The valuation of patent rights sounds like a simple enough concept. It is true that agents routinely appraise and trade individual patents. But small-sample methods (generally derived from basic accounting and finance) are often crude, and their results may bear little relationship to economic fundamentals, especially in litigation. On the other hand, large-sample methods usually lack much invention-specific data on which to condition value estimates. Regardless of sample size, proper valuation methods require both conceptual delineation and empirical ingenuity.

Concepts. Legally, a patent is the right to exclude others from making, using or selling an invention. In economic terms, that right is an asset, yielding a non-negative returns stream while it is enforceable. Because the right is a private means (increased exclusivity) to a public end (increased productivity), a patent's private value only partially conveys its market significance.

Unlike most property rights, patents do not comprise the affirmative right to use the invention. Absent the right to use, patents may generate private value only when combined with complementary assets, such as a license under other patents. Contracting problems (e.g. asymmetric information) may strongly influence value.

A patent may generate private returns apart from the right to exclude rivals. The patentee may use it: to monitor employee performance; to signal otherwise unobservable quality to prospective financiers; to enhance reputation; to signal a willingness to litigate; or to reduce the costs of settlement in the event that litigation occurs ("defensive patenting"). In large samples, it is usually impossible either to observe the magnitude and timing of these sources of value, or to decompose them.

Patents also impose unobservable private costs on the patentee. Chiefly, the inventor must disclose the means for reproducing the invention. Disclosure reduces the cost to rivals of reproducing the invention (static spillover) and conducting R&D (dynamic spillover). Apart from reducing the incentive to invent, these private costs imply social benefits not captured by the patentee.

Cross-sectionally, patents are usually modeled as having a one-dimensional "quality" (which is either synonymous with, or a monotone function of, the patent's value). More precisely, a patent's private value depends significantly on the exclusivity conferred by its claims, but its uncaptured social value depends significantly on the scope of its disclosure (which must be at least as broad as the claims). For various reasons, including rival use of the patentee's disclosure to develop competing innovations ("creative destruction"), the social and private values of a patent may diverge. Thus, it is theoretically preferable, but empirically much less tractable, to model patents as having two-dimensional "quality."

Over time, because of ongoing research by the patentee and his rivals, the private returns to patent protection may fluctuate sharply up or down, in response to complementary or competitive discoveries. The variance is likely to be larger in a patent's early years.

<u>Stylized facts</u>. The following stylized facts bear on the calculation of aggregate private patent values:

1. Whether aggregated by firm, industry or country, patent counts do not vary much from one period to the next.

2. The distribution of patent values is skewed.

3. Social and private patent values are imperfectly correlated.

4. *Ex ante* and *ex post* values are imperfectly correlated.

5. Most patents are not traded.

6. Samples are selected (not all innovations are patented; not all applications are filed in any single country; not all applications are granted).

<u>Related research</u>

Proceeding in the direction of generally increasing complexity and structure, the following categories describe large-sample models that economists have developed to value patent rights. Lanjouw, Pakes and Putnam (1998) surveys recent papers.

Patent counts. A variety of models employ simple patent counts to indicate the value of patent rights. Strictly speaking, patent counts indicate quantities, rather than values. Under certain assumptions, relative quantities may be proportional to relative values. For example, if two patent samples are drawn from the same value distribution, then the ratio of quantities is an efficient estimator of the ratio of values.

Griliches (1990) reviews a large number of studies that, implicitly or explicitly, rely on this assumption. Griliches' view of "patent [counts] as economic indicators" is not encouraging ("The food here is terrible." "Yes, and the portions are so small."). Stylized facts #1 and #2 combine to thwart inference. A firm facing a fixed budget constraint may patent its best *N* inventions, which implies little intertemporal variation in patent counts even if their realized quality varies markedly. Thus, patent counts are a *biased* measure of value. Because R&D outcomes are highly variable and skewed, patent counts are an *imprecise* measure of value. For these reasons, the assumption that patent samples are drawn from the same distribution is difficult to test, and often false.

(On the other hand, fixed budget constraints for R&D and patenting imply that patent counts may proxy for the value of R&D *inputs*. Hausman, Hall and Griliches (1986) model the lag relationship between patent counts and R&D, and find an approximately contemporaneous relationship.)

One may compute implied patent values by associating patent counts with other observable aggregates. On the macro level, McCalman (2005) employs the structural imitation model of Eaton and Kortum (1996) to determine international “trade” in patents. He estimates that the worldwide value of patent applications filed by U.S. inventors in 1988 was about $12.4 billion ($163,700 per application). The estimates for four other large patenting countries vary: France, $147,200; Germany, $82,200; U.K., $53,100; Japan, $47,700.

At the firm level, Pakes (1985) constructs a time series model of patent applications, R&D and the stock market rate of return. Controlling for R&D expenditures, an unanticipated patent application implies an $800,000 increase in market capitalization. (This relatively high value also reflects investors’ revised expectations of research success, and the selection of publicly traded patentees (which are larger and more successful than average).

Patent citations (weighted patent counts). Patent examiners cite prior patents when they decide whether to grant a patent application. Analysts count these citations to indicate the value of the cited patent. Patent counts are then weighted by the number of citations. A recent book-length treatment is Jaffe and Trajtenberg (eds.) (2002).

This branch of the literature divides in two: estimates of the relationship between citations and patent value; and studies that assume that relationship. In the former category, Trajtenberg's (1990) pioneering study showed that citation-weighted patent counts perform better than unweighted counts in explaining aggregate patent value (see Harhoff et al. 2003). However, this and subsequent studies found that citations tend to indicate the social value of the patent, rather than the purely private value (stylized fact #3). Private value is better captured by "self-citations" from the patentee's own later inventions. Hall et al. (2005) show that weighted patent counts are associated with—and predict—higher stock market returns.

Assuming that citations proxy for value, Henderson, Jaffe and Trajtenberg (1998) examine the contribution of university patenting to commercial technology; Trajtenberg, Henderson and Jaffe (1997) find that the "basicness" of university patents relative to corporate patents has narrowed over time. Jaffe, Trajtenberg and Henderson (1993) model the spatial distribution of dynamic spillovers.

Other indicator-based methods. Lanjouw and Schankerman (2004) construct a composite index of patent quality using several indicators (forward- and backward-citations, number of claims, and number of filing countries). This combination of *ex ante* and *ex post* measures (stylized fact #4) efficiently aggregates informationally distinct components of patent value. The composite also explains related *ex post* decisions (e.g., patent renewal and litigation); forward citations (an *ex post* measure) demonstrate the greatest explanatory power.

Structural models: patent renewals and patent applications. Although most patents are not traded (stylized fact #5), patent office rules effectively require patentees to make optimal investments to create and maintain patent rights. These investments reveal information about the expected value of the asset. The information is censored, however, because (conditional on choosing to invest) patentees make the same investment regardless of the expected value. Structural econometric models identify the underlying value distribution.

Most countries require that a patentee pay an increasing fee to keep a patent right in force. Beginning with Pakes and Schankerman (1984), so-called patent renewal models exploit the optimal stopping problem implicit in the annual investment decision. The *ex post* value distribution is identified from the shares of an annual cohort that are renewed each subsequent year when patentees confront known renewal fee schedules, observed over multiple cohorts. In relatively simple *deterministic* models (Schankerman and Pakes 1986; Sullivan 1994; Schankerman 1998), returns are assumed to depreciate at a known rate following an initial draw from the value distribution. In more complex *options* models (Pakes 1986; Lanjouw 1998), returns evolve stochastically. In both models, the average patent value is relatively low (for example, less than $20,000 in Europe during the post-war period). Lorenz plots reveal that the top 10% of patents account for about 47% of the total value distribution.

The value distribution may also be identified from cross-sectional information (Putnam 1996). Under international rules, patent applicants typically determine simultaneously whether to file in each jurisdiction outside their home jurisdiction. Applicants file if the capitalized value of net returns exceeds the application cost. Application models capture filing anywhere in the world, conditional on a common information set, which mitigates both intertemporal (stylized fact #4) and sample selection (stylized fact #6) problems. The *ex ante* value distribution is identified from the combination of filing countries, assuming that national returns are the product of a common invention-level "random effect" and an idiosyncratic national market draw. Putnam (1996) values the mean German patent at about $69,000 in 1974, with the top 10% of patents accounting for about 70% of the value distribution.

<u>Small-sample methods</u>

Small-sample patent valuation typically occurs in a legal or quasi-legal context, such as licensing or litigation. In infringement litigation, the law typically allows one of three measures of damages: the patentee's lost profits; the infringer's incremental profits; or a "reasonable royalty" (conceived as the outcome of a hypothetical licensing negotiation (Weil *et al.* 2001)). Typically, parties employ discounted cash flow methods and "comparable" license transactions to support valuation claims. Both *ex ante* and *ex post* methods are used, not always consistently. The law also allows limited consideration of an infringer's *ex ante* alternatives to infringement, such as inventing a substitute. Generally, the most difficult legal and empirical question is: What fraction of (actual or expected) profits should be imputed to the patent? While much damages jurisprudence remains economically *ad hoc*, courts are increasingly inclined to require the same market analyses that characterize antitrust law (*Crystal Semiconductor v. TriTech Microelectronics*, 246 F. 3d 1336, (Fed. Cir. 2001)).

References

Eaton, J., and S. Kortum. 1996. "Trade in Ideas: Patenting and Productivity in the OECD." *Journal of International Economics* 40: 251–78.

Griliches, Z. 1990. "Patent Statistics as Economic Indicators: A Survey." *Journal of Economic Literature*: 1661-1707.

Hall, B., A. Jaffe and M. Trajtenberg. 2005. "Market Value and Patent Citations." *Rand Journal of Economics* 36: 16-38.

Harhoff, D., F. Narin, F. M. Scherer and K. Vopel. 1999. "Citation Frequency and the Value of Patented Inventions." *Review of Economics and Statistics* 81(3): 511-515.

Hausman, J., B. Hall and Z. Griliches. 1986. "Patents and R&D: Is There a Lag?" *International Economic Review* 27: 265-83.

Henderson, R., A. Jaffe and M. Trajtenberg. 1998. "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988." *Review of Economics and Statistics* 80(1): 119-127.

Jaffe, A., M. Trajtenberg and R. Henderson. 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics* 43(4): 578-598.

Jaffe, A. and M. Trajtenberg. 2002. *Patents, Citations and Innovations: A Window on the Knowledge Economy*. Cambridge, Mass.: MIT Press.

Lanjouw, J. O. 1998. "Patent Protection in the Shadow of Infringement: Simulation Estimations of Patent Value." *Review of Economic Studies* 65: 671-710.

Lanjouw, J. O. and M. Schankerman. 2004. "Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators." *The Economic Journal* 114: 441-65.

Lanjouw, J.O., Pakes, A. and Putnam, J. 1998. "How to Count Patents and Value Intellectual Property: Uses of Patent Renewal and Application Data." *Journal of Industrial Economics* 46(4): 405-433.

McCalman, P. 2005. "Who Enjoys 'TRIPs' Abroad? An Empirical Analysis of Intellectual Property Rights in the Uruguay Round." *Canadian Journal of Economics*: 574-603.

Pakes, A. 1986. "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks." *Econometrica* 54: 755-784.

Pakes, A. and M. Schankerman. 1984. "The Rate of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources." In Z. Griliches (ed.), *R&D, Patents and Productivity*. NBER Conference Series. Chicago: The University of Chicago Press.

Pakes, A. and M. Simpson. 1989. "Patent Renewal Data." *Brookings Papers: Microeconomics:* 331-410.

Putnam, J. 1996. *The Value of International Patent Rights.* Ph.D. Thesis. Yale University.

Schankerman, M. and A. Pakes. 1986. "Estimates of the Value of Patent Rights in European Countries during the Post-1950 Period." *Economic Journal* 96: 1052-1076.

Schankerman, M. 1998. "How Valuable is Patent Protection? Estimates by Technology Field." *Rand Journal of Economics* 29(1): 77-107.

Sullivan, R. 1994. "Estimates of the Value of Patent Rights in Great Britain and Ireland, 1852-1876." *Economica* 61: 37-58.

Trajtenberg, M. 1990. "A Penny for Your Quotes: Patent Citations and the Value of Innovation." *Rand Journal of Economics* 21(1): 172-187.

Trajtenberg, M., R. Henderson and A. Jaffe. 1997. "University versus Corporate Patents: A Window on the Basicness of Invention." *Economics of Innovation and New Technology* 5(1): 19-50.

Weil, R. L., M. J. Wagner and P. B. Frank. 2001. *Litigation Services Handbook: The Role of the Financial Expert.* New York: Wiley.