and headstart incentives combined with complementary research efforts to foster a major innovation.

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[35] The main sources for synthetic rubber developments are Robert Solo, Synthetic Rubber: A Case Study in Technological Development Under Government Direction, Study No. 18 of the Bush reports, cited supra, Stanley E. Boyle, "Government Promotion of Monopoly Power," JIE (April 1961) and Charles F. Phillips, Competition in the Synthetic Rubber Industry, North Carolina, 1963.

But the war quickly broke down this monopoly position insofar as the U.S. market was concerned. Esso sought subsidy, market control and immunity from antitrust prosecution. But the Government chose to contract for the construction and operation of publicly owned feedstock and synthetic rubber plants. On this basis a wartime rubber producing industry was created, supervised ultimately by the War Production Board.

This development provoked criticisms of inefficiency and favoritism from contractors, Congressmen and students of government operations.[36] But nonetheless wartime needs were met and the important technical problems were solved. The question of patent rights to this forced draft engineering work was settled for the time being with an agreement providing that the Government and any postwar purchasers of its plant would receive both patent licenses and know-how. But the terms of such licenses, and the distribution of rubber plants, were left unresolved. Thus, compulsory licensing of technology was decided in advance, but the selection of peacetime participants in the industry, i.e., the licensees, remained a postwar problem.

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[36] Robert Solo's study, "Synthetic Rubber: A Case Study in Technological Development Under Government Direction," cited <u>supra</u>, considered these issues in some detail. He concluded, in part--"[t]he technological incompetence of government in the area of social and strategic choice was everywhere evident. It cannot be too much emphasized that incompetence implies not only a lack of knowledgeable men in the echelons of power, but, more essentially, it implies a failure to develop a special kind of knowledge; not only the lack of system or capacity to deal with highly complex technical choice, but the failure to evolve the basis, the value-criteria upon which such a choice could be made."

After the war a few of the less efficient plants were gradually sold to various private firms. Then the bulk of the wartime plants were auctioned off by a Disposal Commission in 1955. As far as possible an attempt was made to sell off the facilities to the highest bidders, but not more than one bid was submitted for about half the plants. The disposal policy selected by the Eisenhower Administration let the head-start advantages achieved by the existing operators--a group of tire, petroleum and chemical producers dominate in the bidding process. In other words, the Government refused to subsidize more competition in synthetic rubber by accepting less than the highest bids available, or by actively seeking out new entrants to the rubber industry as purchasers.

The wisdom of this policy and its effect upon subsequent industrial performance has been a controversial question among economists. Critics argue that more competition, innovation, and improved price-output efficiency could have been attained with little offsetting cost. Supporters respond that innovative and efficiency performance was satisfactory, and that no greater reduction in industrial concentration was really practical or necessary.[37]

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[37]Robert Solo, ibid., pp. 121-4, argued that more competition could have been obtained, and his view was supported by Stanley E. Boyle, "Government Promotion of Monopoly Power," JIE (April 1961) and "Comment," JIE (March 1962). But Charles F. Phillips, Competition in the Synthetic Rubber Industry, North Carolina, 1965, concluded that competition has been "workable" in this industry, and that no public policy improvements could have been made. See also, Phillips' replies to Boyle, "Market Performance in the Synthetic Rubber Industry," JIE (April 1961) and "Comments," JIE (March 1962).

A subsidiary issue concerned the degree to which compulsory licensing of patents and technology was really effective. The Disposal Commission asked those companies involved in the program whether any private patents were in use in the government plants, and eight firms replied by asserting rights under some 396 improvement patents. The Commission advised prospective buyers of the wartime requirement of compulsory technology licensing, but left the matter of which patents were governed by it up to individual bargaining between buyers and contractors. Some have argued that this policy re-established a patent and technology barrier to entry in synthetic rubber, which helped to reduce the demand for rubber plants by new entrants into the industry. Others have argued that these improvement patents were not a credible deterrent to new entry.[38]

Synthetic rubber is a closer approximation to the polyolefin experience than any of these other industries. Its less vigorous competition is probably the result of much slower postwar demand growth, and therefore a much less forceful pressure for new entry. But regardless of whether a more competitive market structure should have been sought by the Disposal Commission, synthetic rubber's development would have been much less satisfactory if Esso and a few of its allies had been

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[38]Robert Solo, ibid., pp. 121-4 and Charles F. Phillips, Competition in the Rubber Industry, pp. 120-3.

left to develop the industry as a close-knit cartel. Hence, compulsory licensing of technology and divestitive of innovators at the "take off" stage significantly improved industrial performance in synthetic rubber.

The adequacy of incentives for industrial progress

By comparing industrial performance in the polyolefins with aluminum, cellophane, rayon and synthetic rubber, some lessons about the proper balance of incentives for industrial progress seem to emerge. Strong patent protection may be appropriate in the earlier phases of development when investments in technological progress require special incentives. But once this need has passed, ordinary market forces can take over and competition within these markets becomes much more desirable. Strong patent protection is also neither necessary or desirable when substantial headstart advantages ensure ample returns to innovators. Nor is strong patent protection appropriate when large well-established firms enjoy substantial headstarts. Finally, even though interproduct rivalry might be strong--as it certainly was in aluminum, cellophane, rayon and the polyolefins, this kind of competition is not a sufficient substitute for rivalry within markets.[39] Once the initial or pioneering phase has been completed, considerable competition

[39] Only in synthetic rubber is it arguable that interproduct rivalry might not have been significant. Aluminum, cellophane and rayon are all similar to the polyolefins in that substantial interindustry competition was at work throughout their development.

within markets is desirable to maximize price-output competition, efficiency and to quicken the innovative race for process and product improvement.

Consequently, it would seem that patent incentives--as in the case of the polyolefins and synthetic rubber, could be cut back in some industries by compulsory licensing of technology to improve industrial performance. The synthetic rubber and aluminum industries even suggest that divestiture of a very successful innovator might be appropriate. The object of such action would simply be to reduce patent and headstart advantages within an industry when increased competition would evidently improve innovation and efficiency.[40]

But would such action dilute the confidence of innovators and inventors in the return on their investments for technical progress? How much of an offsetting inhibition on industrial progress might result?

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[40]Implicit in this analysis is a 2-stage sequence for industrial innovation--basic pioneering innovations, followed by an accumulation of less important improvements in processes and products. The costs and risks of pioneering are usually much greater than further improvement. Strong patent protection may be appropriate, therefore, in the pioneering stage of industrial development and shortly thereafter. But once a good headstart has been achieved, strong patent dominance over an industry may often do more harm than good.

As major new industries emerge, of course, strong patent and headstart incentives might again be appropriate. The point is that strong patent incentives are not likely to be appropriate to shelter and protect industries as they progress into maturity. Such industries should be able to stand on their own without patent subsidy--except as important new innovations justify new patents.

Basically, there are two kinds of rewards which patent applicants can anticipate to help support their investments in developing new technology. One type comprises the advantages flowing from a moderate degree of patent dominance. These include: bargaining power for complementary technology trading, defensive immunity from competing patents, perhaps a limitation on competitive rivalry within markets, and the possibility of some moderate royalty income. The second kind of reward from patents is much less likely, but can be far more profitable to the successful innovators. This could be characterized as the "big kill" reward, which stems from a major industrial opportunity being successfully dominated by patents and headstarts for many years. Of course, successful entrepreneurship on the grand scale requires good luck and sustained skill in many fields of effort--quite apart from extended patent dominance. But the scale of "big kill" rewards might be significantly reduced in some industries if we were to cut back on patent and headstart advantages by either compulsory licensing or divestiture after an industry's early development.

For example, in the five industries we have considered, the large cumulative profits of Hall and Alcoa in aluminum, and of Dupont on cellophane would undoubtedly have been reduced by such a policy. The success of American Viscose Corporation might also have been less dramatic.[41] But under such a regime, Hall, Alcoa, Dupont and American Viscose would still have gained substantially from patent and head-start advantages. Moderate patent incentives are illustrated in these industries with the gains reaped by the Cowles brothers in aluminum, by Sylvania in cellophane, and by the Tubize Company in rayon. Moderate rewards from patents are also evident in the polyolefins by the gains of the major innovators--ICI, Dupont, Union Carbide, Phillips Petroleum, Ziegler, Natta, Montecatini, Hercules and Standard Oil (Ind.), together with some of the later entrants, which at least obtained some defensive immunity and bargaining power from patents.

How important are "big kill" rewards for modern innovating business enterprises? Some recent successes--such as Polaroid or Xerox, even though they may be few, do serve to fire the imagination and efforts of small and large enterprises. But is it necessary that long lasting, strong patent dominance be the basis for such outstanding performance? Only sustained excellence in innovation and entrepreneurship really deserves the "big kills". The patent system is, fundamentally, a subsidy designed to improve the performance of the competitive system, and it should be extended only so far as innovative needs really require.

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[41] According to Jesse Markham, Competition in the Rayon Industry, at p. 16, the Courtauld's initial investment in what became the American Viscose Corp. was $930,000. This enterprise was expanded entirely out of retained earnings. In 24 years, the company's net profits were $354 million of which $237 million in dividends were paid.

So long as moderate to substantial rewards from patents are reasonably likely to stem from innovative efforts this would seem to be the primary incentive. Patents may properly serve also to get a good headstart on a really "big kill". But patents should not be used to artifically sweeten an already substantial reward, at the price of reduced industrial efficiency and further innovative development.

When due weight is given to the probability of rewards as well as their conceivable size, a limit on the maximum rewards from strong patent dominance to larger, well-established firms would have little impact in diluting incentives for innovation. This is particularly so for some of the very large, diversified corporations which carry on the great bulk of modern industrial research.[42] Such firms often have substantial headstarts, or at least can pool the risks of R&D investment over many markets. However, it is likely that small business innovators would need more freedom and time to make use of strong patent incentives. Therefore, small business should be treated more generously in use of patent protection than well established, big businesses. Such discrimination would be very much in the spirit of the patent system, for it would emphasize the fostering of innovative competition and reduce the burden of sluggish, restrictive monopoly.

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[42]In 1965, the 443 largest firms (employing 5,000 or more employees) spent about 87 percent of R&D outlays in U.S. industry. Basic Research, Applied Research and Development in Industry, 1965, National Science Foundation, Tables 3 and 17.

CHAPTER VII

THE PATENT SYSTEM AND ANTITRUST POLICY

The primary lesson from this study concerns the proper balance of incentives for industrial progress--patents, headstarts, and competition within and among industries. It seems that strong patent and headstart advantages have a momentum of their own. While such incentives are often needed to nurture the early development of an industry or new product market, if they continue beyond this period, long-run efficiency may suffer, and the incentives for further improvements in technology will often be reduced. Therefore, it may be desirable at some point to sharply reduce the strength of patent dominance by compulsory, reasonable royalty licensing of technology.[1]

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[1]When compulsory licensing of technology is discussed in this chapter, we mean the "reasonable royalty" formula which is usually applied by the antitrust agencies. This is standard language in most decrees and orders imposing compulsory licensing of patents and know how.

Fortunately, the antitrust agencies rarely have to investigage or litigate just how much of a royalty is actually "reasonable." The market-place normally performs this function efficiently. If a dominant patent holder is required to license technology for "reasonable" royalties, his bargaining power consists only of setting a moderate royalty which will not prevent determined competitors from using the

Strong patent protection would properly be reduced: (i) when a technology is maturing and substantial market risks are no longer involved in further innovation; (ii) when headstart advantages assure ample returns on innovative investments; or (iii) when well established, large firms with ample resources enjoy substantial headstart advantages. To the extent antitrust enforcement resources are scarce, this effort should be concendrated upon markets which are proven commercial successes, or upon markets where such commercial success seems likely.

Such a policy would tend to encourage more active technology trading when it is most productive. This would strategically enhance competition, and speed up the

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invention. (Such royalties may be substantial in absolute amounts; for example, in LDPE $2 million was paid by each of six initial licensees. But such amounts were not a great percentage burden on newly entering competitors.) If a patent holder seeks more of a royalty than this and tries to preclude entry, his competitors can ignore such claims, or complain to the antitrust agency concerned that the royalties sought were unreasonable. In practice, such complaints rarely reach the antitrust agencies, since the patent holder knows he must settle for a moderate royalty which will not preclude entry into the relevant markets.

innovation process in further refinement of basic inventions. Such action is desirable--not because it was morally wrong or inexpedient for entrepreneurs to strive for profitable fortunes, but because industrial efficiency, innovation and overall performance could be improved by forcing more competition.

This approach to the problem of limiting the scope for patent monopolies is very much in the spirit of the patent incentive. Patents are designed to give an extra measure of encouragement when it is needed by innovators and inventors. But instead of relying on patent monopolies to erode by themselves in precise adjustment to the declining need for them in each industry, we should realize that patents and head starts may have to be cut back substantially to facilitate further industrial progress.[2]

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[2] In other words, the natural tendencies at work in eroding patent dominance over time--(i) inventing around existing patents, and (ii) a reduced scope for improvement patents, do not always work effectively. The object here is to supplement the natural erosion process, and to make patent monopolies conform more accurately to their real purpose.

Although the polyolefin experience is primarily interesting in analyzing excessive patent protection, this in no way contradicts the frequent and opposite complaint that patents are often too weak and unreliable as an incentive, especially for small businesses which need patent protection the most. As we shall indicate at pages 312-315, _infra_, one recommendation which follows from this entire

Hence, public policy action may be needed in some industries to reduce patent and headstart advantages.

What would be the best way to proceed? Fundamentally, we need a more economic approach to the problem of defining excessive patent protection. Excessive patent monopolies grew up because their economic function as incentives for industrial progress was not sufficiently taken into account. This can best be appreciated by a review of the current legal compromise between patent and antitrust law.

Patents and Antitrust Policy

In recent years the U. S. Patent Office has been producing some 57,000 individual patent monopolies each year.[3] This occupies a corps of 1,200 patent examiners, with appropriate staff support and an annual budget of some $37 million.[4] The current stock of patents in force at the

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analysis is that greater scope should be allowed for patent protection to small business, and perhaps also to new entrants into an industry.

[3]The Patent Office budget in fiscal 1967 was $37 million, but it collected nearly $24 million in fees and deposits. Ibid. Altogether, private industry spends a considerably larger amount in prosecuting patent applications, administering patent portfolios, and in litigating infringements.

[4]In the period 1963-67 an average of 57,000 patents on inventions were issued annually. Annual Report of The Commissioner of Patents, 1967.

[illegible]

[illegible]

end of 1967 was about 900,000.[5] Just how many technology and product markets are currently affected by strong patent dominance has never been comprehensively estimated. Yet most students of patents and competition seem to agree that patents have been significant at one point or another as a source of monopolistic behavior in many industries.[6]

From the antitrust point of view a very limited effort has been made in reducing the strength of patent monopolies. In recent years only a few lawyers and an occasional economist within the antitrust agencies have been active at any one time in investigating and prosecuting cases of "patent abuse," or in contesting the legitimate scope of the patent monopoly. These efforts generally involve only a handful of the 700 antitrust lawyers and economists employed by the Federal Trade Commission and the Antitrust Division of the Justice Department. The budgetary investment in this activity would be less than 1 percent of the $15 million allocated to these agencies

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[5] <u>Annual Report of The Commissioner of Patents</u>, 1967.

[6] See, for example, Alfred E. Kahn's survey of the literature, cited <u>supra</u>, at p. 328.

for antitrust work, or less than $150,000 each year.[7]

There can be no doubt that little administrative effort has gone into policing excess patent protection. But equally important, antitrust law on patents is insufficiently developed. This is best seen by reviewing the boundaries between patents and antitrust, which are reflected in two major dimensions--the normal scope of the patent monopoly, and the circumstances in which this scope can be reduced when patents have been "misused." To begin with, the traditional scope of a patent comprises four separate powers or rights--(i) to exclude competitors from using an invetion, (ii) to select licensees, (iii) to charge royalties, and (iv) to discipline the market behavior of licensees--with respect to price, output, product line, and marketing territories.

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[7] The FTC allocated $7.2 million out of its $14.3 million budget in fiscal 1967 to antitrust enforcement functions; the Antitrust Division of the Department of Justice was allocated $7.5 million in fiscal 1967.

In addition, a collateral effort at policing patent abuse has been made in private antitrust cases. Defenses to patent infringement actions frequently incorporate a counterclaim of patent abuse in addition to a denial of patent validity. But it must be emphasized that the investigative authority and resources of private counsel are rarely equal to the efforts which the government antitrust agencies can make in particular cases.

Challenges to patent scope

Antitrust attack on the scope of patents, oddly enough, has been concentrated on only one aspect, the power to discipline licensees. When American antitrust policy became vigorous after the turn of the century, the courts were generally taking the position in patent cases that a patent holder was free to cede use of the invention on conditions specified by him. A patent was considered simply as another form of property. But gradually, the conflicting demand for competition began to limit the conditions which a patentee could impose. The first step was taken in 1917, when the Supreme Court held that patent licenses could not be used to tie customers to the patent holder.[8] The second step was attempted in 1926, but the Court resurrected some of the pre-1917 reasoning in the General Electric case. The Court decided that a patent holder could fix the resale prices of his licensees for the patented product, in this instance, electric lamps or "light bulbs."[9]

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[8] Motion Picture Patents Co. v. Universal Film Mfg. Co., 243 U.S. 502 (1917).

[9] U.S. v. General Electric Co., 272 U.S. 476 (1926).

A dozen years later Thurman Arnold's expanded Antitrust Division began a sustained effort to limit, and then eventually to reverse, the General Electric doctrine. Successively, the government obtained Supreme Court rulings prohibiting resale price maintenance after a patented product has been sold, when the arrangement is part of a mutual agreement among competitors,when participants in cross-licensing agreements are involved, or when such licensing restrictions form part of a price fixing understanding in an industry.[10] In 1948, four out of nine Justices were in favor of overruling General Electric; more recently in 1965 the Court divided equally (4 to 4) on this question.[11] Encouraged by this near success, the Antitrust Division under Donald F. Turner had been seeking a direct reversal of General Electric in a pending suit against the company. This action challenges G.E.'s

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[10] U.S. v. Unives Lens Co., 316 U.S. 241 (1942); U.S. v. Masonite Corp., 316 U.S. 265 (1942); U.S. v. Line Material Co., 333 U.S. 287 (1948); and U.S. v.United States Gypsum Corp., 333 U.S. 364 (1948).

[11] U.S. v. Line Material Co., 333 U.S. 287 (1948); U.S. v. Huck Mfg. Co., 382 U.S. 197 (1965).

current resale price arrangements in sales of electric lamps through distributors.[12] This recent offensive by the Antitrust Division has had the effect of discouraging the use of price and output restrictions in current patent licenses.[13] Recent statements by Richard McLaren, Turner's

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[12] U.S. v. General Electric Co., Civ. No. 66-3118 (S.D.N.Y., complaint issued February 1966). Four other pending complaints by the Justice Department also imply a reversal of General Electric: (i) three of these cases challenge a provision in drug company licenses which prevents resale of drugs in bulk form. U.S. v. Sterling Drug, Inc., Civ. No. 175-68 (S.D.N.Y., complaint issued February 1968), U.S. v. Syntex Corp., Civ. No. 478-68 (D.D.C., complaint issued February 1968), and U.S. v. Glaxo Group Limited, Civ. No. 558-68 (D.D.C., complaint issued March 1968); (ii) the fourth case challenges a restriction which allows only processing of an insecticide, and prevents any resale at all. U.S. v. Farbenfabriken Bayer A.G., Civ. No. 586-68 (D.D.C., complaint issued March 1968).

[13] See the complaint of H. Thomas Austern, former Chairman of the Antitrust Section of the American Bar Association, "Fish Traps, Indians, and Patents--'The Antitrust Validity of Patent License Restrictions on Sales Price, Field of Use, Quantity, and Territory,'" 12 A. T. Bull. 225 (Spring 1967).

successor, suggest he will continue this effort.[14]

The trend of the law in the last 25 years has been toward sharply limiting a patent holder's power to discipline the price and output behavior of his licensees. Whether the law would be pressed as far as per se illegality however, is doubtful. A rule of "resumptive illegality" seems to better express the goal of the Antitrust Division.[15]

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[14] See, for example, McLaren's Address before the Antitrust Section of the American Bar Association, March 27, 1969, at p. 3.

> I anticipate that we will be bringing cases that seem to be logical next steps, i.e., somewhat beyond what the Supreme Court has thus far decided, in the development of the law. As an example, we now have ready for filing a complaint challenging under Section 1 of the Sherman Act patent licenses which require an assignment grant-back of all improvement patents. It is our view that the right to a non-exclusive license back on improvements may be a legitimate provision in the license of a basic patent, but that a grant-back requirement tends unduly to extend the patent monopoly and to stifle research and development efforts of licensees, contrary to the public interest.

[15] The Antitrust Division's preference for a rule of "presumptive illegality" on vertical price-output restrictions in distribution was stated by Mr. Turner in a recent panel discussion before the <u>1968 Antitrust Law Symposium of the New York State Bar Association</u>, published by the CCH Trade Regulation Reporter, at pp. 29-31.

While price-output restrictions are likely to be dangerous when made by large, well established firms, small businesses or new entrants into markets may need more freedom to contract alliances and mobilize resources. A patent holder's power to discipline the market behavior of licensees may be very helpful for a small business or new entrant in assembling complementary resources--technology, financing, and in allocating territories to get his marketing organization established. Just as small business generally have more scope under the antitrust laws in using franchises, agencies, consignments and vertical arrangements generally, it seems reasonable for them to have somewhat more scope for use of their patent property.

No challenge or limitation has been suggested by the antitrust agencies with respect to the general right of a patent holder to (i) exclude competitors, or (ii) select licensees.[16] Since it is these powers which normally

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[16]Although the antitrust agencies themselves have never advocated any general limitations on the right to select licensees, an interesting suggestion was made by a 12 man panel appointed by President Johnson in 1966. They suggested that once a patent holder licenses anyone he should then be forced to license all other qualified licensees. White House Task Force Report on Antitrust Policy, July 5, 1968, released May 21, 1969. However, this panel's report, heretofore unpublished, was primarily concerned with conglomerate mergers and concentrated industries, and it cannot be taken as a systematic review of the proper compromise between the patent system and antitrust law.

restrict competition in product markets most severely, it should be clear that the traditional scope for patent protection has not been greatly diminished.

However, some interesting new law may be taking shape with respect to a renewed scope for patent royalty rates. One case so far has considered directly the level of royalties. In 1966 the Court of Appeals for the 7th Circuit decided that a 24 percent royalty on a patented product was "exorbitant and oppressive," even though the "bulk of the industry" involved had accepted this royalty rate.[17] So far as discrimination in royalty rates is concerned, this has led to several cases in which patents were found to be abused.[18] But no clear legal rule has emerged as to the

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[17] American Photocopy Equipment Co. v. Rovico, Inc., 359 F. 2d 745 (7th Cir., 1966).

[18] Barber Asphalt Corp. v. LaFera Grecco Contracting Co., 116 F. 2d 211 (3rd Cir., 1940); Laitram Corp. v. King Crab, Inc., 244 F. Supp. 9 (D. Alaska, 1965); and Grand Caillou Packing Co., Inc., FTC Docket No. 7887 (1964).

degree of competitive injury which might prompt antitrust relief. These cases are potentially important, for they could lead to significant limitations on another of the basic rights which a patent holder traditionally enjoyed--the power to charge royalties.[19] But--apart from specific compulsory, reasonable royalty licensing decrees, it must be emphasized that, thus far the freedom to charge royalties has not been significantly limited.

Limitations on patent abuse

The second dimension of conflict between the patent system and antitrust policy involves the ways in which patents can be abused. Over the years two major types of abuse have been identified: (i) cross-licensing arrangements among firms which unduly restrain trade; and (ii) undue accumulations of patent power by single firms.[20] When abuse is

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[19]It must be borne in mind, however, that so long as patent holders retain the power to restrict entry and select licenses, more powerful restrictions upon competition are delegated to patent holders.

[20]One other significant form of patent abuse has also been identified, the unreasonable failure to use an invention--i.e., patent "suppression." Suppression of invention to restrain trade is illegal, but the problem is to discover and prove it. The Attorney General's Committee said in its 1955 report, "where there is no affirmative showing that the purpose

established patents are normally declared invalid, rendered unenforceable, or at least subjected to compulsory licensing.

Cross-licensing agreements which unduly restrain trade are clearly illegal. But there have been relatively few antitrust investigations and cases dealing with such cross-licensing arrangements. The leading case on the subject is still the "Oil Cracking" case of 1931, in which the Supreme Court outlined the policy which still prevails:[21]

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or effect of nonuse is unreasonably to restrain trade, to monopolize or attempt to monopolize, the patentee's conduct does not transgress the antitrust laws. Clearly, however, contracts, combination or conspiracy among patentees to refrain from using or to refuse to license others to use patented inventions should be deemed unreasonable _per se_." At page 231. But hardly any enforcement effort has been made in this area. Proof of the required element of restraint of trade or conspiracy has been difficult, even if nonuse is discovered, and cost analysis has never been employed by the antitrust agencies to reveal suppressed inventions.

Almost all other industrial countries, however, have a potentially effective solution in that patents lapse or become invalid automatically after a few years of nonuse, or under certain conditions of "non-working." Such a provision would be appropriate in the U.S. Patent System, and they have been suggested for many years. For example, Vannevar Bush proposed this reform in his 1956 report, study No. 1, "Proposals for Improving The Patent System," Senate Subcommittee on Patents, Trademarks and Copyrights, at pp. 27-28.

[21] _Standard Oil Co. v. U.S._, 283 U.S. 163,168 (1931). See _Antitrust Trade Regulation Today_, B.N.A. 1967, pp. 154-7, for the other important cases.

> "Where domination exists, a pooling of competing process patents, or an exchange of licenses for the purpose of curtailing the manufacture and supply of an unpatented product, is beyond the privileges conferred by the patents and constitutes a violation of the Sherman Act. The lawful individual monopolies granted by the patent statutes cannot be unitedly exercised to restrain competition.***But an agreement for cross-licensing and division of royalties violates the Act only when used to effect a monopoly, or to fix prices, or to impose otherwise an unreasonable restraint upon interstate commerce." at p. 174-175.

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> "An interchange of patent rights and a division of royalties according to the value attributed by the parties to their respective patent claims are frequently necessary if technical advancement is not to be blocked by threatened litigation. If the available advantages are open on reasonable terms to all manufacturers desiring to participate, such interchange may promote rather than restrain competition." at p. 171.

This policy has limited monopolistic combinations to some extent by threat of illegality. In addition, the fact that a competitor outside a patent pool can demand a right to reasonable access to its use, has operated in some cases to reduce entry barriers resulting from patents. But much more aggressive enforcement of this policy by the antitrust agencies would be needed to achieve open licensing in all markets where multiple patents are dominant.

A special type of cross-licensing abuse can arise when the Patent Office declares an interference proceeding.

The law requires that applicants deal honestly with the Patent Office in fully describing and disclosing their inventions.[22] But an obvious danger in an interference proceeding is that rival claimants for a patent monopoly will collusively agree to distort the record on priority of invention, so that a much stronger degree of patent dominance can be obtained. This happened recently in the case of tetracycline, where Pfizer and American Cyanamid agreed to suppress key facts, and then cross-licensed each other to enable joint exploitation of their resulting monopolistic position.[23] The patents resulting were eventually declared invalid. Such patent fraud is unquestionably illegal, but

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[22]As the Supreme Court said in Precision Instrument Mfg. Co. v. Automotive Maintenance Machinery Co., 324 U.S. 808, 818 (1945),

> Those who have applications pending with the Patent Office or who are parties to Patent Office proceedings have an uncompromising duty to report to it all facts concerning possible fraud or inequitableness underlying the applications in issue....Public interest demands that all facts relevant to such matters be submitted formally or informally to the Patent Office, which can then pass upon the sufficiency of the evidence. Only in this way can that agency act to safeguard the public in the first instance against fraudulent patent monopolies.

[23]In the Matter of American Cyanamid, et. al., FTC Docket No. 7221; affirmed by the Court of Appeals for the 6th circuit, Pfizer & Co. v. FTC, Nos. 18336-37 (Sept. 30, 1968).

its extent and the best methods for suppressing it are still unresolved. Of course, this type of abuse can only arise when an interference proceeding is declared, so it would probably be less frequent than ordinary cases of unduly restrictive cross-licensing.

With respect to undue patent accumulations by a single firm, the law seems to be taking shape. Section 7 of the Clayton Act prohibits acquisitions of "assets" where the effect may be substantially to lessen competition or tend to create a monopoly. Although no court has yet held the purchase of a patent to violate this statute, a recent case held that a trademark is such an "asset" whose acquisition could violate Section 7.[24] Hence, it seems likely that acquisitions of patents could also be regulated to this extent.[25]

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[23] U.S. v. Lever Bros. Co., 216 F. Supp. 887 (S.D.N.Y., 1963).

[24] See Les Weinstein, "The Application of Section 7 of the Clayton Act to Patents, Copyrights and Trademarks," The Patent, Trademark, and Copyright Journal, Winter 1961-62. Even the Attorney General's Committee recognized in its 1955 report that patent acquisitions could be illegal, but argued that the mere purchase of a patent in and of itself is not an antitrust violation. "Impropriety will arise only where such acquisition is but of an illegal purpose and plan..., /in other words/ any acquisition should be weighted in its entire context. Important considerations include: (a) the nature, number or the value of the patents acquired, in relation to the market for competing patent or unpatented processes or products;

The same reasoning would apply to an exclusive license where substantial market dominance was transmitted from one firm to another, but no such challenge has been raised in the courts as yet.[25]

Another method of acquiring patents from others involves grant-back covenants on future technological developments in patent licenses. In the Transwrap case it was held in 1947 that such a covenant was not illegal *per se*.[26] But the Court's opinion recognized that grant-backs could have anticompetitive effects which would justify antitrust attack. Subsequent cases in the lower courts have applied this principle.[27] The head of the Antitrust Division

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(b) whether the inventor is using the patent, or has the ability and plans to use it, as against evidence of the purchaser's actual or intended use; (c) whether the purchase had the purpose and probable effect of resolving patent conflict; (d) the purpose and effect of the purchase on the market position of the purchaser and the increase or decrease in competition in the relevant, geographic market." At p. 227.

[25] See Antitrust and Trade Regulation Today, cited *supra*, at p. 142.

[26] Transparent Wrap Machine Corp. v. Stokes & Smith Co., 329 U.S. 637 (1947).

[27] U.S. v. General Electric Co., (carboloy) 80 F. Supp. (S.D.N.Y. 1948); U.S. v. General Electric (lamps), 82 F. Supp. 753 (D.N.J., 1949); U.S. v. Alcoa, 91 F. Supp. 333 (S.D.N.Y., 1950); and Kobe, Inc. v. Dempsey Pump Co., 198 F. 2d 416 (10th Cir., 1952).

indicated recently that he would try to extend it by challenging any exclusive grant-backs involving market power on a per se basis.[28] This would allow R&D cooperation, but prevent strong patent dominance from perpetuating itself unreasonably.

So far as accumulation of patents from a firm's own innovation is concerned, however, existing antitrust law would give very little basis for antitrust challenge. The Court's dictum in Automatic Radio would certainly be emphasized by patent holders in this regard.[29] The Court said, "the mere accumulation of patents, no matter how many, is not in and of itself illegal." To challenge the patents resulting from a firm's own inventive efforts, a theory like Learned Hand's in Alcoa would be necessary. In other words, patent dominance developed by individual innovation would have to reflect a high degree of monopoly and pre-emptive

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[28]This was Donald Turner's policy. See Antitrust and Trade Regulation Today, cited supra, at p. 143. However, Turner's successor, Richard McLaren plans to issue the complaint that initiates this policy. Cf 14/,p.299, supra.

[29]Automatic Radio Mfg. Co. v. Hazeltine Research, Inc., 339 U.S. 827, 834 (1950).

tactics before antitrust relief could be achieved under present law.[30]

What does all this mean in terms of a public policy goal to eliminate "strong" patent protection when it is really unnecessary? Empirically we have seen that "strong" patent protection can generally be dispensed with in at least these circumstances: (i) where technologies or industries are maturing sufficiently, (ii) where headstart inventives ensure ample innovative returns, or (iii) where large firms enjoy substantial innovative headstarts. Existing antitrust law would probably be an adequate basis for a greatly expanded attack on "close-knit" cross-licensing pools, in other words, those which do not allow access to outsiders for reasonable royalties.[31] But where the

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[30]Of course, if predatory tactics were proven, this might justify stronger antitrust relief. But more often than not, as the United Shoe Machinery case illustrates very well, such relief may only correct the directly predatory practices, and leave intact the established market power resulting from patent and headstart advantages. See 33/ at p.312, _infra_.

[31]Such an attack would have to include the imposition of compulsory, reasonable royalty licensing even where no formal pool or joint licensing agreement existed. So long as a pattern of bilateral cross-licenses has the effect of excluding entry and significantly restricting competition, it should be subject to compulsory, reasonable royalty licensing. This might require some extension of the "Oil Cracking" doctrine, but not a very great change in present case law.

excessive patent protection is largely held by just one firm, present law gives very little basis for eliminating such excessive patent protection. Therefore, although a substantially increased antitrust enforcement effort will be partly effective in achieving this policy result, some changes in the law affecting individual patent accumulations will also be needed.

Suggested improvements in patent policy

There are a number of ways in which we can significantly improve upon the present compromise between the patent system and antitrust law. First, we need to take a more economic and industrial approach to the problem of defining the proper scope of patent subsidies. When we do it becomes apparent that, while strong patent and head-start incentives may be appropriate to nurture the early development of a new industry or product, longer lasting patent dominance may often do more harm than good in limiting competition and further progress. This lesson indicates we need to circumscribe patent monopolies more carefully, and pay particular attention to the longrun strength of patent protection in industrial markets.

Second, a substantially greater effort should be made by the antitrust agencies to investigate and prosecute situations of patent abuse. Current efforts are very limited, despite the fact that patents are a significant source of monopolistic behavior in U.S. industry.[32] Furthermore, this effort should be organized systematically along industry lines, in order to reveal the most significant situations of excessive patent protection. In some cases industrywide guidelines on patents and technology licensing might be appropriate, and broader investigations would provide the basis for intelligent action.

Third, the law on patent abuse needs further development. The most important unresolved problem concerns the accumulation of "strong" patent protection by a single

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[32] Reasonable royalty, compulsory licensing clauses are frequently "thrown in" at the last stages in consent settlements of antitrust cases. Such provisions give an appearance of strong relief, but rarely do the companies involved concede any significant patent or headstart advantages. Hence, these limited efforts should not be confused with the serious, extensive investigations of technology markets which are designed to reveal and correct situations where patent protection is excessive and significant.

innovating firm.[33] Unfortunately, present law provides no basis by which this type of excessive patent strength could be attacked in such industries--without proving predatory or pre-emptive tactics. What is needed is some method of correcting a situation in which improvement patents are the source of excessive patent strength, not because innovators were wrong to seek it, but because this degree of patent subsidy is simply unnecessary. One solution to this problem would be to limit the life of improvement patents--let us say, 5 to 6 years.[34]

Fourth, the question of patent scope needs to be considered on a broader scale. To begin with the law should

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[33]Situations of this type are illustrated by cellophane and the shoe machinery industry. (For an account of the shoe machinery experience, see Carl Kaysen, U.S. v. United Shoe Machinery Corp., Harvard, 1956. In the shoe machinery case leasing and tying were also involved, which allowed antitrust relief to eliminate these contractual practices. But the underlying market power of United Shoe seems to have been based upon patent and headstart advantages. This is why the limited antitrust relief in this case did not induce any significant new entry into the shoe machinery industry, for it left undisturbed the strength of this firm's headstart advantages.)

[34]A more cumbersome solution would be to make all patents unenforceable beyond a right to reasonable royalties whenever substantial headstarts or a maturing technology obviated the need for "strong" patent protection. However, proof of such circumstances might often be difficult and make this solution less effective than a reduced life for improvement patents.

recognize the principle that small businesses or new entrants which lack significant headstart advantages are likely to need more latitude in contracting for complementary resources--technology, finances, and marketing organization. In other words, the scope for using patent property should be somewhat broader for small businesses or new entrants into an industry or market than that allowed to large, well established leaders in an industry or market. Thereby patents could be made to conform more accurately to their function as an innovation incentive.

Conversely, we should realize that modern industrial giants have less need for strong patent protection. Their diversified operations usually provide ample resources for R&D efforts and the rapid exploitation of significant technical opportunities, together with cost or selling advantages in some specific markets. The polyolefins illustrate this principle in the R&D efforts of ICI, Dupont and Union Carbide--among others. To the extent such large firms enjoy these headstart advantages, they also have less need for strong patent protection. Although "[t]he large firms are indispensable to technological and economic progress, . . . we are persuaded that a unique cost-benefit opportunity exists in the provision of [greater] incentives . . . [to encourage] independent inventors, inventor-entrepreneurs, and small technologically based businesses. The cost of special incentives to them is likely to be low. The benefits are likely to be high."[35] Therefore, large, well established

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[35] Technological Innovation: Its Environment and Management, U. S. Department of Commerce, 1967, at p. 18. This study also emphasized the fact that a substantial number of inventions and innovations still come from the small company and individual inventor environment, at pp. 16-18.

A similar conclusion was reached by Robert Solo in his Economic Organizations and Social Systems, Bobbs-Merrill, 1967. He writes that "[t]he patent system was devised and evolved as a means of stimulating invention and innovation where choice was decentralized and market-directed. In a situation where the diffused benefits of a creative idea are extremely vulnerable to externalization, it tried to help the individual to capture for himself a greater share of the realized benefits of his . . . invention; and, above all, to give to the individual the means of profiting by systematically disseminating his invention through its sale or license," at p. 255.

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"The patent system is not necessary in providing a profit motive for invention and innovation" with "autonomous organizations" [i.e., with large firms, flundations and universities], "as when choice decentralized and market-directed. With or without the patent system the autonomous organization can cash in on Research and Development. Without the patent system, the autonomous organization would continue to invest in R&D (and perhaps more than before) as a prerequisite for survival. Some firms [of this type] claim to disdain patents as not worth the trouble, preferring to cultivate a sheer capacity to outrace their rivals rather than concentrating on building little islands of special advantage, like a runner who concerns himself with his stamina and form rather than the trivialities of handicap." Ibid., at p. 255.

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"This is not to say that the patent system is without social value [among large firms, foundations and universities.] The patent system in this form of economic organization is surely useful in promoting as a profitable activity the systematic firms should be allowed less scope in patent licensing.

In the same spirit another change in the scope of patents should be considered seriously. Because improvement patents are generally the source of needlessly long lasting, strong patent protection, it would be desirable to cut down substantially on their scope, as opposed to basic patents. Perhaps the simplest solution would be to limit the life of improvement patents to 5 to 6 years. In other words, at least after 5 to 6 years,[36] the holders of mere improvement patents could no longer select licensees or prevent entry

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exchange through sale and licensing of invention and technical information and, therefore, possibly in motivating firms to promote the dissemination of its patents and technical information. Nevertheless the value of patents as a device for motivating inventive effort or investment in this form of economic organization is highly equivocal and there is room for maneuver by government in /diluting patent incentives/ without detrimental effect on invention and transformation." Ibid., at p. 255.

[36]Kaysen and Turner, Antitrust Policy, cited supra, also "suggest that a new class of petty patents be created, which would run for, say, five years, to be granted for inventions of minor importance. Petty patents would be granted either to applicants who requested them, or to applicants for full patents when there was substantial doubt as to the novelty and scope of the claimed invention. The standard of investigation in the patent office, which is effectively the standard of invention on which patents are granted, could be fairly low for petty patents. This would make it easier to raise the standards in the case of major patents, running as they now do for seventeen years." At page 171.

into their industries or product lines, or prevent use of improved processes. But a reasonable headstart advantage of 5 or 6 years would be preserved, which would encourage innovative rivalry on improvements.[37]

Some distinction between basic and improvement patents would have to be specified in new legislation.[38] But practical application of the distinction could largely be imposed upon patent applicants, and upon patent recipients and their

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[37]Five or six years is a substantial period of unlimited exploitation for improvement patents, since to this period would be added one or several years of protection during the time an application is pending.

[38]This problem of distinguishing between basic and improvement patents is not a simple one, unfortunately. Patent lawyers have struggled with it for years in trying to work out a lesser type of patent, with reduced value and difficulty of application, in order to reduce the administrative burden upon the Patent Office in reviewing an increasing volume and complexity of patent applications.

But a solution could be worked out, if it took account of several factors: (i) patent applicants--or at least their attorneys, usually know whether or not an invention will be basic or not, even though the Patent Office examiners would not initially; (ii) a much stronger burden of proof, administrative delay, and fees should therefore be imposed upon the seeker of a basic patent, in order to discourage unwarranted claims to this stronger degree of patent protection; (iii) this extra burden upon seekers of basic patents should include penalty fees for unwarranted claims.

competitors in private bargaining and litigation. So long as the bargaining strength of weak claimants to basic patents could be minimized, no significant burden would be placed on competition. Meanwhile no significant burden would be placed on competition by improvement claims, because they would be limited to only 5 or 6 years. Under such a regime, technology trading would be more likely to flourish, since holders of improvement patents would sacrifice less monopoly power when they engaged in patent or know-how licensing.

Some significant precedent for a 5-6 year improvement patent exists in other countries--W. Germany, Japan, France, Italy, Spain, Protugal, Brazil and the Philippines. Germany was the first to introduce 6 year "gebrauchsmusters" in 1936, which are literally translated as "utility models." These other countries copied this German innovation in recent postwar years.[39] However, the scope of "utility models" in all these countries is narrower than improvement patents, and they really only apply to improvements in certain mechanical devices or utensils, and not to all improved mechanical, chemical, electrical processes or products. Furthermore,

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[39] For further description of these "utility models," see <u>Manual for the Handling of Applications for Patents, Designs and Trade Marks Throughout the World</u>, Octrooibureau Los en Stigter (Sept. 1968).

there is the danger that utility models might merely add to the existing strength of patent protection--unless the standard of invention for basic patents is made much more selective, and far fewer basic patents issue. In other words, improvement patents must substitute in some substantial degree for 17 year basic patents, if such a reform is to achieve its intended result.

So far as royalty rates and discrimination which restrain trade are concerned, this might be a suitable way of limiting excess patent scope. But it must be emphasized that the main barrier to entry in most industries may not be royalties, but a refusal to issue licenses. Action to limit royalty rates in general might have the unwanted effect of inhibiting technology licenses--especially by small firm or individual patent holders. Hence, antitrust policy should proceed with considerable caution in regulating royalty charges--except, of course, where reasonable royalty, compulsory licensing has been decreed to correct patent abuse or excessive patent protection.

Finally, an important procedural reform is needed which would have very significant substantive effects. Attorney's fees should be awarded much more liberally to defendants in infringement cases that involve patent abuse or fraud, and punitive damages should even be considered in such situations.

Although present law prohibits cross-licensing pools which restrain trade, and makes patents obtained through fraud invalid, the competitors who ignore such patents must often make expensive legal defenses. Litigation costs in defending against an unwarranted patent infringement action can easily reach several hundred thousand dollars, and may impose an entrepreneurial risk for some years. Small businesses, particularly, may be inhibited from participating in a market against such illegitimate attack.

But the same principle in remedies should also be applied in favor of patent enforcers when flagrant infringement has been found, and particularly when the victim of patent infringement is a small business or individual innovator. Small business innovators should then be awarded the attorney's fees needed to prosecute the infringement action as part of their recoverable damages. In other words, the small business innovator may need special protection to efficiently enforce his patent rights and sustain the efforts his new competition requires.

These suggestions for improvements in patent policy are offered, not to weaken the patent system, but to perfect and strengthen it. One major reason the Supreme Court in recent years has been so harsh in rarely accepting the validity of patent claims has been the widespread view that patent protection would otherwise be excessive and dangerous. The result has been to generally dilute the value of individual patents. This unfairly reduces the incentives of individual inventors and small business innovators, which need patent protection the most in competing with large firms. In contract, large, well established firms are more likely to enjoy significant protection from extensive patent accumulations and cross-licensing. If these elements of excessive protection were reduced in the present patent subsidy system, the courts could be more generous in protecting the incentives of individual inventors and small business innovators. Thereby the problem of poorly distributed patent incentives for industrial progress could be alleviated. More competition and more innovation would be the likely result of these improvements in public policy.

Technology Trading, Joint Arrangements and Merger Activity

Although this study suggests that excessive patent protection and restrictive licensing are mainly responsible for unduly limiting technology circulation, there is a danger that such restraints of trade can arise with other forms of technology trading--including joint R&D efforts, joint ventures, acquisitions, and mergers. Just as exclusive cross-licensing arrangements among firms may lead to an undesirable increase in the strength of patent and headstart advantages, the same applies to these other methods of technology circulation.

Our concern with such transactions is whether a significant reduction in competition may occur which is not offset by some kind of economy. Such an effect is likely when firms with some degree of market power in the relevant technology markets, arising either from patents or headstarts, combine forces on an exclusive basis. It must be emphasized, however, that this exclusivity need not be formalized as part of a contract--it may merely be evident in the joint effort or merger that outsiders will be excluded from its benefits.

Fortunately, the existing antitrust laws--Sections 1 and 2 of the Sherman Act, Section 5 of the FTC Act, and Section 7 of the Clayton Act, provide ample opportunity to challenge this kind of inhibition on competition. What is needed, though, is more concern for the technology market implications of joint ventures and mergers. The same limited awareness and effort that is evident with respect to antitrust investigation of patent matters also operates here. Much of the difficulty is that far less information is available in published form on the relevant technology markets, and the extent of patent dominance or headstart advantages. But more staff effort could be made in merger and joint venture cases to obtain such information from the companies involved.[40] If such extra efforts were made, we could probably challenge or inhibit most of the joint arrangements and mergers which would represent significant threats to competition in technology markets.

Joint arrangements

One important lesson from the polyolefin experience is that exclusive joint arrangements between firms with market power in technology markets can unduly limit competition. The problem with exclusive R&D cooperation is much the same as with exclusive cross-licensing when market dominating patents are involved. If the partners, enjoying either strong patent protection or headstart advantages, combine forces on an exclusive basis, they may achieve together a much stronger monopolistic position than they could obtain

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[40] Questions on the existence and ownership of any dominating patents could be added to the investigative routine. The expertise of Patent Office examiners could also be used effectively and at little cost. And brief field investigations with knowledgeable industry sources, including securities analysts, could quickly indicate the pattern of headstart advantages.

independently. This, in effect, is what Standard Oil (N.J.) proposed for synthetic rubber development in 1939-40. Fortunately, the government rejected the idea; and no such arrangement arose in the polyolefins or in the other industries we have considered.

Obviously, such collusive action involving R&D exchanges may represent a serious threat to competition and involve an unjustified exaggeration of the normal incentives for innovation arising from headstarts and patents. The appropriate public policy response should be to generally allow R&D exchange, which might even include mutual grant-backs on future technology in cross-licensing arrangements, but to attack their exclusive features and effects. In most of the polyolefin joint arrangements, where the partners enjoyed no competitively dangerous market power in the relevant technology markets, either individually or collectively, no exclusionary effect arose. But when strong patent protection or headstart advantages operate, a joint effort between several of the few viable participants in a technology market may be exclusionary in its effect, even if no such language is incorporated in the relevant contracts. If such exclusive R&D cooperation lasted beyond the nurturing period needed to establish the new product or industry on a viable basis, then antitrust action might be appropriate to enforce reasonable royalty access to the relevant technology. The guiding principle should be to prevent strong headstart and patent advantages from freezing a needlessly monopolistic market structure into poace. But so long as excessive patent dominance is prevented, the natural erosion of innovative headstarts will tend to prevent this problem from arising. Hence,the kind of patent policy that was suggested in the foregoing pages would also tend to obviate restraints of trade in joint R&D efforts.

Another lesson from joint arrangements in the polyolefins concerns the proper scope of R&D agreements. Joint ventures subsidiaries involving production and marketing as well as technology exchange present a greater likelihood of substantially lessening competition. Such joint subsidiaries will probably prevent rivalry between its partners for the life of the venture, in at least the markets where the venture is active, and perhaps also in others. Joint arrangements which merely involve R&D or some other form of technology exchange generally lack this disadvantage. Therefore, joint R&D arrangements are less likely to involve serious threats to competition than the more complete alliances typical of joint subsidiaries.

Acquisitions and mergers

A similar principle applies with respect to acquisitions and mergers involving significant technology transfers. To the extent technology needs to be exchanged or transferred, a lesser arrangement involving only patents or know-how is likely to be sufficient. Such limited transactions have the great advantage that they leave the participants free to participate and compete in the relevant product markets. Consequently, it is not likely that economies involving technology exchange will justify the acqusitions or mergers which substantially lessen competition in their relevant product or technology markets.

But this analysis of technology markets and the polyolefins does suggest there may be significant diseconomies from some mergers affecting technology circulation, and that such transactions should be challenged under Section 7 of the Clayton Act. Three kinds of merger transactions may occur which may unduly restrict technology circulation: (i) vertical integration mergers; (ii) horizontal mergers; and (iii) conclomerate mergers.

Most of the horizontal or vertical mergers which would cause anti-competitive effects in technology markets would now be challenged under current merger law, because they also involved significant market shares and anticompetitive effécts in the relevant product markets. But very few conglomerate acquisitions have been successfully challenged as yet under Section 7. Therefore, although the antitrust agencies should be alert to technology market implications with all mergers, serious problems involving technology markets are likely to arise only in connection with conglomerate mergers--i.e., diversification acquisitions involving new products or industries which would otherwise escape antitrust interest.

Under present law the main question which arises with respect to conglomerates concerns their effect in reducing the force of potential competition.[41] Extending this policy to cover technology market implications requires that we do not overlook new products and industries. In such new fields it is possible that the acquisition of one of a few successful

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[41] Actually three theories have been employed by the antitrust agencies in challenging conglomerate mergers: (i) "Deep pockets," the first theory to emerge, has largely been abandoned. This involved the argument that the superior wealth, or "deep pockets" of the large acquiring firm represented a threat to competition in the acquired relevant markets. This theory suffered from excessive vagueness. It was difficult to differentiate the diversification acquisitions of the top 500 or so firms, and it was hard to demonstrate that entry by direct investment would be any less dangerous to competition. (ii) "Reciprocity,"the second theory to

innovators by well established giants in related markets or industries could so enlarge headstart or patent advantages as to inhibit the increasing competitive rivalry that would normally ensue as the new market developed. Although no acquisitions of this type occurred in the polyolefins--Gulf having acquired Spencer well after the low-density polyethylene market had become a relatively competitive oligopoly, such a threat to potential competition would have appeared, if, for example, DuPont or Union Carbide had acquired Hercules Powder Company, when the latter was the most successful innovator in polypropylene production and enjoyed substantial headstart advantages.

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emerge, is still being applied. But in only a few cases has reciprocal bargaining power been found a significant threat to competition in the relevant markets. Although reciprocal bargaining power could be significant in technology markets, this would normally involve situations of significant patent dominance and possible patent abuse, especially where cross-licensing arrangements involved. (iii) "Potential competition," the third theory to emerge, is now dominant in challenging conglomerate mergers under present law. A substantial reduction in potential competition will arise either where the number of potential entrants into a market was significantly reduced, or where entry barriers into a market were significantly increased. In either case the result may be to reduce the force of potential rivalry as a competitive discipline in the relevant product or technology markets. A convenient review of these theories in conglomerate merger cases is available in John Narver, Conglomerate Merger and Market Competition, California (Berkeley), 1967, Chapter 5, pp. 77-103.

Because antitrust enforcement policy has been least stringent against conglomerate mergers, it is more likely that this kind of acquisition has not been sufficiently challenged in recent years. Many modern, large corporations seek out growing markets as prime areas for diversification, and the successful innovators are prime targets for conglomerate acquisitions. Therefore it seems likely that "picking off the innovators" in a new product market or industry has been a significant and numerous type of acquisition. Unfortunately, no careful empirical study has been made of their relative importance or competitive consequences. In light of the recent rise in conglomerate merger activity, at least a potential danger is manifest in that large firms could unduly pre-empt the growth paths of successful, smaller innovators.[42] If this happened on a sufficient scale it could unduly limit the competitive contribution from smaller innovators which healthy, longrun industrial progress requires.

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[42] The significant recent rise in conglomerate merger activity is reported by Harrison Houghton, "The Federal Trade Commission's In-Depth Investigation of the Conglomerate Merger Movement," a statement for a seminar of Advanced Management, Inc., N.Y., N.Y., Sept. 19, 1968. See also the testimony of Willard Mueller before the House Ways & Means Committee, March 12, 1969.

APPENDIX TABLES

Appendix Table A-1

Shipping Costs

Transport costs (for bulk rail shipping) for finished polyolefin resins range from about one-third up to one cent per pound, depending on the distance from the polymer plant. The following are illustrative rail freight costs: 1/ Consequently transport costs are not a significant

Shipping Point	Receiving Point	Mileage	Total Cost in Cents Per Pound
Houston	Atlanta	814	.80
	Chicago	1,085	.71
	Denver	1,410	1.02
	St. Louis	794	.71
Philadelphia	Atlanta	766	.79
	Boston	307	.44
	Washington, D.C.	136	.30 1/2
	Pittsburg	291	.46 1/2
	Chicago	739	.81
Los Angeles	San Francisco	440	.33
	Seattle	1,151	.94
	Denver	1,128	2.76

fraction of resin price for either resin makers or fabricators; nothing like a zone pricing or multiple basing point system is necessary in the polyolefin resin markets. One national price plus freight charges is a natural development--except, perhaps, in the far west.

1/ Estimates were made by General Service Administration railroad tariff specialists. An even lower rate was announced for bulk shipments from the Gulf Cost to the New York City area as of August 20, 1963. The rate was challenged before the I.C.C. by a barge line and eventually sustained in a U. S. district court a year later. Sea Train Lines, Inc., v. U. S., 233 F. Supp. (D.N.J., 1964).

Appendix Table B-1

Plant capacities of low-density polyethylene producers
July 1968 1/

Producer	Location	Annual capacity (millions of pounds)
Union Carbide	Charleston, W.Va.	160
	Taft, La.	250
	Seadrift, Tex.	180
	Texas City, Tex.	290
	Torrance, Calif.	80
	Whiting, Ind.	100
DuPont 2/	Orange, Tex.	350 (est.)
	Victoria, Tex.	350 (est.)
National Distillers 3/	Tuscola, Ill.	215
	Houston, Tex.	210
Gulf Oil (Spencer) 5/	Orange, Tex.	200
	Cedar Bayou, Tex.	200
Rexall-El Paso	Odessa, Tex.	300
Dow 4/	Freeport, Tex.	140 (est.)
	Plaquemine, La.	130 (est.)
Eastman Kodak	Longview, Tex.	200
Monsanto	Texas City, Tex.	130
Koppers-Sinclair	Port Arthur, Tex.	125
Allied 6/	Tonawanda, N.Y.	25
	Orange, Tex.	25

1/ Standard Oil (N.J.) was scheduled to enter production with a plant of 200 million pounds capacity in late 1968. Chemplex Co. (Joint venture of American Can-Skelly Oil) planned entry in early 1969, with 100 million pounds annual capacity.

2/ DuPont expanded its capacity to 700 millions pounds in 1967, but no breakdown is available between the two plants--except that in July 1966, the Orange plant was rated at 300 million pounds.

3/ National Distillers operated the Houston, Tex. plant in 1964-65 as a joint venture with Phillips Petroleum.

4/ Dow expanded its capacity to 270 million pounds since 1966, but the current breakdown between the two plants is not available.

5/ Gulf acquired Spencer in 1963.

6/ Allied produces a medium density-narrow spectrum polyethylene which has been characterized both as low-and high-density polyethylene; for the years 1959-62, Allied reported production of both types of resin to the FTC.

Source: Directory of Chemical Producers, Stanford Research Institute, Menlo Park, Calif., July 1968.

These capacity estimates are representative trade press estimates but cannot be taken as strictly accurate representations of the actual production or capacity of particular firms. Estimates such as these for particular companies differed significantly in several instances from actual production in 1959-62, as reported to the FTC. However, these estimates do reflect with reasonable accuracy the scale of plants in typical use, and the aggregate supply situation.

Appendix Table B-2

Plant capacities of high-density polyethylene producers
July 1968 1/

Producer	Location	Annual capacity (millions of pounds)
Phillips Petroleum	Pasadena, Tex.	160
Allied (Grace) 2/	Baton Rouge, La.	140
Celanese	Houston (Pasadena) Tex.	130
National Petrochemicals (National Distillers-Owens Illinois)	La Porte, Tex.	125
Union Carbide	Seadrift, Tex.	130
DuPont	Orange, Tex.	100
Hercules	Parlin, N.J.	80
Koppers-Sinclair	Port Reading, N.J.	80
Monsanto 3/	Texas City, Tex.	50
	Freeport, Tex.	60
Dow	Plaquemine, La.	50
Chemplex (American Can-Skelly Oil)	Clinton, Ia.	50

1/ Gulf is planning to enter in the summer of 1969, with a 100 million pound plant.

2/ Allied acquired the Grace plant in 1965.

3/ Monsanto is planning to expand capacity substantially by the end of 1969.

Source: Directory of Chemical Producers, Stanford Research Institute, Menlo Park, Calif., July 1968. Note the limitations of this data, which are described at Appendix Table III- 1.

Appendix Table B-3

Plant capacities of polypropylene producers
July 1968 1/

Producer	Location	Annual capacity (millions of pounds)
Hercules 2/	Lake Charles, La.	120
	Parlin, N.J.	25
Standard Oil (Ind.) [Avisun] 3/	New Castle, Del.	100
Standard Oil (N.J.)	Baytown, Tex.	100
Shell Oil	Woodbury, N.J.	80
Diamond-Shamrock (Phillips) 4/	Houston, Tex.	70
Eastman-Kodak	Longview, Tex.	60
Rexall	Odessa, Tex.	50
Montecatini 5/	Neal, W.Va.	40

1/ No new producers are known to be planning entry into polypropylene, except that Phillips is planning a 70 million pound plant in Puerto Rico.

2/ Hercules is planning a 100 million pound expansion of its Lake Charles plant. The Parlin, N.J. plant is reported to be no longer in use for polypropylene production.

3/ Standard Oil (Ind.) purchased the Avisun plant in 1967, from its sole owner at that time, Sun Oil.

4/ During 1964-66, the Diamond-Shamrock plant was operated as Alamo Polymer Corp., a joint venture of Phillips-National Distillers. Diamond Alkali and Shamrock Oil purchased this plant as the result of FTC divestiture, after the Phillips-Distillers joint venture was challenged under Section 7 of the Clayton Act.

5/ Montecatini has a plant expansion under construction.

Source: Directory of Chemical Producers, Stanford Research Institute, Menlo Park, Calif., July 1968. Note the limitations of this data, which are described at Appendix Table III- 1.

Appendix Table B-4.--Assets of polyolefin producers, in year of entry and in 1967

Surviving producers (and their successors)	Assets in year of first entry into polyolefin production (millions of dollars)	Year of entry	Assets in 1967 (millions of dollars)
DuPont	$857	(1942)	$3,071
Union Carbide	427	(1942)	3,088
Eastman Kodak	524	(1953)	2,233
Monsanto	377	(1954)	1,859
Dow Chemical	705	(1954)	1,910
Spencer (Gulf Oil)	68	(1954)	6,458
National Distillers	388	(1954)	799
Koppers 1/	221	(1957)	2,137
Phillips Petroleum	1,520	(1957)	2,787
Hercules	181	(1957)	656
Grace (Allied Chemical)	498	(1958)	1,603
Avisun 2/ (Standard Oil [Ind.])	667	(1958)	4,058
Allied Chemical	785	(1959)	1,603
Celanese	378	(1959)	1,820
Standard Oil (N.J.)	10,090	(1960)	15,197
Rexall 3/	159	(1960)	2,213
Montecatini	N.A.	(1961)	4,463
Shell Oil	1,989	(1962)	3,073
Diamond-Shamrock 4/	512	(1967)	512
Chemplex 5/	1,841	(1967)	1,841
Unsuccessful producers that dropped out			
Foster Grant 6/	29	(1961)	
Goodrich-Gulf 7/	4,699	(1961)	
Firestone	879	(1961)	

1/ Later reinforced in a joint venture by Sinclair, which had $1,810 million in assets for 1967.
2/ A joint venture entry of American Viscose and Sun Oil. (Combined assets are indicated.)
3/ Later reinforced by El Paso Natural Gas, which had $1,773 million in assets for 1967.
4/ A joint entry of Diamond Alkali and Shamrock Oil. (Combined assets are indicated.)
5/ A joint entry of American Can and Skelly Oil. (Combined assets are indicated.)
6/ Supported financially by Socony Mobil Oil, which had $3,608 million in assets for 1961.
7/ A joint entry of Goodrich Rubber and Gulf Oil. (Combined assets are indicated.)

Source: Fortune, 1968 for assets in 1967; Moody's Manual for assets in other years.