PATENT PROTECTION AND INCENTIVES TO INNOVATE: TRENDS AND EFFECTS IN ITALY

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(ABSTRACT)

The relationship between patent protection, incentives to innovate, the generation of innovations, and the accrual of benefits from innovation was investigated. The study was based on an analysis of research and development, patenting, productivity and output data for Italy.

In 1979, Italy made significant changes in its patent law to conform with European Economic Community standards. Previously, the Italian law had provided weak protection of intellectual property, which includes product or process innovations, publications, and art. Economic theory predicts that, under certain conditions, such a change should increase the amount of resources devoted to innovation. Furthermore, an increase in successful innovative activity is expected to lead to increases in the growth of per capita gross domestic product.

The relationship between research and development was analyzed using a polynomial distributed lag model. As expected, the results indicated that there is a strong relationship between research and development in Italy and the number of U.S. patents granted to Italians. A significant relationship was also found between the number of patents granted and output per worker-hour in Italy. The data indicate that Italy has significantly increased its level of spending on research and development since 1979. The data also indicate that Italy's per capita gross domestic product has tended toward convergence with several of its European neighbors. These results are consistent with the above hypotheses.

A description of the theoretical framework, the methodology applied, and the detailed results is included.

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CHAPTER ONE

INTRODUCTION

Intellectual property protection is a topic which has received much attention throughout the years. In recent years, evaluating the costs and benefits of intellectual property protection has become more important since it was a point of contention in the Uruguay Round of the General Agreement on Trade and Tariffs (GATT) talks. Many developing countries look upon such protection as a device used by western countries to maintain their technological dominance over poorer neighbors. Still, patent laws are increasingly under review in countries which have historically provided for little or no protection of intellectual property. Such countries as Argentina, Brazil and Turkey are currently considering strengthening their laws.

In this paper, I intend to analyze the effect of strengthening patent protection from a theoretical perspective and by reviewing evidence from a country which has changed its patent laws relatively recently--Italy. The Italian experience provides a unique opportunity to analyze data under both weak and strong patent protection regimes without having to control for cross-country effects. By analyzing information from before and after the change in Italy's patent law, it may be possible to determine whether a behavioral change may have occurred as a result of the new legal provisions.

I will test the hypothesis that research and development (R & D) translates into increases in technical knowledge, as measured by patents. This, in turn, translates into benefits to the economy in the form of increased productivity. I will then test the hypothesis that stronger patent protection leads to increased R & D expenditures. Specifically, I will analyze: (1) whether there is a strong relationship between R & D in Italy and U.S. patents granted to Italians; (2) whether there is a relationship between U.S. patents granted to Italians and productivity in Italy; and (3) whether there was a change in the level of R & D spending in Italy after the change in Italian patent law. I will also briefly review Italy's economic performance in relation to other developed countries.

CHAPTER TWO

THE ITALIAN ECONOMY AND PATENT LAWS

A Brief History of the Post-War Italian Economy: 1950-1979

After World War II the Italian economy, like other Western European economies, was devastated. Also like other countries, Italy grew quickly in the years after the war. In the 1950s and 1960s, Italy had cheap labor and energy, and easy credit. These factors contributed to high levels of investment in heavy industries and encouraged the manufacture of other goods such as footwear, textiles, jewelry, leather goods and household appliances. Exports went from 10 percent of gross national product (GNP) in 1950 to about 20 percent in 1970. Average annual productivity growth in manufacturing during the 1960s was over 7 percent. Farm employment fell from about 50 percent in 1950 to 20 percent in 1970. For the same period, real GNP growth averaged about 6 percent per year.[1]

Around 1970, this strong rate of growth was stifled. In mid-1969, labor dissatisfaction led to strikes; the result was a 20 percent increase in wages. Another devastating blow to the Italian economy came with the oil crisis. Italy

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[1]Arthur S. Banks, ed., *Economic Handbook of the World: 1982* (New York: McGraw-Hill Book Company, 1982), 271-274.

is second only to Japan in its dependence on foreign energy sources. As a result, Italian industry was greatly effected by the increase in oil prices.[2]

Despite Italy's tripling of its per capita income between 1950 and 1979, only Ireland, among European Economic Community (EEC) members, had a lower per capita income in 1979. Italy's per capita income trailed the United Kingdom's by 20 percent and it trailed the other six members at that time by 45 percent or more.[3]

Italian Patent Laws

The basis for Italy's patent law is Royal Decree No. 1127 from 1939, but this act has been substantially changed since then. The patent law was amended in 1968, 1972, 1975, 1979, 1985, and most recently in 1987. In particular, Royal Decree No. 540, on June 22, 1979 (effective August 22, 1979), marked a major revision in Italy's policy towards patent protection.[4] To understand why this change took place, it is helpful to understand the European Patent Convention and its influence on national laws.

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[2]Ibid.

[3]Ibid.

[4]Alan J. Jacobs, ed., *Patents Throughout the World* (New York: Clark Boardman Callaghan, 1992), I37-I44.

European Community member states began working on drafts of the Convention for European Patents for the Common Market in 1959.[5] The first draft of the Convention was produced in 1962, but for political reasons it lay dormant until 1969.[6] The European Patent Convention was finally signed on October 5, 1973 and was effective in October 1977. The first patent applications were actually accepted on June 1, 1978. Through 1991, the Convention had been ratified by Austria, Belgium, Denmark, France, Germany, Greece, Italy, Liechtenstein, Luxembourg, Netherlands, Spain, Sweden, Switzerland, and the United Kingdom.[7]

The European patent law does not supersede national patent laws, it only provides a mechanism for the granting of a single patent that will be effective in all of the signatories' countries. The rights and provisions granted to patent holders still depend on the laws of each country. As a result, an effort was made to make patent laws in each country more comparable. It was because of this effort that Italy's patent law underwent significant modification.

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[5]Edward J. Hayward, "Patent Licensing in the EEC," *Business Lawyer* Vol. 35, No. 2 (January 1980): 455-484.

[6]Edward Armitage, "The Law and Practice of the European Patent Conventions," in *The New European Patent System and Its Implications for Industry in London, January, 8, 1974*, by the Confederation of British Industry (London: Confederation of British Industry, 1974), 3.

[7]Jacobs, E23-E31.

The following key changes were made to the Italian patent law in 1979:

- The patent term was extended from 15 to 20 years from the date of application.[8] This clearly has positive implications for patent holders in that it increases the present value of each patent. This increase in value may be significant because it may take years between the filing of a patent application and the marketing of a product, especially if regulatory review is required. During this process the patent term is running down.
- The provision for examination of patent applications by the Minister of Health to determine toxicity was abolished.[9] This review process may have contributed to delaying the awarding of patents. As stated above, this may be significant since the time on the patent term is running down during the review process.
- Pharmaceutical products were granted protection for the first time.[10]

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[8]Ibid, I37.

[9]Ibid.

[10]G. Jori, "The Impact of Pharmaceutical Patents--The Italian Experience," paper presented at the Seminar on the Proposal to Change Turkish

- The terms under which compulsory licenses would be granted were made more restrictive, but compulsory licenses were not abolished.[11] Compulsory licensing is a common feature of patent laws around the world.[12] Compulsory licensing generally means that an innovator is required by law to grant a license to any firm that wants one at a royalty rate that is determined by the government.

Italy is still regarded as an easy place to patent. Patents are not rigorously examined, but are merely registered with the government. However, the changes due to the European Patent Convention make its patent system relatively stronger. There may also be evidence that enforcement was somewhat stronger after the change in patent law. Enforcement provisions now include both criminal and civil penalties for counterfeiting, appropriation or imitation.[13] Still, the U.S. cites problems with Italian enforcement of intellectual property

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Patent Law, sponsored by the Minister of Health, Ankara, Turkey, August 26, 1992.

[11]Jacobs, I38.

[12]Before 1987, Canada allowed open compulsory licensing. However, in 1987 Canada amended its law to severely restrict the conditions under which a compulsory license can be granted.

[13]Lester Nelson, Esq., ed., *Digest of Intellectual Property Laws of the World* (New York: Oceana Publications Inc., August 1991), Release 91-3.

rights in the areas of computer software, video and audio cassettes, and television programs.

Taken together, the changes described above are considered significant by many observers.[14]

[14]Jori, 5; Professor F.M. Scherer, Harvard University, Boston, telephone interview by author, April 2, 1993; and William J. Brunet, Esquire, Chairman of Division I: American Bar Association Section on Patents, Trademarks and Copyrights, New York, telephone interview by author, April 1, 1993.

CHAPTER THREE

INTELLECTUAL PROPERTY PROTECTION: THEORETICAL FRAMEWORK

Intellectual property rights provide for ownership of inventors' innovative or original creations. Novel products, processes, art, and manuscripts are all forms of intellectual property which are afforded some level of protection under the law.[15] Common forms of protection for this type of property include patents, trademarks, copyrights and trade secrets. I will be focusing on patents.

The first U.S. patent law was enacted in 1790.[16] U.S. laws governing intellectual property are still evolving as new issues emerge, such as protection of computer software. For example, the 99th Congress dealt with patents, trademarks and copyrights in approximately 200, 100 and 90 bills, respectively.[17]

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[15]A novel invention is one which is industrially applicable and "new and unobvious, i.e. it must represent more than the mere routine application of ordinary skill by the competent worker in the field." See, The Intellectual Property Committee (USA), Keidanren (Japan) and UNICE (Europe), *Basic Framework of GATT Provisions on Intellectual Property, Statement of Views of the European, Japanese and United States Business Communities* (Unknown publisher, June 1988), 34-35.

[16]This law was the first national patent law on record. See Table 1 for the dates in which several countries enacted their first patent laws.

[17]Richard P. Rozek, "Protection of Intellectual Property Rights: Research and Development Decisions and Economic Growth," *Contemporary Policy Issues* Vol. V (July 1987): 54.

Table 1

YEAR OF ADOPTION OF FIRST PATENT LAW, BY COUNTRY

Country	Year	Country	Year
United States	1790	Zaire	1886
Netherlands	1809	Switzerland	1889
Austria	1810	Ecuador	1892
Sweden	1819	Denmark	1894
Spain	1826	Hungary	1894
Brazil	1830	Costa Rica	1896
Mexico	1832	Finland	1898
Chile	1840	Australia	1903
Portugal	1852	Romania	1906
United Kingdom	1852	South Africa	1910
Belgium	1857	Pakistan	1911
Bolivia	1858	Poland	1919
India	1859	Greece	1920
Argentina	1864	Israel	1924
Italy	1864	Ireland	1927
Liberia	1864	Iran	1930
New Zealand	1865	Iraq	1935
Canada	1869	Taiwan	1944
Peru	1869	Egypt	1949
Germany	1877	China	1950
Venezuela	1878	Vietnam	1957
Turkey	1880	Libya	1959
Japan	1885	Congo	1963
Norway	1885	Madagascar	1963
Uruguay	1885	Sudan	1971

Source: Richard T. Rapp and Richard P. Rozek, "Benefits and Costs of Intellectual Property Protection in Developing Countries," *Journal of World Trade* Vol. 24, No. 5 (October 1990): Appendix, Table A-1.

Why Patent Protection is Important

To predict the response to a change in the patent law, one must identify the microeconomic incentives that are affected by patent laws. One must also take into account how patent protection might contribute to a country's economy.

Patent protection is important in promoting technical progress for two reasons. First, it provides a mechanism for the compensation of inventors which provides them with incentive to innovate. Without this incentive, potential innovators might devote their efforts to imitative pursuits, where the cost is lower and the payoff is just as great. In this way, patent protection helps create an atmosphere conducive to technical progress.

Second, patent protection provides for the diffusion of knowledge. Patent protection is not intended to provide innovators with a monopoly. Ironically, patent protection provides both for the protection of innovative ideas and for their rapid dissemination. Rapid dissemination provides competitors with state-of-the-art knowledge that can be used as is (through licensing) or modified to "invent around" the patent. Thus, the patent not only provides for a period of exclusivity, but also provides information to others who might attempt to shorten the useful life of the innovation. Below I discuss these issues in more detail.

Incentives for Innovation

Protection of intellectual property is important because it provides incentive for individuals to innovate. The incentive to invest resources in the creation of a new technology through research depends, in part, on the rewards for successful innovation. If the rewards are relatively high compared to the costs, the incentive to innovate is greater. However, if innovations can be copied and distributed at low cost, inventors may be unable to appropriate an adequate return for their research.

The Returns to Innovation

The return to innovators should be equal to the additional economic or societal value of their innovation. The economic value of an innovation is equal to the present discounted value of all improvements in products, processes, etc., that occur as a result of that innovation, less improvements that would have occurred in the absence of innovation.[18] When making a decision whether to engage in innovative activity, the potential gain from the work must be compared to the costs. These costs include the opportunity cost of foregoing other ventures, the cost of R & D, marketing costs, regulatory costs, etc. Another factor to consider is the extent to which the innovation might be copied. This is the cost of revealing the innovation. Thus, the expected value of a patent is

[18]This abstracts from search and transactions costs.

equal to the economic value of the invention times the probability that the patent will be granted, times one minus the probability that the innovation will be copied, less the costs associated with the production of the innovation. This relatively simple model yields the equation:

$$E[P] = (V \times p_g)(1 - p_c) - C \qquad (1)$$

where *E[P]* is the expected value of the patent, V is the economic value, p_g is the probability of obtaining a patent grant, p_c is the probability of the invention being copied, and C is the cost of developing and utilizing the invention. The value of V depends on the innovation itself; if it represents a breakthrough in technology the economic value may be quite high. The probability of obtaining a patent is a function of the novelty of the invention.[19] The probability of the

[19]If a patent is not granted because the invention was not considered novel, the economic value of the invention should be considered relatively low or zero. In essence, the patent examiner has concluded that no meaningful innovation occurred.

invention being copied depends on the patent protection regime under which the invention is revealed. This is the term I will be most concerned with.[20]

The probability that the innovation will be copied impacts on the proportion of the economic returns one can expect to realize after being granted a patent. This is commonly referred to in the literature as the appropriability of the returns. A high level of appropriability means that the innovator will receive a high proportion of the net economic value of the patent as compensation.[21] The level of appropriability is determined by the structure of the patent system under which the innovation is disclosed. A strong system of patent protection will compel users of technology to pay for the use of the innovation. If patent protection is less than full (i.e., weak statutory protection, weak enforcement, or inefficient means of technology transfer) the appropriability of the returns may be decreased. Weakness in any of these three areas may cause inventors to provide relatively less innovation.

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[20]There are other important considerations in determining the appropriate allocation of resources to research and development. For instance, there may be uncertainty about the value of the project or patent; there is the possibility that the development period will be longer and more expensive than anticipated; or a competitor may either innovate first or imitate a new invention. For a discussion of these issues see Jennifer F. Reinganum, "A Dynamic Game of R and D: Patent Protection and Competitive Behavior," *Econometrica* Vol. 50, No. 3 (May 1982): 671-688.

[21]The net economic value of an innovation is the economic value net of costs, or $V - C$.

Limits on the Level of Appropriability

Piracy is one factor that limits the appropriability of returns. While it is important to provide for a high degree of appropriability, it may be very difficult to prevent illegal copying. Piracy and illegal use of intellectual property is often difficult to detect and prevent. Copying of literature, art, music and computer programs is relatively inexpensive and easy. While quantifying the effect of piracy on various industries is difficult, the U.S. International Trade Commission estimated that the worldwide losses to U.S. businesses due to inadequate intellectual property protection was between $43 billion and $61 billion in 1986.[22]

A second limiting factor is the fact that in terms of a relevant product market, a patent does not provide a monopoly; a patent only provides its holder with exclusivity.[23] A monopoly may exist when a firm is the only supplier of a good with no close substitutes. U.S. patent laws provide holders with the exclusive right to a specific technology which is narrowly defined in the patent

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[22]The Intellectual Property Committee (USA), Keidanren (Japan) and UNICE (Europe), 12-13.

[23]Equating patent protection with monopoly power is an error often made by commentators from developing countries. See, for example, Pablo Challu, "The Consequences of Pharmaceutical Product Patenting," *World Competition* Vol. 15, No. 2 (December 1991): 65.

application. In many cases where a patent is granted, other products compete with the patented invention.

As a conceptual example, if a firm builds and patents a better mousetrap, it will probably be able to sell its invention at a higher price than the old-style mousetrap. However, the introduction of the new mousetrap may not drive the old technology from the market, particularly if its cost of adoption is substantially higher. To a certain extent, the old-style mousetrap may constrain the price of the new mousetrap since it may be a close, effective and relatively cheaper (by assumption) substitute. A real-life example of patent protection not providing monopoly power is in the market for hypertensive drugs. More than 40 products are approved in the U.S. for the treatment of hypertension. Some were approved in the 1960s, while others were approved in the late 1980s and are still under patent protection.[24] These products all treat the same symptom (hypertension) but they do it in different ways and cause different side effects.[25] For instance, diuretics can cause significant water loss and may cause hypokalemia, a shortage of potassium. ACE inhibitors, on the other hand, do not cause hypokalemia, but may have other side effects that certain patients must

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[24]Richard P. Rozek and Carla Salisbury, "Discounted Cash Flow Analysis in Patent Infringement Litigation," *Licensing Economics Review* (August 1991): 8-9.

[25]Different types of antihypertensive products include diuretics, beta blockers, calcium channel blockers and ACE inhibitors.

avoid. Physicians often substitute one hypertensive drug for another or combine them until the desired (or best possible) effect is achieved. Hence, these drugs are close substitutes and there is no monopoly despite the existence of patent protection.

Diffusion of Technology

Besides providing incentive to engage in innovation, a patent system provides for more rapid dissemination of new discoveries. Even if a firm is granted an exclusive right to its innovation, the information about the innovation provided in the patent application is available to the public. This information can be used by a firm's competitors to more quickly and easily understand new discoveries. This, in turn, can assist those competitors in inventing around or improving that innovation. This is the "creative destruction" process described by Joseph Schumpeter in his 1943 work, *Capitalism, Socialism and Democracy.*[26] Under Schumpeterian competition, patent protection is only a temporary shield from competitors. In his theory of creative destruction, new technologies supersede old technologies and dominant firms continually face competition from firms wishing to become dominant.

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[26]Joseph Schumpeter, *Capitalism, Socialism and Democracy*, (London: Unwin University Books, 1943).

Mansfield, Schwartz and Wagner uncovered evidence of this process of creative destruction.[27] They found that about 60 percent of the patented innovations in their survey were imitated within four years. Firms introduced new products even though they knew that other firms could imitate them, often at less than 65 percent of the cost and in less than 70 percent of the time. Furthermore, they found that:

> Although patents generally increased the imitation costs, they did not increase the costs enough in these cases to have an appreciable effect on the rate of entry.[28]

Other factors, such as brand name and reputation encouraged innovation despite the relative ease of imitation. That is, although innovators knew their product could be imitated, they still felt they could make a profit on it.

Incentives for Countries to Provide Strong Intellectual Property Protection

Developing countries frequently assert that intellectual property protection laws are designed to keep them at a relative disadvantage to industrialized countries. They contend that the advancement of human knowledge is a public good that should be available for all to benefit. It is true

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[27]Edwin Mansfield, Mark Schwartz and Samuel Wagner, "Imitation Costs and Patents: An Empirical Study," *Economic Journal* Vol. 91, No. 364 (December 1981): 907-918.

[28]Mansfield, Schwartz and Wagner, 916.

that society would tend to benefit from widespread availability of new discoveries. However, this must be balanced by a mechanism to ensure that inventors receive and appropriate compensation for their work. This is why adequate, but not excessive, patent protection is desirable.[29] Inventors choose to innovate because the expected value of their patent is positive.[30] Thus, for substantial innovation to occur, some form of compensation for invention must probably exist. Furthermore, since the probability of successful innovation is relatively low, high levels of compensation may be necessary to encourage high levels of R & D. If this is true, there may be a need for a high level of appropriability.

In terms of consumer surplus, Nordhaus has found that the U.S. patent system is very efficient. He found that the welfare loss due to exclusivity is insensitive to the life of a patent once a life of between six and 10 years has been reached. Nordhaus estimates that a patent system with a 17 year life is roughly 90 percent efficient, with efficiency defined to mean that it achieved 90 percent of the maximum possible consumers' surplus.[31]

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[29]For example, granting a firm the exclusive right to manufacture and sell automobiles would probably be considered excessive.

[30]See equation (1).

[31]William Nordhaus, *Invention, Growth, and Welfare* (Cambridge, MA: M.I.T. Press, 1969); cited in Hal R. Varian, *Intermediate Microeconomics, A Modern Approach* (New York: W. W. Norton & Company, 1987), 424-425.

Other things equal, economic theory predicts that a country with full protection of intellectual property may exhibit greater improvement in its standard of living than a country with limited or no protection. This result is expected for several reasons.

First, patent protection promotes competition between inventors to be the first to file a patent application.[32] Even after a new innovation appears on the market, other innovators may strive to introduce a competing product. This is why a patent race is not necessarily an all-or-nothing contest to create one single product. Rather, it is an ongoing process through which new learning may be applied to a number of innovations. Even if it loses a patent race, a firm which invests significant resources in the development of an idea may be well equipped to develop a product to compete with the patented invention. It can introduce a new invention or simply improve the innovation that made it to market earlier. Through this competition, a country can expect its researchers to expand their base of knowledge as they compete both amongst each other and with other innovators throughout the world. Strong protection encourages

[32]There is also the possibility that firms which decide they may not win a patent race will decide not to participate in the first place. This would result in *less* competition for a patent. Still, it is likely that in a market with several firms there will be some degree of competition for a patent. In fact, there are some that argue that there is excessive duplication of R & D. These commentators would presumably argue for either less competition or a change in the patent system.

domestic innovators to invest in innovation rather than imitation. Absent patent protection or some other compensation mechanism, they might have greater incentive to imitate other innovations, which is usually substantially cheaper than developing a new product.[33]

Second, innovative products can be exported to other countries. Exports of intellectual property are stimulated when innovators in a home country send their output to other countries that protect intellectual property (i.e., they allow a return on innovative efforts).[34] The R & D that domestic innovators engage in will provide employment and training for domestic researchers and support staff, and investment in new plants, laboratories and equipment. The returns that accrue to domestic innovators may be spent on consumption goods (perhaps produced domestically) or reinvested in some form of domestic capital. These direct and indirect benefits may result from domestic

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[33]Without intellectual property protection, educated and technically capable members of the work force may also have an incentive to leave the country to seek rewards from innovation in countries which allow them to collect those rents.

[34]Frame shows that the more advanced developing countries which have weak patent protection tend to have a higher level of patenting in the U.S. than their less advanced counterparts. See J. Davidson Frame, "National Commitment to Intellectual Property Protection: An Empirical Investigation," *Journal of Law & Technology*, Vol. 2, No. 2, Fall 1987, pp. 209-227.

R & D. One way to stimulate this research is to assign exclusive property rights to the creators of innovative products.[35]

Third, intellectual property protection stimulates development by encouraging imports, for example through licensing agreements. Intellectual property protection encourages foreign inventors to share their discoveries with domestic firms by allowing them a return on their efforts.[36] As a result, countries with strong patent protection may receive new innovations more quickly than those with weak protection. Depending on the relative costs and benefits, it might be in a firm's best interests to devote resources to ensuring that those countries which would copy an innovation do not have easy access to it.[37]

The import of technology can provide a host of indirect benefits.[38]

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[35]Rozek, *Protection*, 55.

[36]Ibid.

[37]There may be some optimal level of protection that a developing country must choose to gain technology most efficiently. The "best" mode of technology transfer is through a lump-sum licensing fee plus a royalty. Foreign direct investment is characterized as the worst outcome for a developing country. See Sharmila Vishwasrao, working paper entitled "Intellectual Property Rights and the Mode of Technology Transfer," presented at the Southern Economic Conference, Washington, D.C., November 24, 1992.

[38]Greif showed that there exists a direct relationship between foreign patent applications and GDP. See S. Greif, "Economic Growth and Patents," paper prepared for the Interpat Seminar in Taiwan, September 10, 1985; cited in Richard P. Rozek, "Protection of Intellectual Property Rights: Research and

In addition to providing employment and investment, R & D by foreign or domestic firms might involve increased activity for local financial, insurance, legal and technical services. To the extent that the educational, financial and physical benefits of technology transfer are distributed throughout the population, the country as a whole may benefit from intellectual property protection. Also, gains from selling in a particular market may be reinvested in that market in the form of additional products, services or capital accumulation.[39]

Finally, the innovations generated in a country can provide technological advancement to that country. The link between technical progress and economic growth is well established in the literature.[40] Deolalikar and Roller have shown that even in a developing country such as India, the limited amount of patent protection that exists may contribute to significant gains in productivity for industries that can patent.[41] Thus, all else equal, a country

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Development Decisions and Economic Growth," *Contemporary Policy Issues* Vol. V (July 1987): 55.

[39]Rozek, *Protection*, 55.

[40]See, for example, Robert Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* (August 1957); and Edward Denison, *Accounting for United States Economic Growth, 1929-1969* (Washington, D.C.: The Brookings Institution, 1974); both cited in Rudiger Dornbusch and Stanley Fischer, *Macroeconomics* 5th ed. (New York: McGraw-Hill Publishing Co., 1990) 716-717.

[41]Anil B. Deolalikar and Lars-Hendrik Roller, "Patenting by Manufacturing Firms in India: Its Production and Impact," *Journal of Industrial*

which offers patent protection may see larger gains in productivity than it counterparts.

In some cases, developing countries have come to understand the benefits of providing intellectual property protection. For example, in meetings of the Food and Agriculture Organization (FAO), a resolution was considered that would have made all germ plasms freely available to all countries.[42] In 1983, developing countries voted to support this resolution. By 1985, many of these countries had developed new crop varieties of their own. Consequently, at the FAO meeting in 1985, these same countries voted against the resolution, and it was defeated.[43]

In 1985, countries where the lack of patent protection was identified as particularly troublesome for U.S. firms included Argentina, Brazil, Canada, India, Korea, Mexico, Norway, Taiwan, Thailand and Venezuela.[44] Since then Canada has modified its patent law. Currently, Argentina and Brazil are among those countries that are considering strengthening their patent laws.

Economics Vol. XXXVII, No. 3 (March 1989): 303-314.

[42]Germ plasms are the hereditary components of germ cells.

[43]Rozek, *Protection*, 55-56.

[44]Executive Office of the President, Office of the U.S. Trade Representative, *Annual Report on National Trade Estimates 1985* ([Washington, D.C.]: Executive Office of the President, Office of the U.S. Trade Representative, October 31, 1985).

Other Suggested Mechanisms for Providing Incentives for Innovation

Other suggested means of compensating innovators include a non-voluntary licensing system, an award system and a contractual mechanism.[45] To analyze the merits of these systems relative to the patent system, "...one must weigh the static inefficiency created through exclusivity against the dynamic efficiencies created through increased innovation."[46]

The award system grants an award to the first firm completing a specified project whose results become public property. The non-voluntary licensing system allows firms to acquire licenses for patented technologies at a government-specified royalty rate, even without the patenting firm's consent. In the contractual system, the government signs a contract with one or more firms to complete a specific project. These alternative compensation mechanisms suffer from the same defect. The level of compensation is determined by a group of individuals rather than market forces. Thus, compensation does not have a direct link to the societal value of the innovation and the innovator cannot be assured that the reward will cover the cost of R & D. In a patent system,

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[45]See Jean Tirole, *The Theory of Industrial Organization* (Cambridge, MA: M.I.T. Press, 1988), 400-401.

[46]Richard P. Rozek, "The Consequences of Pharmaceutical Product Patenting: A Critique," forthcoming *World Competition*: 12.

patent holders will make profits that relate, perhaps imperfectly, to the societal value of their inventions. Other features of the contractual method are that it limits the amount of duplication in R & D but also restricts competition, reducing the incentive to innovate efficiently.[47]

In summary, adequate patent protection can provide potential innovators with the incentive to engage in innovative, rather than imitative endeavors. The appropriability of the returns to R & D will probably have a key role in providing incentive. In addition, patent protection can provide ancillary benefits to a country by encouraging investment, education and consumption.

[47]Ibid.

CHAPTER FOUR

METHODOLOGY

To estimate the empirical relationship between R & D and Italian patenting, I used a model developed by Pakes and Griliches in relating R & D to patents at the firm level.[48] I modified this model to reflect the fact that I did not have to account for interfirm (or intercountry) differences. The Pakes and Griliches model was chosen for two reasons. First, it is general enough to allow estimation using aggregate data. I did not need to change the underlying assumptions of the model to go from a firm-level model to an aggregate level model. Other than dummy variables, there are no firm-specific variables which would not be applicable in my study. Second, the model estimates a simple and clearly defined relationship; patents are the result of the application of R & D expenditures over time. Since the estimation of this equation is only an intermediate step in my study of Italian patenting this simple model suits my purpose, which is to show the R & D has a strong influence on knowledge increments as measured by the patent variable. From this model, I will be able to estimate the lag structure between R & D and patenting.

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[48]Ariel Pakes and Zvi Griliches, "Patents and R & D at the Firm Level: A First Look," in *R & D, Patents, and Productivity*, ed. Zvi Griliches (Chicago: University of Chicago Press, 1984), 55-72.

Estimating the Relationship Between Research and Development and Patenting

Pakes and Griliches' patent equation is part of what they call a "knowledge production function." In this function, R & D, along with other unspecified inputs[49], is translated into inventions. Patents are an imperfect measure of new inventions produced by this process. If the expected benefit of the patent is higher than the cost (i.e. the expected value of the patent is positive), a patent will be applied for. If the proportion of patentable inventions to total inventions remains fairly constant and increased R & D leads to an increased number of patents, then an increase in patents can be interpreted to indicate an increase in knowledge.

The form of the equation used by Pakes and Griliches is:

$$lnP_t = \alpha + \delta T + \sum_{n=0}^{5} \beta_n lnR_{t-n} + \varepsilon_t$$

[49]In their model, these unspecified inputs enter the equation in the error term.

where P is the patent variable at time t, T is a time trend, and R is a measure of R & D. β is interpreted as the elasticity of patents with respect to incremental R & D.[50]

There is no compelling theory regarding the appropriate lag between research and patenting. Pakes and Griliches used five lags, but gave no justification for this choice. Since the number of lags that affect the current level of patenting may be quite high, I estimated the above equation as a polynomial distributed lag (PDL) or Almon distributed lag model. The PDL model is flexible in that it allows estimation of different shapes of lag distribution depending on the order of the polynomial. Furthermore, statistical tests can be used to choose the appropriate number of lags and order of the polynomial. Another reason for choosing the PDL model is that there is strong correlation between the explanatory variables (i.e., there is a high degree of multicollinearity).[51] A polynomial distributed lag model is particularly suited to dealing with the problems of long lags and multicollinearity.

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[50]Pakes and Griliches, 69-70.

[51]The condition number is a diagnostic tool for the detection of multicollinearity. Values above 20 or 30 mean that the multicollinearity problem should be considered serious. The condition number for the current and four lagged values of the logarithm of research and development expenditures is 151.06.

The PDL model deals with multicollinearity by reducing the number of parameters that must be estimated. To do this, a PDL model assumes that the lag weights can be represented by a polynomial of degree $q < N$, where N is the maximum lag length. This method imposes less structure on the lag distribution than arithmetic or inverted-V lags.[52] A general polynomial structure is imposed on the lag parameters (instead of a specific shape) and the sample data determines the specific shape.

The PDL model can be estimated as a restricted regression where **H** is the matrix of restrictions. The effects of applying incorrect restrictions in the **H** matrix are as follows[53]:

- If the assumed polynomial degree is correct, but the assumed lag length is greater than the true lag length, the polynomial distributed lag estimator will generally be biased. It will definitely be biased if the difference between the assumed and true lag length is greater than the degree of the approximating polynomial.

[52]Actually, an arithmetic lag is a special case of the PDL where the order of the coefficient is one. An arithmetic lag is imposed when the effect of the independent variables decreases linearly over time.

[53]This list is from George G. Judge et. al., *Theory and Practice of Econometrics* 2d ed., (New York: John Wiley and Sons, 1985), 359-360.

- If the assumed polynomial degree is correct, then understating the true lag length usually leads to bias in the polynomial distributed lag estimator.
- If the assumed lag length is correct, but the assumed polynomial is of an order higher than the true polynomial, the polynomial distributed lag estimator is unbiased but inefficient.
- If the assumed lag length is correct, but the assumed polynomial is of lower order than the true polynomial, then the polynomial distributed lag estimator is always biased.

I did not impose any endpoint constraints on the model.[54] There is no *a priori* reason to believe such restrictions should be necessary. Imposing endpoint "constraints may imply restrictions for the possible lag shapes the researcher has no intention to impose."[55] Since there is no additional information concerning the appropriate lag structure, no such restrictions were imposed.

I estimated polynomial distributed lags ranging from one to six and polynomial orders from one to N, where N is equal to the number of lags. In none of these models was the coefficient on the time trend variable (T)

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[54]The PDL model allows the researcher to impose zero constraints on the first, last or both lag coefficients.

[55]Judge et. al., 359.

significant, so I eliminated it from the regression. The residuals for each regression were tested for serial correlation using the Durbin-Watson statistic and the Ljung-Box statistic. When these tests indicated there was serial correlation I specified an appropriate autoregressive error process.[56]

Both Judge and Greene suggest a two-step procedure to choose the appropriate model.[57] The first step is to estimate the lag length; the second step is to determine the appropriate polynomial degree. To choose the appropriate lag length, I used Akaike's Information Criterion (AIC).[58] The goal is to choose the model that minimizes the AIC. The regression of four lagged R & D observations with a fourth order polynomial had the lowest AIC of all the regressions I tested.[59]

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[56]If several of the regressions with N lags were found to have autocorrelated disturbance terms, I assumed that all of the regressions with N lags had autocorrelated disturbances. This was done: (1) because there is no reason to believe that changing the order of the polynomial distributed lag equation would eliminate autocorrelation; and (2) because, in testing the coefficient restrictions, there is no basis for comparing the sum of squared errors of the regressions with and without autoregressive error processes. The same error process was then applied to each regression with N lags, regardless of the Durbin Watson or Ljung-Box statistics.

[57]See Judge et. al., 363; and William H. Greene, *Econometric Analysis* (New York: Macmillan Publishing Company, 1990), 557.

[58]Greene, 546-547.

[59]See Table 2. This regression also has the highest adjusted R^2.

Table 2

SUMMARY RESULTS OF REGRESSIONS OF RESEARCH AND DEVELOPMENT EXPENDITURES ON PATENTS

Lags	Polynomial Order	Error Process	Observations	Adjusted R–squared	Standard Error of Regression	Durbin–Watson Statistic	Sum of Squared Errors	F–Statistic	Ljung–Box (p value)	AIC	F–test for Lags
1	1	AR(1)	20	0.7557	0.0949	1.9886	0.1440	20.5920	0.3387	−4.8339	–
2	1	AR(1)	19	0.7241	0.0985	2.0132	0.1455	16.7507	0.1467	−4.6616	0.2333
2	2	AR(1)	19	0.7090	0.1012	1.9646	0.1433	11.9623	0.2207	−4.6770	–
3	1	AR(1)	18	0.8303	0.0783	2.6134	0.0858	28.7322	0.6882	−5.0131	1.1756
3	2	AR(1)	18	0.8212	0.0803	2.6967	0.0839	20.5208	0.6046	−5.0349	2.0213
3	3	AR(1)	18	0.8324	0.0778	2.6673	0.0726	17.8831	0.2716	−5.1794	–
4	1	AR(2)	16	0.9097	0.0566	2.9526	0.0385	51.3858	0.7874	−5.5305	1.3622
4	2	AR(2)	16	0.9016	0.0591	2.9664	0.0384	35.3600	0.7794	−5.5314	2.0373
4	3	AR(2)	16	0.8934	0.0615	2.9835	0.0379	26.1333	0.7604	−5.5463	3.8663
4	4	AR(2)	16	0.9146	0.0551	2.6648	0.0273	27.7573	0.5847	−5.8732	–
5	1	AR(1)	16	0.8514	0.0726	2.6527	0.0633	29.6423	0.7501	−4.9070	2.9922
5	2	AR(1)	16	0.8842	0.0641	2.3171	0.0452	29.6402	0.9028	−5.2438	1.9910
5	3	AR(1)	16	0.8950	0.0611	2.3234	0.0373	26.5717	0.8774	−5.4368	1.6726
5	4	AR(1)	16	0.8833	0.0644	2.3242	0.0373	19.9296	0.8755	−5.4368	3.3445
5	5	AR(1)	16	0.9043	0.0583	2.3927	0.0272	21.2519	0.9001	−5.7528	–
6	1	–	16	0.7820	0.0880	1.6386	0.1006	27.8989	0.9412	−4.3187	4.3467
6	2	–	16	0.8967	0.0606	2.6729	0.0440	44.3956	0.9631	−5.1456	1.2514
6	3	–	16	0.8972	0.0604	2.7505	0.0402	33.7142	0.8856	−5.2372	1.2890
6	4	–	16	0.8888	0.0628	2.8792	0.0395	24.9735	0.8719	−5.2542	1.8337
6	5	–	16	0.8819	0.0647	2.8975	0.0377	19.6771	0.8937	−5.2999	3.1456
6	6	–	16	0.9047	0.0582	2.6092	0.0271	21.3361	0.8477	−5.6315	–

– not applicable

The next step in choosing an appropriate model is to determine the correct order for the polynomial. This was done using a nested testing procedure suggested by Greene.[60] I began with the unrestricted model where the order of the polynomial ($p=p^*$) equals the number of lags (q). Then I tested whether the restrictions imposed by sequentially decreasing the polynomial order could be rejected. The F-statistic for this test is:

$$F_{(p^*-p,T-p^*-2)} = \frac{[e'e|p - e'e|p^*] \; / \; (p^*-p)}{e'e|p^* \; / \; (T-p^*-2)} \; .$$

The appropriate polynomial degree is the lowest p for which the F-statistic is lower than the critical value. Since the probability of a Type II error changes with each iteration, I adjusted the significance level using a method suggested by Trivedi and Pagan.[61] The adjusted significance level for iteration j is:

$$\alpha_j = 1 - (1 - \alpha)^j \; .$$

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[60]Greene, pp. 555-556.

[61]P. Trivedi and A. Pagan, "Polynomial Distributed Lags: A Unified Treatment," *Economic Studies Quarterly* Vol. 30 (1979): 37-49; cited in William H. Greene, *Econometric Analysis* (New York: Macmillan Publishing Company, 1990), 556.

I failed to reject any of the polynomial restrictions.[62] Therefore, the appropriate polynomial distributed lag model is a first degree polynomial with four lagged values. Since a first order polynomial was chosen, the PDL is a special case where the lag distribution is linear.

Estimating the Strength of the Relationship Between Patenting and Productivity

The second step in my study is to determine whether there is a significant relationship between patenting and productivity. If R & D explains a significant proportion of knowledge increments as measured by patents, and patents explain a significant proportion of productivity increases, a link between R & D and productivity can be inferred. If this link exists, it might demonstrate a benefit to encouraging R & D.

To analyze the strength of the relationship between patenting and productivity, I regressed patent applications and a constant on output per worker-hour. I also regressed the first differences of these series to determine the relationship between changes in the two series. The form of the equation used

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[62] I chose α equal to 0.05.

for these regressions is:

$$O/W_t = \alpha + \beta_1 P_t + \beta_2 T$$

where *O/W* is output per worker-hour, *P* is patents and *T* is a time trend. The regressions exhibited autocorrelated disturbances, so I specified an appropriate error process to correct this problem.

Data Sources

Below is a discussion of the sources for the data used in the regressions described above and reasons why these particular sources were chosen.

Patent Data

In this study, patents were used as an indicator of knowledge increments. Patents are the result of a concerted R & D effort over some period of time. When an innovative firm decides that the expected value of a patent is positive, it will file a patent application. This is a key advantage to using patent data as indicators of technical advance. Patents are applied for when the firm has gone far enough in the development process to be able to reasonably assess the expected value of a patent. As a result, patents may be a closer approximation of the timing of an innovation than an index of innovations measured as they reach the market. Measuring patents from the filing date of the application will also allow some degree of separation between the R & D process and the process by which innovations are brought to market or used in a process.

The primary criticisms of using patents to indicate technical advance are that not all inventions are patented, and that patented inventions can differ markedly in their value to society. In their paper, Pakes and Griliches addressed these problems by attempting to measure the "quality" of the patent variable. Their measure of quality is the adjusted R-squared of the patent equation excluding the time trend.

Pakes and Griliches' results indicate that much of the variance in the patent variable is systematic. They report:

> For the seven industries in our sample, about 85 percent of the variance in p [the patent variable] is associated with variance in r, and in some industries, notably scientific instruments and office, computing, and accounting machinery, the lower bound of the systematic to total variance in patents is closer to .95.[63]

From their results, Pakes and Griliches conclude that patents are in fact a good measure of knowledge increments.

[63]Pakes and Griliches, 61.

Patent data was collected from the Patent & Trademark Office's *All Technologies Report*.[64] Two relevant forms of patent data are available: patents issued by year of grant and patents issued by year of application. The data by year of application include only those applications for which patents were eventually issued. Patents were assigned to countries based on the residence of the inventor. Data by date of application should include the same patents as data by date of grant; the only difference is that it is categorized differently.

Identifying patents by date of application is more appropriate since it more closely identifies the time at which research culminated into a patentable technical advance. Furthermore, Griliches has demonstrated, and the U.S. Patent Office confirms, that administrative factors can have a large influence on the number of patents issued by date of grants.[65] These administrative factors include the patent office's workload, budget and manpower levels, and patent printing schedules. For instance, the patent grant data appear to show a decrease

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[64]Table 3 shows the number of U.S. patents awarded to certain foreign countries by date of application.

[65]See Zvi Griliches, "Patents: Recent Trends and Puzzles," in *Brookings Papers on Economic Activity: Microeconomics*, ed. Martin Neil Baily and Clifford Winston (Washington, D.C.: The Brookings Institution, 1989), 291-319; and Department of Commerce, Patent & Trademark Office, *All Technologies Report* ([Arlington, VA]: U.S. Department of Commerce, Patent & Trademark Office, August 1992).

Table 3

NUMBER OF U.S. PATENTS GRANTED TO SELECTED COUNTRIES, BY YEAR OF APPLICATION

1965–1988

Year	Italy	Germany[1]	United Kingdom	France	Switzerland	Canada	Japan	Sweden
	(Number of Patents)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1965	388	3,376	2,377	1,327	790	865	1,358	516
1966	527	3,865	2,691	1,583	950	911	1,708	633
1967	535	3,925	2,779	1,663	1,009	943	2,279	578
1968	590	4,520	2,894	1,762	1,038	1,026	2,842	684
1969	628	4,773	2,944	1,895	1,111	1,082	3,752	729
1970	716	5,029	2,726	1,854	1,175	1,143	4,370	651
1971	670	4,996	2,580	2,021	1,183	1,140	4,754	728
1972	698	5,048	2,668	2,113	1,279	1,135	4,588	709
1973	645	5,745	2,780	2,213	1,282	1,166	5,864	864
1974	741	5,856	2,884	2,225	1,353	1,197	6,324	956
1975	704	5,456	2,668	2,152	1,389	1,131	6,072	893
1976	747	5,572	2,620	2,128	1,322	1,206	6,578	856
1977	766	5,969	2,636	2,099	1,319	1,228	7,078	843
1978	809	6,191	2,524	2,272	1,358	1,172	7,477	805
1979	918	6,201	2,499	2,226	1,236	1,210	8,417	825
1980	857	6,243	2,374	2,305	1,261	1,124	9,558	748
1981	716	6,125	2,202	2,074	1,131	1,159	10,018	689
1982	800	6,055	2,208	2,131	1,122	1,108	11,317	672
1983	726	5,536	2,154	2,080	1,047	1,089	10,794	743
1984	945	6,328	2,366	2,251	1,147	1,294	12,422	808
1985	953	6,881	2,391	2,360	1,156	1,298	14,324	789
1986	1,098	7,192	2,472	2,575	1,241	1,401	15,352	770
1987	1,133	7,323	2,735	2,709	1,185	1,663	16,902	746
1988	1,256	7,507	2,665	2,899	1,307	1,856	19,582	718

[1] Figures do not include patents issued to the German Democratic Republic.

Source: U.S. Department of Commerce, Patent and Trademark Office, All Technologies Report: December 1983, April 1990 and August 1992.

in the level of total patenting from 66,102 in 1978 to 48,854 in 1979. However, this drop in the number of patents issued actually reflects budgetary problems rather than a downward spike in inventive activity. According to the Patent & Trademark Office, the average delay between the application for a patent and its grant is currently 18 months. In the mid-1960s it was two years or more.

The patent data used in this analysis show the number of U.S. patents granted to residents of Italy, by year of application. These data are available for the years 1963 through June 1992. However, due to the lag between application and grant, the data are only complete through 1988.

U.S. patent data were used because these data are readily available and the aggregate annual data are directly comparable over the entire time period. Since Italy's patent law changed significantly during the time period, the standards by which patentability is judged may have changed as well, either explicitly or implicitly. If these standards did change, it would be difficult to separate the effects on the incentive to innovate from the effects on the ability to patent. For instance, if the change in the patent law made it more difficult to get a patent approved (say, by making the standards for novelty higher), it may be that there was actually a decrease in the number of patents applications filed. Furthermore, suppose the patent law granted a monopoly for new products (i.e. no competing products would be allowed). Such a change might increase the incentive to innovate[66], but the patent data might show a decrease in patenting. Thus, data on patents granted in Italy may not be directly comparable over the entire period. Since U.S. patent applications have been evaluated using relatively stable processes and benchmarks, the data are more comparable throughout the period.

It is reasonable to assume that U.S. patent data for patents granted to Italy will capture changes in the level of Italian inventive activity. Since the U.S. is one of the largest, most accessible markets in the world and provides a high degree of protection, it is a good place to patent. The high degree of appropriability available in the U.S. is attractive to inventors worldwide because it promises higher returns for successful innovation. Also, the sheer size of the U.S. market makes it a relatively attractive place to do business and, thus, makes a marketable innovation more valuable.[67] Because the U.S. has been a good place to patent throughout the relevant time period, there should be little, if any, effects due to the strength of the U.S. economy. Thus, the number of

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[66]Assuming no spillover effects in the applicability of research (i.e., R & D is dedicated to the development of a single product and is only useful for that product) this scenario might also decrease the incentive for firms who do not believe they can win a "patent race" since there might be no return on their research.

[67]In Rozek, *Consequences*, he found a strong relationship between the size of a country's pharmaceutical market (in terms of revenues) and the number of pharmaceutical innovations patented in that country.

U.S. patents granted to Italians may be considered a reasonably good indicator of Italian technological advance.

Research and Development Data

As stated above, R & D expenditures applied over some time period result in increases in knowledge are sometimes patented. If this hypothesis is correct, a strong relationship should exist between current and past R & D expenditures and patenting. This is the purpose of the regression of R & D on patents.

R & D data were collected from the National Science Foundation's *International Science and Technology Data Update: 1991*. The figures I used are national expenditures on R & D in constant 1982 dollars.[68] These expenditures were converted from Lire to dollars using Organization for Economic Cooperation and Development (OECD) purchasing power parity exchange rates.[69] These figures include all R & D expenditures: (1) financed

[68]Constant 1982 dollars are based on GNP implicit price deflators from the U.S. Department of Commerce.

[69]The data reported by the NSF is from Instituto di Studi sulla Ricerca e Documentazione Scientifica, *Quaderni: Consiglio Nazionale della Ricerche*, Vol. 22 (Roma: Instituto di Studi sulla Ricerca e Documentazione Scientifica, 1989).

by industry;[70] (2) financed by the government, including defense; and (3) financed by educational institutions.[71]

I used data on national R & D expenditures because it is the most conservative approach. It includes expenditures by the government which should tend to be less responsive to compensation incentives. This should be true because the government presumably engages in R & D for defense purposes and for projects with higher risk.

Output Per Worker-Hour

Output per worker-hour is one measure of productivity. To analyze whether changes in the level of patenting have had any effect on changes in productivity I used data on output per worker-hour in Italian manufacturing. These data will not provide a measurement of general or economy-wide productivity gains; they will only provide a measurement of the effects of some of the gains that impacted labor productivity. It is likely that output per worker-hour is affected, to a certain extent, by both process and product innovations. As more efficient processes are found and better equipment is used in them,

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[70]See Table 4 for the percentage of national research and development financed by industry.

[71]The NSF does not provide a comprehensive list of which sources of R & D are included. This may only be a partial list, though it probably includes the primary components of national R & D spending.

Table 4

PERCENTAGE OF NATIONAL R & D
FINANCED BY INDUSTRY IN ITALY

1970–1988

Year	Percent of R&D Financed by Industry
	--(Percent)--
1970	51 %
1971	52
1972	52
1973	49
1974	51
1975	51
1976	50
1977	47
1978	50
1979	55
1980	52
1981	50
1982	49
1983	45
1984	44
1985	45
1986	40
1987	42
1988	41

Source: National Science Foundation, "International Science and Technology Data Update: 1991 Special Report NSF 91–309, p. 21.

output per worker-hour can be expected to increase. If this hypothesis is correct, a relationship should exist between output per worker-hour and technological advances as measured by patents.

Data on output per worker-hour is from the U.S. Department of Labor, Bureau of Labor Statistics and was used as reported in the NSF's *International Science and Technology Data Update: 1991*. The figures are indexed with a base year of 1982. Data are available for the period 1960 through 1989.

CHAPTER FIVE

INTERPRETATION OF THE RESULTS

The results of my regressions indicate that there are strong relationships between R & D and patenting, and between patenting and at least one measure of productivity. These results support the economic theory outlined above. However, because of the short length of the time series, these results should be interpreted cautiously.

The Relationship Between Research and Development and Patenting

Table 5 presents the estimates of β_t and the sum of its values for the PDL regression with current and four lagged values of R & D and a first order polynomial. The coefficients on the individual lags are all significant and the adjusted R-squared is high (.91). I also reported the F-statistic for the null hypothesis that the coefficients are jointly equal to zero. This hypothesis is strongly rejected.

The negative (and statistically significant) sign on the first and second lag coefficients is disturbing. This sign does not meet with my *a priori* expectations. Interpreted literally, these coefficients indicate that the more spent on R & D in the current and previous year, the fewer the number of patents that will be applied for and granted.

Table 5

RESULTS OF REGRESSION OF R & D ON PATENTS
(FOUR LAGS AND FIRST ORDER POLYNOMIAL)

Variable	Coefficient	Standard Error	t-statistic	Two-tail Significance Level
Constant	5.4487	0.1377	39.5654	0.0000
PDL1	0.2215	0.0245	9.0449	0.0000
PDL2	0.4915	0.0988	4.9731	0.0003
AR(2)	0.1397	0.1028	1.3587	0.1992
Lag 0	−0.7614	0.1781	−4.2757	
Lag 1	−0.2699	0.0799	−3.3770	
Lag 2	0.2215	0.0245	9.0449	
Lag 3	0.7130	0.1198	5.9534	
Lag 4	1.2045	0.2182	5.5195	
Sum	1.1077	0.1225	9.0449	

Observations	16
Degrees of Freedom	12
Adjusted R−squared	0.9097
Standard Error of Regression	0.0566
Durbin−Watson Statistic	2.9526
Sum of Squared Residuals	0.0385

	Statistic	p−value
F−statistic	51.3858	0.0000
Box−Pierce Statistic	7.84	0.9300
Ljung−Box Statistic	10.50	0.7874

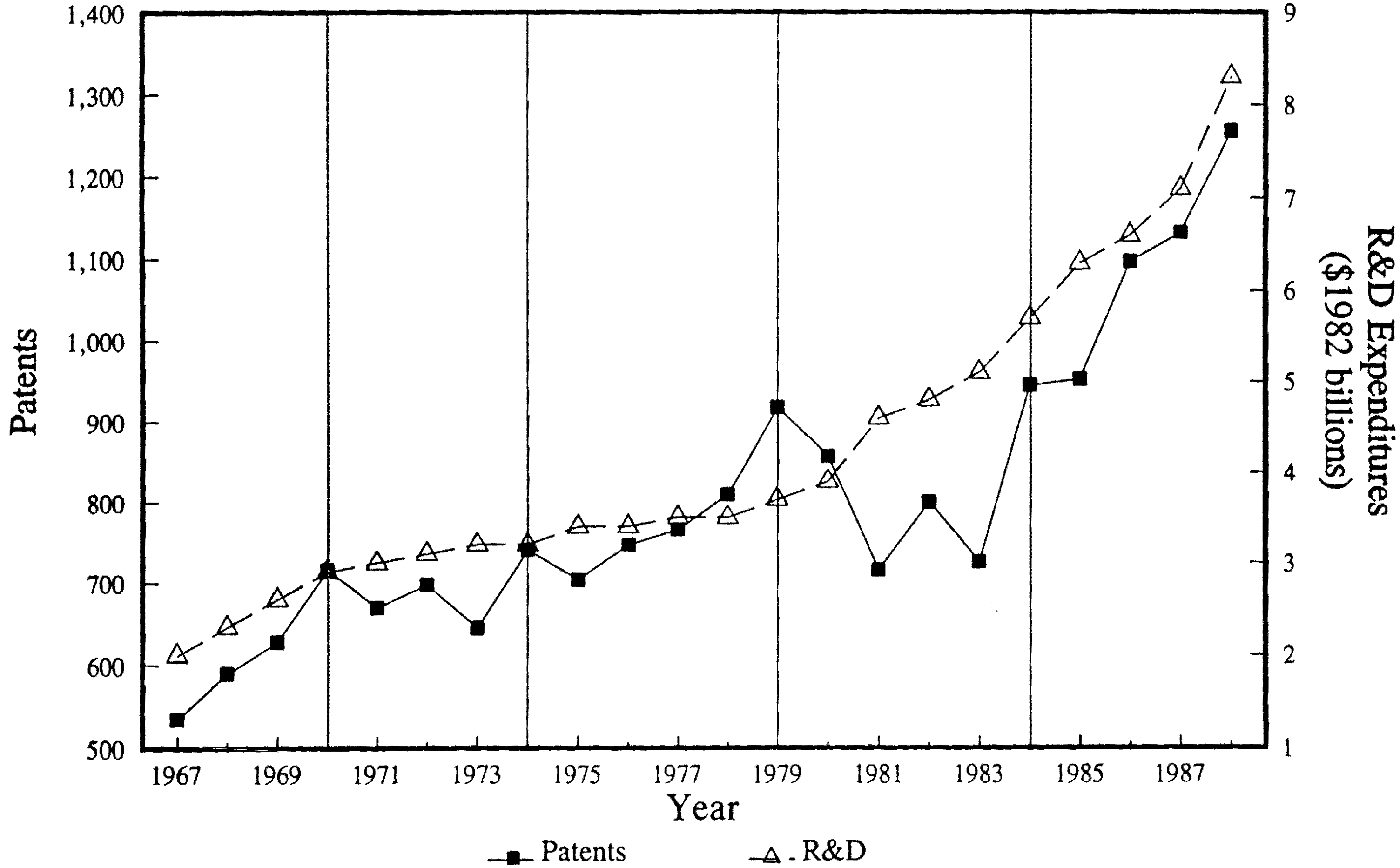

Figure 1: Number of Patents Granted and R & D Expenditures.

While this result may be caused by the high level of multicollinearity in the data, it may also have a plausible explanation--it may indicate that Italian patenting in the U.S. is cyclical. Figure 1 does seem to indicate that patent in the U.S. by Italian residents has been cyclical. In Figure 1, lines were drawn through the relative "peaks" in patenting. These peaks seem to occur every four or five years. In passing, it may be worth noting that if a line were drawn between each of these peaks and the slopes of these lines compared, the last line seems to promise the greatest slope. While this apparent cyclical pattern is interesting and possibly deserves further study, it is not directly relevant to the objective of this analysis. Therefore, I will reserve further analysis of this "phenomenon" for a future study.

These results indicate that there is a strong relationship between R & D and patenting. The lag distribution suggests that the early-year expenditures are more influential on current patenting than recent expenditures. The sum of all the coefficients on the current and first lagged values is -1.03, while the sum of the coefficients on the third and fourth lagged values is 1.92. The sum of the individual coefficients, or the long-run multiplier, is 1.11 with a standard error of 0.12. This is interpreted to mean that the elasticity of patenting with respect to all current and future R & D is 1.11, assuming all R & D effects are captured in the regression. This estimate is generally consistent with certain of the elasticities estimated by Bound et. al.[72] Other researchers have estimated smaller elasticities.[73] However, both the Bound et. al. and the other studies may not be directly comparable since there could possibly be intercountry differences in the elasticity of patenting with respect to R & D.

Since the number of observations is small (16 when four or more lags are estimated) it is useful to see whether the results are sensitive to the specific number of lags and the coefficient order estimated. As I indicated earlier, mis-estimating either of these factors could bias the results or make them less efficient. I summarize the results of the regressions with four or more lags in Table 6. The results indicate that if the number of lags is estimated correctly, but the order of the polynomial is too low the elasticity estimate will change by no more than 0.02. In these regressions, fewer of the individual coefficients are statistically significant.[74]

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[72]Bound et. al. estimated that the elasticity of patenting with respect to research and development is above one for U.S. firms who spend at least $1 billion on research and development. Using a Poisson regression, they estimated an elasticity of 1.13. See Table 2.9 in John Bound et. al., "Who Does R&D and Who Patents?," in *R & D, Patents, and Productivity*, ed. Zvi Griliches, (Chicago: University of Chicago Press, 1984), 44.

[73]For example, Pakes and Griliches estimated an elasticity of 0.61.

[74]Statistical significant was tested using the *t*-statistics reported in my regression output and the critical value at the 0.05 level.

Table 6

RESULTS OF REGRESSION OF R & D ON PATENTS
(FOUR OR MORE LAGS)

Lags	Polynomial Order	Error Process	Adjusted R–Squared	Sum of Lag Coefficients
4	1	AR(2)	0.9097	1.1077
4	2	AR(2)	0.9016	1.1098
4	3	AR(2)	0.8934	1.0924
4	4	AR(2)	0.9146	1.0853
5	1	AR(1)	0.8514	1.0640
5	2	AR(1)	0.8842	1.0048
5	3	AR(1)	0.8950	0.9736
5	4	AR(1)	0.8833	0.9740
5	5	AR(1)	0.9043	1.0229
6	1	–	0.7820	0.7935
6	2	–	0.8967	1.0461
6	3	–	0.8972	1.0476
6	4	–	0.8888	1.0425
6	5	–	0.8819	1.0541
6	6	–	0.9047	1.0534

If the number of lags is not estimated correctly, but is really five or six, the estimates are slightly lower. Using the nested *F*-test for polynomial restrictions (described in Chapter 4), I found that the appropriate polynomial order for both five and six lags was a second order polynomial. The estimates of the elasticity for five and six lags were 1.00 and 1.05, respectively. These models both have inverted U-shaped lag distributions with the last lag coefficient not statistically different from zero.[75] Taken together, my results indicate that the elasticity of patenting with respect to R & D is probably between 1.00 and 1.11.

The Impact of Patenting on Productivity

Output per worker-hour is one measure of productivity. To analyze how well Italian technological advances, as measured by patents, are reflected in productivity gains, I regressed patents, a time trend and a constant on output-per worker. I also regressed the first differences of these series on each other. The disturbances were autocorrelated, so I specified an appropriate error process. Table 7 summarizes the results of the former regression with an AR(1) error process.

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[75]Statistical significant was tested using the *t*-statistic reported in my regression output and the critical value at the 0.05 level.

Table 7

RESULTS OF REGRESSION OF PATENTS ON OUTPUT PER WORKER–HOUR

Variable	Coefficient	Standard Error	t–statistic	Two–tail Significance Level
Constant	–12.2056	26.2509	–0.4650	0.6470
Patapp	0.0181	0.0076	2.3827	0.0272
Time	4.3727	1.0765	4.0622	0.0006
AR(1)	0.8395	0.1286	6.5278	0.0000

Observations	24
Degrees of Freedom	21
Adjusted R–squared	0.9915
Standard Error of Regression	2.5957
Durbin–Watson Statistic	2.3086
Sum of Squared Residuals	134.7524

	Statistic	p–value
F–statistic	896.5393	0.0000
Box–Pierce Statistic	9.43	0.9908
Ljung–Box Statistic	15.38	0.8454

The coefficient on the patent variable is significant at the 0.05 level even after accounting for a time trend, which is also significant at the 0.05 level. The adjusted *R*-squared for this regression is quite high (0.99), indicating that 99 percent of the variation in output per worker-hour is explained by variation in patenting. The *F*-statistic for testing the hypothesis that the coefficients are jointly zero is also quite high, indicating a strong rejection of this hypothesis. This indicates a strong relationship between patents and output per worker-hour.

Table 8 shows the results when the series were differenced once and the regression was run again.[76] This regression relates newly issued patents to changes in output per worker-hour. The results indicate that the number of new patents is useful in explaining changes in output per worker-hour. The coefficient on the new patents variable is statistically significant at the 0.01 level. The adjusted *R*-squared indicates that 53 percent of the variance in output per worker-hour is explained by the variance in new patent applications. The *F*-statistic for testing joint significance is also significant at the 0.01 level. These results indicate that technical progress, as measured by patents, is often reflected in productivity increases as measured through output per worker-hour.

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[76] I specified an MA(1) error process to correct for autocorrelation of the disturbances.

Table 8

RESULTS OF REGRESSION OF DIFFERENCED PATENTS ON DIFFERENCED OUTPUT PER WORKER–HOUR

Variable	Coefficient	Standard Error	t–statistic	Two–tail Significance Level
Constant	0.270522	2.0625	0.1312	0.8970
Patapp	0.0148	0.0052	2.8529	0.0098
Time	0.1835	0.0780	2.3510	0.0291
MA(1)	–1.0016	0.1776	–5.6392	0.0000

Observations	24
Degrees of Freedom	21
Adjusted R–squared	0.5338
Standard Error of Regression	2.0878
Durbin–Watson Statistic	1.6661
Sum of Squared Residuals	87.1809

	Statistic	p–value
F–statistic	9.7772	0.0004
Box–Pierce Statistic	11.45	0.9677
Ljung–Box Statistic	20.96	0.5233

CHAPTER SIX

APPLICATION OF THE RESULTS: WHAT WAS THE EFFECT OF CHANGING THE PATENT LAW IN ITALY?

Economic theory predicts that under certain conditions stronger patent protection may encourage more innovation. As I stated before, R & D is a concerted process to develop new products and processes which are sometimes patented. I have demonstrated a strong link between R & D and patenting that tends to support this assertion. I have also demonstrated that there is a relationship between innovation and productivity gains in Italy. But my fundamental question remains: Did Italy experience the changes that economic theory predicts after changing its patent law? Below, I will attempt to shed some light on this question.

Was There a Change in the Growth Rate of Research & Development Spending in Italy After 1979?

Table 9 shows national R & D expenditures for selected countries for period 1967 through 1988.[77] Casual observation reveals that since 1967 Italy has quadrupled its spending on R & D, a feat exceeded only by Japan. Spending on R & D in Italy more than doubled between 1980 and 1988. Japan's spending nearly doubled over this same interval. In fact, 70 percent of the increase in

[77]These are the only countries listed in the source.

Table 9

NATIONAL RESEARCH AND DEVELOPMENT EXPENDITURES

1967–1988

Year	Italy	Germany [1]	United Kingdom	France	Japan	Sweden	United States
	(Billions of 1982 Dollars)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1967	$2.0	$ 7.9	$ 8.9	$ 6.8	$ 7.6	$ 0.8	$ 64.4
1968	2.3	8.4	9.1	7.0	9.0	na	65.2
1969	2.6	8.3	9.4	7.1	10.5	0.8	64.4
1970	2.9	9.9	na	7.1	12.4	na	62.2
1971	3.0	10.9	na	7.4	13.3	1.1	60.1
1972	3.1	11.4	9.3	7.7	14.7	na	61.3
1973	3.2	11.3	na	7.7	16.1	1.2	62.0
1974	3.2	11.5	na	8.1	16.4	na	60.9
1975	3.4	11.9	10.1	8.1	16.7	1.4	59.4
1976	3.4	12.1	na	8.4	17.3	na	61.9
1977	3.5	12.4	na	8.6	18.0	1.5	63.6
1978	3.5	13.3	11.1	8.9	19.1	na	66.6
1979	3.7	15.0	na	9.4	21.0	1.6	69.9
1980	3.9	15.3	na	9.8	23.1	na	73.0
1981	4.6	15.9	12.2	10.8	25.5	2.0	76.5
1982	4.8	16.5	na	11.7	27.4	na	80.0
1983	5.1	16.0	11.9	12.0	29.9	2.3	85.8
1984	5.7	17.0	na	12.7	32.4	na	93.9
1985	6.3	18.8	12.8	13.1	36.1	2.8	102.5
1986	6.6	19.3	13.6	13.4	36.6	na	105.3
1987	7.1	20.2	13.8	13.9	39.2	3.0	108.4
1988	8.3	20.8	13.8	14.5	42.3	na	111.5

na not available

[1] Figures do not include R&D expenditures in the German Democratic Republic.

Source: National Science Foundation, "International Science and Technology Data Update: 1991," Special Report NSF 91–309, p. 5.

Italy's R & D expenditures between 1967 and 1988 took place between 1980 and 1988, after the change in the patent law. No other country listed in Table 9 experienced this level of growth in R & D spending.

Table 10 shows the annual percentage change in R & D spending for the selected countries.[78] In the period 1968 through 1970, Italy experienced strong growth in R & D spending. In 1968 and 1969 Italy's growth in research spending outpaced that in Germany and France. Between 1970 and 1978, growth in Italian expenditures was sporadic, varying between zero and roughly six percent per year, with a (simple) average growth rate of 2.4 percent per year. This growth rate was lower than any other country listed in Table 10 but the United States. In 1979 Italian R & D expenditures began to increase steadily. Between 1980 and 1988, Italian R & D expenditures grew faster than German and French expenditures in all but one year. Italian expenditures grew faster than American expenditures in all but two years in that period. Growth in Italian expenditures exceeded growth in Japan's expenditures in five of the nine years between 1980 and 1988. The (simple) average growth rate of Italian

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[78]Due to missing data, annual percentage changes are not meaningful for the United Kingdom or Sweden.

Table 10

ANNUAL PERCENTAGE CHANGE IN
NATIONAL RESEARCH AND DEVELOPMENT EXPENDITURES

1968–1988

Year	Italy	Germany[1]	United Kingdom	France	Japan	United States
	(Percent)					
	(1)	(2)	(3)	(4)	(5)	(6)
1968	15.0 %	6.3 %	2.2 %	2.9 %	18.4 %	1.2 %
1969	13.0	(1.2)	3.3	1.4	16.7	(1.2)
1970	11.5	19.3	–	0.0	18.1	(3.4)
1971	3.4	10.1	–	4.2	7.3	(3.4)
1972	3.3	4.6	–	4.1	10.5	2.0
1973	3.2	(0.9)	–	0.0	9.5	1.1
1974	0.0	1.8	–	5.2	1.9	(1.8)
1975	6.3	3.5	–	0.0	1.8	(2.5)
1976	0.0	1.7	–	3.7	3.6	4.2
1977	2.9	2.5	–	2.4	4.0	2.7
1978	0.0	7.3	–	3.5	6.1	4.7
1979	5.7	12.8	–	5.6	9.9	5.0
1980	5.4	2.0	–	4.3	10.0	4.4
1981	17.9	3.9	–	10.2	10.4	4.8
1982	4.3	3.8	–	8.3	7.5	4.6
1983	6.2	(3.0)	–	2.6	9.1	7.3
1984	11.8	6.3	–	5.8	8.4	9.4
1985	10.5	10.6	–	3.1	11.4	9.2
1986	4.8	2.7	6.3	2.3	1.4	2.7
1987	7.6	4.7	1.5	3.7	7.1	2.9
1988	16.9	3.0	0.0	4.3	7.9	2.9

– not applicable

[1] Figures do not include R&D expenditures in the German Democratic Republic.

Source: Derived from National Science Foundation, "International Science and Technology Data Update: 1991," Special Report NSF 91–309, p. 5.

R & D expenditures between 1979 and 1988 was 9.1 percent. This growth rate is significantly higher than that in any other country in Table 10.[79]

Table 11 shows Italian R & D expenditures as a percent of other countries' R & D expenditures. If Italy is increasing its spending faster than the other countries there should be a convergence toward 100 percent. The figures indicate that there is, in fact, such a trend with most countries. After hovering around 30 percent of Germany's expenditures in the 1970s, Italy began to gain on Germany in the 1980s. A similar trend can be observed in France. Italy gained two percentage points on the United States between 1967 and 1980. In just eight years since 1980, Italy has achieved the same percentage gain. Of these countries, only in Japan has Italy's relative percentage of R & D spending fallen, though it has caught up slightly since 1985.

The data indicate that growth in Italian R & D expenditures has accelerated significantly since 1979. The change in the patent law may have given Italian inventors additional incentive to invest in innovation by giving them an increased opportunity to reap the rewards of their labor. Although the absolute level of Italy's R & D spending still falls short of that of other countries', it has made significant gains relative to Germany, France and the

[79]Other countries' average growth rate between 1979 and 1988 were: Germany, 4.7 percent; France, 5.0 percent; Japan, 8.3 percent; and the United States, 5.3 percent.

Table 11

RESEARCH AND DEVELOPMENT EXPENDITURES IN ITALY
AS A PERCENT OF RESEARCH AND DEVELOPMENT
EXPENDITURES IN SELECTED COUNTRIES

1967–1988

Year	Germany[1]	United Kingdom	France	Japan	Sweden	United States
	(Percent)					
	(1)	(2)	(3)	(4)	(5)	(6)
1967	25.3 %	22.5 %	29.4 %	26.3 %	250.0 %	3.1 %
1968	27.4	25.3	32.9	25.6	–	3.5
1969	31.3	27.7	36.6	24.8	325.0	4.0
1970	29.3	–	40.8	23.4	–	4.7
1971	27.5	–	40.5	22.6	272.7	5.0
1972	27.2	33.3	40.3	21.1	–	5.1
1973	28.3	–	41.6	19.9	266.7	5.2
1974	27.8	–	39.5	19.5	–	5.3
1975	28.6	33.7	42.0	20.4	242.9	5.7
1976	28.1	–	40.5	19.7	–	5.5
1977	28.2	–	40.7	19.4	233.3	5.5
1978	26.3	31.5	39.3	18.3	–	5.3
1979	24.7	–	39.4	17.6	231.3	5.3
1980	25.5	–	39.8	16.9	–	5.3
1981	28.9	37.7	42.6	18.0	230.0	6.0
1982	29.1	–	41.0	17.5	–	6.0
1983	31.9	42.9	42.5	17.1	221.7	5.9
1984	33.5	–	44.9	17.6	–	6.1
1985	33.5	49.2	48.1	17.5	225.0	6.1
1986	34.2	48.5	49.3	18.0	–	6.3
1987	35.1	51.4	51.1	18.1	236.7	6.5
1988	39.9	60.1	57.2	19.6	–	7.4

– not applicable

[1] Figures do not include R&D expenditures in the German Democratic Republic.

Source: Derived from National Science Foundation, "International Science and Technology Data Update: 1991," Special Report NSF 91–309, p. 5.

United Kingdom. The fact that Italy has managed to more than double its spending on innovation between 1980 and 1988 (a feat it did not accomplish in the previous 12 years) indicates that the change has had a substantial impact on behavior. Although the new patent law is probably not sufficient, in itself, to bring about this change, it was likely a necessary condition.[80]

Was There an Effect on Italy's Gross Domestic Product?

The link between technical progress, productivity and development is well established. In a study of the sources of growth in national income, Solow concluded that over 80 percent of the growth in output per labor hour in the U.S. between 1909 and 1949 was due to technical progress.[81] Using data from the period 1929 through 1982, Denison confirmed that technical progress accounted for most of the increase in output per labor hour.[82]

More technological progress is probably preferred to less if rapid development is desired. To encourage both technical progress (i.e. innovation) by domestic firms and the importation of technology from foreign sources, strong intellectual property protection is generally preferred to weak protection. Thus,

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[80]Other factors such as political stability, inflation, interest rates, and the education level of the population will have an influence on incentives to invest in innovative endeavors.

[81]Solow; cited in Dornbusch and Fischer, 716-717.

[82]Denison; cited in Dornbusch and Fischer, 717.

countries wishing to increase their rate of development should, among other things, offer a strong enough level of patent protection to achieve this end. The World Intellectual Property Organization (WIPO), an organization set up under United Nations auspices, has developed model laws that define what is thought to be an adequate level of patent protection. An appropriate level of patent protection can increase the incentive to engage in activities that will lead to innovations, which in turn could be used to improve products, processes and productivity in that country.

Strong patent protection is one of the conditions that may be necessary, but not sufficient, to achieve the level of prosperity enjoyed by developed countries. In the late 1970s and 1980s Italy took several measures to help establish a climate conducive to economic growth. Among these measures were strengthening the patent law, lowering the inflation rate, and continuing integration into the EEC. All of these measures together have provided an environment that is receptive to innovation: I have already discussed the effect of changing the patent law; lowering the inflation rate makes investment less risky; and integration into the EEC provides for recognition of patents across much of Europe and may also provide an increased level of confidence in the national government.

Because Italy took several steps toward establishing an economic and legal structure similar to its EEC partners, it is likely impossible to isolate the effects of the change in the patent law on gross domestic product (GDP). However, without the change in Italy's patent law its EEC partners may have been less receptive to certain Italian products and less likely to introduce easily duplicated products in Italy. Also, Italy might have continued to lag behind in innovation and productivity and remained one of the poorer countries in the EEC.

Table 12 shows real per capita GDP for Italy and several other countries.[83] Italy began the period with lower real GDP per capita than any of the other countries listed but Japan. Since 1967, Italy has been passed by Japan, but has also nearly caught its European neighbors. Italy's real GDP per capita is now less than $1,000 below most of the other European countries listed.

Table 13 shows real Italian GDP per capita as a percent of each countries' real GDP per capita. Figure 2 shows the graph of these series. Figure 2 reveals a clear trend toward convergence of Italy's per capita GDP with that of most of these countries. Notably, much of the convergence with France, Germany, Sweden, and the United Kingdom has occurred since the late 1970s. This clearly shows that, at least since the late 1970s, Italy has taken steps necessary to catch up to other developed countries.

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[83]Data are from Computer Disk Supplement (#5.0) to Robert Summers and Alan Heston. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." *Quarterly Journal of Economics* Vol. CVI, No. 2 (May 1991): 327-368.

Table 12

REAL GROSS DOMESTIC PRODUCT PER CAPITA

1967–1988

Year	Italy	Germany [1]	United Kingdom	France	Japan	Sweden	United States
	(1985 International Prices)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1967	$ 5,991	$ 7,258	$ 7,438	$ 7,292	$ 4,998	$ 8,326	$ 12,381
1968	6,302	7,714	7,712	7,605	5,603	8,586	12,801
1969	6,663	8,250	7,778	8,128	6,153	8,953	13,047
1970	6,937	8,664	8,006	8,536	6,688	9,279	12,923
1971	7,005	8,808	8,078	8,848	6,896	9,254	13,161
1972	7,182	9,095	8,388	9,177	7,381	9,451	13,645
1973	7,690	9,441	8,981	9,626	7,971	9,868	14,194
1974	8,050	9,462	8,785	9,853	7,781	10,161	13,936
1975	7,775	9,267	8,727	9,745	7,833	10,307	13,531
1976	8,328	9,861	8,995	10,118	8,164	10,255	14,174
1977	8,600	10,140	9,227	10,411	8,518	10,096	14,677
1978	8,934	10,472	9,605	10,711	8,864	10,410	15,315
1979	9,518	10,850	9,893	11,019	9,262	10,778	15,532
1980	9,986	10,993	9,680	11,148	9,615	10,910	15,310
1981	10,061	11,034	9,567	11,200	9,873	11,035	15,510
1982	10,070	10,903	9,737	11,366	10,058	11,175	14,968
1983	10,130	11,130	10,092	11,280	10,265	11,424	15,441
1984	10,440	11,501	10,309	11,300	10,649	11,884	16,464
1985	10,584	11,646	10,679	11,376	10,781	12,382	16,779
1986	10,955	11,958	11,000	11,662	11,220	12,398	17,251
1987	11,310	12,124	11,495	11,831	11,620	12,702	17,735
1988	11,741	12,604	11,982	12,190	12,209	12,991	18,339

[1] Figures do not include gross domestic product for the German Democratic Republic.

Source: Computer Diskette Supplement (#5.0) to: Robert Summers and Alan Heston, "The Penn World Table (Mark 5): International Comparisons, 1950–1988," Quarterly Journal of Economics, May 1991, pp. 327–368.

Table 13

ITALIAN REAL GROSS DOMESTIC PRODUCT PER CAPITA
AS A PERCENT OF REAL GROSS DOMESTIC PRODUCT PER CAPITA
IN SELECTED COUNTRIES

1967–1988

Year	Germany[1]	United Kingdom	France	Japan	Sweden	United States
	(Percent)					
	(1)	(2)	(3)	(4)	(5)	(6)
1967	82.5 %	80.5 %	82.2 %	119.9 %	72.0 %	48.4 %
1968	81.7	81.7	82.9	112.5	73.4	49.2
1969	80.8	85.7	82.0	108.3	74.4	51.1
1970	80.1	86.6	81.3	103.7	74.8	53.7
1971	79.5	86.7	79.2	101.6	75.7	53.2
1972	79.0	85.6	78.3	97.3	76.0	52.6
1973	81.5	85.6	79.9	96.5	77.9	54.2
1974	85.1	91.6	81.7	103.5	79.2	57.8
1975	83.9	89.1	79.8	99.3	75.4	57.5
1976	84.5	92.6	82.3	102.0	81.2	58.8
1977	84.8	93.2	82.6	101.0	85.2	58.6
1978	85.3	93.0	83.4	100.8	85.8	58.3
1979	87.7	96.2	86.4	102.8	88.3	61.3
1980	90.8	103.2	89.6	103.9	91.5	65.2
1981	91.2	105.2	89.8	101.9	91.2	64.9
1982	92.4	103.4	88.6	100.1	90.1	67.3
1983	91.0	100.4	89.8	98.7	88.7	65.6
1984	90.8	101.3	92.4	98.0	87.8	63.4
1985	90.9	99.1	93.0	98.2	85.5	63.1
1986	91.6	99.6	93.9	97.6	88.4	63.5
1987	93.3	98.4	95.6	97.3	89.0	63.8
1988	93.2	98.0	96.3	96.2	90.4	64.0

[1] Figures do not include gross domestic product for the German Democratic Republic.

Source: Derived from Computer Diskette Supplement (#5.0) to: Robert Summers and Alan Heston, "The Penn World Table (Mark 5): International Comparisons, 1950–1988," Quarterly Journal of Economics, May 1991, pp. 327–368.

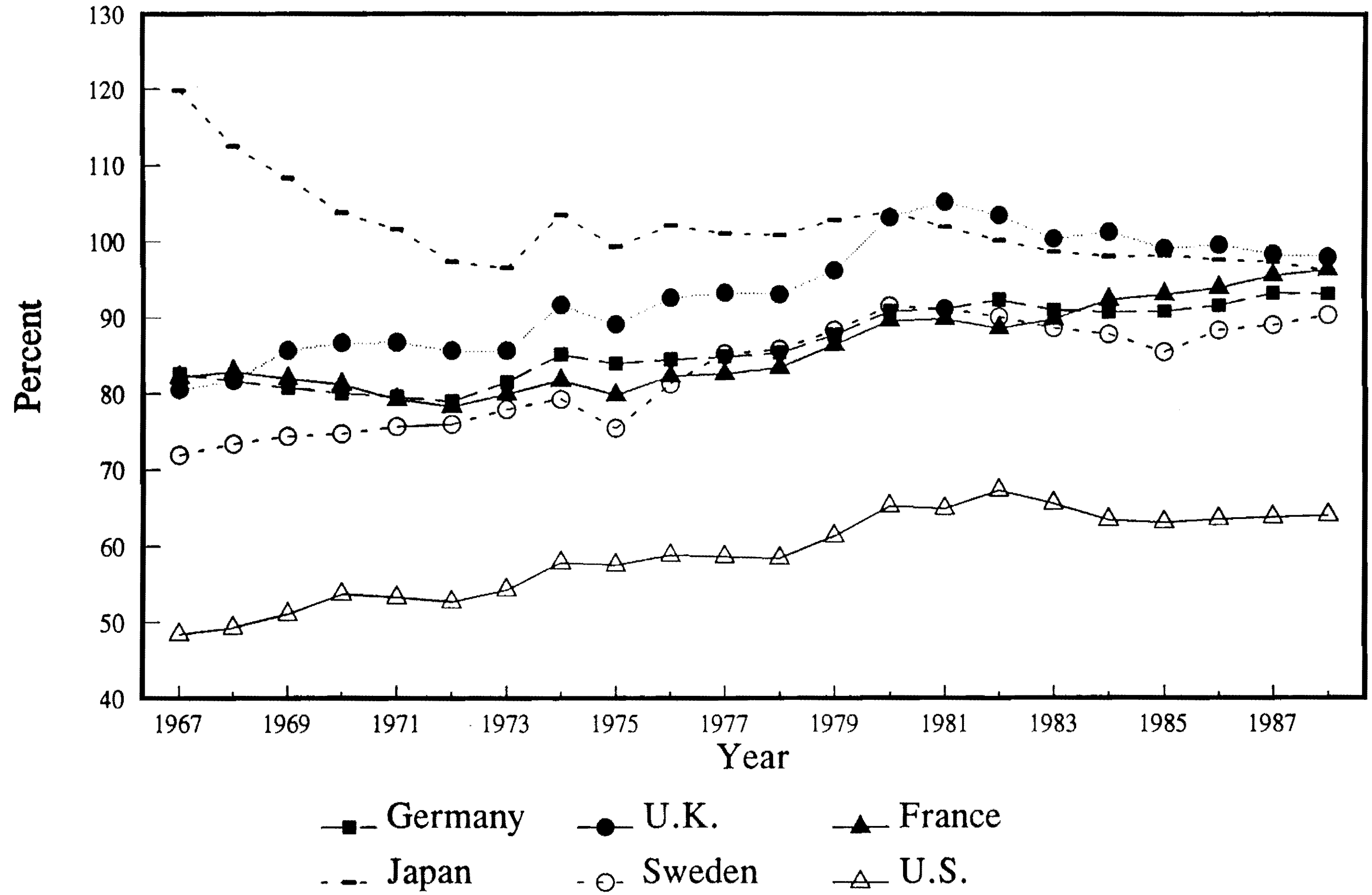

Figure 2: Italian GDP Per Capita as a Percent of GDP Per Capita in Selected Countries.

CHAPTER SEVEN

CONCLUSIONS

Intellectual property protection is an important factor in economic development. It can provide incentive for domestic inventors to create new innovations rather than copy old technology. It also encourages foreign inventors to share their technological advances with the home country. Without strong intellectual property protection, less incentive may exist.

Patents are an indicator of technological innovation. A patent is the product of a concerted effort to develop a new product or process through R & D. Estimating the relationship between R & D and patenting using a polynomial distributed lag model with current and four years of lagged R & D expenditures, I found that there is a strong relationship between R & D and patent applications. I estimate that the elasticity of patenting with respect to R & D is approximately 1.11, and is not likely to be less than 1.00. This estimate is consistent with certain results of other researchers.[84] The high value for the adjusted R-squared (.91) indicates that the relationship is strong.

I also found a relationship between both the level of patenting and the change in the level of patenting and productivity. This indicates that technical

[84]Bound et. al., 44.

progress often contributes to increased productivity. Increased productivity may help fuel economic growth.

All of these results should be interpreted cautiously since the time series is relatively short and there is a high degree of multicollinearity in the data.

The change in Italy's patent law appears to have encouraged higher levels of investment in R & D. Italian R & D spending doubled between 1980 and 1988. This rate of growth rivals that of Japan. These observations support the hypothesis that strong patent protection increases the incentive to invest in R & D.

Strong patent protection may be a necessary, but not sufficient, condition for economic development. Other factors will play key roles in determining the level of investment research in a country, but strong patent protection is unique in that it can turn these investments from imitative projects to innovative endeavors. The Italian example may be a good illustration of the benefits of adequate intellectual property protection.

BIBLIOGRAPHY

Armitage, Edward. "The Law and Practice of the European Patent Conventions." In *The New European Patent System and Its Implications for Industry in London, January, 8, 1974*, by the Confederation of British Industry. London: Confederation of British Industry, 1974), 3-13.

Banks, Arthur S., ed. *Economic Handbook of the World: 1982.* New York: McGraw-Hill Book Company, 1984.

Bound, John, Clint Cummins, Zvi Griliches, Bronwyn H. Hall, and Adam Jaffe. "Who Does R&D and Who Patents?" In *R & D, Patents, and Productivity*, ed. Zvi Griliches, 21-54. Chicago: University of Chicago Press, 1984.

Brunet, William J., Esquire, Chairman of Division I: American Bar Association Section on Patents, Trademarks and Copyrights, New York. Telephone interview by author, April 1, 1993.

Challu, Pablo. "The Consequences of Pharmaceutical Product Patenting." *World Competition* Vol. 15, No. 2 (December 1991): 65-126.

Cichon, Deborah R. *International Science and Technology Data Update: 1991.* [Washington, D.C.]: National Science Foundation, Division of Science Resources Studies, 1991.

Denison, Edward. *Accounting for United States Economic Growth, 1929-1969* Washington, D.C.: The Brookings Institution, 1974; cited in Rudiger Dornbusch and Stanley Fischer. *Macroeconomics.* 717 5th ed. New York: McGraw-Hill Publishing Co., 1990.

Deolalikar, Anil B., and Lars-Hendrik Roller, "Patenting by Manufacturing Firms in India: Its Production and Impact." *Journal of Industrial Economics* Vol. XXXVII, No. 3 (March 1989): 303-314.

Executive Office of the President. Office of the U.S. Trade Representative. *Annual Report on National Trade Estimates 1985.* [Washington, D.C.]: Executive Office of the President, Office of the U.S. Trade Representative, October 31, 1985.

Frame, J. Davidson. "National Commitment to Intellectual Property Protection: An Empirical Investigation." *Journal of Law & Technology* Vol. 2, No. 2 (Fall 1987): 209-227.

Greene, William H. *Econometric Analysis.* New York: Macmillan Publishing Company, 1990.

Greif, S. "Economic Growth and Patents." Paper prepared for the Interpat Seminar in Taiwan. September 10, 1985; cited in Richard P. Rozek. "Protection of Intellectual Property Rights: Research and Development Decisions and Economic Growth." *Contemporary Policy Issues* Vol. V (July 1987): 55.

Griliches, Zvi. "Patents: Recent Trends and Puzzles." In *Brookings Papers on Economic Activity: Microeconomics*, ed. Martin Neil Baily and Clifford Winston. Washington, D.C.: The Brookings Institution, 1989.

Hayward, Edward J. "Patent Licensing in the EEC." *Business Lawyer* Vol. 35, No. 2 (January 1980): 455-484.

Instituto di Studi sulla Ricerca e Documentazione Scientifica. *Quaderni: Consiglio Nazionale della Ricerche* Vol. 22 (Roma: Instituto di Studi sulla Ricerca e Documentazione Scientifica, 1989); cited in Deborah R. Cichon, *International Science and Technology Data Update: 1991* [Washington, D.C.]: National Science Foundation, Division of Science Resources Studies, 1991.

The Intellectual Property Committee (USA), Keidanren (Japan) and UNICE (Europe). *Basic Framework of GATT Provisions on Intellectual Property, Statement of Views of the European, Japanese and United States Business Communities*, unknown publisher, June 1988.

Jacobs, Alan J., ed. *Patents Throughout the World.* New York: Clark Boardman Callaghan, 1992.

Jori, G. "The Impact of Pharmaceutical Patents--The Italian Experience." Paper presented at the Seminar on the Proposal to Change Turkish Patent Law. Sponsored by the Minister of Health. Ankara, Turkey: August 26, 1992.

Judge, George G., W. E. Griffiths, R. Carter Hill, Helmut Lutkepohl, and Tsoung-Chao Lee. *Theory and Practice of Econometrics.* 2d ed. New York: John Wiley and Sons, 1985.

Mansfield, Edwin, Mark Schwartz and Samuel Wagner. "Imitation Costs and Patents: An Empirical Study." *Economic Journal* Vol. 91, No. 364 (December 1981): 907-918.

Nelson, Lester, Esquire, ed. *Digest of Intellectual Property Laws of the World.* Release 91-3. New York: Oceana Publications Inc., August 1991.

Nordhaus, William. *Invention, Growth, and Welfare.* Cambridge, MA: M.I.T. Press, 1969; cited in Hal R. Varian. *Intermediate Microeconomics, A Modern Approach*, 424-425. New York: W. W. Norton & Company, 1987.

Pakes, Ariel, and Zvi Griliches. "Patents and R & D at the Firm Level: A First Look." In *R & D, Patents, and Productivity*, ed. Zvi Griliches, 55-72. Chicago: University of Chicago Press, 1984.

Reinganum, Jennifer F. "A Dynamic Game of R and D: Patent Protection and Competitive Behavior." *Econometrica* Vol. 50, No. 3 (May 1982): 671-688.

Rozek, Richard P. "The Consequences of Pharmaceutical Product Patenting: A Critique." Forthcoming *World Competition.*

______. "Protection of Intellectual Property Rights: Research and Development Decisions and Economic Growth." *Contemporary Policy Issues* Vol. V (July 1987): 54-65.

Rozek, Richard P. and Carla Salisbury. "Discounted Cash Flow Analysis in Patent Infringement Litigation." *Licensing Economics Review* (August 1991): 7-10.

Scherer, Professor F.M., Harvard University, Boston. Telephone interview by author, April 2, 1993.

Schumpeter, Joseph. *Capitalism, Socialism and Democracy.* London: Unwin University Books, 1943.

Solow, Robert. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* (August 1957); cited in Rudiger Dornbusch and Stanley Fischer. *Macroeconomics*. 716-717 5th ed. New York: McGraw-Hill Publishing Co., 1990.

Summers, Robert, and Alan Heston. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." *Quarterly Journal of Economics* Vol. CVI, No. 2 (May 1991): 327-368.

Tirole, Jean. *The Theory of Industrial Organization*. Cambridge, MA: M.I.T. Press, 1988.

Trivedi, P., and A. Pagan. "Polynomial Distributed Lags: A Unified Treatment." *Economic Studies Quarterly* Vol. 30 (1979): 37-49; cited in William H. Greene. *Econometric Analysis*, 556, New York: Macmillan Publishing Company, 1990.

U.S. Department of Commerce, Patent & Trademark Office. *All Technologies Report*. [Arlington, VA]: U.S. Department of Commerce, Patent & Trademark Office, August 1992.

Vishwasrao, Sharmila. Working paper entitled "Intellectual Property Rights and the Mode of Technology Transfer." Presented at the Southern Economic Conference. Washington, D.C. November 24, 1992.

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