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Innovation, Competition and Growth:

A Schumpeterian Perspective on Canada's Economy

Peter Howitt

In this issue...
To sustain growth, Canada must engage in a never-ending process of economic development and transformation. To do so, new growth theory indicates that Canada should ensure that competition policy boosts innovation, beware of further extending patent protection, and welcome international trade and technological change.

The Study in Brief

The conflict between winners and losers from new technologies is a recurrent theme in economic history, as demonstrated by the fate of handloom weavers in the early 19th century or the former giants of mainstream computing in the 20th century. A new generation of growth theory, based on Joseph Schumpeter's concept of "creative destruction" yields a number of insights of surprising currency to Canadians.

The new growth theory sees a free enterprise economy as constantly shaken by technological innovations from which some people gain and others lose, an economy in which competition is a struggle and whose survivors are businesses that succeed in creating, adopting, and improving new technologies.

Thinking of economic growth in these terms drives several broad conclusions that matter to current policy debates:

- Competition policy should not be relaxed in hopes of boosting innovation, because more competition actually strengthens the incentive to innovate. Recent empirical work points to a positive relationship between product market competition and productivity growth or innovativeness within a firm or industry.
- Canada needs to be wary of further extensions of patent protection, which could serve to discourage innovation more than stimulate it. The more broadly we extend patent rights to include such things as software and genetic combinations, the more we discourage follow-on inventors and inhibit the flow of ideas.
- Without sacrificing academic values that sometimes conflict with commercial interests, Canadian universities should continue to develop ties with private enterprise, to see that innovative ideas turn into adopted technologies.
- Openness to international trade is crucial for keeping pace with global technological change, as is a favourable R&D environment, offering clear messages for trade and tax policy.
- The effects of innovation on income inequality can be mitigated by strengthening the educational system and reducing mobility barriers, implying that federal and provincial governments should examine their approaches to education, with close attention to fundamental analytical skills, and emphasize policies that support labour mobility.

Attention to the growth implications of policy choices remains crucial, because even tiny increases in long-run growth rates imply enormous economic gains.

The Author of This Issue

Peter Howitt is Lyn Crost Professor of Social Sciences at the Department of Economics, Brown University, Providence, RI.

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Concern over lagging growth in living standards over many years, growing awareness of the looming pressure of demographic change on government and private budgets, and the rise of vigorous new competitors in the world have turned Canadians' attention to the question of economic dynamism and the factors that support growth. Happily, a new generation of endogenous growth theory based on Joseph Schumpeter's concept of "creative destruction" yields a number of insights of value to Canadians. The new theory portrays a free enterprise economy that is constantly being disturbed by technological innovations from which some people gain and others lose, an economy in which competition is a Darwinian struggle whose survivors are those that succeed in creating, adopting, and improving new technologies. This Schumpeterian point of view is particularly relevant to the current Canadian and global situation, in which technological revolutions in information, communications, and biology are transforming national economies.

This *Commentary* discusses some of the insights that the new endogenous growth theory offers into contemporary issues. The discussion touches on competition policy, the protection of intellectual property, the role of universities in an economic system, domestic research and development (R&D) in a world of innovation and open borders, the importance of openness, globalization and the gap between rich nations and poor, the macroeconomic costs of technological paradigm shifts, and rising wage inequality.

The new theory leads to several broad conclusions that are relevant for current policy debates:

- Competition policy should not be relaxed in hopes of boosting innovation, because more competition actually strengthens the incentive to innovate.
- Canada needs to be wary of further extensions of patent protection, which could serve to discourage innovation more than stimulate it.
- Canadian universities should continue developing ties with private enterprise, but without sacrificing academic values that sometimes conflict with commercial interests.
- Openness to international trade is crucial for keeping pace with global technological change, as is a favourable R&D environment.
- The effects of innovation on income inequality can be mitigated by strengthening the educational system and reducing mobility barriers.

New Theories of Technology and Economic Growth

Economists traditionally have viewed the relationship between technology and the economy as a one-way street. Introductory economics textbooks tell the student that the state of technology forms part of the background conditions — for scientists and engineers to analyze, perhaps, but for economists to take as given. According to the neoclassical growth model of Solow (1956) and Swan (1956),

This paper draws on joint work with Philippe Aghion on all aspects of growth theory, with Gianluca Violante on growth and wage inequality, and with Christopher Harris and John Vickers on growth and competition. I thank Bill Robson for his valuable suggestions.

technological change has a profound influence on our well-being — indeed, the economy's long-run growth rate is determined exclusively by the rate of technological progress — but it emanates from a scientific process that operates outside the realm of economics.

This mainstream view of technology has never been accepted universally. In particular, specialists in economic history and the economics of technology have argued that technological progress comes in the form of new products, new techniques, and new markets, which do not spring directly from the scientific laboratory but come from discoveries made by private profit-seeking business enterprises. For example, the transistor, which underlies so much recent technological progress, was discovered by scientists working for AT&T on the practical problem of how to improve the performance of switch boxes that were using vacuum tubes.[1]

The New Growth Theory

Until 20 years ago, this dissenting view had little influence on the mainstream of economic thinking. Then came the introduction of "endogenous growth theory" by Romer (1986) and Lucas (1988), which showed that mainstream economics can be used to analyze the two-way relationship between economics and technology, including the feedback from the economy to technological change.

In the first generation of the new growth theory to enter the economics mainstream, technological progress is just another form of capital accumulation. That is, technological progress consists of the accumulation of knowledge, which is a kind of intellectual capital, much like physical or human capital except that it is not embodied in machines or people. Technological knowledge, like other forms of capital, can be accumulated with the expenditure of current economic resources (R&D expenditures) and can be used to augment future production possibilities.

In this theory, technological progress, like capital accumulation, arises from decisions to save. Some saving goes to finance the accumulation of physical and human capital, and some goes to finance the R&D that causes technological knowledge to accumulate. Thus, if society saves a larger fraction of national income, the pace of technological progress rises, permitting a higher rate of economic growth to be sustained indefinitely.

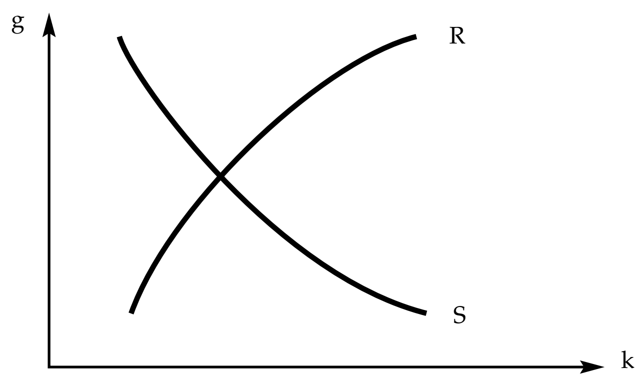
Besides bringing endogenous technological change into the mainstream of economics, the new growth theory revived interest in long-term economic growth as an objective of economic policy. The old theory presented a pessimistic view of what economic policy could do in this regard, arguing that, in the long run, economic growth is limited by progress in physics, biology, and engineering, rather than by economic forces. But the new growth theory says that an economy's long-run growth rate depends on people's willingness to save, which is very much affected by economic policy. Moreover, standard cost-benefit analysis shows that a policy that produces even a tiny increase in long-term economic growth can generate benefits whose discounted present value are enormous.

1 Rosenberg (1981) describes many other examples of scientific and technological breakthroughs that originated in profit-oriented economic activity.

A Simple Model of Endogenous Growth with Creative Destruction

Technically, a model of growth through creative destruction can be seen in terms of two long-run relationships between the rate of economic growth (that is, the growth rate of GDP per worker) and the amount of capital per efficiency unit of labour. (Here, I measure labour input not in hours worked but in efficiency units — hours times productivity.) One relationship, included even in the early Solow and Swan model, shows how much capital per efficiency-unit of labour the economy would end up with in the long run, given the rate of economic growth. In the figure, this is the downward-sloping “saving” curve S, which takes as given the economy’s propensity to save out of national income. A higher rate of growth would imply a faster rate of technological progress, and hence a faster-growing labour force measured in efficiency units. This, in turn, would imply a lower steady-state amount of capital per efficiency unit — a movement back up the curve to the left. An increase in the saving rate would shift the curve to the right, resulting in a higher steady-state capital stock per efficiency unit for any given long-run growth rate.

The Relationship between the Rate of Economic Growth (g) and the Stock of Capital per Efficiency-Unit of Labour (k): A Schumpeterian Explanation



The other relationship is the “research” curve R in the figure, which reflects the incentive to perform R&D. The assumption is that firms choose a level of R&D that maximizes the expected current value of their profits. This choice depends on the institutions, policies, and customs with respect to property rights, patent protection, competition policy, and so forth that affect both the costs of R&D and the expected profits from successful innovation. These factors are all assumed to be held constant along the R curve. The economy-wide level of R&D determines the flow of innovations in the economy, which, in turn, governs the rate of technological progress and, therefore, the long-run rate of economic growth.

Given the institutional and policy variables held constant along the R curve, an increase in the steady-state capital stock per efficiency unit of labour raises the incentive to perform R&D through a “scale effect.” That is, more capital per worker results in more production per worker, and hence more income per person, for any given level of technology (see Howitt and Aghion 1998). And when people have larger incomes, they spend more on newly invented products, which raises the incentive to perform R&D, and results in a faster rate of economic growth — a movement up the R curve. Likewise, any changes in institutions, policies, or other variables that affect the incentive to perform R&D shift the R curve, resulting in different rates of R&D and of long-run growth for any given capital stock per effective worker.

According to this theory, the long-run growth rate is determined by the intersection of the two curves in the figure. Thus, anything that strengthens the incentive to perform R&D, and hence shifts the research curve R upward, or anything that raises the economy’s propensity to save, and hence shifts the S curve to the right, will result in a higher long-run growth rate.

The New New Growth Theory

The first-generation endogenous growth theory portrays economic growth as basically a private activity: economies become richer in the same way an individual might, by saving at a rate determined by how thrifty they are. This simple theory is useful for many purposes, especially for analyzing government policies that affect national saving. But by portraying technological change as a uniformly beneficial process that raises everyone's standard of living, it ignores a critical social aspect of the growth process: technological change is a game with losers as well as winners.

From the handloom weavers of early 19th-century Britain to the former giants of mainframe computing in the late 20th century, workers' skills, capital equipment, and technological knowledge are devalued and rendered obsolete by the same inventions that create fortunes for others. The conflict between winners and losers from new technologies is a recurrent theme in economic history, and the difficulty of mediating the conflict presumably affects society's willingness to foster economic growth. Yet first-generation new growth theory supposes that growth will take place as if the conflict did not exist.

More recently, however, a second wave of endogenous growth theory has broken on the economics shore, which Philippe Aghion and I call *Schumpeterian theory* (elaborated in Aghion and Howitt 1998a). This new new theory emphasizes the distinction between technological knowledge and capital, and analyzes the process of technological innovation as a separate activity from saving. The new wave is explicit about who gains from technological progress, who loses, how the gains and losses depend on social arrangements, and how such arrangements affect society's willingness and ability to create and cope with technological change. (Box 1 describes a simple economic model that captures the essential features.)

The distinguishing feature of Schumpeterian theory is what Schumpeter called "creative destruction" — the process whereby each innovation creates some new technological knowledge that advances our material possibilities, while rendering obsolete some of the technological knowledge that was created by previous innovations. Creative destruction offers a new view of how competitive markets work, one that is more in line with the observations of such writers as Porter (1990), who see innovation, rather than price, as the main instrument through which firms compete. It sees economic growth as a social process bound up with policies, institutions, social customs, and many other phenomena that affect not only the incentive to save but also the incentive to create new knowledge and the willingness to adapt to change. Schumpeterian theory offers a new perspective on a number of important economic issues that interact with economic growth.

Thinking of economic growth in these terms sheds new light on a number of important policy issues that technological progress affects. The rest of this essay illustrates this different perspective by considering the effects of technological progress on six issues: competition policy, patent policy, higher education, globalization, technological revolutions and wage inequality.

Competition Policy and Economic Growth

Competition tends to align private and social objectives. Given enough competition and the absence of externalities, markets should produce socially efficient outcomes, because firms that do not serve their customers efficiently will lose out to those that do. On the other hand, competition can reduce or even destroy long-run economic growth. This is because, in many cases, the main reward to a successful innovator comes in the form of monopoly rents that a firm captures by learning how to supply something its competitors cannot, or at a cost competitors cannot match. Increased competition, however, reduces a firm's ability to capture monopoly rents and discourages the innovations that underlie long-run growth. Indeed, this is what the first generation of Schumpeterian growth models predicted.[2]

The available evidence, however, seems to contradict this prediction. Recent empirical work (for example, Nickell 1996; Blundell, Griffith, and Van Reenen 1995) points to a positive correlation between product market competition (as measured either by the number of competitors in the same industry or by the inverse of a market share or profitability index) and productivity growth or innovativeness within a firm or industry. Evidence also supports the view that product market competition is good for growth because it forces firms to innovate in order to survive (see Porter 1990). Moreover, economic historians have documented cases in which competition from a new technology spurred improvements in earlier technologies.[3]

This evidence sent theorists back to the drawing board. The result of their rethinking is a more sophisticated version of Schumpeterian theory that contains a variety of channels through which competition might, in fact, spur economic growth. The simplest of these channels involves barriers to entry. To the extent these barriers raise the cost to outside firms of introducing a new technology, they reduce both the incentive to perform R&D and the growth rate. Thus, to the extent competition is measured (inversely) by barriers to entry, it ought to be favourable to economic growth.

Consider next the role of agency costs that allow managers to operate businesses in their own interests rather than maximizing the owners' profits. When these costs are severe, competition can act as a stimulus to growth through a channel much like the "innovate or die" story Porter tells.[4] To the extent an increase in competition reduces the firm's flow of profits, it reduces the scope for managerial slack and forces managers to innovate more often. To paraphrase Hicks ([1935] 1982), competition stimulates innovation by depriving managers of the opportunity to enjoy a quiet life.

Another channel is incremental profits from innovation — that is, the difference between the profits of a firm that innovates and those of one that does

2 In terms of the figure in Box 1, an increase in the intensity of competition should shift the research curve R down, resulting in a lower growth rate.

3 See, for example, Harley's (1973) analysis of the "sailing-ship effect."

4 Aghion, Dewatripont, and Rey (1999) describe a world in which each firm is controlled by a manager who is interested primarily in minimizing effort, but who wants the firm to remain solvent in order to continue enjoying the nonmonetary benefits of control. Since innovation takes effort, the manager will innovate only as often as needed to remain solvent.

not (see, particularly, Aghion et al. 2001). In the basic first-generation Schumpeterian model (Aghion and Howitt 1992), such a distinction does not arise because, in equilibrium, all important innovations are made by outside firms, since they do not internalize the losses generated by their own creative destruction. For firms that are already producing and earning profits, however, the incentive to innovate is lower, since innovations would cannibalize existing profits (see Arrow 1962). Despite this effect, incumbent firms might engage in at least some R&D if there were decreasing returns to R&D effort at the firm level. Although an increase in the intensity of competition tends to reduce the absolute level of profits a successful innovator realizes, it tends to reduce the profits of an unsuccessful innovator by even more. Therefore, competition can have a positive overall effect on the rate of innovation, because firms will try to innovate in order to *escape* competition.

Another channel through which increased competition can stimulate economic growth is described in a model of fundamental and secondary innovations created by Aghion and Howitt (1996). In that model, society faces a tradeoff between engaging in fundamental (basic) research that generates the underlying ideas that ultimately lead to new products, and engaging in secondary (applied) research or development that realizes the potential created by the fundamental research. To the extent the output of fundamental research is more difficult for a private firm to appropriate than the output of secondary research, fundamental research is relatively underprovided in the absence of government support, in the sense that a reallocation of existing research away from secondary and toward fundamental research has a positive overall effect on the long-run growth rate. And an increase in the intensity of competition indeed leads to such a reallocation. That is, when new products can compete more freely with existing ones, someone who makes a basic innovation can attract developers more easily, which raises the returns to the basic innovation.[5] Thus, more competition raises the rate of economic growth by encouraging a reallocation toward more fundamental research.

The key insight from this second-generation growth theory is that concerns of earlier researchers about a conflict between encouraging competition and fostering growth might have been misplaced. To the extent competition policy authorities, regulators, or trade liberalizers might have shrunk from promoting competition for fear that innovation-promoting profits might erode, the “new” new growth theory suggests they should take a more aggressive stand in favour of more competitive markets.

Patent Policy

Technological progress clearly requires the protection of intellectual property. If patent and copyright laws were so weak that people could copy innovations with little effort or penalty, then no one would have an incentive to innovate. Patent laws are intended to solve a fundamental dilemma involving the production and use of technological knowledge: how to give people the incentive not just to

5 More competition also implies that developers leave the new product line sooner when new ones become available, but as long as the rate of interest exceeds the growth rate, this effect is dominated by the increased speed with which developers arrive when the product line is first invented.

produce knowledge but also to share it. The dilemma arises from the nonrivalrous aspect of knowledge: the fact that, once produced, it can be used any number of times without adding to the costs of production. Knowledge is, to use a metaphor of Thomas Jefferson, a house that can be shared by any number of people without diminishing its capacity. How can we give people an incentive to produce the house and then allow the widest possible use of it? If an innovator gives his knowledge away freely, how will he be compensated for having produced it? And if he charges for its use, how will society be able to use it to the fullest?

Dealing with this dilemma in patent law involves distinguishing two different ways in which knowledge can be used: to produce goods or to produce further knowledge. A patent gives the producer of an idea the exclusive right to use that idea for producing a specific kind of good for a specific period of time. But it does not give the producer the right to monopolize the idea for producing further ideas. Indeed, the disclosure requirements of patent laws require the patent holder to describe the idea in enough detail that others can build on it and possibly even learn how to render it obsolete.

In practice, however, the distinction between producing goods and producing ideas is not always clear cut. And the more broadly we extend patent rights to include such things as software and genetic combinations, the more we inhibit the flow of ideas by discouraging follow-on inventors with the threat of litigation and uneven competition. The problem is illustrated by the recent Microsoft court case. An exclusive monopoly in one form of intellectual property (the source code to Windows) might give its owner a market advantage over other firms in the production of downstream products (applications) that has a chilling effect on innovation in those products. If another firm wins a downstream patent race against the upstream monopolist but can tie into the upstream product only on terms dictated by the monopolist, there is likely to be less innovation than if the upstream product is in the public domain, or at least not controlled by a direct competitor. The Open Software Movement often makes this argument, and it makes a great deal of sense from a Schumpeterian perspective. Clearly, however, in this era of rapid technological change, we need better patent laws. Meanwhile, as the recent BlackBerry case warns, Canadians should be wary of following the US lead in granting patents for an increasingly broad variety of increasingly dubious inventions and ready injunctions against those accused of infringement, both of which can have a chilling effect on innovation.

Science versus Technology and the Role of Higher Education

Enthusiasm for patent protection has spread beyond the commercial sector and into higher education: universities in Canada and the United States are increasingly urging professors to patent their discoveries. Many would like to emulate the financial success of pioneers like Stanford University, whose income from one patent alone — the Boyer-Cohen patent for recombinant DNA — exceeds US$150 million. This development has generated a backlash from those who believe that the intrusion of commerce into academic life threatens a university's core values.

From the perspective of Schumpeterian theory, open science — research conducted with a shared ethic of disclosure, disinterestedness, and respect for technical expertise; and motivated mainly by intellectual curiosity and a desire for recognition — is a set of institutional arrangements to deal with the same dilemma that the commercial patent system is intended to solve: how to reward the production of knowledge without discouraging the dissemination of knowledge. In open science, the reward for producing knowledge is not so much monetary as recognition for being the first to make a discovery. As with patents, this is a winner-take-all system: the second person to publish an idea gets no credit. Hence, as readers of James Watson's *The Double Helix* learned, scientific competition can be as fierce as any commercial competition, even when the monetary stakes are small. The incentive to disseminate knowledge, which in the commercial patent system comes from the disclosure requirement, comes in open science from the mandate to publish or perish. No credit accrues to one who claims priority without publication.

The highly evolved institutional apparatus of open science works best where the commercial patent system is prone to failure — that is, where basic scientific knowledge is involved whose benefits are very long term, uncertain, and hard to appropriate, and where the potential spillovers are so great that disclosure would be an inadequate means of dissemination. And there is indeed a tension between the value system that supports open science and the values of the commercial patent system. Universities that become involved with commercial R&D are exposed to a variety of dangers flowing from the conflict between these values and the rewards of the market place. The lure of money threatens to displace basic research of great scientific but little commercial value. The allocation of promotions, dissertation topics, and lab space might be unduly influenced by profit rather than academic merit. Most important, the displacement of publications by patents threatens the free flow of information that lies at the very core of open science.

Such dangers do not imply, however, that universities should ban patentable research and shun joint ventures with private industry. On the contrary, universities in Canada and the United States owe much of their vitality to the strong links they maintain with both industry and government research (see, for example, Rosenberg and Nelson 1994). The spinoffs from very applied R&D to basic science have been enormous, especially in such fields as medicine, physics, genetics, and computer science; and researchers who maintain an active involvement in technological developments are often in the forefront of developments in basic science.

Complementarity between academic and commercial R&D is nowhere stronger than in the life sciences. Advances in biotechnology are opening up unprecedented opportunities for cooperation — witness the proliferation of joint ventures between bio-tech firms and universities. Universities can ill afford to waste these opportunities. The problems the private sector is tackling are apparently of sufficient scientific interest — and the pay so attractive — that universities face being unable to hire the best people unless they take an active role in such research. Moreover, the possibility of sharing in the profits from biotechnology presents a golden opportunity for supporting the many commercially nonviable components of a university that are vital to its mission.

The challenge facing universities is thus to design ways to take advantage of the opportunities for commercial R&D without compromising their essential values of openness and disinterestedness. Here, I urge universities to insist on full freedom of publication of any research results to which they lend their names and facilities. Private interests will oppose this, but universities have a lot to offer private enterprise in the form of access to academic research at the highest level, and that gives them plenty of bargaining power with which to resist threats to their essential values.

Globalization

Cross-country comparisons of per capita gross domestic product (GDP) have been the main testing ground of growth theories in recent years. No theory has fared well in these tests. The first-generation model of endogenous growth implies that differences in per capita GDP among countries should widen over time and that random shocks to a country's income should have permanent effects. Since the variance of a random walk grows without bound, so should the variance of the cross-country distribution of per capita GDP. But this prediction is clearly refuted by postwar data from the Organisation for Economic Co-operation and Development (OECD) showing that, among these advanced countries, differences in standards of living have been decreasing, not increasing (see Evans 1996).[6]

Proponents of the older neoclassical model argue from these convergence tendencies that what accounts for differences in income between rich and poor nations is differences in capital accumulation, and that differences in technological progress (the factors stressed by endogenous growth theory) are relatively unimportant. Yet convergence appears limited to a select group of rich countries: the data tend to support a theory of "club convergence," according to which some rich countries are converging to parallel growth paths — that is, long-run paths with similar growth rates in per capita GDP — whereas the gap between these countries and the poorest countries of the world is steadily diverging over time (see Durlauf and Johnson 1995; Quah 1996). The neoclassical model is one in which all countries should belong to the convergence club, no matter how poor.

One possible explanation for club convergence is the role that technology transfer plays in a world where some countries have domestic incentives for innovation and others do not.[7] In any country, the growth rate of productivity equals the product of the frequency and size of its innovations. A country that innovates a lot might temporarily grow faster than the rest of the convergence club, but in the long run the technology currently in use in almost all its industries becomes close to the world frontier. When that occurs, each new innovation

6 Similar refutations of early endogenous growth theories have come from the growth regressions of writers following the lead of Mankiw, Romer, and Weil (1992), which show that, after controlling for the influence of different saving rates and population growth rates, income gaps between countries tend to diminish over time at a rate of about 2 percent per year.

7 In Howitt (2000), I present a multi-country Schumpeterian model with technology transfer, in which each time a firm in one sector of a country invents a new intermediate product, the productivity of that intermediate product in producing final output is determined by a world-wide technology frontier that grows as a result of innovations throughout the world. As long as a country maintains enough incentives that some domestic innovation takes place, it will join the convergence club, and its growth rate will ultimately converge to that of all the other members.

represents a relatively small improvement over the technology already in place in that industry. In other words, a high frequency of innovations ultimately generates innovations of small size. Eventually, the product of frequency and size becomes the same as in the rest of the convergence club. By the same token, a country with conditions relatively unfavourable to R&D might have infrequent innovations, but in the long run most represent a large improvement over the relatively old technology already in place in its industry. A low frequency of innovations results in innovations of a large average size, and, again, the product of frequency and size approaches that of the other countries in the convergence club.

A key, and not immediately obvious, implication of this way of thinking about growth is that domestic R&D is important. Although the country that invests a lot in R&D will not ultimately grow any faster than countries that invest less, nevertheless its per capita GDP will be larger because its producers will be using more up-to-date and, hence, more productive intermediate products and processes. The growth paths of countries in a particular club might be parallel, but the growth paths of the most innovative counties will lie permanently above those of less innovative countries. Countries in which conditions are so unfavourable to R&D as to shut down domestic innovation entirely, moreover, will not grow at all. They will stagnate, falling further and further behind the other countries.

Whether this multicountry Schumpeterian theory will bear up under further empirical investigation remains to be seen.[8] But it warns us that countries that neglect R&D do so at the risk of falling ever further behind in the world income distribution. Moreover, in an increasingly globalized world where rich countries are able to command an ever-increasing fraction of the world's resources, countries that fall behind are likely to experience not just stagnant but declining standards of living, as countries whose incomes are growing without bound bid the price of scarce resources increasingly higher.

These considerations also carry a strong message about the value of openness. The extent of international R&D spillovers among developed and less-developed countries — which are central to the multicountry Schumpeterian model — are estimated to be substantial, and they tend to be mediated by international trade (see, for example, Coe and Helpman 1995; Coe, Helpman, and Hoffmaister 1997). Countries that are relatively closed to international trade — more specifically, countries with a small ratio of imports to GDP — tend not to enjoy the productivity gains that flow from foreign R&D. Thus, countries should encourage innovation and participate in the global trading economy to avoid falling victim to an international form of creative destruction.

General Purpose Technology

The destructive side of creative destruction is a phenomenon that affects not just individual firms and workers; the whole economy can suffer, at least during a transitional period, as a result of widespread technological change. This is especially true when technological change involves the introduction of a new "general purpose technology" (GPT) — a new technology that is used throughout

8 Some initial empirical support for the theory is provided by Feyrer's (2003) demonstration that the emergence of twin peaks in world income distribution is largely accounted for by emerging twin peaks in the level of technological development.

the economy, has a profound effect on the way economic life is organized, and gives rise to a wave of complementary innovations associated with its increasing use.[9] The succession of GPTs — including the steam engine, electric power, and the computer — introduced since the Industrial Revolution has greatly enhanced standards of living. However, the period during which a new GPT is being introduced can be one of wrenching adjustment for individuals, firms, and the economy as a whole.

This adjustment cost has many aspects. One, which Helpman and Trajtenberg (1998) emphasize, is the lost output that occurs when a GPT arrives but cannot be used until the invention of a set of complementary components. As labour is drawn into developing the necessary new components, it is removed from producing final output, which leads to a fall in the economy's overall level of output. To the extent R&D expenditures are not capitalized in a country's income and expenditure accounts, this fall in output is, in part, a measurement error. R&D expenditures produce intangible intellectual capital, just as fixed investment expenditures produce tangible physical capital. If the introduction of a new GPT draws labour out of a sector in which its output (in the form of intermediate products) is measured and into another sector in which its output (in the form of blueprints for new components) is not measured, the reallocation reduces the measured, if not the actual, level of economic activity. Nevertheless, workers who suffer from the drop in tangible output are unlikely to be comforted by the thought that an intangible gain is taking place elsewhere in the system.

A variety of additional channels exists through which the cost of adjusting to a new GPT can show up at the macroeconomic level. For example, learning to use the new GPT consumes real resources (see Greenwood and Yorukoglu 1997). Also, workers who are displaced from sectors using older technologies might take time to find replacement jobs in sectors using the new GPT, which temporarily raises the economy's unemployment rate (see Aghion and Howitt 1998b). Moreover, the introduction of a new GPT and the resulting obsolescence of both human and physical capital can, for many years, reduce the level of per capita GDP below the path it would otherwise have followed, even when the eventual impact is a level of GDP much higher than it would otherwise have been (see Howitt 1998).

This last point indicates a general phenomenon associated with the macroeconomic dynamics of Schumpeterian growth models. In the short run, as in the neoclassical model, the growth rate in output per person can be divided into two components: one depending on the rate of "capital deepening" (the increase in capital per worker) and the other on the rate of technological progress. In the long run, however, technological progress is the only component that matters, because the amount of capital per worker stops growing as it approaches its long-run equilibrium value. But capital deepening is quantitatively the component that dominates the economy's adjustment dynamics, often for long periods of time, and it very often goes in the opposite direction to technological progress. An increase in the pace of innovation that increases the rate of capital obsolescence can depress the stock of capital per worker for much longer than the duration of the typical business cycle.

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9 The term was first introduced by Bresnahan and Trajtenberg (1995). Lipsey, Carlaw, and Bekar (2005) analyze the crucial role of GPTs in the growth process.

Thus, it seems that Schumpeterian growth theory might have something to say about the productivity slowdown that occurred between the mid-1970s and the mid-1990s. Robert Solow's often-quoted remark that computers could be seen everywhere except in the productivity data might have reflected a misinterpretation: computers could indeed be seen in the productivity data, because they were inducing the observed productivity slowdown. This reinterpretation of the data that Schumpeterian theory suggests also bodes well for the future, for it implies that, sooner or later, the costs of adjusting to computer technology will be behind us. Indeed, the speedup of productivity growth since the mid-1990s suggests that this is the case.

Increasing Inequality

Since the 1970s, Canada and many other OECD countries have witnessed rising wage and income inequality, for which economists have come up with two main explanations: trade liberalization and skill-biased technical change (see, for example, Wolfson and Murphy 2000). The trade explanation arises from a standard presumption that, in developed countries, globalization is driving up the demand for skilled labour, which is relatively abundant, and driving down the demand for unskilled labour, which is relatively scarce, thus widening the wage gap between more- and less-educated workers. The argument for skill-biased technical change is that new technologies are inducing an increase in the relative demand for college-educated workers. Neither explanation, however, helps explain the Canadian experience, where the wage gap between college-educated workers and other workers has not widened since the 1960s (Morisette, Ostrovsky, and Picot 2006; see also Burbidge, Magee, and Robb 2002). In Canada, inequality has increased *within*, not between, educational groups.

Schumpeterian growth theory, using the concept of general purpose technology, provides an alternative explanation. It is not that new technologies *per se* are necessarily more skill biased than old ones, but that the recent wave of information technology innovations has been especially rewarding for people with the mobility, adaptability, and creativity to profit from rapid change. How quickly a worker adapts to new technology might be a matter of education, but also of personal characteristics that are hard to quantify — and of luck. Thus, when a new GPT raises the economy-wide demand for adaptability, the adaptable — who are already likely to be in the upper end of the wage distribution — find their wages rising relative to other workers. Indeed, the greatest wage increases go to those who are lucky several times in a row — who are able to transfer their experience with the GPT in one sector to implementations of that new technology in other sectors (see Aghion, Howitt, and Violante 2002).

Schumpeterian theory also helps to explain the slowdown or even cessation of inequality growth since the 1990s (see Wolfson and Murphy 2000). The differential reward to adaptability that a new GPT creates is transitory: in the long run, technological progress tends to automate skills. Ballpoint pens make penmanship easier, photocopiers make copying documents easier, driving a car is easier than riding a horse, electronic calculation is easier than mental arithmetic. In other words, there seems to be no skill bias to technological change in the long run.

Eventually, information technology will be as easy to use as the automobile; in a generation that has grown up with computers, adaptability to computer technology will no longer earn a scarcity premium.

In the meantime, however, inequality remains much higher than it was in the 1960s and 1970s. What should we do about it? Schumpeterian theory focuses on two particular remedies. The first is to promote regional and sectoral mobility. Of course, regional barriers to mobility have always been a serious problem for Canada. But in a knowledge-based economy, the problem is even more serious because technical change is rapid and unpredictable, and those who unwilling or unable to move are at the mercy of fortune. Removing mobility barriers would result in a more adaptable workforce, which, in turn, would reduce the premium the economy pays for adaptability, thereby lowering overall wage and income inequality.

The second remedy has to do with the nature of education. In particular, Schumpeterian theory suggests that general education — the teaching of fundamental analytical and problem solving skills, and the fostering of creativity and an open attitude to novel intellectual challenges — does more to reduce inequality than the teaching of narrow, technology-specific skills. Investing in skills that complement current technologies becomes riskier as the pace of uncertain change accelerates, whereas investing in fundamental skills fosters needed adaptability.

Conclusion

Development economics, in Debraj Ray's (1998) widely used textbook on the subject, is defined as "the economic transformation of developing economies." That transformation is usually thought of as a holistic process involving a broad range of interrelated phenomena: politics, institutions, regulations, demographic patterns, social customs, standards of health and education, degrees of economic inequality, market imperfections, and so forth. Development is what very backward economies supposedly are trying to accomplish; more advanced economies, such as the OECD countries, have already undergone the development transformation.

Economic growth, in contrast, is typically thought of as a much narrower topic: the growth rate of per capita income among developed economies. However, developments in new growth theory are eliminating the distinction between the two fields, throwing light on many questions of concern to relatively wealthy countries such as Canada.

Sustained economic growth — even if one narrowly defines it as sustained growth in income per person — is everywhere and always a process of continual transformation. The economic progress that rich nations have enjoyed since the Industrial Revolution would not have been possible had people not undergone wrenching changes. Economies that cease to transform themselves are destined to fall off the path of economic growth. The countries that most deserve the title of "developing" are not the poorest of the world, but the richest. To stay rich, countries like Canada must engage in a never-ending process of economic development and transformation.

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