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tant markets today than we did just five years ago, there are a number of gaps in our knowledge.

Perhaps the most glaring gap is a dynamic economic model of the integration process. Currently, we do not have an asset pricing theory that allows for a gradual and anticipated process of liberalization. This model would help us understand the complex economic and financial changes that I document in some of my research. Further, many corporations are wrestling with proposals to make direct investments in emerging markets. In order to evaluate these proposals, they need an asset pricing model that suggests appropriate hurdle rates for each potential investment. As corporations expand their operations to emerging markets, this need becomes more acute. The next generation of emerging markets research will have to meet this challenge.

Editor's note: Professor Harvey submitted this article for publication three weeks before the Russian equity market crashed.

[1] *C.R. Harvey, "Predictable Risk and Returns in Emerging Markets,"* Review of Financial Studies, *8, 3, (Fall 1995), pp. 773–816.*

[2] *W. Goetzmann and P. Jorion, "Re-Emerging Markets," NBER Working Paper No. 5906, January 1997.*

[3] *G. Bekaert and C.R. Harvey, "Emerging Equity Market Volatility,"* Journal of Financial Economics, *43, 1, (January 1997) pp. 27–77.*

[4] *G. Bekaert, C.B. Erb, C.R. Harvey, and T.E. Viskanta, "Distributional Characteristics of Emerging Market Returns and Asset Allocation,"* Journal of Portfolio Management, *24, 2, (Winter 1998), pp. 102–16.*

[5] *C.R. Harvey and A. Siddique, "Conditional Skewness in Asset Pricing Tests," Working Paper, Duke University, 1998.*

[6] *Harvey, "Predictable Risk and Returns in Emerging Markets."*

[7] *G. Bekaert and C.R. Harvey, "Time-Varying World Market Integration,"* Journal of Finance, *(June 1995), pp. 403–44.*

[8] *Bekaert and Harvey, "Emerging Equity Market Volatility."*

[9] *G. Bekaert and C.R. Harvey, "Foreign Speculators and Emerging Equity Markets," unpublished working paper, Duke University and Stanford University, 1998.*

[10] *G. Bekaert, C.R. Harvey, and R.L. Lumsdaine, "Dating the Integration of World Capital Markets," unpublished working paper, Duke University, Stanford University, and Brown University, 1998.*

[11] *Following J. Bai, R.L. Lumsdaine, and J.H. Stock, "Testing for and Dating Breaks in Stationary and Nonstationary Multivariate Series,"* Review of Economic Studies, *forthcoming, 1998.*

[12] *L. Tesar and I.M. Werner, "U.S. Equity Investment in Emerging Stock Markets,"* World Bank Economic Review, *9, 1, (January 1995), pp. 109–29.*

[13] *G. Bekaert and C.R. Harvey, "Capital Flows and Behavior of Equity Market Returns," unpublished working paper, Duke University and Stanford University, 1998.*

Patents, Patent Citations, and the Dynamics of Technological Change

Adam B. Jaffe*

Economists accept that technological change contributes powerfully to long-run improvements in living standards. Yet, we know surprisingly little about the determinants of technological change, including the relative contributions of different economic agents to the change process, the empirical sensitivity of the process to economic incentives, and the extent of market failure surrounding decisions affecting investments in new knowledge and technology. In part, this lack of knowledge is attributable to the fact that, until recently, some economists have tended to view technology as a "black box" that affected the economic system but that was itself driven largely by exogenous noneconomic forces, such as the advance of science. Pioneering work by Schmookler, Griliches, and others showed that this was not true; more recently the so-called New Growth Theory of Romer, Lucas, Grossman and Helpman, and others, has placed technology squarely within the economic system. However, grappling with these ideas empirically requires confronting the reality that many of the relevant activities, although endogenous to the political-economic system, are carried out in institutions such as universities and government laboratories, and may not be amenable to analysis with the standard tools of the theory of the firm.

More fundamentally, microeconomic analysis of the process of technological change must confront severe measurement problems. Fundamentally, technological change is driven by an investment process that produces a form of capital that is hard to see or measure. Moreover, technological change is inherently an interrelated and cumulative process: an important part of the economic consequence of investments made by one agent is the effect that such

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investments have on the marginal product of other (either subsequent or made by others) investments. Thus, empirical implementation of New Growth Theory, and the broader agenda of quantifying the determinants of technological change, requires the development of methods 1) to measure the output of investments in new knowledge and new technology, including investments made in the university and government sectors, and 2) to quantify the linkages across time and institutional boundaries by which the "spillovers" and cumulative impact of new knowledge are manifested. Along with various coauthors, I have explored the use of data on patents and patent citations for these purposes.

Patents are an interesting "economic institution." In return for a government-enforced monopoly franchise on the commercial exploitation of an invention, the patentee must disclose and explain the invention, in principal with sufficient detail that a knowledgeable practitioner of the relevant technology could reproduce the invention using the patent document. When a patent is issued, a large amount of information is publicly recorded, and most of this information is now available in computerized form. The information that is available includes the following: 1) the names and postal addresses of the inventor(s); 2) the organization, if any, to which the patent property right was assigned or transferred when the patent was issued, and its legal address; 3) a detailed technological classification of the invention; 4) the patentee's specific claims regarding what the invention can do that could not be done before; and 5) citations that indicate previously existing knowledge, embodied in prior patents or other publications, upon which the patent builds.

Constructing a Database of Patents

Michael Fogarty, Manuel Trajtenberg, Bronwyn H. Hall, and I are engaged in an NBER project, funded by the National Science Foundation, to assemble patent information into a dataset for economic research. The data file, which eventually will reside on an Internet site accessible to all qualified researchers, contains most of the foregoing information for about 3 million U.S. patents granted since 1963. The dataset tracks the citations in all patents since 1977 and permits convenient merging of data relating to citing and cited patents. For example, one can look specifically at patents granted to inventors residing in the United States and ask what fraction of the subsequent patents citing them are also from the United States. Because of the detail in the patent data, one can ask about specific time periods or specific technological fields separately, and can look at finer geographic breakdowns, such as states or metropolitan areas.

Using these data, my coauthors and I have begun to explore two broad categories of questions about the dynamics of technological change. First, we examine the number and composition of citations that a patent receives from subsequent patents as an indicator of an invention's technological and economic impact. We also explore the use of these citation-based measures of impact to quantify the effects of changes in incentives for research organizations. Second, we consider patent citations as proxies for the flow of "knowledge spillovers" *from* the inventors whose patents are cited *to* the inventors making the citations. In this context, we examine the effects of geographic proximity, technological relatedness, organizational boundaries, and passage of time on these spillover flows.

Citation-Based Measures of "Basicness" of Inventions

My research in this area began with a paper written in 1990 with Manuel Trajtenberg and Rebecca Henderson and published recently.[1] We tested whether patent citations could be used to identify "basic" inventions, using the hypothesis that inventions coming out of universities were, on average, more basic than those coming from private firms. We proposed several measures of the basicness of inventions, based on patent citations. These include both "backward" measures (derived from the citations *made* by a patent) and "forward" measures (derived from the citations that a patent subsequently *receives* from other patents). For both forward and backward citations, the measures fall into three categories: *importance measures* are based on the number of citations made or received; *distance measures* relate to the proximity or remoteness of the cited or citing patents, across both time and technology space; and *originality* or *generality* measures relate to the dispersion of citations made or received across different areas of technology space. We also examined the extent to which the citations made by patents were to scientific articles rather than to other patents as an indicator of the closeness of the invention to basic science.[2] We found that the forward measures of basicness based on citations generally were significantly higher for university patents, but the differences in the backward measures were typically not significant, except for the citations to scientific papers, which were significantly higher for university patents.

We also proposed that the fraction of "self-citations"—citations that come from patents assigned to the same organization—was an indicator

of the originating organization's successful appropriation of the subsequent fruits of that research. The data confirm that this fraction was much higher for firms than for universities, and it was higher for large firms than for small firms (as high as 25 percent for the largest firms).

That first paper was based on patents from the 1970s and early 1980s. In 1980, Congress changed U.S. law, making it much easier for universities to get patents and license them to commercial firms. Following this change, the number of patents taken out by universities has exploded, from about 500 per year in 1980 to about 2,000 per year today. The motivation for the policy change was to increase the rate of technology transfer from universities to the private sector. The increase in the number of patents suggests that the policy was enormously successful. However, because patenting is now so much easier for universities, one wonders whether inventions in the current flood of patents are comparable in technological significance to those patented when doing so was more difficult. In another paper, Henderson, Trajtenberg, and I show that, according to citation-based measures, the technological impact of university patents declined dramatically during the 1980s, suggesting that the effective increase in technology transfer has been significantly less than the raw patent numbers suggest.[3]

In recent work with Michael Fogarty and Bruce Banks, I applied a similar analysis to patents assigned to U.S. government research labs.[4] We found that, unlike university patents, federal labs' patents historically were less frequently cited than corporate patents, except for National Aeronautics and Space Administration (NASA) patents approved during the 1970s. The federal patents, particularly NASA patents, were somewhat more basic than corporate patents, as indicated by their "generality" or the dispersion of their citation effects across many areas of technology. This paper also includes qualitative analysis based on interviews with inventors in both the government labs and in firms. These discussions show that, although there is a lot of "noise" in citations data, there is a systematic relationship between citations and technological impact.

A related paper written with Ricardo J. Caballero integrates citations as evidence of research spillovers into the theoretical framework of New Growth Theory.[5] In the context of a general equilibrium dynamic growth model, we use citations to measure the cumulative impact of research on research productivity in subsequent periods. Our estimation of the model based on aggregate annual data suggests that a decline in the aggregate "fertility" of invention in the United States in the second half of this century was a factor in the productivity slowdown experienced in the 1970s.

Work in progress with Hall and Trajtenberg examines the relationship between the stock market's valuation of firms and the number of citations the firms' patents receive.[6] Preliminary results suggest that firms' possession of frequently cited patents is correlated with market participants' perceptions of the value of firms' knowledge stocks. Further analysis will explore the timing of these relationships, possible connections among citations, private returns to inventions, and obsolescence of technology as other firms develop competing technologies.

Patterns of Citations as Evidence of Paths of Knowledge Flows

Turning to the use of citations to trace the flows of knowledge spillovers, my 1993 paper with Henderson and Trajtenberg examines whether patent citations come from geographically proximate inventors. Because citations tend to come from inventors pursuing technologically related research, and inventors working in particular areas tend to be concentrated in certain locations, our analysis controls for the nonrandom geographic distribution of researchers working in particular fields. We also exclude self-citations, to limit the analysis to citations that might indicate spillovers. We find that at the levels of metropolitan areas, states, and the United States as a whole, citations are concentrated locally to a statistically significant extent, although the actual magnitude of the effects is rather modest.[7]

Trajtenberg and I have extended this analysis in two more recent papers.[8] Adapting the "citation function" formulation developed by Caballero and Jaffe, we examine the flows of citations across countries and time. We find strong evidence that citation flows are geographically localized, not only within the United States but also within the United Kingdom, France, Germany, and Japan. For example, even though we examined patents taken out in the U.S. patent system, patents from Japanese inventors are more likely to cite Japanese patents than German, French, or British patents; we find similar localization for all countries. We also find important time effects: citation localization is strongest in the first few years after a patent issues, and fades significantly over time. The results suggest strongly that, although knowledge eventually diffuses fully around the globe, inventors that work near important sources of new ideas benefit significantly sooner from their spillovers than do inventors that are farther away. We also find that self-citations arrive much more quickly than non-self-citations.

Overall, geographic localization is partly a result of self-citation at the level of individual firms, but it is still significant even after self-citations are eliminated.

Ongoing work will extend this research in several directions. We are preparing a survey of inventors to explore in more detail the relationships among patent citations, communication among inventors, research spillovers, and cumulative technological impact. We are also continuing to explore the finer detail of the geographic, institutional, and technological dimensions of the citation patterns. Because of the richness of the data, the potential range of research questions is large, including the following: What role do factors other than geographic distance (for example, language, culture, and economic ties) play in flows of knowledge around the globe? Do particular firms or kinds of firms play central roles in the flows of knowledge? Do particular kinds of research or technological fields generate measurably large spillovers? We are also pursuing further work linking patent citations to other economic observables, such as market value and productivity at the levels of firms, industries, and countries.

While I doubt that we will ever be able to measure "invention" or "knowledge" as well as we measure labor or even capital, I do believe that this line of research is gradually increasing our ability to give empirical content to economic constructs that play crucial roles in economic theory and economic life.

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[1] *M. Trajtenberg, R. Henderson, and A.B. Jaffe, "University versus Corporate Patents: A Window on the Basicness of Invention,"* Economics of Innovation and New Technology, *5, (1997), pp. 19–50. Also presented as "Telling Trails Out of School: University versus Corporate Patents and the Basicness of Invention," at the 1991 AEA Annual Meeting.*

[2] *This last idea has been carried further by Francis Narin, who has looked in detail at the citations to scientific literature in biotechnology patents and has shown close links to research funded by the U.S. National Institutes of Health and other basic research agencies. See F. Narin,* Linkage Between U.S. Patents and Public Science, *CHI Research, Inc., 1997.*

[3] *R. Henderson, A.B. Jaffe, and M. Trajtenberg, "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965–1988,"* Review of Economics and Statistics, *LXXX, 1, (February 1998), pp. 119–27.*

[4] *A.B. Jaffe, M. Fogarty, and B. Banks, "Evidence from Patents and Patent Citations on the Impact of NASA and Other Federal Labs on Commercial Innovation," NBER Working Paper No. 6044, May 1997. Forthcoming in the* Journal of Industrial Economics.

[5] *R.J. Caballero and A.B. Jaffe, "How High are the Giants' Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth" in* NBER Macroeconomics Annual, *Vol. 8, O. Blanchard and S. Fischer, eds. Cambridge, MA: MIT Press, 1993.*

[6] *B.H. Hall, A.B. Jaffe, and M. Trajtenberg, "Patent Citations and Market Value: A First Look," paper presented at the NBER Program Meeting on Productivity, March 6, 1998.*

[7] *For example, we found that about 6 percent of citations come from the same metropolitan area, compared to an expectation of about 1 percent based solely on the geographic concentration of inventors. A.B. Jaffe, R. Henderson, and M. Trajtenberg, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations"* Quarterly Journal of Economics, *Vol. CViii, (August 1993), issue 3, p. 577.*

[8] *A.B. Jaffe and M. Trajtenberg, "Flows of Knowledge from Universities and Federal Labs: Modeling the Flow of Patent Citations over Time and Across Institutional and Geographic Boundaries,"* Proceedings of the National Academy of Sciences, *93, (November 1996), pp. 12671–7; A.B. Jaffe and M. Trajtenberg, "International Knowledge Flows: Evidence from Patent Citations" NBER Working Paper No. 6507, April 1998.*

The Economics of Mass Migrations

Jeffrey G. Williamson*

The mass migrations that ended early in this century raise four fundamental questions: What explains them? How did they affect labor markets? Did their impact create a policy backlash? Does the experience offer lessons for today?

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Explanations for the Mass Migrations

Almost 60 million Europeans left for the New World during the half century or so prior to World War I. This impressive figure would be even higher if it included the Italians who went north, the Poles who went west, the Irish who went to England, and the other European migrants who sought better lives within Europe. Although wars, pogroms, religious discrimination, ethnic cleansing, and racist restrictions played important supporting roles, the prime motivation for these migrations was economic fundamentals. One way those fundamentals were manifested was through self-selection. Overwhelmingly, the migrants were young male adults, the very people who are most sensitive to and who have the biggest impact on labor market events. Those economic fundamentals also were manifested by the timing of the mass migrations: when to move was driven by unemployment, business cycles, and industrial crises. But who moved and