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contributions to economic analysis

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(with Pei Syn Wee)

Patent Activity and Technical Change in US Industries

PATENT ACTIVITY AND TECHNICAL CHANGE IN US INDUSTRIES

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Introduction to the Series

This series consists of a number of hitherto unpublished studies, which are introduced by the editors in the belief that they represent fresh contributions to economic science.

The term 'economic analysis' as used in the title of the series has been adopted because it covers both the activities of the theoretical economist and the research worker.

Although the analytical method used by the various contributors are not the same, they are nevertheless conditioned by the common origin of their studies, namely theoretical problems encountered in practical research. Since for this reason, business cycle research and national accounting, research work on behalf of economic policy, and problems of planning are the main sources of the subjects dealt with, they necessarily determine the manner of approach adopted by the authors. Their methods tend to be 'practical' in the sense of not being too far remote from application to actual economic conditions. In addition they are quantitative.

It is the hope of the editors that the publication of these studies will help to stimulate the exchange of scientific information and to reinforce international cooperation in the field of economics.

The Editors

Abstract

Innovation is universally recognized as an important source of economic growth. Patents may be considered as a potential measure of innovation. As such, patents may alter isoquant maps, and measuring their elasticities is both intuitively and empirically appealing. This book investigates the impact of US patent activity on technical changes in 35 industries given in the KLEM (Jorgenson, 1996) data set for the period 1958–1996. Four patent variables, namely total patent applications, total patents granted, unsuccessful patent applications and foreign patents granted, are introduced as technology-changing parameters into the generalized Fechner–Thurstone (GFT) production function to determine the effect on the elasticity of the marginal rate of technical substitution (MRTS) between inputs of the GFT production function over time. It is found that all four patent variables have significant impacts on the MRTS between various production inputs over time, with foreign patents granted being the most "effective" parameter, and unsuccessful patent applications the least effective. In addition, the elasticity of the MRTS between materials and energy is found to be the most affected by patent activity, and that between materials and labor the least. The extent of technical change by patent activity varies across industries. Patent activity is found to be less effective as technology changers in some traditionally high patenting industries and more effective in others, which indicates that there are significant spillover effects of patents. Patent activity is found to have the greatest impact on technical change in the metal mining industry and the least impact in the chemicals industry.

CHAPTER 1

Introduction

Economists have long been concerned about issues related to economic growth, specifically with respect to how to improve and control it and issues in understanding and quantifying technological change. A key aspect of economic growth is differential inventiveness in the production function. In light of the difficulties in measuring innovation, patent statistics appear to be one potentially attractive method for examining factors that may contribute to technical change. A patent is an intellectual (industrial) property (IP) that confers to its owner or holder the monopoly rights to a product or process over a stipulated period of time. Applications are granted on the basis of innovation and non-obviousness (Besen and Raskind, 1991). The United States Patent and Trademark Office (USPTO) has been collecting data on patent applications and patents granted since 1790. As the USPTO website notes, for over 200 years the basic role of the Patent and Trademark Office (PTO) has remained the same: to promote the progress of science and the useful arts by securing for limited times to inventors the exclusive right to their respective inventions (Article 1, Section 8 of the United States Constitution), cf. http://www.uspto.gov. They further note that the PTO is a non-commercial federal entity and one of 14 bureaus in the Department of Commerce (DOC). To understand the magnitude of the USPTO, its official website tells us that the office occupies a combined total of over 1,400,000 square feet, in numerous buildings in Arlington, VA. The office employs over 5000 full time equivalent (FTE) staff to support its major functions—the examination and issuance of patents and the examination and registration of trademarks. Finally, the website notes as follows:

PTO programs are conducted under the following principal statutory authorities:

- 15 USC 1051–1127 contains provisions of the Trademark Act of 1946 that govern the administration of the trademark registration system of the Patent and Trademark Office.
- 15 USC 1511 states that the Patent and Trademark Office is under the jurisdiction and supervision of the Department of Commerce.
- 35 USC contains basic authorities for administration of patent laws, derived from the Act of July 19, 1952 and subsequent enactment. Revenues from fees are available, to the extent provided for in appropriations acts, to the Commissioner to carry out the activities of the Office. The Patent and Trademark Office is authorized to charge international fees for activities undertaken pursuant to the Patent Cooperation Treaty. Deployment of automated search systems of the Office to the public is authorized.
- 44 USC 1337–1338 contains authority to print patents, trademarks, and other matters relating to the business of the Office.

These laws and statutes have served as the basis for the regulation of IP in the US for many years. To understand the magnitude of the importance of these legal acts, one can keep reading to see how patents (in particular) have impacted the industrial arts across many diverse industries. The use of patent statistics in empirical research is not without its risks, suffering from classification problems and incompatibility issues with the Standard Industrial Classification (SIC) that was widely used in practice until recently. More importantly, patent statistics are intrinsic variables in technical and economic significance (Griliches, 1990). Despite these problems, patent statistics are plentiful and objective. Patents are, by definition, related to inventiveness, and they have been long considered a reasonable measure of innovation (Hall et al., 1986).

There is an extensive literature on the use of patent statistics in economic research (see Griliches (1990) for a useful review). These range from the use of patent renewal data to determine the stock market returns of firms, to the valuation of patent rights held by firms in Europe (Pakes and Simpson, 1989). Lanjouw and Lerner (1997) explored the optimality of patent structures and the effects of litigation on innovative activity. McAleer, Chan and Marinova (2005) investigated the time series properties of patent activity from the perspective of modeling the volatility inherent in monthly patent shares, and developed an Innovation Strengths Model for the purposes of international comparisons.

A different paradigm is to introduce patents into the production function (Furman et al., 2002). Within a firm, innovation can lead to a change in the way inputs are used in the production function. Hence, patents should alter isoquant maps, and measuring their elasticity is both intuitively and empirically appealing. Basmann et al. (2003) analyze a production function of the generalized Fechner–Thurstone (GFT) form that allows patent activity as instruments for technology changers to be estimated directly. They found that patent activity is a significant catalyst for technical change at the aggregate level in US manufacturing.

The purpose of this book is to use the method introduced by Basmann et al. (2005) to examine the effectiveness of patent activity as technology changers across 35 US industries from 1958 to 1996. A technology changer is defined as a variable that has an impact on the elasticity of the marginal rate of technical substitution (MRTS) between inputs of the GFT production function over time (Basmann et al., 2005). Four types of patent activity, namely total patent applications, total patents granted, unsuccessful patent applications and foreign patents granted, are used as instruments for technical change in the GFT production function. This book examines how (if at all) the impact of patent activity as a catalyst for technical change differs across industries.

The results obtained herein corroborate those of Basmann et al. (2005) and indicate that patent activity has caused technical change at the aggregate level, with foreign patents granted being the most "effective" parameter, and unsuccessful patent applications the least effective. Thus, the elasticity of the MRTS between materials and energy is found to be the most affected by patent activity, and that between materials and labor the least. More significantly and perhaps not surprisingly, the extent of technical change by patent activity varies widely across the industries investigated. The metal mining industry was found to have benefited the most from patent activity with respect to technical change, and the chemicals industry the least.

The plan of the remainder of the book is as follows. Chapter 2 reviews the literature on the economics of patent statistics. Chapter 3 describes the data. Chapter 4 presents the GFT aggregate production function and the model to be estimated. Chapter 5 discusses the empirical results. The book concludes with some recommendations for future research in Chapter 6.

CHAPTER 2

Literature Review

2.1. INTRODUCTION

Patent statistics has been an area of increasing research by economists in recent years. The key issue that continues to challenge researchers is the extent to which technological advances are captured by patent statistics.

2.2. PROBLEMS OF PATENT STATISTICS

A major problem cited by Griliches (1990) in using patents for economic analysis is their classification. Since patents data are organized by firms or by patent classes, it is difficult to match them to the relevant industries or product groups. The USPTO attempted to resolve the problem by developing a "concordance" between patent classes and the Standard Industrial Classification (SIC) for industries. However, the assignment is arbitrary and many of the basic classification issues remain unanswered.

Another problem is the intrinsic variability of patents, which differ greatly in their technical and economic significance. Many patents reflect minor improvements of little future economic value, while others are extremely valuable. Currently, there is no adequate procedure for "weighting" different patents appropriately.

2.3. TRENDS AND VOLATILITY IN PATENTS DATA

McAleer et al. (2005) investigated the time series properties of patent activity for various leading inventive countries with registered patents in the USA to model the volatility inherent in patent shares over time. An Innovation Strengths Model (ISM) based on patent statistics was also developed to capture the two major aspects of the innovation process, namely novelty and commercialization. Using US patents data, Marinova and McAleer (2005) also developed international rankings of innovation strengths in the fields of environmental technology and nanotechnology. Pavitt and Soete (1980) have also used patents data to analyze the relative "competitiveness" of various countries in order to construct "revealed technology indexes".

2.4. PATENTS AND RESEARCH AND DEVELOPMENT

Research and development (R&D) expenditures, an input (and indicator) of inventive activity, have been identified as necessary for technological progress. Unfortunately, R&D data by industry are scarce. Thus, a motivating force for economic research in this area is to use the relatively abundant data on patents as a proxy for the output of the inventive process. This would also help to provide a link between patents and innovative activity. Acs et al. (2002) concluded that patents provide a fairly reliable measure of innovative activity. Other leading examples include Schmookler (1966), Scherer (1965), Hall et al. (1986), and Acs and Audretsch (1989). The major conclusion reached in these papers, and emphasized by Pakes and Griliches (1984), is that there is a strong relationship between R&D and the number of patents received at the cross-sectional level, namely across firms and industries. This finding provides one piece of evidence in support of the hypothesis that patents are a reasonable indicator of unobserved inventive output.

Pakes and Griliches (1984) also found that the same relationship, though statistically significant, is much weaker for firms in the time series context. Mueller (1966) corroborated this finding and argued against the use of patent statistics in time series analysis. Such a relationship is also found to be close to contemporaneous, with small lagged effects, which are not precisely estimated (Hall et al., 1986). This finding is consistent with the fact that patents tend to be registered early in the life of a research project, but the bulk of R&D expenditures are spent on development. Thus, most of the time series variability would arise from developing existing projects, rather than initiating new projects. The seemingly low correlation between patents and R&D in time series as alleged by these researchers would imply that patents are a relatively poor indicator of short-term changes in the output of inventive activity. The relationship between patents and R&D also differs with firm size. Small firms appear to be more efficient and receive more patents per R&D expenditure (Bound, 1984), which may have resulted from the higher amount of informal, and hence undeclared, R&D expenditure in small firms (Griliches, 1990). Moreover, small firms are more likely to be dependent on current patents as a potential source of exponential growth, and are thus more driven to patent. There is no evidence of diminishing returns to the size of the R&D effort for larger firms (Scherer, 1983).

Not surprisingly, the patents–R&D relationship also differs across industries. Cockburn and Griliches (1988) observed that industries with a low propensity to patent (i.e. low patents per R&D dollar) include large R&D industries such as motor vehicles and aircraft. Conversely, industries with a high propensity to patent include the communications sector, and low R&D sectors such as screws and nuts. The latter sectors appear in this category because, despite conducting little R&D, they still manage to register the occasional patent. Indeed, using European data, Arundel and Kabla (1998) concluded that patents are a particularly poor measure of innovation in sectors such as food and tobacco, petroleum refining and basic metals, as a large majority of innovations in these sectors are not patented.

2.5. PATENT RIGHTS AND PATENT VALUE

Since individual patents can vary widely in terms of economic significance, there is great interest in determining the average value of patent rights and inventions captured by particular patents. The former refers to the value associated with the differential legal situation created by the possession of a patent.

There are several ways of determining aggregate patents rights and patent value. It is important to understand that these methods are all intended as proxies to value broad aggregate patent rights in macroeconomic analysis, not necessarily methods used to value a single patent or portfolio per se such as in the context of IP damage analyses, cf. Slottje and Perry (2003). First, direct surveys of patent owners with questions pertaining to past returns and potential market value of patent rights can be conducted. Sanders (1962,1964) conducted a detailed and extensive survey, and found that a large fraction of sampled patents have been "used" commercially; he concluded this dispels the myth that most patents are not used or commercialized. The survey also found that the reported economic gains from innovations associated with these patents were highly dispersed, with a mean patent value of $577,000 per patent, but a median value of only $25,000. Under the assumption of log-normality, this implies a coefficient of variation of 2.5 and a standard deviation of around $1.5 million. Alternative surveys by the Chemistry Program of the National Science Foundation and SRI International (1985) also found substantial economic gains from patents, and that these gains were also highly dispersed (Griliches, 1990).

A second method of deriving broad, average value of patents and patent rights is to model implicitly the valuation into the decision of paying a fee to renew the patent (Pakes, 1986). In many countries, and only recently from 1982 in the USA, patent holders have had to pay an annual renewal fee to retain their patents. If the payment lapses in any given year, the patent is cancelled permanently. Assuming that renewal decisions are based on economic criteria, patent holders would only renew their patents if the value of holding those patents for an additional year exceeds the renewal costs. The ratio of different cohort of patents that are renewed at alternative ages, together with the renewal fee schedules, contains information on the distribution on the values of holding patents, and also how this distribution function is formed over the lifespan of the patents. As patent rights are seldom marketed, patent renewal data are one of the few sources of information regarding their value. Lanjouw et al. (1996) conclude that attaching renewal weights to patent count indices yield a more precise measure of innovative output than raw patent counts. Scotchmer (1999) and Cornelli and Schankerman (1999) examined the optimality of patent renewal systems and compared them to existing systems in order to illustrate the potential welfare gains from an optimal policy.

Pakes and Schankerman (1984) estimated a deterministic patent renewal model and used it to examine the value of patent rights in the UK, France and Germany in the post-1950s period. In a deterministic model, each cohort of patents is endowed with a distribution of initial returns, which decays deterministically. Patentees are assumed to choose a lifespan for their patents to maximize the expected discounted value of the net returns (current returns minus renewal fees). Their results concluded that Germany had the lowest estimate of the rate of decay in the returns from holding patents in the 1950s. They argued that this is an indication that the relatively stringent German patent granting procedures have generally achieved success in selecting patents with higher initial returns and lower subsequent decay in those returns. Germany also had the highest mean patent value and the highest private value of patent rights among the three countries. The most important finding of their paper was that the distribution of the private value of patent rights is sharply skewed. There is a concentration of patent rights with very little private economic value, but the tail of the distribution contains extremely valuable patent rights. Schankerman (1998) also derived similar results using disaggregated patent renewal data for France.

Pakes and Schankerman (1986) extended this framework to incorporate uncertainty about the sequence of returns that will accrue to a retained patent. This uncertainty helps to reconcile the fact that agents tend to apply for patents at an early stage of the innovative process when they are still exploring the embedded economic potential. Moreover, it is also prompted by the incentive of low renewal fees during the early years of a patent, which yields an optimal renewal rule. Pakes and Schankerman (1986) found that most of the uncertainty about the economic potential of patents is resolved by the fifth year. They incorporated this result and reverted to a deterministic model for patents older than 5 years. They argued that this effectively fine-tuned the model, and led to a better explanation of the value of patents and patent rights.

Using disaggregated patent renewal data for Scandinavian countries, Pakes and Simpson (1989) found that, even after conditioning for nationality, there are distinct differences in the distributions of patent values among patents in different industries. They also found that distinct differences exist in the value distributions of different cohort of patents. This supported the theory espoused by Schmookler (1966) that there is a negative correlation between the number of patents in a cohort and the average value (or quality) of such patents. In order to refine the model, Lanjouw and Lerner (1997) and Lanjouw (1998) included the costs of legal expenses to enforce patents into their model, and concluded that the increasing propensity by firms to enforce their patents via litigation has had a significant effect on the private value of patent rights. These papers also considered the impact of intellectual property litigation on the innovation process itself.