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In this issue ...

Salting Economic Activity with Information

Information is a neat thing. In fact, it is a positively peculiar thing. For one, it does not conform to the usual laws of conservation. That is, it can be used over and over again with no deterioration or decay. It can be given to another yet it still resides with the giver. And unlike objects, information cannot be multiplied; a ton of steel can be added to another to make two tons of steel, but learning the same fact twice is no different from knowing it once.

So why the concern with information? Simply put, the accumulation of appropriate information is called knowledge, and knowledge is key to economic activity. For instance, knowledge is needed to know how to produce goods or how to locate markets where the goods can be sold. Investors acquire knowledge about products and marketing plans when deciding to invest. Consumers acquire knowledge about prices, contents or use when making their purchasing decisions. Information and experience, or acquired knowledge, are used in every facet of every economic transaction.

Knowledge is the common thread binding together the articles in this issue. Jeffrey Bernstein and Surendra Gera, Wulong Gu and Frank Lee touch upon new ideas and knowledge developed abroad, and their impacts on productivity in Canada. Nathan Rosenberg discusses the relationship between rapid technological change and productivity growth. Wayne and Robert Clendenning summarize the knowledge and experience gained in the evolution of international and national dispute settlement mechanisms, and they suggest how that knowledge can be applied toward improving the settlement mechanism under the Canadian Agreement on Internal Trade. Kenneth J. Arrow speaks at length about information and its role in the context of a theory of innovation. Richard R. Nelson discusses the patenting and licensing of ideas and knowledge developed by university researchers. Finally, David Aschauer contributes to our knowledge by presenting the results of his research on public infrastructure.

Industry Canada   Industrie Canada

INDUSTRY CANADA RESEARCH AND PUBLICATIONS PROGRAM

RECENT RELEASES

WORKING PAPER SERIES

No. 20: *Information Technology and Labour Productivity Growth: An Empirical Analysis for Canada and the United States*, Surendra Gera, Wulong Gu, and Frank C. Lee.

This study examines the relationship between investment in information technology (IT) and labour productivity growth for Canada and the United States, emphasizing the role of domestic and international R&D spillovers from the IT sector.

No. 21: *Capital-embodied Technical Change and the Productivity Growth Slowdown in Canada*, Surendra Gera, Wulong Gu, and Frank C. Lee.

This paper investigates whether the relative aging of Canada's capital stock, or the vintage effect, has played an important role in the post-1973 productivity growth slow-down.

FORTHCOMING

WORKING PAPER SERIES

No. 23: *Restructuring in Canadian Industries : A Micro Analysis*, Sunder Magun.

OCCASIONAL PAPER SERIES

No. 20: *Aboriginal Businesses: Characteristics and Strategies for Growth*, David Caldwell and Pamela Hunt.

DISCUSSION PAPER SERIES

No. 6: *International Market Contestability and the New Issues at the World Trade Organization*, Edward M. Graham.

ANNOUNCEMENT

BRIEF SURVEY SO THAT WE MAY SERVE YOU BETTER

We are conducting a brief survey so that we may serve you better. Please fill out and return the survey form on page 15 of this issue. We thank you in advance for your participation.

MICRO is a quarterly newsletter highlighting micro-economic research findings, published by the Micro-Economic Policy Analysis Branch of Industry Canada. This edition was prepared under the general editorship of Mr. Rick Cameron. Mr. Gilles Mcdougall has also contributed to this issue. Abstracts of Industry Canada research volumes, and the full text of working papers, occasional papers, discussion papers, and MICRO can be accessed via STRATEGIS, the Department's online business information site, at http://strategis.ic.gc.ca. For more information about our research publications, or to place an order, contact the Micro-Economic Policy Analysis Branch, Industry Canada, 5th Floor, West Tower, 235 Queen Street, Ottawa, ON, K1A 0H5. Telephone: (613) 952-5704; facsimile: (613) 991-1261. ISSN 1198-3558.

Spillovers from American R&D reduce Canadian manufacturing costs more so than domestic R&D spillovers.

FEATURED RESEARCH

R&D SPILLOVERS: A NET BENEFIT FOR CANADA?

In a recent Industry Canada working paper*, Jeffrey Bernstein investigates the public good aspect of research and development capital accumulation, focussing on the extent of inter- (between) and intra- (within) industry R&D spillovers from U.S. to Canadian industries. In particular, there are R&D spillovers that involve the transmission of knowledge between industries and nations. Because the benefits of R&D efforts cannot be completely appropriated by whoever performs it, those benefits spill over to other producers. Thus a country's stock of knowledge depends on its own R&D investment as well as the R&D investment of other nations.

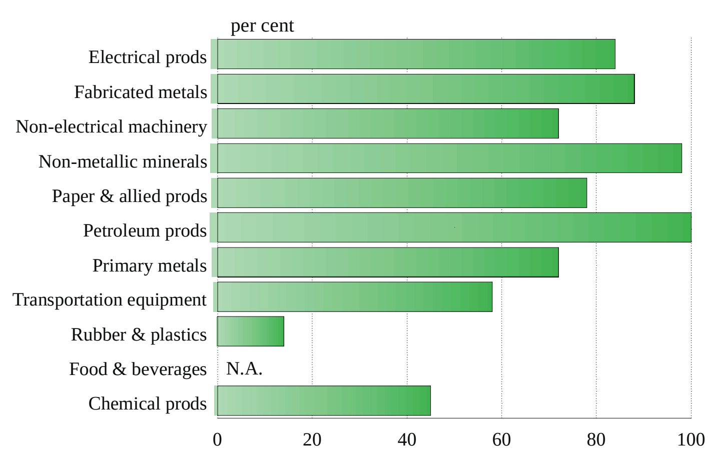
Mr. Bernstein describes three sources of R&D spillovers for Canada. First are domestic inter-industry spillovers — that is, spillovers from other domestic producers. The next source is intra-industry spillovers from the United States (i.e., from American to Canadian producers in the same industry). The third source is inter-industry spillovers from the United States (from American producers in other industries). The effects of spillovers are estimated over the period 1966-1991 for eleven Canadian manufacturing industries: chemical products, electrical products, food and beverages, fabricated metals, non-electrical machinery, non-metallic minerals, paper and allied products, petroleum products, primary metals, rubber and plastics, and transportation equipment.

Spillovers have effects on production costs, factor intensities (i.e., inputs per unit of output) and productivity growth. Mr. Bernstein finds that in eight of the industries examined, there are no significant U.S. inter-industry spillovers. For the remaining three industries (food and beverages, fabricated metals, and rubber and plastics), U.S. spillovers are both inter-industry and intra-industry. This, he argues, is hardly surprising; international links tend to be stronger within an industry rather than across industries. In addition, as domestic inter-industry spillovers are influenced by U.S. spillovers in the same industry, U.S. inter-industry spillovers are indirectly related through Canadian spillovers.

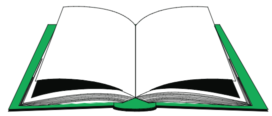
As for R&D spillovers from domestic sources, Bernstein interprets the results as implying that a majority of Canadian manufacturing industries are becoming more knowledge-intensive. He names two reasons for the increase in knowledge intensity: First, knowledge diffuses between Canadian industries through inter-industry spillovers. Second, in response to these spillovers, industries increase their own R&D intensities.

The general conclusions emerging from the results on foreign R&D spillovers from the United States suggest that U.S. spillovers reduce Canadian manufacturing costs, and these reductions exceed the effects from domestic spillovers. This means that efficiency gains from spillovers originating in the United States dominate efficiency gains from domestic spillovers. In addition, U.S. spillovers increase capital intensities and reduce the non-capital input intensities in Canadian manufacturing industries. In response to growing spillovers from the United States, production structures become relatively more

Contribution of U.S. intra-industry R&D spillover effects to Canadian TFP growth: 1966-1991



IT investments and international spillovers, particularly those embodied in imports of IT goods, contribute to higher labour productivity growth in Canada.



intensive in physical and R&D capital, and relatively less intensive in labour and intermediate inputs.

Finally, Mr. Bernstein turns his attention toward determining the contribution of R&D spillovers to total factor productivity (TFP) growth rates. To this end, the author decomposes TFP growth rates into a returns-to-scale effect and a spillover effect.

Mr. Bernstein finds that U.S. same-industry spillovers are the principal reason for productivity gains in a majority of Canadian manufacturing industries. Spillovers (more broadly defined) are also the main contributors to TFP growth in the remaining industries, with the exceptions of chemical products and of food and beverages — where output growth, through scale, dominates the elements of TFP. Even in these industries, however, the U.S. spillovers contribute to productivity growth.

** Inter-Industry and U.S. R&D Spillovers, Canadian Industrial Production and Productivity Growth*
Working Paper # 19
By Jeffrey I. Bernstein

DOES INFORMATION TECHNOLOGY ENRICH PRODUCTIVITY?

The implications of information technology (IT) for productivity growth have given rise to considerable debate. There is little empirical evidence that IT capital has contributed to increases in output and productivity growth, and this has led to a debate about the so-called "productivity paradox." The issue is further magnified by the inroads made by the information revolution and the forces of globalization throughout the industrial and even the developing worlds.

Communications and information processing costs have fallen markedly, and this has spurred and deepened globalization. The internationalization of business activities has, in turn, driven technological change by intensifying competition and accelerating the diffusion of technology through trade and foreign direct investment.

Against this background, a recent Industry Canada working paper by Surendra Gera, Wulong Gu and Frank Lee examines the relationship between IT investment and labour productivity growth for Canada and the United States, emphasizing the role of domestic and international R&D spillovers from the IT sector.

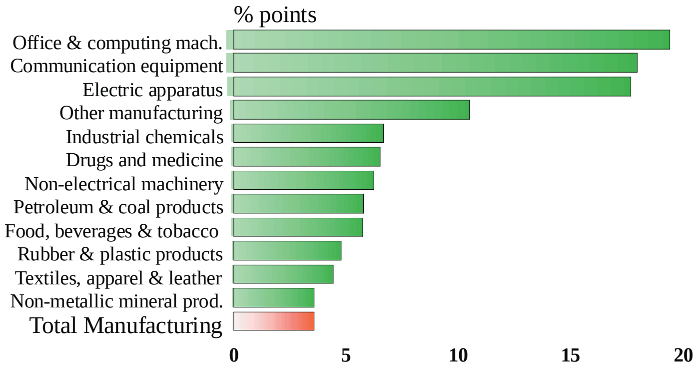
The authors document the underlying trends of IT investment and R&D in Canada and the United States. In both countries, the share of IT investment has increased in the last two decades, with the bulk of the increase being in the services sector. The authors note that the extent of IT investment is much lower in Canada than in the United States. Canada also lags behind the United States in terms of IT investment rates in virtually all industries, except for transport and communications industries. Moreover, the R&D investment rate is much lower in Canada than in the United States. However, when measured by total technology intensity, the gap in technological sophistication between industries in the two countries is smaller than the direct R&D investment rates would suggest. Here, total technology intensity includes direct R&D, R&D embodied in purchases of domestic goods, and R&D embodied in purchases of imported goods. This is simply due to the fact that embodied R&D, or acquired technology, represents a much larger share of total technology intensity in Canada than in the United States. Finally, the share of IT in total acquired technology is increasing in Canada but declining in the United States.

To assess the importance of these underlying productivity factors, the authors relate labour productivity growth to IT investment and measures of technology, such as performed R&D and R&D spillovers. In the latter case, they differentiate between IT-producing industries (i.e., computers and office machines, and communications equipment) and other (i.e., non-IT) industries.

Messrs. Gera, Gu and Lee find strong support for the proposition that IT investments and international

Interprovincial trade in Canada is greater than that between similarly-sized and -spaced American states.

Change in the Share of Real IT Investment in Manufacturing Industries, Canada, 1971-90



spillovers, particularly those embodied in imports of IT goods, contribute to higher labour productivity growth in Canadian industries. The private rates of return on IT investments are found to run between 27 and 36 per cent annually. The results on the U.S. side are generally consistent with the Canadian results, although somewhat less robust. Further, international R&D spillovers are much more important than domestic R&D spillovers in Canada, and international R&D spillovers embodied in IT imports are more important than those embodied in non-IT imports in their contribution to productivity growth.

However, the authors caution that the existence of large international spillovers should not be interpreted as suggesting that they are substitutes for domestic R&D. It is quite possible that own R&D and R&D spillovers are complementary, meaning that firms must invest in their own R&D to benefit from R&D by other firms and from R&D in other countries. They conclude that the significance of IT investments and large international R&D spillovers embodied in IT imports for productivity growth in Canada suggests that industrial and commercial policies should increasingly focus on these industries to help Canadians capture new ideas and knowledge developed abroad and to improve their competitive position.

* *Information Technology and Labour Productivity Growth: An Empirical Analysis for Canada and the United States*
Working Paper Series # 20
by Surendra Gera, Wulong Gu, and Frank C. Lee.

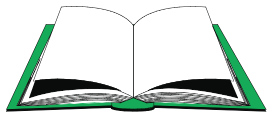
CREATING TRADE DISPUTE SETTLEMENT MECHANISMS

The Agreement on Internal Trade (AIT) is the obvious means for liberalizing trade, investment and knowledge flows, and for improving labour mobility within Canada. The AIT has come into existence in the face of persistent difficulties in strengthening Canada's economic union. Our constitution contains provisions for the regulation of interprovincial trade in goods but is silent on trade issues involving non-tariff barriers, capital, services or labour, each of which has been the focal point of many interprovincial trade flow restrictions.

To be sure, Canada has already achieved a great deal of internal harmonization and interdependence in trade, fiscal policy and legal systems. According to statistics, interprovincial trade, including exports and imports, is sizable (amounting to more than $314 billion in 1995, for example). Trade among ourselves is much greater than that between similarly-sized and -spaced U.S. states. However, a great deal more can be done to further liberalize trade. Calls for renewed efforts to strengthen our economic union, along the lines of intergovernmental commitment to free trade, have marked the political landscape from time to time, reaching a zenith in the early 1990s.

From this environment Canada's Agreement on Internal Trade was borne. The round of negotiations leading to the signing of the AIT sought to address all existing interprovincial trade barriers at the same time. The Agreement contains provisions for dispute settlement. The procedures derive largely from those in the GATT/WTO framework and under the NAFTA, so we can be sure of a well-founded approach with strong credibility in dispute resolution. But look again! There is much more to the dispute settlement mechanism established under the AIT than meets the

Some areas of the Agreement on Internal Trade may not be sufficiently developed to provide the criteria and rationale for dealing with certain types of disputes.



eye, argues E. Wayne Clendenning and Robert J. Clendenning. To a large degree, the AIT is still a work in progress, and there is considerable scope for improvement in the area of dispute settlement through further negotiation and agreement. This is the central tenet of a recent study by the Clendennings, in which they examine recent developments and changes to international and national dispute settlement mechanisms and their implications for the dispute settlement mechanism entrenched in the Canadian Agreement on Internal Trade.

Five examples are contrasted: the European Union (EU) model, the World Trade Organization (WTO) prototype, the Canada–United States Free Trade Agreement and its successor the North American Free Trade Agreement (FTA/NAFTA) mechanism, the Australian constitution design, and the existing dispute settlement mechanism entrenched in the Canadian Agreement on Internal Trade. The international mechanisms, in particular, have evolved in response to new requirements imposed on them, to increased globalization of the activities of individuals and firms, and to the experience gained through operation of the mechanisms over the years. At their most fundamental level, the task of all the international agreements is to prevent slippage back to unilateralism, and to lessen temptations to manage rather than liberalize trade. Meeting the challenge involves designing and fine-tuning a dispute settlement mechanism that strikes a balance between credible enforcement and informal dispute resolution.

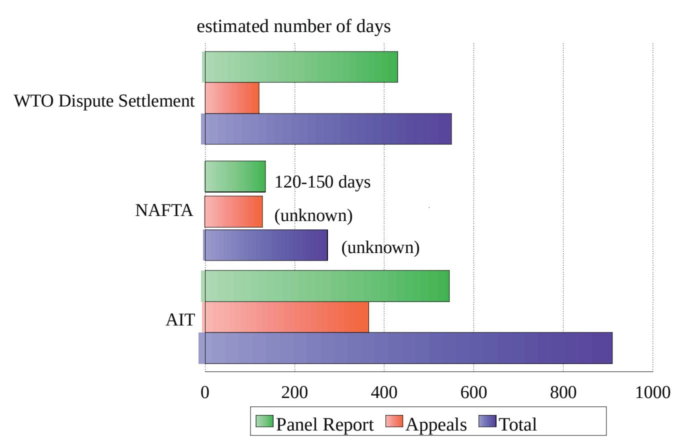
Substantial differences have emerged in the structure and operation of the various mechanisms; these range from court-based mechanisms, with very legalistic structures and procedures, to more informal panel-based systems. Of the international dispute settlement models, all (save that of the EU) rely on panel-based systems.

The effectiveness of a dispute settlement mechanism depends on four crucial factors: its scope for dealing with disputes across a wide range of economic activity; the frequency of its use; the credibility of its decisions and rulings; and its ability to enforce compliance with decisions and rulings on the part of the parties to a trade dispute.

Several changes in the evolution of dispute settlement from the GATT to the WTO have implications for the future development of the AIT mechanism. The GATT mechanism had not been applied to services prior to the Uruguay Round. Although the AIT has the scope to deal with disputes over trade in both goods and services, some areas of the Agreement may not be sufficiently developed to provide the criteria and rationale for dealing with certain types of disputes, such as those pertaining to trade restrictions arising from the application of non-harmonized government regulations.

The WTO mechanism also represents a shift toward a rules-based system, one that removes ambiguous and loose terms and replaces them with specific guidelines for various stages of the process. A uniform approach to disputes in all sectors, the principle of automaticity in the formation of panels, the adoption of reports, and retaliation rights are other positive changes. The WTO has addressed the issue of bias and panelist impartiality by ensuring that there are no improper relationships between disputants and panelists. Another key feature is a new Appellate Body to hear appeals against rulings by panels. It is suggested that these leading-edge developments in the WTO should be considered in examining ways of improv-

Comparison of timeliness in resolving trade disputes between parties



There is room to increase the level of public capital spending and still obtain substantial positive effects on economic growth.

ing and strengthening the AIT dispute settlement mechanism.

A number of changes instituted at the time of establishing the NAFTA mechanism parallel developments in the WTO mechanism, particularly with regard to the automaticity of the process and the selection of panelists. These developments again highlight the need to reconsider the AIT, argue the authors.

In addition, the EU and Australian mechanisms offer further lessons for the AIT, in particular the wider access granted to businesses and individuals. More direct access to the mechanism can ensure broader support for it among voters, and can place more pressure on governments to ensure its effective operation and use. Australia's efforts to develop less formal alternatives to the court system for dealing with disputes should also be kept in mind as we examine ways of improving and strengthening the AIT mechanism.

** Analysis of International Trade Dispute Settlement Mechanisms and Implications for Canada's Agreement on Internal Trade*
Occasional Paper Series # 19
by E. Wayne Clendenning and Robert J. Clendenning

DISTINGUISHED SPEAKERS SERIES

DAVID ASCHAUER BUILDS A CASE FOR PUBLIC INFRASTRUCTURE

The true contribution of public capital expenditures to long-term economic growth has yet to be determined, says David Aschauer, who is the Elmer W. Campbell Professor of Economics and Chairman of the Department of Economics at Bates College in Lewiston, Maine. In a recent Distinguished Speakers in Economics presentation, Professor Aschauer shared with Industry Canada staff the results of his research on the importance of public capital in the long-run performance of the economy.

There are two broad approaches to linking public infrastructure movements to productivity movements — simple deterministic (or static) modelling and higher-order dynamic modelling — and several methodologies for estimating this link, says Dr. Aschauer. First, the most common technique is via the production function. Here, one estimates the sensitivity of productive output to changes in public infrastructure, or what economists call the output elasticity of public capital, and then multiplies this estimate by the change in the growth rate of public capital in order to obtain the portion of change in productivity ascribed to changes in public infrastructure. However, cautions Aschauer, there are problems with directly linking public infrastructure and private production via this approach.

Alternatively, there are cost function and profit function approaches, where output is used as an additional explanatory variable in estimating the impact of public capital on costs of production or firm profits.

In a review of the literature, Professor Aschauer pointed out that many styles of estimation had been used. For example, various studies for various countries have used time series data, panel data and even data at national, state and metropolitan levels. The results are not always clear-cut. He noted that a handful of studies using the production function approach have found no effect of public infrastructure on output. However, both cost and profit

The growth-maximizing level of public capital is approximately 60 per cent of the level of the private stock of capital.

approach studies have unambiguously found an important role for public capital in economic performance.

The static approach, as outlined above, does not give much information about the true importance of public capital to long-term economic growth, employment and other important economic variables, asserts Professor Aschauer. While they signify that public capital is an important determinant of economic performance, they still leave open the question of the dynamic effects of an increase in public capital investment. Exactly what happens over time to transitional growth rates as the economy departs from one steady state and moves toward another?

It is possible, continues Aschauer, that relatively small initial impacts of public infrastructure on output or costs/profits may have very large impacts on the levels of productivity or per-capita income if the initial public capital shock has a very high persistence effect on the economy. It is therefore important to unscramble the initial effect and the persistence effect when looking at the impact of infrastructure on the economy.

Professor Aschauer reports that his current research involves a three-pronged attack on the problem. The first objective is simply to separate the impacts of the initial effects from the persistence effects. The second objective is to allow other important factors of production to fall under the microscope — for example, not only to look at the impact of public capital on output, income or productivity, but also to examine the potential impact on employment growth. There are non-linear impacts to be examined as well. To accomplish this, he presented a simple two-equation dynamic model incorporating more complex relations between certain variables.

- *Various studies for a number of countries have almost unambiguously found an important role for public capital in economic performance.*
- *It is possible that relatively small initial impacts of public infrastructure on output may have very large impacts on the level of productivity.*
- *Permanent increases in public capital lead to permanent increases in the levels of output and employment.*
- *The cumulative effects of public capital are significantly reduced once the source of funding is taken into account: initial growth rates are diminished and convergence is quicker.*

The non-linear relationship between public capital and output/employment implies a growth-maximizing level of public capital, states Dr. Aschauer He finds that the growth-maximizing level of U.S. public capital is estimated at approximately 60 per cent of the level of the private capital stock (for both output and employment). However, the actual level of U.S. public capital stock is about 45 per cent of private capital stock. This suggests that there is room to increase the level of public capital spending and still obtain substantial positive effects on economic growth, concludes Professor Aschauer. He also notes that permanent increases in public capital lead to permanent increases in the levels of output and employment.

In conclusion, Dr. Aschauer reports that the cumulative effects of public capital are significantly reduced once the source of funding is taken into account. Public capital must be financed by debt and/or taxes, and both have adverse effects on the level of economic performance: initial growth rates are diminished and convergence is quicker.

The most important of "inventive" activities may be the invention of new uses for technological capabilities that have already been invented.

NATHAN ROSENBERG TALKS ABOUT REASONABLE EXPECTATIONS FROM TECHNOLOGY

Whatever happened to those jet packs, robot dogs, Mars colonies and 15-hour work weeks that were just around the corner back in 1965? Why did the prognosticators of the 1960s miss the personal computer, the fax machine and the Internet? Scientists seem poor at predicting future innovations, and economics is much less exact than physics. In a recent Distinguished Speakers in Economics presentation, Nathan Rosenberg, who is the Farleigh S. Dickinson, Jr. Professor of Public Policy at Stanford University, spoke about the difficulties in explaining and forecasting connections between technological progress and productivity improvements.

There are several key reasons why we do not see high rates of productivity in association with rapid rates of technical change, says Dr. Rosenberg. In a brief review of the major technologies of the 20th century, he notes that for some technologies there were uncertainties of a purely technical nature. In other words, no one was certain that the actual technology itself would work. For instance, no one was certain whether heavier-than-air flight was even possible until the Wright brothers actually did it. Not only have there been huge uncertainties at the outset concerning applications, but those uncertainties have persisted even after the technologies have been around for several decades or more, maintains Rosenberg.

- *New technologies generally enter the marketplace in rather primitive form; to understand their eventual impact on productivity, it is necessary to understand their trajectory of later improvement.*
- *Some new technologies have a special feature that when combined with some other separate technology powerfully strengthens the effectiveness of one of them and sometimes the combination of the two provides a platform that opens a new realm of commercial possibilities.*
- *For some technologies, there are uncertainties of a purley technical nature; not only have there been uncertainties at the outset, but those uncertainties have persisted sometimes for decades or more.*

New technologies generally enter the marketplace in rather primitive form; to understand their eventual impact on something as fundamental as productivity, it is necessary to understand their trajectory of later improvement, says Professor Rosenberg. The situation is further complicated because some new technologies have a special feature that sometimes has especially powerful economic consequences. Sometimes two previously separate technologies can be combined in a way that will powerfully strengthen the effectiveness of one of them; sometimes the combination of the two provides a platform that opens a whole new realm of commercial possibilities. In economic terms, there is a relationship of complementarity in that an improvement in one technology will enhance the performance of (and presumably the demand for) the other technology. Economists call these general-purpose technologies, or GPTs. Consider that when the electronic digital computer became available in 1945, it faced poor prospects since its operation was dependent on the vacuum tube and the inherent problems associated with having thousands upon thousands of vacuum tubes all operating at the same time. The great cyber-revolution came some 15 years later, when the electronic transistor was incorporated into computers as a substitute for the vacuum tube. That substitution initiated a striking synergy between two separate and apparently unrelated technologies, and has since opened new realms of technological and commercial opportunities where none had existed before.

Only a few technologies are members of the small, exclusive club of GPTs. Among them, according to Professor Rosenberg, are the steam engine, machine tools, *Economists have been too preoccupied with the generation of new technologies and not concerned enough with how they might subsequently be utilized.*

electricity, transistors and computers. He believes that laser technology is on the way to joining this elite group.

GPTs provide opportunities for other technologies to build on them. They may thus have a critical role in productivity growth. While the underlying technology and scientific principles are common to all applications, it is difficult to link the specific characteristics of the technologies to a variety of economic and social contexts where they could provide platforms for innovative activity in both products and services. Nonetheless, a GPT makes possible an increase in the productivity of research and development conducted in downstream sectors of the economy. As the GPT advances, it enlarges the range of opportunities for other downstream applications, and the awareness of such possibilities has a feedback effect on the incentives for performing R&D in the GPT sector and in the downstream sectors. In other words, there is dynamic interaction between research at the GPT level and in the application sectors. The possibilities for pervasive use of a GPT become a basis for eventual widespread improvements in productivity.

According to Professor Rosenberg, the most important of "inventive" activities may be the invention of new uses for technological capabilities that have already been invented. This is the essence of all GPTs, he says. It implies that the widespread diffusion and, therefore, the productivity impact of GPTs depends on the success of the research that is directed toward the development of specific applications.

History shows that the process takes a very long time, maintains Dr. Rosenberg. Using electricity as an example, he suggests that it took about 40 years before the commercial availability of electricity had been translated into measurable productivity improvements in the United States. The key complementary invention at that time was the electric motor, which was central to the electrification of the factory as well as of so much else. This suggests that the benefits of computers (i.e., their impacts on productivity) may be around the corner, he says. It has been about 25 years since the invention of the microprocessor, the key complementary invention of the computer.

Still, there are other explanations for why productivity improvements aren't more apparent, adds Dr. Rosenberg. For one, standard measures are much better at capturing cost reductions than capturing quality improvements. Established procedures fail to capture the impacts of new products in a timely fashion, specifically the large price declines and associated productivity improvements that typically occur in the early stages of the product cycle. Prevailing practices measure the price of goods without taking adequate account of the increasing volume of services that flow from such goods. Moreover, the economy to which standard measures are being applied is now overwhelmingly a service economy and not a manufacturing economy, and the application of established procedures to this new regime is far more complex and subtle than their application to a manufacturing economy. Finally, he believes that a large part of the unmeasured productivity improvement is being taken in the form of consumers' surplus; in other words, the competitive process in a high-tech world is providing much greater access to a wider variety of consumer goods and services than otherwise would be the case, and is driving down the price of many goods and services so that consumers are able to acquire them for a good deal less than they would otherwise be willing to pay.

The concept of GPTs is pointing to certain conclusions, suggests Professor Rosenberg. First, economists have been too preoccupied with the generation of new technologies and not concerned enough with how they might subsequently be utilized. And they have underestimated the degree of complexity of the problem in its relation to the measurement of productivity.

The concept of information as a component of the economic system is really quite old.

KENNETH J. ARROW ON THE PERSISTENCE OF INFORMATION

It is a mistake to think that we are in a peculiarly information-driven era of unprecedented character, asserts the 1972 winner of the Nobel Prize for Economics, Kenneth J. Arrow of Stanford University. The concept of information as a component of the economic system is really quite old. For millennia, back at least to the domestication of animals, we have seen steady changes in the way the economic system functions — the outputs produced, the inputs needed — as the result of an accumulation of knowledge, with the most conspicuous examples being innovations. Moreover, at least since the Industrial Revolution, the flow of information has been accelerating.

So why is information important, asks Professor Arrow? His answer is multi-faceted. Information is important because it enables us to predict the future better or have better control over possibilities. It has commodity-like properties: it is costly to produce and it has value, in that others may be willing to pay for it. Yet information also has properties that a standard economic commodity does not have: it can be given to another but still remains in its entirety with the giver, and it can be used over and over without being diminished.

Information about technology is but a small fraction of the information continuum, cautions Professor Arrow.

- *Information is important because it enables us to predict the future better or have better control over possibilities.*
- *There are several types of information. For example, there is technical information, information relating to the operating of economic systems, routine or repetitive information, and tacit knowledge.*
- *Information has both commodity-like properties and properties that standard economic commodity does not have.*
- *The cost of obtaining information to a given level of precision is independent of the scale at which one operates; the benefits, however, depend on the scale of the investment.*

Several types of information may be differentiated. For example, there is technical information, used in the production of goods. There is also information relating to the operating of economic systems, such as locating markets and knowing the forward and backward links in the market chain. Another example is routine or repetitive information, such as hockey, baseball and other sports statistics.

Distinguishing between the various types of information is necessary when thinking about a theory of innovation, declares Professor Arrow. He admonishes much of the current literature on information and the knowledge-based economy for not making these distinctions. According to Arrow, many commentators are mixing concepts: they confuse the knowledge needed for new products or processes with the ability to transmit routine knowledge. If one thinks about the so-called information industries of today, such as telecommunications, the bulk of the information transmitted over channels is new, he says, but it is repetitive or routine knowledge rather than innovation. An implication is that one further type of information — tacit knowledge — is not transmittable. Tacit knowledge is a form of knowledge that is largely inexpressible and comes from learning-by-doing and from experience.

The role of information in economic behaviour was the subject of a recent Distinguished Speakers in Economics presentation by Professor Arrow. He gave his thoughts on a framework for the demand for information, and its implications for the acquisition and use of information by an individual. Essentially, the demand for information is dependent on the choice of signal to observe — in other

One of the implications of the role of information is the presence of increasing returns.

words, on how much information one wants. This choice, in turn, is influenced by factors such as the process and the cost, which govern the payoff from acquiring the information.

If one has to buy information, because it can be used over and over again, it affects behaviour, says Professor Arrow. Thus, one of the implications of the role of information is the presence of increasing returns. For example, consider the use of information in the selection of investment portfolios when an individual is allocating her assets among a number of securities. In this case, the individual can devote some of her resources to acquiring information, specifically information about the probability of payoffs from different securities. Of course, if the investor knew which security was going to pay off, she would know where to invest. She does not know this but she may alter the probability distribution by acquiring a signal (i.e., information) before making the investment.

Moreover, in a certain sense, continues Professor Arrow, there are increasing returns to scale, where scale represents the amount of initial assets. This is because investors get improved accuracy at improved cost. Thus, if one investor has a greater bundle of assets than another investor, he can achieve greater accuracy and hence can invest better simply by spending the same proportional amount of his initial assets as the investor with fewer initial assets. He will then have devoted more resources, in absolute amounts, to obtaining signals. This, in turn, implies increasing returns to scale. In other words, the cost of obtaining a given level of precision is independent of the scale at which one operates; the benefits, however, depend on the scale of the investment. It follows that initial inequalities in the distribution of income could be exacerbated by the acquisition of information because those with more to invest in acquiring information will benefit much more from the additional investment.

RICHARD R. NELSON EXPLAINS THE UNIVERSITIES' LICENCE TO PATENT

Universities have long cultivated the image of bastions of pure research, unfettered by concerns about practical applications. Not true, counters Richard R. Nelson, who is George Blumenthal Professor of International and Public Affairs at Columbia University. According to him, the view of the university as an ivory tower is largely a myth. Significant numbers of American universities have traditionally been involved in research with quite practical objectives, and many have had close links with industry for quite some time. This has been the case especially with the Land Grant universities and their agricultural experimentation stations, as well as with medical and engineering schools.

Still, the ivory tower image has persisted, and with some justification: before 1980, American universities together were awarded fewer than 250 patents per year, or less than 1 per cent of total U.S. patents. However, over the past 15 years or so, the rate of university patenting has increased greatly. Today the number exceeds 1500, or about 2.5 per cent of the total, and the figure still seems to be rising. Moreover, he adds, there is now in place an institutional infrastructure, known as technology licensing and transfer offices; these screen patentable material, apply for patents, and license innovations coming from university research.

In a recent Distinguished Speakers in Economics Program presentation, Professor Nelson gave the results of his study on the reasons for this significant increase in university patenting and rising university-industry interactions. He identifies two key factors concerning intellectual property rights. First, is the Bayh-Dole Act of 1980. Prior to this legislation, there was a general assumption that the social benefits of government-funded research at U.S. universities would be maximized if the results were placed in the public domain through open publication. Among the main arguments that led to Bayh-Dole was the assertion

The Bayh-Dole Act is a major factor behind the rise in patenting and licensing activity at American universities.

that when research findings or embryonic inventions were placed in the public domain, industry had no incentive to develop and commercialize them. Though the case for this argument was weak and unnuanced, it carried the day, noted Dr. Nelson. After Bayh-Dole, the assumption and expectation has been that universities would aggressively patent and license to give incentives for commercial application.

Bayh-Dole was representative of a broader movement in U.S. public law bearing on intellectual property rights. For some time, legal protection of software has also been reinforced.

The second key factor concerning intellectual property rights was a key court decision: Diamond v. Chakrabarty, 477 U.S. 303 (1980). This established that the results of biotechnology research were patentable. A considerable share of university patenting and licensing is in this area.

Added to these factors were fears that the era of large-scale, relatively unconstrained government research funding was drawing to a close. In fact, the overall proportion of government-funded university research did decline, from around 65 per cent in the early 1970s to 60 per cent in 1995. But far from falling, absolute government funding rose, and in several areas significantly. However, such research support has increasingly been accompanied by the expectation that the results would quickly be commercialized; this was a change in emphasis from the earlier era. At the same time, both federal and state governments began to fund certain projects at universities, such as engineering centres, on the condition that business firms be actively involved in project selection or in overall evaluation of the program, or both.

Concurrently, many business firms were becoming more interested in research interactions with universities, for several reasons. Support of basic research in their own laboratories was becoming increasingly problematic because of intensified competition, particularly from foreign firms, and because of the U.S. companies' growing awareness that their competitors were often benefiting nearly as much from that research as they were; this made piggybacking on university research attractive, particularly if the companies could have some control over commercially usable results. New fields of university research were emerging that seemed to promise commercial payoffs to firms that could tap into them — for example, the development of electronic apparatus and/or software in biotechnology research.

The product of these multiple forces shows up in the university technology licensing and transfer offices as an invention reporting system. Researchers file a university invention report describing the innovation, its funding, its uses, etc. Professor Nelson summarized the Columbia University invention reporting system from its inception, dating back to Bayh-Dole. Columbia is ranked second among all U.S. universities in terms of licensing fees collected annually. Columbia has experienced a steep rise in the number of university invention reports since the 1980s, with many of the reports coming from the medical

- *Bayh-Dole and related forces are responsible for the formation of university technology licensing and transfer offices.*
- *Key changes to intellectual property rights affected software and biotechnology research, areas where a considerable share of university patenting and licensing takes place.*
- *After Bayh-Dole, the assumption and expectation has been that universities would aggressively patent and license.*
- *Federal and state governments began to fund certain projects on the condition that business firms be activley involved in project selection, evaluation of the program, or both.*
- *Piggybacking on university research has become attractive to business, particularly where companies have some control over commercially usable results.*

To the present, Bayh-Dole and related intellectual property rights changes have done no serious harm to fundamental research in American universities.

area. There was little patenting activity in the early 1980s but then it began to rise. By and large, the patent data follow the invention report data, with an average lag of about three years. Next comes licensing of the technologies, again with a lag on the patent data.

The evidence is conclusive that Bayh-Dole itself is a major factor behind the rise in patenting and licensing activity at Columbia and at other U.S. universities, says Dr. Nelson. Bayh-Dole had two effects: first, it dramatically altered the philosophy about what should happen to usable results from university research; and second, it helped set up the necessary machinery leading to the reporting of potentially patentable or commercially viable university innovations.

A key question is the extent to which Bayh-Dole has shifted the emphasis away from fundamental basic research. There is no indication of a slide toward applied research, according to publications in journals considered as basic research publications, finds Professor Nelson. And what of the success of Bayh-Dole in facilitating the transfer of technology? The answer is mixed; several technologies need further development before they can become commercially viable, whereas others are licensed widely and would have been picked up quickly no matter what. However, Bayh-Dole poses one potential obstacle to facilitating the development of new technologies, notes the Columbia academic. With intellectual property rights moving further and further into the realm of science (e.g., in research techniques), the potential exists for raising the transaction costs of doing science if university researchers have to obtain permission from intellectual property holders to use various types of techniques, materials and so on, which otherwise would have been in the public domain. This has not yet been a problem for university researchers but it is a looming threat, says Dr. Nelson. He concludes that, up to now, Bayh-Dole and the related changes have done no serious harm to research in American universities.

NOTES

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