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Communiqué

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Sustained, technology-led boom will follow current economic stress in Western countries if past is any guide, says economist Richard Lipsey

The economic disorder that Western countries have experienced in the past two decades is being driven by the introduction of major changes in information and communication technology, economist Richard G. Lipsey said today in a lecture delivered in Vancouver. Such upheaval is a transitional phase typically associated with the introduction of any new, pervasive technology, Lipsey said, and if the past is any guide, it should be followed by a period of sustained boom within a more stable economic structure, beginning around the start of the next millennium and lasting for decades.

Lipsey, who is a Fellow of the Canadian Institute for Advanced Research and Professor of Economics at Simon Fraser University, made his remarks in a lecture entitled *Economic Growth, Technological Change, and Canadian Economic Policy*, the fifth in the C.D. Howe Institute's annual Benefactors Lecture series.

Lipsey concedes that many people are confused and apprehensive about the massive economic changes that have taken place in the past 20 years. Yet, he argues, such changes are part of a necessary process of deep structural adjustment across the whole economy, and are being driven by forces too fundamental to be stopped. To try to do so, he says, would be as unproductive as was the Luddite resistance against the introduction of labor-saving textile machinery in early nineteenth-century England.

It may be possible to design policies to shape these fundamental historical changes at the margin and to lessen some of their more undesirable consequences, Lipsey argues, but Canadians should understand that such policies can be only limited in scope, and their effects over the decades would be fairly trivial compared to what can be accomplished by sustained economic growth.

Lipsey dramatizes the benefits of long-term economic growth by noting that, since 1896, relative purchasing power has increased tenfold. Moreover, this vastly increased value of consumption has come about not by producing ten times as many products and services as the late Victorian economy did, but by the introduction of wholly new commodities with technologies that were unknown a century ago. In other words, Lipsey says, technological advance not only raises incomes; it transforms people's lives by permitting the invention of new things and allowing the manufacture of them in new ways.

In response to those who maintain that sustained economic growth must lead to the eventual depletion of natural resources and severe degradation of the environment, Lipsey argues that most natural resources are in no danger of running out and that it is the richest countries that have the best record in terms of cutting pollution and preserving the environment. Moreover, while the technologies of the 1980s probably could not raise a rapidly increasing world population to Western standards of living without disastrous environmental consequences, twenty-first century technologies are likely to make it possible to do so. The key, Lipsey says, is to create conditions conducive to sustained economic growth in the poorer countries, not to redistribute wealth or production facilities wholesale to them from the richer countries.

The Benefactors Lecture, which is presented annually in the autumn, was sponsored this year by Hongkong Bank of Canada. The text of the lecture is available free of charge from the C.D. Howe Institute. Past lecturers include economists John McCallum, Richard Harris, and Thomas J. Courchene, and political scientist Richard Simeon.

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Economic Growth, Technological Change, and Canadian Economic Policy, Benefactors Lecture, 1996, by Richard G. Lipsey (C.D. Howe Institute, Toronto, November 1996). Free of charge.

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Communiqué

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Une vague de prospérité durable axée sur la technologie succédera aux tensions économiques actuelles dont souffrent les pays occidentaux, si l'on peut se fier au passé, affirme l'économiste Richard Lipsey

La confusion économique qu'éprouvent depuis quelque 20 ans les pays occidentaux est menée par l'introduction d'importants changements en matière de technologie de l'information et des communications, a affirmé l'économiste Richard G. Lipsey, dans le cadre d'une conférence donnée à Vancouver. Ces bouleversements représentent une phase de transition liée à l'introduction de toute nouvelle technologie d'importance; et, ajoute Lipsey, si l'on peut se fier au passé, ils devraient être suivis d'une période de prospérité économique durable au sein d'une structure économique plus stable, laquelle devrait commencer au début du prochain millénaire et durer plusieurs décennies.

Lipsey, qui est membre de l'Institut canadien des recherches avancées et professeur d'économique à l'Université Simon Fraser, a émis ces remarques dans le cadre d'une conférence intitulée *Economic Growth, Technological Change, and Canadian Economic Policy (Croissance économique, changements technologiques et politique économique au Canada),* la cinquième dans la série des conférences annuelles des bienfaiteurs de l'Institut C.D. Howe.

Lipsey admet que nous sommes nombreux à être déconcertés et troublés par les énormes changements économiques qui ont marqué les 20 dernières années. Toutefois, soutient-il, ces changements sont un processus nécessaire d'une adaptation structurelle majeure du contexte économique tout entier, et ils sont menés par des forces qui sont trop fondamentales pour être stoppées. Tenter de les freiner serait aussi futile que l'opposition luddite le fut, au début du XIX^{e} siècle en Grande-Bretagne, à l'introduction de machines de filature textile économisant de la main-d'œuvre.

On pourrait certes concevoir des politiques qui façonneraient les contours de ces changements historiques fondamentaux et atténueraient certaines de leurs conséquences indésirables, indique Lipsey; cependant, il importe que les Canadiens comprennent que de telles mesures ne pourraient avoir qu'une envergure limitée, et que leurs effets avec le temps seraient assez insignifiants comparativement à ce que peut accomplir une croissance économique durable.

Lipsey dramatise les avantages d'une croissance économique à long terme en notant que depuis 1896, le pouvoir d'achat relatif s'est multiplié par dix. De plus, cette valeur de consommation grandement accrue ne s'est pas produite par la fabrication de dix fois plus de produits et de services que n'en produisait l'économie de la fin de l'ère victorienne, mais par l'introduction de produits totalement nouveaux grâce à des technologies inconnues il y a 100 ans. En d'autres mots, indique Lipsey, les progrès techniques n'entraînent pas seulement une hausse des revenus; ils transforment l'existence en permettant l'invention de nouveaux produits et leur fabrication selon des moyens novateurs.

En réponse à ceux qui soutiennent qu'une croissance économique durable mènera à un tarissement des ressources naturelles et à une sérieuse détérioration de l'environnement, Lipsey soutient que la plupart des richesses naturelles ne courent pas de risque d'épuisement et qu'en fait, ce sont les pays les plus nantis qui ont fait preuve du plus grand nombre d'initiatives en matière de réduction de la pollution et de conservation de l'environnement. De plus, alors que les technologies des années 80 n'auraient pas été en mesure de relever le niveau de vie d'une population mondiale en croissance rapide aux niveaux de vie occidentaux sans des conséquences catastrophiques pour l'environnement, les technologies du XXI^{e} siècle seront probablement en mesure de le faire. La clef consiste à créer des conditions favorables à une croissance économique durable dans les pays les moins nantis, et non aux pays nantis de redistribuer leur richesse ou leurs installations de fabrication vers ces pays, indique Lipsey.

La conférence des bienfaiteurs, qui est donnée annuellement à l'automne, était parrainée cette année par la Banque HongKong du Canada. On peut se procurer gratuitement un exemplaire écrit de cette conférence auprès de l'Institut C.D. Howe. Parmi les conférenciers des années précédentes, figuraient les économistes John McCallum, Richard Harris et Thomas J. Courchene, ainsi que le politicologue Richard Simeon.

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C.D. Howe Institute
Benefactors Lecture, 1996

Economic Growth, Technological Change, and Canadian Economic Policy

by

Richard G. Lipsey

Fellow,
Canadian Institute for Advanced Research
and Professor of Economics,
Simon Fraser University

Vancouver, November 6, 1996

Sponsored by
Hongkong Bank of Canada

Foreword

The slow pace of economic growth in recent years and the confusion engendered by what seems to be continual and rapid technological innovation has caused many Canadians to query the benefits of change. Some have begun to question the benefits of technological progress.

It was in this context that, for the occasion of the 1996 Benefactors Lecture, the C.D. Howe Institute turned to noted economist Dr. Richard G. Lipsey, Fellow of the Canadian Institute for Advanced Research and Professor of Economics at Simon Fraser University, to investigate the pressures on public policy and the possible fallout if the value of technological innovation is misunderstood.

Dr. Lipsey views technological innovation from the very long term historical perspective as the major engine of economic growth. He argues that the job losses and institutional breakdown that accompany the introduction of a pervasive new technology are a painful yet necessary part of the adjustment process. If history is any guide, however, that painful transition period should be followed by renewed and more vigorous economic growth and prosperity.

In presenting the Benefactors Lecture this year, Dr. Lipsey extends the line of previous distinguished lecturers: John McCallum, Richard Harris, Richard Simeon, and Thomas Courchene.

The C.D. Howe Institute's aim in presenting the Benefactors Lecture series is to raise the level of public debate on issues of national interest by presenting diverse points of view — whether or not it agrees with them — in publications that are well researched and well grounded. The Institute hopes that, in so doing, it will give Canadians much to think about, including the information they need to exercise their responsibilities as citizens.

I wish to thank our benefactor for this year's lecture, Hongkong Bank of Canada, and in particular its President and Chief Executive Officer, William R.P. Dalton, whose support also enabled us to make copies of the lecture available free of charge.

The text of this lecture was copy edited by Lenore d'Anjou and prepared for publication by Barry A. Norris. As with all C.D. Howe Institute publications, the opinions expressed here are those of the

author, and do not necessarily represent the views of the Institute's members or Board of Directors.

Thomas E. Kierans
President and Chief Executive Officer
C.D. Howe Institute

Introduction

Technology is a dirty word in some circles. For example, the *Globe and Mail* recently referred in an editorial ("A response to the Unabomber," September 21, 1995, p. A20) to

> [t]he university professor who messages his colleagues on the Internet, cooks an instant dinner in his microwave oven and takes insulin shots for his diabetes [and who insists] that technology has done little for the good of humankind.

As this passage hints, humans are fundamentally technological animals, whether they realize it or not. Indeed, technology is as old as the first hominid creatures, taking early forms in weapons, tools, clothing, methods of preparing food and the control of fire. Modern archaeological research suggests that, from the very outset of human evolution, technology has played a critical role.

> Technology is probably *the* most significant element in determining what we are today, not just in forming modern "civilization," but in directing the course of our evolution from a distant apelike ancestor....Genetically, anatomically, behaviorally, and socially, we have been shaped through natural selection into tool makers and tool users. This is the net result of more than .5 million years of evolutionary forces working on our biology and behaviour[,]...the evolution of human beings as profoundly technological creatures. (Schick and Toth 1993, 17–18.)

In the long run, technology helped to turn us from apes into humans and then altered our behavior from animal-like hunting and gathering to creators of civilizations of a sophistication and complexity that would have been unimaginable to our cave-dwelling ancestors. The long-run theme of this essay is the place of technology and technological change in shaping our past, present, and future and the risks we take if we do not understand its place in our lives.

My short-run theme concerns disruption and confusion. From 1945 to 1975, the industrialized world experienced a prolonged secular boom. Economic growth proceeded at a rapid rate. Real incomes rose steadily. Income differentials narrowed, so almost everyone was getting better off, *and* the poor were advancing relative to the rich. Unemployment was low. Young people asked themselves, "What job shall I select or train for?" The structure of industries seemed relatively stable. Iron mines, blast furnaces, large mass-production assembly plants, decentralized parts manufacturers, wholesalers, retailers, supermarkets, and personal and financial services, all seemed part of the structure not only of of the current economy but of capitalism itself. Textbooks wrote about *the* structure of the economy as if it were as permanent as the pyramids, not a progression of constantly changing structures.

In the years from 1975 to 1985, all this changed. Economic growth slowed. Many people's real incomes stopped rising, and not a few suffered reductions. Differentials in earned incomes widened. Unemployment rose in many industrialized countries. Young people asked themselves, "Will the job that I select or train for be available when I enter the labor force?" People who had held down what seemed to be secure jobs on established assembly lines, in middle and upper management and in government found themselves out of work. These newly and unexpectedly unemployed workers were often in an age group that finds retraining difficult and from which many employers are reluctant to hire. Massive structural changes began to take place in such areas as the organization of production within manufacturing plants, the organization and management of firms, the relations among firms, and the structure and geographic locations of industries.

By now, the old established order of the postwar decades seems to have vanished and to have been replaced not by a new order but by endemic disorder. The current climate of opinion among the general public and many policymakers is one of confusion. People wonder: "Did these massive changes just appear from nowhere?" "What is causing them?" "What harm are they doing?" "Will they persist indefinitely?" and "How can they be resisted?"

In this essay, I argue that these changes did not come out of the blue but are being driven by a group of related shifts in our information and communication technology (ICT). They are doing a lot of transitional harm but also a lot of longer term good. They will not continue indefinitely. What we are experiencing is not without historical precedent; instead, it is a typical upheaval associated with the transition phase of the introduction of a new, pervasive technology. These transitional phases are ones of deep structural adjustment across the whole economy, adjustments that are often conflict ridden as institutions and behavior patterns that have worked for decades become obsolete and even dysfunctional, necessitating their rapid replacement. *Insofar as the past is any guide*, such an upheaval should be followed by a period of sustained secular boom within a more stable economic structure, beginning around the start of the next millennium and lasting for a period measured in decades. The changes are being driven by forces too fundamental to be stopped. Trying to do so would be as unproductive as was the Luddite resistance of breaking up automated textile machines in early nineteenth-century England. However, policies designed to shape these changes at the margin and to relieve some of their more undesirable consequences may be possible, at least if we understand the forces with which we are dealing.

This essay is mainly about diagnosis rather than treatment. Although at the conclusion I briefly discuss some obvious policy implications, some of which are general and some Canada-specific, my main concern is that we understand what is happening to us as a prerequisite to designing sensible policies for managing it.

Part I

Technological Change Past and Present

Long-Term Economic Growth

What we are seeing today is the latest manifestation of a process of long-term economic growth that has been going on continuously in some times and places and intermittently or not at all in others. Economists are fond of saying that there are no free lunches. It is true that if, at any moment in time, we want more of one thing, we must have less of something else. Over time, however, economic growth is the ultimate in free lunches. Over the decades, centuries, and millennia, economic growth has given us more and more output for the same amounts of resources and human effort.

Just as we may get indigestion if we eat a free lunch too fast, we may get undesirably large adjustment costs if we grow too fast, but the growth that causes these adjustments *is* a free lunch. Throughout the nineteenth century and the first three-quarters of the twentieth, consumption and investment in the industrialized countries (which I follow convention by calling "the West") increased together as growth raised the total national income available for both of these purposes.[1]

The Power of Growth

Economic growth at 3 percent per year doubles national income every 24 years and doubles it again until income has been multiplied by 20-fold in a century! Even at the modest rate of 1 percent per year, income doubles in about 70 years and then doubles again, to four times the starting point, in another 70 years. Typical catchup growth rates of 7 percent, which have been registered by some Asian countries over recent decades, double the national income every 10 years and have raised the citizens from abject poverty to levels about half those currently enjoyed in Canada and the United States (and to levels that Canadians and Americans experienced as recently as the early 1960s).

All the other concerns of economic policy — full employment, efficiency in resource use, and income redistribution — pale into insignificance when set against growth. The removal of all but frictional unemployment in Canada today might raise national income between

1 Of course, there is always a cost in the sense that, at any moment in time, the rate of increase of consumption could be temporarily raised by transferring resources out of new investment. But the stern message of the no-free-lunchers — that we must sacrifice some of our current living standards if we wish to have higher living standards in the future — is not true once the growth process is started, so that an increasing gross domestic product can support both increasing consumption and increasing investment.

5 and 10 percent; removing inefficiencies due to monopolies and state interventions of all sorts might add at most another 5 percent for everyone. These two heroic achievements would produce, at the maximum, a once-and-for-all increase in gross domestic product (GDP) of 15 percent. Economic growth at the historically modest rate of 2 percent per annum would accomplish the same increase in fewer than 7 years and then go on to double GDP in about 35 years. Further redistributions of income, over and above what now occur, might raise the incomes of those below the official poverty line by a once-and-for-all 2 or 3 percent (at the expense of lowering incomes of those with more) — an increase that growth would bring *for everyone* in a couple of years.

I hasten to add that the above is not an argument for abandoning policies for full employment, for achieving efficiency, or for redistributing income.[2] I am only arguing, as Joseph Schumpeter did earlier in this century (Schumpeter 1943), that these policies are limited in scope and can do only a paltry amount over the decades compared to what is accomplished by economic growth. All citizens, both rich and poor, are massively better off materially than were their ancestors of a hundred years ago who were in the same relative position on the income scale. That improvement has come to pass not because unemployment or economic efficiency or income distribution is massively different from what it was a century ago but because economic growth has increased the average national incomes of the industrialized countries about tenfold over the period. In other words, for every $1 of purchasing power earned by someone in 1896, a person who is in the same position in the relative income scale today earns about $10 worth.

Long-Term Growth Driven by Technological Change

Long-term growth is driven by technological change — that is, by changes in the goods and services that we produce and changes in the

2 Involuntary unemployment is undesirable because of the human misery that it often causes and is thus worth reducing even if the income gain is small. Similarly, extreme income inequalities are socially unacceptable — although there is debate about how much inequality is "acceptable" — and so we always want redistributive policies, no matter how high the nation's average income may soar.

way we produce them.[3] These changes make the calculations in the previous section radical understatements of the impact of economic growth on the average person. Although we do have ten times as much market value of consumption as did our Victorian ancestors, we consume it largely in terms of *new commodities* made with *new techniques* that were unknown to the Victorians. They could not have imagined modern dental and medical equipment, penicillin, painkillers, bypass operations, safe births, personal computers, compact discs, television sets, automobiles, opportunities for cheap, fast, worldwide travel, affordable universities, safe food of great variety, or central heating, much less the elimination of endless kitchen drudgery through the use of detergents, washing machines, electric stoves, vacuum cleaners, and a host of other new household products that their great grandchildren take for granted.

The point is important. Technological advance not only raises our incomes; it transforms our lives by permitting the invention of new, hitherto undreamed of things and allowing us to make them in new, hitherto undreamed of ways.

Those who, like myself, accept the supreme importance of technological change in determining our long-term economic situation do not have to be economic determinists, holding as did Karl Marx that technology is sufficient to determine all social and economic outcomes. Instead, they accept that the same technology introduced into different social and economic structures will produce very different results (which would not be the case if technology determined everything). They also recognize at least two other sources of economic growth: growth whose source is the accumulation of physical and human capital within the confines of given technology; and growth whose source is the extension of markets, which allows the reaping of scale economies.[4]

3 This section, including the list of technologies, is drawn from Lipsey and Bekar (1995).

4 Let *GDP* (or any other economic output in which we are interested) be a function of T and N where T is a vector of technological variables and N a vector of nontechnological variables. The technological determinist believes that the partial derivatives of GDP with respect to N are all zero, while many of those with respect to T are nonzero. Economists of my persuasion believe, however, that there are significant nonzero partials with respect to some of the elements of both T and N.

Economic Theory

To trace the argument in this essay, I need to make a small excursion into a few issues of economic theory, one that I hope is neither too long nor too esoteric.

Two Models of Growth

The Neoclassical Model. The standard model that most economists use to study growth is illustrated in part A of Figure 1. In this "neoclassical" growth model, inputs of raw labor, physical capital, and human capital are transformed by an aggregate production function into total output (measured by some variable such as GDP). The production function is a black box within which reside technology, institutions, and all other structural variables that help to determine how much output is produced by given amounts of inputs. The technique for measuring the effects of technological change is to account for as much of the change in GDP as can be associated with these inputs and to call the rest the manifestation of technical change or in the jargon, the "Solow residual."

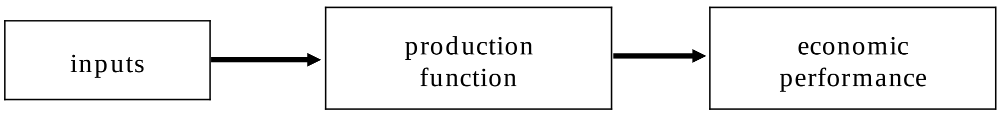
This approach has many problems.[5] We need to observe only two of them here. First, since neither the technology nor the structure of the economy is modeled, this theory is not set up to deal with the questions about economic restructuring that are of current public concern. Second, since the only observable actors in this theory are labor and capital (physical and human), the theory focuses the attention of those who use it on capital accumulation through saving and investment, rather than on technological change, which goes on entirely behind the scenes.

Yet this model is the one that most economists use to study the growth process. Its use goes a long way toward explaining why traditional growth economics has so little to say about technological and structural change and places most of its emphasis on saving, investment and capital accumulation.

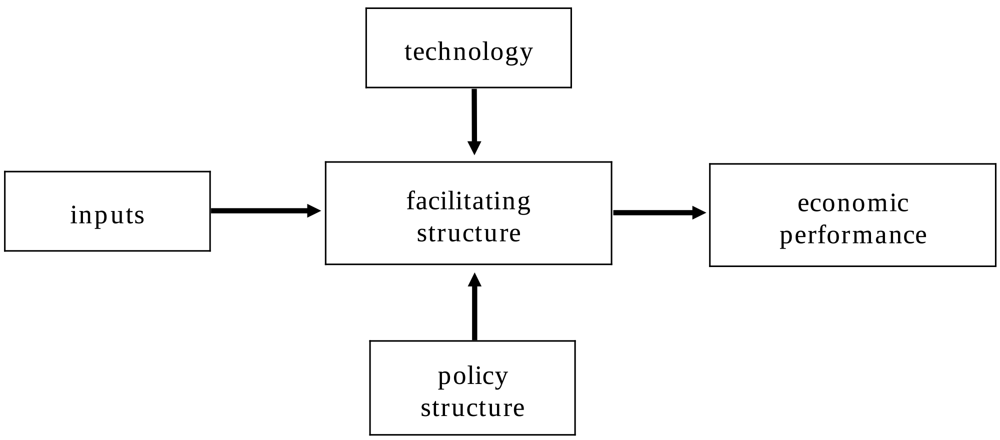
5 These include the difficult (and in my view insurmountable) problems of how to separate technological knowledge from human capital and how to separate technology from the physical capital that embodies it.

Figure 1: ***Two Models of Economic Growth***

A. The Neoclassical Model



B. A Structuralist Model



Part A shows the neoclassical approach. Inputs of labor, materials, and the services of physical and human capital flow through the economy's aggregate production function to produce economic performance, as measured by total national income. The form of the production function depends on the economy's structure and its technology, but these things are hidden in a black box, the only manifestation of which is how much output emerges from a given amount of inputs.

Part B shows a structuralist approach. Technology — the blueprints for the products an economy makes and the processes by which they can be made — works through the facilitating structure, including the internal organization of the firm, the geographical location and concentration of industry, the infrastructure, and the financial system, to produce economic performance, measured by such variables as total national income, its distribution, and the total amount of employment and unemployment. Changes in policy can cause changes in the structure, as when a change in competition policy allows more national mergers. Changes in policy can also affect technology directly, as when research and development (R&D) tax credits lead to more R&D and hence to more technological change. Changes in the facilitating structure can also cause changes in the rate of technological progress, as when the reorganization of an industry leads it to do more R&D.

A Structuralist Model. To talk about structural change, one must go inside the black box of the neoclassical model. The approach used by myself and my collaborators, Cliff Bekar and Ken Carlaw,[6] is derived from the theory of the technoeconomic paradigm (TEP) that comes from Christopher Freeman and Carlotta Perez (1988). They treat technology and all of the other elements that we call the facilitating and policy structures in one overarching concept called the TEP. This approach is a big advance on neoclassical theory in that it brings so much of what matters out of the black box of the macro production function into the open where it can be seen and analyzed.

We find it revealing, however, to disentangle their TEP into the separate components shown in part B of Figure 1. We define "technology" as the specification of the products that are made and the methods that are used to make them. When technology is embodied in physical and human capital, it becomes part of the economy's facilitating structure. Inputs of labor and materials are passed through that structure to produce economic performance, as measured by such variables as GDP, employment, and unemployment.

The economy's "facilitating structure" in our model is made up of the following:

- plant and equipment and other forms of real capital that embody specific technologies;[7]
- human capital (which is embodied in people);[8]
- the organization of production facilities;

6 See, for example, Lipsey (1994; forthcoming); Lipsey and Bekar (1995); Lipsey and Carlaw (1996a; 1996b); Lipsey, Bekar, and Carlaw (forthcoming).

7 Throughout this essay, I follow the growth theory practice of using the term "capital" to refer to real capital — all the machines, buildings, equipment, and other forms of produced goods that are an aid to further production. The total is called the "capital stock," which is augmented by investment and diminished by physical depreciation and obsolescence.

8 Growth economists use the term "human capital" in various ways. Some, who stress accumulation, define it as the sum of all knowledge. Since "all knowledge" includes technical knowledge, this definition is not suitable for distinguishing the contribution of human capital from the contribution of technology. Because my colleagues and I wish to make that distinction, we use a narrower definition of human capital: the sum of all existing codifiable and tacit knowledge related to the operation of all current technologies.

- the managerial and financial organization of firms;
- the location and concentration of industries;
- infrastructure; and
- the institutions, such as banks, insurance companies, trust companies, and savings and loan institutions, that assist in financing productive activity in monetary economies, and the instruments, such as bills of exchange, credit cards, and negotiable certificates of deposit, that they create.

This facilitating structure is affected by and affects the nation's "policy structure," by which we mean the political and economic institutions that provide the background for economic activity. The policy structure includes such institutions as private property and freedom of contract as well as government policies at the local, national, and international levels, including zoning laws, business licensing, competition policy, taxes, tariffs, subsidies, labor legislation, and (at the supranational level) the World Trade Organization (WTO) and the International Monetary Fund.

Every technology has its own best facilitating and policy structures. For example, when electricity replaced steam by the third decade of the twentieth century, once the unit drive had been fully established, one outcome was a reorganization of the entire facilitating structure: different machines, different plant layouts, different management organization and practices, different degrees of industrial concentration, different infrastructures, different financial arrangements, different patterns of international trade, and different governmental rules and regulations. Only when these structural adjustments had occurred was the full payoff of electrification reaped in terms of increased productivity.

In the neoclassical model, technological change can be observed only when it causes GDP to deviate from what can be predicted by the amounts of capital and labor that are employed — that is, by the Solow residual. We allow technology to be observed directly and place the facilitating structure between it and economic performance. We can thus study two important phenomena excluded from the neoclassical model: the structural changes that are caused by changes in technology; and the source of the delays between changes in technology and changes in economic performance that occur because the latter responds to the former only after the facilitating structure has been adapted to it in a process that is subject to long lags, which vary across each of the elements of the structure.

Two Debates

Related to the differing models are two current debates among economists.

Accumulation or Technological Change. The first debate concerns how much growth is due to pure accumulation of capital arising out of saving and investment and how much is due to technological change. Those who stress accumulation almost invariably use the neoclassical growth model. They account for most of the changes in GDP by associating them statistically with changes in labor and an index of the size of the capital stock, which is assumed to be independent of technological change. This approach requires knowing what is meant by the stock of capital separate from technology when that stock actually is composed of plant equipment and other goods that embody constantly changing technologies. What does it mean to say that our economy has ten or a hundred times as much capital as the Victorian economy?

Without getting involved in esoteric considerations of how to measure capital independent of the technology that it embodies, I suggest a simple thought experiment to argue the long-term primacy of technological change. Imagine freezing technological knowledge at the levels existing in, say, 1900, while continuing to accumulate more 1900-vintage machines and factories and using them to produce more 1900-vintage goods and services and while training more people longer and more thoroughly in the technological knowledge that was available in 1900. It is obvious that today we would then have vastly lower living standards than we now enjoy (and pollution would be a massive problem). The contrast is even more striking if the same thought experiment compares the knowledge and the product and process technologies of today with those that existed at earlier times — say, in 1750 at the beginning of the First Industrial Revolution, in 1500 at the beginning of the age of European global expansion, in 1000 when the water wheel was mechanizing European manufacturing for the first time, in 1200 BC at the beginning of the iron age, and in 2700 BC at the beginning of the bronze age.

This thought experiment illustrates what economic historians and students of technology are agreed on: technological change is *the* major determinant of long-term, global economic growth. So the problem of explaining growth over time and across countries is mainly one of explaining the generation, adaptation within one country, and international diffusion of new product and process technologies. In the long term, these technologies transform peoples' standards of living, their economic, social, and political ways of life, and even their value systems.

Is the conclusion, then, that saving, investment, and capital accumulation do not matter? The answer is no because virtually all new technology is embodied in new capital equipment, whose accumulation is measured as gross investment. So technological change and investment are complementary, the latter being the vehicle by which the former enters the facilitating structure. Anything that slows the rate of embodiment through investment, such as unnecessarily high interest rates, will slow the rate of growth, just as any slowdown in the development of new technology will do so in the long term.

So just because new investment can statistically account for economic growth does not imply it is the cause of that growth. Both technological change and investment are needed. Nonetheless, faced with the choice, I would prefer to live in a society in which technology advanced but was embodied only through replacement investment with net investment (and hence capital accumulation) being held at zero, rather than in a society in which technology was frozen at the levels of 1900 and more and more of that physical capital was produced, allowing more and more output of Victorian goods.

Incremental versus Big Changes. Economists also disagree about whether or not the growth process is a matter of small incremental changes *unpunctuated* by occasional big shifts. The neoclassical model measures the impacts of technological change by changes in the Solow residual, which by its very construction will not show large discontinuous shifts.

My colleagues and I argue, however, that two observations about economic growth are critical to understanding what we see around us today, and we build these into our theories. First, technological change occurs in a combination of continuous small incremental changes, discontinuous radical inventions,[9] and occasional massive shifts in some pervasive technology that underlies most of the rest of the prevailing technologies. Cliff Bekar and I (1995) dubbed these pervasive technologies enabling technologies but the literature now calls them general purpose technologies (GPTs).

Second, technological change always requires some changes in the structure of the economy, but often these changes can proceed incrementally for decades. When a major change in a GPT comes along, however, massive changes in the facilitating structure are often required across the whole economy. These are what Bekar and I (1995) call deep structural adjustments (DSAs). It is possible, however, for technological change to cause a massive restructuring of the economy in terms of such variables as the organization of work and the location and concentration of industry without having a discontinuous effect on the Solow residual or even on the overall measured growth of national income. This is why, if one wishes to deal with questions of structural change, one must go beyond the neoclassical model and separate structure from technology on the one hand and from economic performance on the other.

Growth in History

The study of history suggests that the GPTs that have transformed the world and caused DSAs in the process of doing so are all grouped into three main categories of information and communication, materials, and power-delivery systems.[10] Finding GPTs in these categories should not be too surprising since all production involves three basic activities: relevant information is generated, acquired, analyzed, and used; materials are employed; power is used to combine and transform the materials into goods and services and often to drive the resulting products in use.

Examples of General Purpose Technologies

In what follows, I give a few dramatic examples of the massive changes brought about by new GPTs.

9 A radical new technology is one that could not have evolved by incremental improvements to the technology that it replaces.

10 Most of the historical cases described in this section are discussed in more detail in Lipsey and Bekar (1995).

Information and Communication Technologies

Writing. The invention of writing in Sumer around 3000 BC transformed the entire society. It did so by allowing the development of sophisticated systems of taxation and public spending that had been quite impossible when all records were held in memory or in simple devices for keeping track of numbers (bags filled with counters). The resulting public saving financed the building of irrigation works that turned dry deserts into fertile cropland. As the technology of irrigation improved, a positive feedback loop was set up in which improvements in irrigation induced improvements in writing and recordkeeping, and these, in turn, allowed more elaborate systems of taxes to finance further improvements in irrigation systems. The consequences were dramatic. Villages that for millennia had had populations in the hundreds grew into cities of tens of thousands. Architecture changed. Temples were built that exceeded anything then known in size and complexity (although puny by today's standards). Standards of living rose (as shown by the higher proportion of city dwellers). New, specialized activities and trades developed. All of this happened within a century or two.

It is worth noting that, like most GPTs, writing did not just emerge as an act of isolated creative genius. Instead, it had a long history in number-recording systems that stretched back nearly to the neolithic agricultural revolution and that slowly evolved into the abstract concept of number and finally into symbols for words and sounds (Schmandt-Besserat 1992).

Printing. Before the invention of movable type, the costs of reproducing manuscripts had been mainly the variable cost of laboriously copying a document one page at a time. Printing transformed the costs of reproduction: the largest portion became the fixed cost of typesetting. The marginal cost of an extra copy became a small, almost trivial part of the total cost. This new cost structure made mass communication feasible.

As publication on a large scale became cheap, learning exploded. Monopolies of knowledge were upset. Thinkers could communicate with the masses in ways that had been quite impossible when the only texts available were in scarce supply and written in Latin. Mass communication enabled the Protestant Reformation since its direct appeal to the people would have been impossible without the many pamphlets addressed to ordinary people and hence written in the vernaculars. Changes in the structure were resisted by those with vested interests, so a period of great strife accompanied the socioeconomic DSA.

Printing spread most rapidly in the peripheral areas where the power of established authority was weakest. The United Provinces of the Netherlands became one of the most highly and broadly educated societies in history to that time. Enormous efficiency gains followed on the creation of the Dutch information network. Between 1590 and 1620, the multinational corporation, the stock exchange, efficient year-round financial intermediation, the federal state, and a systematically drilled army all made their first appearances. These profound changes in structure allowed the Dutch to bear a load of taxes that astonished their European contemporaries and in turn allowed them to defeat Spain, establishing a worldwide economic empire as a result (Dudley 1991, chap. 5).

The Current ICT Revolution. The invention of electricity made possible a series of innovations in communication that started with the telegraph, went on to radio and television, and is culminating in the group of closely related technologies that make up the modern ICT Revolution, including computers, faxes, satellite transmissions, interactive TV, fiber optics, and the Internet. These developments, which are causing dramatic changes in design, production, marketing, finance, and the organization of firms while giving rise to a range of new products associated with computers and software, are discussed in more detail below.

Materials

Bronze. Stone, clay (pottery), and wood were the universal materials before the age of metals. The discovery of bronze, a metal malleable enough to be worked but strong enough for most uses facilitated a vast range of new technologies for both civilian and military uses. Stone was displaced from almost all of its uses, and wood from many. Old products were improved, while new products that could never have been made with stone and wood became possible. These new technologies led to such wide-ranging structural changes as the beginning of organized warfare and multicity empires, the displacement of religious by lay leaders as the main organizers of collective action, and the replacement of the command system by markets as the main method of allocating resources. If ever there were deep structural adjustments following on a new general-purpose technology, these were they (see Dudley 1991, chap. 2).

Iron and Steel. Whereas bronze was expensive (because it required scarce tin), iron, the next major metal to be used in profusion, was cheap. Iron weapons changed the world, contributing to the advent of the dark ages about 1200 BC, when every major city from Crete to the Egyptian border was sacked and destroyed. Although historians have debated the causes of the defeats, recent research suggests that the barbarians overwhelmed established civilizations because of iron-based changes in military technology that allowed hoards of relatively untrained footsoldiers to overwhelm the technologically sophisticated chariots used by the rich cities (Drews 1992).

Iron made less decorative but much cheaper and stronger tools and implements available to the masses. An important example was the iron plow, which caused major changes in agriculture. Eventually steel became important. It had been known since the discovery of iron, but craftsmen were unable to produce it systematically until developments in the eighteenth century allowed blast furnaces to produce a stable, high temperature for a sufficient duration. When it came into reliable production, its applications were many, and its use ranged across much of the economy.

Made-to-Order Materials. The latest materials GPT is not any specific material but the ability to create new materials on demand. When new materials began to become important after the development of the chemical industry at the end of the last century, they first were merely fitted into the structure of the then-dominant technologies. A new material was invented in isolation and usually substituted for some existing material in an unchanged structure. Today, instead of new materials being discovered more or less by chance and applications then being searched for, the developers of new products or processes specify the material that would be best to use and such a material is routinely developed. New materials are seen as crucial to the continued expansion of many important growth sectors, including microelectronics, transportation, architecture, construction, energy systems, aerospace engineering, and engineering and production practices in the automobile industry — to say nothing of fusion reactors, artificial human organs and solar conversion cells. Once again, there are spillovers, creating a cluster of related innovations in often widely differentiated industries.

> Changes in materials innovation and application within the last half century...have occurred in a time span which was revolutionary rather than evolutionary. The materials revolution of our times is qualitative as well as quantitative. It breeds the attitude of purposeful creativity rather than modification of natural materials, and also a new approach — an innovative organization of science and technology. (Kranzberg and Smith 1988, 88.)

Power-Delivery Systems

Animals. The domestication of animals provided the first power-delivery revolution associated with homo sapiens. Tamed animals were nonhuman power sources (as well as the first source of meat that did not need to be hunted and that did not migrate at will). Yokes, reins, and halters allowed this power to be delivered to plows and wheeled vehicles, where it was transformed into various types of useful work. Animal power remains important in many places even today.

The Waterwheel. The first water mills were introduced during the Roman era, but although a series of major improvements multiplied their efficiency more than tenfold, they were not used extensively. By the ninth century, however, water mills were becoming important. As with so many GPTs, the full power of the generic technology was not developed until it was supported by a string of important ancillary inventions. In the case of the waterwheel, one of the most important was the invention of the cam, which turns rotary motion into linear motion. Waterpower was soon being used to make beer, drive hammers, treat hemp, drive tanning mills, and make paper. It was also used to full cloth, with the centuries-old technology based on workers trampling the raw material being replaced by hammers operated by a set of waterwheel-driven cams, a mechanization that was accompanied by technological unemployment and widespread protest riots.

During the Middle Ages, waterpower (in conjunction with windpower where reliable waterpower was unavailable) replaced animate power, mechanizing the West's industries. This development set Europe on a technological path different from that of Islam and China, neither of which made the decisive step of transferring its main industrial power source from animate to inanimate power. Eventually, the use of waterpower spread to include the development of floating mills, large dams, and tidal-powered mills. Further structural adjustments occurred with the development of a complex system of share-issuing mills (the floating mills were very capital intensive) and of new property rights surrounding the use of the river for power (Gies and Gies 1994).

Waterwheels remained the dominant industrial power delivery system up to and through the early stages of the Industrial Revolution.

Steam. The development of steampower followed a pattern seen with many new GPTs. Commercial use started with Newcomen's 1712 invention of a crude but effective technology designed to do one specific job: pumping water from mines. James Watt made a series of improvements that first transformed Newcomen's engine into one in which steam, rather than atmospheric pressure, did the driving and then greatly improved its efficiency.

Steam replaced water as the main source of industrial energy throughout the first half of the nineteenth century. At first, steam did a little more efficiently what water had done earlier — working within a factory structure suited for waterpower. As steam replaced water in factories of older design, however, it started to transform them as well. Locational advantages altered drastically as factories were no longer tied to fast-moving water. The economies of scale associated with steampower made large factories more efficient than smaller ones. The total amount of power available to industry increased manyfold over water-based factories. As is typical of the competition between an old and a new GPT, water-based technology fought back, and a series of advances improved its efficiency through the early part of the nineteenth century; by the end of the century, water was still used in significant amounts to power factories, particularly in the textile industry.

As is also typical with new GPTs, steam allowed for the creation of new products, new production techniques, and, eventually, many new industries. Steam slowly replaced wind at sea (although not finally until the 1920s) and long-distance horse transport on land. The railways transformed the patterns of industrial location that had resulted from road and water transport, opening up new areas for the growing of grain and significantly lowering the price of food.

The increasingly important role of steam-driven industry in the economy of England induced alterations in many existing services. Financial services were refined, a transportation infrastructure was constructed, and a labor market was created. Without these three key structural adjustments, much of the advantage of steam would have been left largely unexploited.

Electricity. The dynamo replaced mechanical power with flows of electrons, which had multiple uses. It is probably the most pervasive energy-delivery innovation of all time. Like all GPTs, this one started slowly, its original uses being in limited areas such as lighting, the telegraph, and the telephone. (The telegraph was an important ICT revolution in its own right: for the first time in history, a generally accessible technology allowed information to travel faster than human messengers.) Slowly, as technical problems were solved, the uses of electricity expanded, transforming the techniques and locations of production and leading to a massive range of new products and industries. Living standards were raised, and ways of life altered dramatically in myriad ways.

Electric power made possible a range of hitherto undreamed-of products, such as radio and the computer. An assortment of electricity-driven machines for washing clothes and dishes, for cleaning, for ironing, for food storage, and for cooking transformed domestic work and eliminated the battery of servants that had been required to run middle-class households in 1900.

The exploitation of the full potential of electricity required substantial alterations in the entire facilitating structure. One of the most important was a drastic change in the layout of factories. With water and steam, the power source drove a central drive shaft whose power was distributed throughout the factory via a set of pulleys and belts. Because of heavy friction loss in belt transmission, machines that used the most power were placed closest to the drive shaft, and factories were built with two stories to get more machines close to the shaft. At first, electricity merely replaced steam or water as the power source for the central drive shaft; the structure — countershafts, belts, pulleys, clutches, machine layout, and so on — remained adapted to the old power source. Later, the practice of attaching a separate motor on each machine (the unit drive) was adopted (after an intermediate stage of group drives). It then occurred to people that the factory could be built as a single story and the machines arranged in the order of the flow of production. This innovation was easy to accomplish in new factories but expensive to install in existing ones, and it took decades for the whole adjustment to occur. So at first the dynamo was seen everywhere *except* in the productivity figures. When the restructuring of factories was completed, however, there was an enormous productivity gain associated with the replacement of steam by electricity (David 1991). After factories had been restructured to follow the flow of production, it was only a small step for Henry Ford to add a continuous belt that automated the flow of the product through the plant.

Electricity altered scale economies. In some lines of production, particularly those that used assembly lines, scale economies increased; in others, however, small-scale production became more cost efficient. In parts manufacture, the attachment of a motor to each machine led to a system of small decentralized producers supplying large centralized assembly plants — a method of production that is still dominant today. The 1890s were also a time of intense merger activity, which was sometimes the cause and sometimes the effect of electrification.

The rapid diffusion of electric power resulted in dramatic cost savings but caused high rates of transitional unemployment and labor de-skilling. The machinist in a steam plant had been skilled at maintaining and repairing his own machine, but electric machines required such infrequent maintenance and repair that a few specialists could keep them running.

The Internal Combustion Engine. The internal combustion engine is another important power-delivery system. The engines power aircraft, ships (diesel electric), railways engines, and motor vehicles. Byproducts of the petroleum that fuel them (in the form of gasoline and diesel oil) have become important inputs for many other industries, including chemicals, fertilizers, and space heating.

The automobile transformed society in myriad ways, creating among other things the modern suburb, the suburban shopping center, and the large-scale domestic tourist industry. These are but a few of the massive set of structural adjustments that followed on the spread of automobile ownership.

Conclusion

What all this tells us is that, along with the masses of incremental changes in technology that are important sources of economic growth from year to year, every once in a while comes a new GPT that causes deep structural adjustments and massive changes in our way of life as well as rejuvenating the growth process by presenting a whole new research program for finding improvements in and new applications for the new basic technology.

Neoclassical growth economists would explain everything I have just discussed by some variant of the simple model sketched in part A of Figure 1. Surely this view of history misses some of the richness of the process of technological change, and very possibly, it is downright misleading to force economic growth into this mold of a single aggregate production function.

The Current ICT Revolution

To set the stage for understanding the current period of deep structural adjustments, I need to go back to the postwar boom of 1945–75. The electrification of factories was complete in Canada and the United States by 1945, and the major industries on which the boom depended were in place.

The postwar decades did see some structural changes. For example, the rise of the aircraft industry challenged many existing transportation modes, and then, with the arrival of jets, the era of cheap, fast international travel began. One could now take a two-week holiday anywhere in the world, whereas merely crossing the Atlantic by liner had formerly consumed about that much time. People whose parents were well traveled if they had crossed the continent once or twice found themselves vacationing in the Canary Islands, Rome, Athens, Kashmir, Bali, Tokyo, Sydney, and Rio de Janeiro. Major league sports expanded out of the area that could be reached by an overnight bus journey.

Petrochemicals also underwent major changes during this period, as a result of a continuous series of incremental innovations, rather than a few large revolutionary ones. Although most petrochemical products are intermediate inputs used in a wide range of final products and thus have the broad-based character necessary to cause big structural adjustments, these did not occur, and most changes were accommodated within the existing structure.

Finally, the computer industry, which had its electronic roots in the 1940s, grew, but its products were fitted into the structure of the older technologies. For much of the period, computers were expensive pieces of equipment that lacked the flexibility necessary to be productive over a wide range of applications. Toward the end of the postwar period, they were falling in cost, increasing in flexibility, and winning wider acceptance among users; however, they still operated within the old paper-moving structure of the previous technologies.

The 1970s were a transitional decade, and by the early 1980s major structural adjustments were occurring rapidly in response to at least two major changes in technology: the ICT Revolution associated with computers, satellites, and related communications advances; and the materials revolution associated with the creation of new materials such as ceramics, composites, advanced polymers, and plastics.

Changes in the IC Technology

At the core of the ICT Revolution, driving its DSAs, is the computer. Its story parallels in many ways the story of past changes in GPTs that brought long-term increases in living standards but widespread structural adjustments in the short term.

Like most revolutionary GPTs, electronic computers came into the world in crude form to produce a few very specific services. No one even remotely conceived of what these original crude monsters would do to the world when, at the end of World War II, the civilian demand for commuters was estimated to be five. Computers slowly improved, through many incremental changes and several radical ones (such as von Neuman's substitution of software for hard wiring). As they were improved, their range of applications grew, creating pressure for further improvements in a typical positive feedback loop.

Electronic computers evolved first in a structure adapted to the precomputer, paper-pushing age. Before they could really pay off, offices had to be redesigned both physically and in their command structure. Slowly, as had happened with electricity, the whole process of producing, designing, delivering, and marketing goods and services was — and still is being — reorganized along the lines dominated by computing technologies. There is every reason to expect that, as with electricity, the latent power of the new technology to raise productivity will be increasingly reflected in productivity growth but only after the restructuring is largely completed.

With large increases in both the productivity and the scope of computer applications, almost every aspect of the economy has been affected. Researchers can generate and analyze massive amounts of data in ways unthinkable a decade or two ago. The design of new products, such as the Boeing 777, is now often accomplished fully on computers. On the factory floor, computerization and automation are aiding the techniques of lean production pioneered by the Japanese. In lumber mills, X-rays and computers now decide, much more effectively than an experienced sawyer was ever able to do, where to put the first cut in a large log. In the chemical industry, materials advances are being made that would have been impossible without the newly available advanced computing power. Consumer goods and "intelligent" buildings incorporate reactions initiated by computers, large and small. Financial industries use computers to gather, store, analyze, and retrieve information. Computers in tanks, naval vessels, smart bombs, aircraft, and satellites are revolutionizing warfare. In education, the days of the traditional textbook are numbered. Interactive, computerized instruction modes are replacing the older lectures delivered from on high.

Distant learning is becoming more and more powerful and is beginning to allow more staff-student and student-student interaction than many traditional face-to-face teaching technologies. (As is typical with new technologies, many of the older generation of teachers refuse to acknowledge that the new methods could be better than the ones they have been using for decades.)

Computers have altered scale economies by making it possible to produce short runs of individually tailored variations on a generic blueprint. One result is a proliferation in product differentiation. Nonetheless, a computerized production process must have a large total output to recover its cost, so scope economies have increased in many related lines of activity.

Improvements in transportation technologies, particularly containerization and the development of very large ships (following the closure of the Suez Canal in the Crisis of 1956), were already greatly reducing the costs of shipping goods around the world, and the ICT Revolution has greatly increased our ability to coordinate economic activities worldwide. For example, parts that had to made within a few hundred miles of the assembly plant 50 years ago can now be made anywhere in the world and delivered to centralized assembly plants when and where they are wanted.

ICT-driven globalization is also affecting many services industries. Accounting of all sorts is increasingly being decentralized to areas where labor is relatively inexpensive. Ireland, the Caribbean, and India are all locations in which large transnational corporations, such as credit card and travel companies, do much of their recordkeeping and accounting. Software firms are moving much of their coding work to places outside of North America, and India is now one of the world's fastest growing sources of computer code.

The scale of research and development (R&D) in the new applications of ICT, the extraordinary growth of the software industry and related business services, the scale of investment in computerized equipment and in the telecommunications infrastructure, the rapid growth of industries supplying ICT products and services, and the use of computers within every function of every industry make the ICT Revolution comparable to the First Industrial Revolution. The historian Peter Drucker (1993) argues, with not much exaggeration, that the current revolution is working one of the three most profound sets of social and economic changes in this millennium. This shift is surely something more than the mere accumulation of more capital driven by savings and investment.[11]

Changes in the Facilitating Structure

Today's changes in technology are causing massive structural adjustments across most of the economy.

The Passing of Fordist Production Techniques. Administratively, the old hierarchical firm was organized on the military command model in which large numbers of middle managers passed information and orders up and down the chain of command. This structure has now given way to the new more flexible management form; in the process, many middle managers have lost their jobs to new electronic information systems. On the shop floor, the days of dedicated machines tended by unskilled or semiskilled labor engaged in the repetitive tasks of mass production are numbered; firms increasingly are turning to lean production methods with workers organized in teams and the teams organized as flexible production units capable of executing many tasks (requiring a much higher skill level than was previously needed).

Labor. Flexible production techniques, along with the development of a global market in low-skilled labor, have led to a redefinition of the role of unions. In more and more industries, rigid job descriptions are becoming obsolete. Effecting the required changes in the organization of labor is proving yet another conflict-ridden process, as occurs with many changes that must be made in the facilitating structure in response to technological change.

In the past, if an automobile was to be made in Detroit, all of the parts, including those that required only "metal bashing," had to be

11 Although, of course, as we have already observed, investment in new capital is required to embody the new technologies, incorporating them into the facilitating structure.

made nearby. Today, each part can be made anywhere in the world where its costs are lowest (always allowing a small margin for today's modest shipping costs). As a result, labor in general and unskilled labor in particular is in intense competition in a globalized market. Meanwhile human capital has become increasingly important. The requirements for previously low-skilled jobs have risen as wealth creation increasingly involves creating and processing information. So labor's international advantage often depends on having skills that are scarce relative to the total world's supply.

Economies of Scope and Scale. Whereas economies of scale were a driving force in the postwar expansion, the introduction of computers and other information technologies has drastically lowered the minimum efficient scale of production in many product lines. Furthermore, the uses of both advanced materials and computers have eliminated economies of scale in such traditional industries as steel manufacturing — witness the rise of the minimills. As occurred with printing in the fifteenth and sixteenth centuries, the ratio of fixed to variable costs is presently rising in manufacturing. Falling labor costs and rising design costs have important implications for industrial locations. As product cycles accelerate, the time available for a new product to cover its fixed costs of design and distribution falls and the risks associated with competition in innovation increase.

The organization of service production has also changed rapidly. On the one hand, firms operating on a global scale in law, accounting, and other traditional services are replacing many of the old individual operators. On the other hand, many service activities are being developed by independent contractors who often work out of their homes.

Locational Effects. Recent technological changes have also had serious impacts on the location of industry; communications and transport revolutions have allowed production units to be delinked from design units. Design and other high-value-added activities can be concentrated in the relatively advanced countries in order to take advantage of high levels of human capital, while production facilities are relocated to lower-wage areas, particularly in Asia and Latin America.

These developments have led many governments to stress the creation of technologically relevant human capital and infrastructure.

> By the end of the 1980s, in most advanced industrial economies, not only were natural factor endowments assuming a less important locational role, but also the actions of governments, through their willingness and ability to affect the quantity and quality of these endowments and their organization, were assuming a new significance. (Dunning 1993, 601.)

Social Organizations. Ways of life are changing. If the First Industrial Revolution took work out of the home into the factory, the current ICT Revolution is putting much of it back. The new technologies allow many providers of services to work out of their homes, rather than where their services are consumed. This shift is permitting flexible work relations and flexible hours, a situation that will benefit many people, including those who will no longer have to choose between the mutually exclusive alternatives of full-time work in an office and staying at home to look after small children or other dependant family members.

The new technologies are causing changes to information transmission and human interaction that are comparable to those wrought by the printing press. They are effectively redefining our notions of time and distance and in some ways creating the much-heralded global village.

> By linking people and groups, e-mail encourages work across space, time, and group boundaries. Indeed, the absence of constraining nonverbal cues and social controls in e-mail may make it easier to communicate with unknown or peripheral people than through face-to-face means. Such wide-ranging ties are especially useful for linking socially diverse people, obtaining innovative information and integrating organizations. (Wellman and Buxton 1994, 12.)

Globalization. New technologies have created powerful private sector bodies in such forms as transnational corporations (TNCs). Investment has become a complement to trade, rather than a substitute as it was with the older technologies. Knowledge-intensive industries are footloose industries. Distance and transport costs no longer protect local markets.

Changes in Policy

With major changes in technology that cause deep structural adjustments, the policy structure always becomes seriously maladjusted to the requirements of the new technology. Old policies need to be altered or scrapped, and until this is done, existing policies inhibit needed changes. New policies need to be established. All of this takes place in yet another conflict-ridden situation; those with vested interests in old laws, rules, and regulations resist change, while others press for it. I discuss some of today's policy issues later.

Changes in Performance

Changes in economic performance are, of course, accompanying the current technological revolutions and the deep structural adjustments that follow in their wake. Here are some examples.

Growth. The overall rate of growth of GDP has slowed. Current research suggests that such a slowdown may well be typical of a period of DSA in which a new technology cannot produce at its full potential until the economy's facilitating and policy structures have been altered and much of the old physical capital has been replaced.

Incomes. Inequalities in the distribution of market-determined incomes are widening in Canada and the United States as the pattern of the geographical, occupational, and sectoral demands for labor appear to be shifting faster than the supplies. In some cases, this phenomenon may be temporary, lasting only for a decade or two until the supplies (particularly of new labor market entrants) react to the new patterns of demand; in other cases, the changes may be long lived.

Although their precise nature is still debated, the effects of the new organizational arrangements on production, design, employment, and income distribution are likely to be profound. While some analysts insist that the new economy will demand a relatively high level of human capital from all workers, others claim that the new technologies will create two types of workers: knowledge workers with much human capital earning high incomes, and an underclass of low-skill, low-wage workers competing in a global market that no longer rewards geographic location (see, for example, Reich 1991).

Employment and Unemployment. The pattern of employment is shifting rapidly in many dimensions, including a shift from goods to services. Unemployment rates are rising where the pattern of demand is shifting and rigidities inhibit equilibrating changes in prices and adjustments in the economy's facilitating structure (such as are caused by many union and management practices). Some of this maladjustment is clearly transitional as the patterns of demand shift more rapidly than supplies can adjust.

One debated issue concerns the long-term effects of the new technologies on the level and structure of future employment. Will there be a "jobless society," and will "bad jobs" predominate over "good jobs"? I return to this issue later. Here I observe only that, when patterns of work change dramatically, some things that seem beneficial in the long term look harmful when viewed in the short term from the perspective of old patterns. For example, does a young college graduate really have a "bad job" when Wal-Mart starts him on the floor in order to enhance his long-term productivity and the firm's competitiveness?

Some Generalizations from History

Why is the West so much richer than the rest of the world today? A quick scan of history suggests some reasons — as well as some warnings.

How the West Grew Rich

In 950 AD, Europe was technologically backward and uncivilized by the standards of both Islam and China. In 1950, Europe and its offshoots in the English-speaking nations that had been seeded by Europeans were the technological leaders and possessors of the world's dominant civilization. While left-wing political thinkers disparaged modern capitalism, the West had become the economic envy of the rest of the world, which sought to copy its capitalistic successes.

How the West did it has been the subject of massive research and debate. Although there can be no finality in such broad historical questions, some parts of the answer seem clear, both from the West's own history and from the experience of those other countries that have tried noncapitalist routes in pursuit of economic success. No one is quite sure what are sufficient conditions for growth, but we can be reasonably clear about some necessary conditions.[12]

Freedom to Innovate. The West has grown rich in comparison to other societies by giving its citizens freedom to innovate in products, processes and organizations. As Rosenberg and Birdzell say in *How the West Grew Rich*, its success was not based on inventing a particular technology but in creating a society in which innovation was continuously encouraged.

> We have often referred to the obvious fact that economic growth is a form of change, so that the West's path to wealth involved and required a society willing to tolerate and accept social and political change far more drastic than any previous revolution....The West has grown rich, by comparison to other economies, by allowing its economic sector the autonomy to experiment in the development of new and diverse products, methods of manufacture, modes of enterprise organization, market relations, methods of transportation and communication and relations between capital and labor. (Rosenberg and Birdzell 1986, 332–333.)

Technological change takes place under conditions of extreme uncertainty. No one knows if a particular avenue for R&D is empty or full of an immensely rich pot of gold. Time and money must be spent investigating each alley before one knows its contents. Furthermore, unexpected things happen all the time, massive expenditures sometimes yield nothing, and trivial expenditures unexpectedly reveal lucrative possibilities. In market societies, there is a diversity of experiment

12 The next few subsections rely mainly on Rosenberg and Birdzell (1986) and Huff (1993).

determined by decentralized decisionmakers, each of whom invests no more than is needed to investigate each alternative. Experience shows this approach to be a better route to technological advance than using a central decisionmaking body to select from the available R&D alleys those few that seem most promising in advance, as is done in any system of centralized decisionmaking.

Market Rather than Political Decisionmaking. The test for adopting something in the market sector is, can it be made profitable? The test in the political sector is, can it pass political debate that calls for foreseeing the consequences at the outset. Since most innovations are surrounded by great uncertainty, it is unlikely that many of the West's innovations would have met the test of political debate against those determined to oppose them. *This point is important and subtle.*

> As between two economic systems, one using market methods of decision making to adopt or reject organizational innovations and another using political verbal decision making, the latter will almost inevitably lag behind the first in adopting innovations and will as well often reject innovations which have advanced material welfare. (Rosenberg and Birdzell 1986, 311.)

Rewards and Penalties. The market institutions that grew up in the West, particularly private property and patent laws, permitted large gains to successful innovators. In contrast, those who try and fail or who are already established in markets and do not try at all lose their investments. The incomes of a Carnegie, a Krupp, a Nuffield, or a Gates seem almost obscenely large when viewed statically. But when set against the gains that growth through innovation has conferred on all citizens, they are a small price to pay if the alternative is no technological advance (and try as they might, nonmarket economies, which do not allow large gains to innovators, have been unable to come close to the West's ability to innovate).

Pluralism. The West succeeded in unleashing the market sector to generate innovation and change that have increased living standards by large amounts and in multidimensional ways over one lifetime, to say nothing of over the last millennium. In this accomplishment, the West gained diversity from divorcing political and economic activities and, hence, removing innovation from authoritarian control. Since technological change is revolutionary, established vested interests — whether governments, unions, or entrenched firms — typically resist it. Rosenberg and Birdzell (1986) provide the following list of institutional innovations that were all bitterly resisted in their time because each hurt some groups with political power: the joint stock company, the department store, the mail-order house, the chain store, the supermarket, the trust, the integrated process enterprise, the branch bank, the conglomerate, and the multinational corporation. At the same time, the established authorities have often defended forms of organization that were at best economically marginal. Costly examples include cooperatives, marketing boards, Canadian supply management, small farms in Japan and Europe, and small retailers in the United States, Japan, and elsewhere.

At the heart of the Western growth revolution was the concept, developed in the twelfth and thirteenth centuries, of treating a whole body of people as having a corporate identity distinct from the individuals who made it up. Universities were one of the first corporate institutions. They developed standards and rules that were independent of the people who administered them at the moment. Guilds and many other organizations also gained corporate status.

> [E]ach collectivity that achieved corporate status...enacted laws to govern its members and thereby whole new systems of law — for example urban law, merchant law, royal law — developed that served to counterbalance jurisdictions and prevent the monopoly of power and authority over the whole realm. Thus guilds, associations of merchants, and various assortments of workers and tradesmen became law-making bodies. They enacted ordinances to regulate their membership, to fix prices, control trade, and standardize business transactions. (Huff 1993, 137.)

Notice that bodies such as the guilds, which eventually became reactionary (and were roundly condemned by economists as monopolies), were, at the beginning, an important departure from an even more undesirable set of arrangements. Universities and guilds represented the beginning of the corporation, a body separate from the sum of its members, an institutional innovation that helped to diffuse power and thus increase productive efficiency.

Free Scientific Enquiry. The growth of western science has shaped and nurtured Western economic growth. In the twelfth century, the corporate status achieved by the emerging Western universities made them independent of the particular individuals who were their staff at any moment in time. This independence gave each institution great power and allowed it to go beyond its original purpose, since its current members could react to changing situations by pursuing courses of action not imagined by its founders.

At this critical point in the revival of learning, Christian thinkers argued that the world was governed by nature's laws and that to discover these laws was to discover God's purpose. Scientific enquiry was not, therefore, in conflict with religious beliefs. In contrast, Islamic thinkers held that God determined the world's behavior each day according to his will. To predict the future, whether through scientific laws or by any other means, was, therefore, blasphemous.

The European universities emphasized science, believing that knowing how the world worked was important for all educated students. By establishing a curriculum that was strong in science, the West took a decisive step toward accepting the powers of reason and seeing the universe as a rationally ordered system. (Compare this outlook with that of the late twentieth century, when most of the West's university graduates have received exactly zero instruction in the vast, exciting body of knowledge about the nature of the universe accumulated in this century.)

In the twelfth and thirteenth centuries, the West discovered and taught the scientific works of earlier Greek and Islamic thinkers. Aristotle believed that the world had always existed and would always exist. When the European universities accepted Aristotle, they granted philosophy (which then included physical science) a *de facto* independence from theology that had previously been unavailable in the West, and was not achieved in either Islamic or Chinese institutions of higher learning until the twentieth century. Although the Christian church reacted with hostility in the thirteenth century, its reaction was too little and too late; the university as a corporation had by then achieved too much autonomy and power.

The Rule of Law. At the same time as the rise of the universities, Europe underwent a revolution in legal concepts.

> What took place in the eleventh, twelfth and early thirteenth centuries in Western Europe was a radical transformation that created, among other things, the very concept of a legal system with its many levels of autonomy and jurisdiction and its cadres of legal experts.... [This] was not only an intellectual revolution, but a social, political, and economic revolution whereby new legal concepts, entities, procedures, powers, and agencies came into being and transformed social life. (Huff 1993, 124.)

In 1140, the monk Gratian developed, among other revolutionary ideas, the doctrine of natural law, a concept still used in the legal system more than 800 years later. Interposing this law between divine law and human law, he reasoned that, although divine law is revealed law, natural law is also God's will and is found in both divine revelation and in human reason and conscience. Therefore, went his argument, *neither the law of rulers nor the law of the church should prevail over natural law*.

Gratian's incredible achievement was in establishing that reason and conscience must prevail over custom, revelation, or the power of autocrats. As a result, Western law became an evolving system that reacted to changing conditions and needs, rather than the static, revealed system of universal rules desired by many religious and autocratic lay rulers. (Modern advocates of political correctness and anti-hate laws typically have no idea of the enormous power and value of the freedom of expression that they would eliminate.)

Why the Rest Did Not Grow Rich

Why did the rest of the world not grow with the West? A great deal of ink has been spilt on this question, and here I can do no more than mention one or two key points. One thing that is clear is that the state in China and the religious authorities in the Islamic countries gained control over science and technology. Up until the twelfth century, Islamic and Chinese science and technology led those of the West. (Indeed, many of the new technologies that assisted the West around that time were imported from Islam and China.) But then the forces of religious orthodoxy in Islam and of state power in China gained control and stifled both scientific enquiry and technological advance.

In Islam, small groups of physicians and philosophers held scientific values but were opposed by the elite. Indeed, the very idea of innovation implied impiety, if not outright heresy. According to Huff, one tradition of the prophet in wide use claims that "the worst things are those that are novelties, every novelty is an innovation, every innovation is an error and every error leads to Hell-fire" (Huff 1993, 234).

As Bernard Lewis puts it,

> In the extreme form, this principle has meant the rejection of every idea and amenity not known in Western Arabia in the time of Muhammad and his companions, and it has been used by successive generations of ultra-conservatives to oppose tables, sieves, coffee and tobacco, printing presses, artillery, telephones, wireless and votes for women. (Lewis 1953, 52, and quoted in Huff 1993, 234.)

Just as the West was asserting its pluralism and the rule of reason, Islamic religious authorities gained full power and attacked the science that existed outside the centers of established learning. At the beginning of the twelfth century, Islam had astronomical observatories, hospitals, and universities, but all slowly came under the influence of religious conformism, and many of the great libraries and observatories were destroyed by religious zealots. The consequences were momentous; for example, as late as the nineteenth century, Islamic thinkers were denying the sun-centered view of the solar system.

Importantly, the concept of a corporate body independent of the individuals that belong to it never took hold in Islam. The university was just the sum of the teachers who taught in it, and each gave a certificate of competence without any corporate standards. This lack of corporate status left a power vacuum where independent power was growing in the West, leaving Islamic learning open to successful attack by religious conformists.

When printing by movable type was invented in the West, religious authorities everywhere understood the revolutionary power of this new technology. Let the masses read the holy scriptures for themselves, and they would make their own judgments independent of what the clergy or the state told them. In both Islam and China, printing was successfully suppressed, and learning remained rote memorization of lengthy texts repeated to faithful students by literate teachers. In Europe, the Catholic church took the same antiprinting stance. Fortunately, the Protestant revolutionaries made the printed text — in the vernacular — their vehicle for revolt. Within a century, the Catholic church admitted defeat, and printing spread throughout Europe, contributing decisively to the independence and literacy that facilitated the Renaissance.

Could the West Grow Poor?

If Westerners accept the material living standard that capitalism has provided without understanding its sources, they risk loosing it. Could the West grow poor? Yes, and it could do so by denying the basic conditions laid out above (and a few others that there is no time to enumerate). Fortunately, this denial would be harder to do in today's globalized world than in earlier, more isolated, times. But it could happen here, which is why it is important not to grossly misread history and carelessly throw away the characteristics that have made the West rich. This is what many modern movements of both a religious and a secular nature would do if they gained power in the West, and it is what fundamentalist Islamic zealots did when they gained power in the thirteenth century and what they doing today in some countries.

The recipe for stopping growth is simple enough. Reverse the conditions noted above. First and foremost, make it difficult to innovate; substitute political for economic decisionmaking; and remove the personal profit and loss motives from those responsible for innovation. Then abandon pluralism, and concentrate power in some central authority. Finally, compromise the rule of law.

This is what communism did. (The contrast between East and West Germany stands as a modern cautionary tale.) It is also to a much lesser but still significant extent what the nationalization of industries by modern left-wing governments did, particularly after World War II. (The current worldwide movement toward privatization is a recognition that innovation is best left in private hands.) It is also what is happening in many ways today with powerful tribunals that operate outside of the normal legal system, with retroactive corporate liability for actions that no one thought harmful when they were done, with unlimited liability for corporate directors, with sometimes confiscatory levels of taxes, with political correctness in all of its varied forms, and with a host of other things that go against, without being strong enough to negate, some of the necessary conditions for the West's growth.

It is also what Westerners are doing when they fail to defend the rule of law and the right to free expression at every opportunity. In my experience, most high school students have never heard of the rule of law, let alone thought about its importance to political freedom and economic progress. The Supreme Court of Canada's recent decision accepting the prohibition on the publication of poll results three days before an election and laws regulating what private groups can spend on electioneering suggest a casual attitude to freedom of expression and once again a failure to appreciate its importance to political freedom and economic progress.

Misreadings of History

Many myths that arise from misreadings of history suggest actions that would threaten the underpinnings of the West's success.[13]

The first such myth concerns the sources of the technological changes that transformed ways of life in the West (and elsewhere when they spread beyond the West in this century). These technologies were first created by a relatively small group of European men and then augmented by people who lived in countries, such as the United States and Australia, whose social and cultural attitudes were rooted in the European tradition. This is a politically incorrect thing to say, and many people are busy rewriting history to make it seem otherwise. Sadly, universities exist today where one could lose one's job for saying what I have just said. It is currently popular for the authors of US textbooks to downgrade the contributions of Thomas Edison, one of the great technological geniuses of all time, while searching for the occasional excellent contributions made by women and blacks. My original observation is not racist. No one believes that technological inventiveness is exclusively found in European genes — if it were, neither China and

13 This section draws heavily on Lipsey (1994).

Islam would have flowered so magnificently until the forces of centralized repression gained control, nor would several Asian countries have reached the technological leading edge in recent years. There were, however, forces in Western social, political, and economic culture that made the society technologically dominant, and if we do not recognize them, at least in broad outline, we risk not preserving them.

Second, nineteenth-century capitalism was not the unmitigated evil that the contemporary social reformers thought it was or that my children were taught it was by their teachers. But for eighteenth- and nineteenth-century capitalism, Westerners would currently be living on a per capita income somewhere near that of modern Bangladesh.

Third, it is a mistake to believe that the conditions of the majority of ordinary workers were initially made worse off by the Industrial Revolution.[14] Braudel (1979) documents in great detail the appalling conditions of the masses of lower-class urban dwellers of pre-industrial Europe. Reviewing this and other evidence, Rosenberg and Birdzell conclude:

> The romantic view that workers in pre-industrial Europe lived well may safely be dismissed as pure fantasy....The low wages, long hours, and oppressive discipline of the early factories are shocking in that the willingness of the inarticulate poor to work on such terms bespeaks, more forcibly than the most eloquent words, the even more abysmal character of the alternatives they had endured in the past. (1986, 173.)

Fourth, the ordinary working person was not unaffected by the changes brought about by the first 50 or so years of the First Industrial Revolution, although it took a while to notice these effects. Rosenberg and Birdzell put the point this way:

> Only as the West's compounded growth continued through the twentieth century did its breadth become clear. It became obvious that Western working classes were increasingly well off and that the

14 The initial effects of the Industrial Revolution are still hotly debated, partly because the answer varies with the group being considered — such as displaced agricultural workers, skilled artisans, or handloom weavers. My argument requires only that the conclusion — that the Industrial Revolution reduced lower-class living standards — is wide of the mark.

> Western middle classes were prospering and growing as a proportion of the whole population. Not that poverty disappeared. The West's achievement was not the abolition of poverty but the reduction of its incidence from 90 percent of the population to 30 percent, 20 percent, or less, depending on the country and one's definition of poverty. (Ibid., 6.)

Fifth, an even more serious misreading followed on the previous two when many twentieth-century observers misinterpreted the contribution of nineteenth-century public policy. Believing that the First Industrial Revolution had reduced living standards compared with the pre-industrial age and then left them static over time, these analysts took the obvious next step and decided that the working class was saved from poverty by nineteenth-century pro-labor legislation. Many went on to conclude that pro-labor legislation was all that was needed to create working class prosperity. This view guided public policy in many countries and brought misery to the very laboring groups the policies were meant to help. Argentina under Juan Peron was a typical case in point.

Even today, many observers in advanced industrial countries blame low incomes in poorer countries on the absence of advanced social legislation. In doing so, they neglect the fact that, if productivity is low, then the nation's total output *must* be low, and if its total output is low, then its average living standards *must* also be low. What alleviates low overall living standards is the growth of per capita output, not the redistribution of existing output (*no matter how desirable some redistribution might be for other pressing social reasons*).

This mistaken view of the place of social policy guides many current attempts to impose Western living standards on poor countries by fiat. For example, it appears that trade sanctions are about to be levied on countries that use child labor. Yet when productivity and hence wages are desperately low, the only way many families can earn a living income is for husband, wife, and children all to work — as they typically have done in *peasant agriculture* since the neolithic agricultural revolution and do so even to this day. Before Westerners let their compassion deny these jobs to child labor, they should ask, what is the alternative? All too often, it is life on the street, a life of petty crime, or child prostitution. People with active social consciences who are busy attacking child labor do not like to be told that they may be contributing to child prostitution. But how many of them really know what alternatives there are for the children that they would throw out of jobs?

Of course, some pro-labor legislation does good in many ways, but what it cannot do is to legislate living standards that are higher than the productivity of labor will support. Of course, it is good to eliminate child labor when there are superior alternatives, such as staying on in school, but, sadly, all too often those superior alternatives are not the ones that are available.

The Non-West Today

So far I have concentrated on the success story of growth in the countries of the West. What of the non-Western countries today, those we politely call less-developed countries (LDCs)? What strides have they made in recent decades, and what hope lies on the horizon? The answers depend on the growth models they have followed and are pursuing today.

The Discredited Model

After World War II, accepted development policy followed a pattern set by the planned economies. The model was inward looking in the sense that local industries were to be fostered to replace imports, protected by high tariffs, and supported by large subsidies and favorable tax treatment. Governments were hostile to foreign investment and made it difficult for multinationals to locate in their countries. Much new investment was by government-owned industries. Industrial activity was often controlled by licenses and quotas. The exchange rate was almost always fixed, and multiple rates were often used. The currency was usually overvalued, leading to an excess demand for foreign exchange and rationing of the available supplies. The argument for keeping export prices high was based on the assumption that traditional exports faced inelastic foreign demands, while new, more industrialized exports could not be developed because these markets had already been preempted by the advanced countries. Little thought was given to technological change.

These interventionist measures gave great power to state officials, and bribery and corruption were (and are) rife in these interventionist economies. As a result, scarce resources were often allocated to those with most political power or the greatest ability to bribe, rather than to those who could use them most efficiently. Most such economies fell short of full central planning and full state ownership of the means of production, so there was still some private initiative and some profit seeking through normal market means, but the overall policy thrust was inward looking and interventionist.

These economies fared poorly during the 1960s and 1970s. Economies as varied as Argentina, Burma, Indonesia, Tanzania, Ethiopia, and Ghana were all interventionist, and the best performers grew slowly, while the worst actually became poorer.

The NICs

In the late 1950s and early 1960s, a few non-Western economies took a quite different course, creating the phenomenon of newly industrializing countries (NICs). South Korea, Taiwan, Hong Kong, and Singapore each made an independent decision to abandon the traditional model. Within the course of three decades, all four turned themselves into thriving industrial countries with per capita incomes currently about half those of the United States.

Although these countries differed greatly in their amount of government intervention, their policies had some common features. First, they initially built local industries under tariff protection and with government assistance. Their policies for industrial growth, however, switched from import substitution to export promotion. The new industries were required to export, contending in the fierce world of international competition. This requirement forced dynamic competitiveness on them in the way that was not necessary for import-substituting industries serving protected home markets. It helped them to learn about and then copy international standards of design, quality of product, and marketing. Export orientation also provided a cutoff for unsuccessful attempts. With import substitution, a failure could remain in business more or less indefinitely serving a protected home market; with export orientation, those that did not make it in the fierce world of international competition had their support cut off.

In contrast to what the traditional development model assumed, markets in the West turned out not to be static and fully dominated by already established firms. New product and process technologies were continually coming into use, giving scope for newcomers to enter and succeed in new markets. Also, as already mentioned, falling costs of transport and the ICT Revolution allowed parts to be manufactured anywhere in the world, creating new comparative advantages in such production.

The first four NICs had a much more managed capitalism than is typically found in the West, but market-oriented capitalism it surely was, compared with the stagnating rest of the less-developed world. Today, many other countries are seeking to copy the NICs, and a second round of economies, including Malaysia, Indonesia, Thailand, Vietnam, and to some extent the Philippines, are succeeding in raising real incomes at higher rates than were achieved under the old, inward-looking policies.

New Growth Policies

By and large, the conditions for growth are no secret. We know the conditions that it is necessary to create in a country that wishes to catch up by adopting Western technology. This cannot be done overnight because it requires a vast amount of physical and human capital, as well as decades of learning by doing. But what is needed includes an open society with freedom of the market to operate in a relatively unrestricted way (which is not to say that citizens should not be protected from arbitrary abuse), heavy investment in mass education, and fulfillment of the other conditions mentioned earlier. In a way, the NICs did not create a miracle. They just stopped banging their heads against the walls of intervention, and the “miracle” was that their interventionist-induced headaches went away. Most of those countries that are lagging behind the NICs are clearly not fulfilling a battery of the necessary conditions; instead, they are preserving their many interventions that enrich local vested interests but inhibit private risk taking and investment. India, for example, still labors under the handicap of an archaic, nationalized banking system that is run mainly for the benefit of its employees, as well as subsidies that misdirect resources into many inefficient activities, including some agricultural lines in which the country lacks market competitiveness.

Countries with few natural resources will stay poor until they develop the human resources that can yield rising incomes, and even then they will not become paradises overnight. Nonetheless, if they want the kind of growth that the West and the NICs have achieved, they can at least stop doing a number or things that are clearly counter-productive.

Sub-Saharan Africa is, with a few notable exceptions, a basket case because of its own, often Marxist policies that in many places have destroyed natural agricultural bases and indigenous industries. The West can give help, but it will not be effective in any serious way as long as local government policies are not seriously directed toward market-driven growth.

Currently, a neoclassical counterattack is under way against the interpretation I have just given of the NICs' success. Economists such as Alwyn Young (1994) argue that, because they can fit the neoclassical aggregate production function to the NICs' data with only a small Solow residual, all those countries did was to accumulate capital. In this view, the NICs' microtechnology transfer and development policies did little or nothing to promote their growth. It would take a whole paper to rebut this view properly, so I do nothing more here than record its existence and my objections to it. When capital embodies new technology, it is difficult, if not impossible, to split its contribution between pure capital accumulation and the acquisition of new technology. Just because the changes in national income can be correlated with the changes in the value of capital and labor, there is no necessary implication that accumulation was all that was needed. If it were, the Soviet Union would have been a much greater success than it was.

Part II

Whither the World?

Sustainable Growth

I have talked so far about the power of growth. It has raised the West to where it is today, with high incomes and a nonrefundable ticket to a totally new world that is driven by the new information and communication technologies. It is raising the incomes of those LDCs that have dared to fulfill the necessary conditions discussed earlier. But is continued growth really possible? Is it desirable? Will we not run out of resources or pollute ourselves out of existence?

The worry about running out of resources is a myth with respect to resources in general (although not for some individual resources), but fatal pollution of the environment is certainly possible, although by no means inevitable. Indeed, those countries that are in most danger of doing themselves serious harm through pollution and environmental degradation are the poorest, not the richest. Such countries suffer from a combination of desperation coming from poverty and of corruption that allows those in power to get rich by despoiling the environment.

Population Growth

One much-cited threat to sustainable economic growth is population growth. It took some hundred thousand years, from the beginning of homo sapiens until about 1800, for the world's population to reach 1 billion. Today, less than 200 years later, the population is close to 6 billion, and it is expected to peak in the range of 10–12 billion in the middle of the twenty-first century.

People in the advanced countries often talk as if the population explosion were an unmitigated disaster. Yet its main cause is an increase in life expectancy — from 40-odd years, as is still typical of really poor countries, toward the 70 or 80 years that is typical of more advanced countries. Surely this rise is not without some benefit to those affected.

Nonetheless, the population explosion has brought with it enormous problems. Poor countries must make heroic efforts to increase their GDPs merely to keep pace with population growth, so that average living standards do not fall. In rich and poor countries alike, population growth puts enormous pressures on specific resources and the carrying capacity of the environment.

The technologies of the 1980s could probably raise a world population of 1 billion to the West's current living standards without disastrous environmental consequences. They could not, however, do it for a population of 10–12 billion. Although some people dissent, most believe that pollution, environmental degradation, and exhaustion of key resources would be widespread if 10 billion people were raised to US and Western European living standards using technologies completely frozen in their 1980s' form.

If technological change today were producing its continued economic growth in a world whose stable population was 1–2 billion people, the issue of sustainable growth might never have become globally prominent. Individual countries might still embark on unsustainable growth paths by exhausting nonrenewable resources or exploiting renewable resources, such as forests, fishing grounds, and agricultural land, beyond their natural recuperative powers. And individual resources, such as fossil fuels, would still become exhausted from time to time and be replaced. Just as wood supplies were largely depleted in late medieval times and finally replaced by coal as an energy source, oil supplies eventually may be depleted and replaced, probably by some nonfossil energy source. These examples suggest why the exhaustion of some key resources typically poses no long-run threat to growth. New technologies are developed to allow some hitherto unused resource to replace the depleted one.

As it is, however, the world's population is still expanding, making sustainability a real problem. If growth is to be sustained into and through the twenty-first century, a host of real environmental problems need to be solved (while the many imaginary ones need to be laid to rest).

Why Growth?

The environmental issue raises the broader question: Why does the world need more growth? I have four answers.

First, feeding a world population of 10–12 billion in the twenty-first century will require further advances in the technology of food production. In Malthus's time, it seemed impossible for 2 billion people to be adequately fed. Today, the world feeds nearly 6 billion people, and agricultural surpluses, not shortages, are the problem in major food-producing areas, such as North America and the European Union. The green revolution brought vast increases in agricultural production to developing countries, allowing them to feed rapidly growing populations and sometimes even to export surplus food. Today's famines are associated mainly with civil wars (when food supplies are often used as a weapon); gross mismanagement such as has occurred with attempts to collectivize agricultural production (or otherwise interfere with normal market incentives), particularly in Africa; and the use of nonsustainable agricultural techniques where sustainable ones are available. Technologies already in their early stages, especially aquiculture and biotechnology, will be capable of feeding 10–12 billion people once they are fully developed. *The world has reason to give thanks that no earlier-day antigrowth, antitechnology advocate was able to persuade national governments to freeze agricultural technologies at their 1945 levels.* If that had happened, the Malthusian disasters of famine, plague, and pestilence would long ago have become endemic as the world became unable to feed its growing population.

Second, the best hope for saving the environment while raising living standards is through further growth-inducing technological change. *Most new technologies use less of all inputs per unit of output than do the older technologies they replace.* Technological change thus tends to result in increasingly economical use of the world's resources. Furthermore, many newer technologies are much less polluting than many older technologies. Until communist governments fell, a trip from Western to Eastern Europe, where 1950s' technologies produced environmental degradation on a vast scale, made this point strikingly to even the most casual observer. Much of the increasing environmental friendliness of newer technologies happens naturally as firms follow economic incentives to produce at lower cost and greater efficiency. When normal economic incentives do not produce this result, public policy can create incentives that pressure technological change to increase environmental friendliness. Of course nothing can ever be certain, and new technologies sometimes produce quite unforeseeable environmental or public health problems. But that is a reason for caution and quick reaction, not for stopping technological advance.

Third, the *only* way for the citizens of the poorer countries to raise their living standards to those that citizens of advanced countries accept as normal is through further economic growth. I say more about this point below.

Fourth, further growth provides the only possible route to higher living standards for those who live in the West. They still worry about such issues as poverty for lower-income groups, generally inadequate education, and medical and hospital care that are becoming increasingly difficult to fund. These problems are much easier to deal with in a growing economy rather than in a static one. Today's level of expenditure on health care in Canada, which is clearly inadequate for fully satisfactory services and which is being curtailed by hard-pressed governments, would be easily handled in an economy with a GDP of 1.5 times the current level. Three percent growth would produce that level of GDP in 15 years — that is, by 2011. It would also raise the living standards of most of the rich *and* the poor by 50 percent over that period, and it is not beyond public policy to ensure that those who did not enjoy this growth through normal market transactions could benefit at least to some extent. Again, achieving equity and equality of opportunity and preventing a permanent rich / poor divide is easier in a society that is growing and constantly changing than in a static society.

Underassessing the Power of Growth

Many people underassess the power of growth — an attitude that leads to many misguided policy views, including the belief just discussed that further growth is unnecessary. They do so for many reasons. Here are a few of them.

The Teachings of Economists. First and foremost, economists themselves put insufficient stress on the importance of technological change. Many devote most of their thought and teaching to static efficiency and redistribution and little to growth. Surveys show that professors routinely skip the growth chapter in my first-year economics textbook in order to make time to teach the largely short-term neo-Keynesian national income model. It is possible to get a BA, an MA, and a PhD in economics without having had any exposure to growth theory and related empirical evidence. Furthermore, if a student does take a course in growth, it typically will start and end with aggregate production function models in which technology is hidden away in a black box. In such a treatment, growth is driven by savings and investment (accumulated in the capital stock), and technological change is seen only in so far as it alters the Solow residual.

I myself was taught nothing about technological change as a student. Most economists of my acquaintance know little about technology, and, more the scandal, they do not think this lapse is a deficiency. Yet, as I observed at the outset of this essay, technological change is the single most important economic force for altering our living standards, both in the narrow sense of raising measured GDP and in the broader sense of changing how we live. More than half a century after Joseph Schumpeter decried the excessive emphasis that economists give to static efficiency and the neglect of the economics of technological change (Schumpeter 1943), the profession continues largely to ignore this criticism.

Short Memories. Individuals' memories of past technologies are confined to their own lifetimes. The majority of young people take for granted the massive alterations that technology has wrought, even over the short period since the end of World War II. It is hard for today's youth to imagine even the world in which I grew up, let alone that into which my parents were born in 1900. I knew no computers and did my first econometric work on a mechanical calculator that took ten or more seconds to do one division. Two moderate regressions, done by inverting matrices using the Doolittle method, were a good day's work. International phone calls were expensive and difficult. Letters were the only method of communicating hard copy over distances, and they took days or weeks to reach their destination. Travel was expensive and rare;

what there was used two-lane highways, rail, ocean liners, and, only in emergency, slow and expensive propeller aircraft. Ballpoint pens were unknown. There were no credit cards or automatic teller machines, and to be caught away from one's hometown without cash on a weekend was a disaster. Dental work was slow and painful, and medical diagnosis, without CAT scans and other high-tech devices, was rudimentary by today's standards. (For elaboration, see Lipsey 1992.)

I could go on for pages on this theme. I could also list pages of the things I took for granted that were not available to my parents in their early childhood (either because these items had not yet been invented or because they were so rare that many ordinary people had not come into contact with them). That list would include automobiles, airplanes, antibiotics, dial telephones, radios, and so on. For my parents, indoor plumbing and electric lights were among the latest technological marvels (and marvels they surely were).

My point is that, unless we Westerners are students of social and economic history, we have no idea of how technology has transformed and improved the ordinary person's lot — even over the lifetime of people still alive today and much more so over the centuries. Not long ago, I was talking in a similar vein about the household revolution made possible by electricity, which released women (or their servants) from the backbreaking, seven-day-a-week drudgery that had been their lot since the neolithic agricultural revolution. At question time, a woman in the audience commented that she refused to believe a few gadgets contrived by men had mattered much to women. Unfortunately, I had no way to transfer her in a time machine to the pre-electricity farmhouse in which the majority of our forbears lived, even in the last century, without electric light, central heating, indoor plumbing, vacuum cleaners, sewing machines, refrigerators, electric or gas stoves, washing machines and dishwashers, grease-dissolving detergents, frozen and prepared foods, and so on. Those who went through the household transformation wrought by the technology of electricity were under no such illusion as was held by the woman in my audience. For decades, Franklin Roosevelt received enormous devotion from farmers for bringing electricity to rural areas in the 1930s. (As a young boy, ignorant of the technologies of the past, I wondered why farm people in the United States spoke with such awe about Roosevelt and "*rural electrification*.")

So Westerners underassess the power of technological change because most of us have little idea of what it would be like to live under the technologies of 50, 100, 200, or 500 years ago.

Concern with the Present. Not surprisingly, current problems dominate our thinking. Anyone who reads political debates and letters to the editor from the 1950s or 1960s surely thinks that people in the West were living through very trying economic times. The stress was on problems — too much inflation and unemployment, too little growth — not on the things that were going well. These discussions gave few hints that people were living through what we now see as a period of secular boom, one to whose general conditions (if not the details of its technology) we would gladly return.

The attitude that little is ever right about current circumstances is, of course, aided and abetted by the press, which, then as now, mainly reported problems, misery, and woe. It rarely produced an upbeat story, one pointing out, for example, that compared with the 1930s things really were very, very good in the 1950s and 1960s.[15]

Although it is customary to castigate the press on this point, I understand the market well enough to realize that, if people really wanted to read about how good things are, the press would provide that information. By and large, we get the kind of reporting we want and deserve — and we then indulge in the self-serving luxury of criticizing the press for giving it to us.

Slow Change. National income changes so slowly that people barely notice its variations from year to year. To most Westerners, Taiwan and South Korea look relatively poor (although better off than Bangladesh or India). Yet the average citizen in an Asian NIC lives at the same measured real income as Canadians did only two or three decades ago. It is easy to ignore growth of 1 or 2 percent per year but anyone who

15 The exception that proves the rule was in Europe from 1945 until the end of the 1950s, where memories of wartime disasters were so strong that people really were acutely aware that they were better off than they had been in the past. In Britain, for example, Harold Macmillan won an election in 1957 on the slogan "You've never had it so good."

was taken back 50 or 100 years would see the enormous power of such growth to alter living standards and to reduce the blight of poverty. Describing how the slow growth that transformed the living standards of working people over the course of the nineteenth century went unnoticed for nearly a century, Rosenberg and Birdzell write:

> Over a year, or even over a decade, the economic gains [of the late eighteenth and the nineteenth centuries], after allowing for the rise in population, were so little noticeable that it was widely [and incorrectly] believed that the gains were experienced only by the rich, and not by the poor. (1986, 6.)

Measurement Problems. Over the decades, technological change typically leads to massive quality improvements in existing products and a large array of new goods and services. The full effects of these changes cannot be captured in traditional statistics such as the GDP. Yet such changes are particularly important when new general purpose technologies are altering the whole set of underlying technologies as well as the facilitating structure. Thus, many experts suspect that the slowdown in measured growth rates associated with the transition between GPTs, such as we are living through today, may be partly spurious.

Rosenberg and Birdzell (1986, 3–4) give the following list of changes that accompanied the First Industrial Revolution. One must wonder how much these changes would have been reflected in the national income statistics had they been collected at the time.

- In 1700, average life expectancy was about 30 years; in early eighteenth-century France, one in five babies was dead by the end of its first year, and 50 percent of registered children were dead by age ten. (And many were not registered because they died before their births had been registered or were victims of parental infanticide.) Life expectancy rose dramatically after the Industrial Revolution (data from Blum 1982).
- The West's economic growth reduced famine and hunger. Not only did per capita food production rise, but its year-to-year variation fell, which was important in poor times, when fluctuations on the downside could mean famine.

- The Industrial Revolution removed terrible diseases that maimed, crippled, and killed — plague, tuberculosis, cholera, dysentery, smallpox, and leprosy, to mention only the most common.
- The urbanization that accompanied the Industrial Revolution increased education and literacy and broadened experience.
- Privacy was enhanced even in a two-bedroom slum. It had been unavailable to peasants because families typically lived in a one-room hut.
- Job mobility vastly increased. Instead of doing what one's forbears had done, one could and did do other things. The choice then available seems limited to us, but it was far more than had been available to a peasant in an early eighteenth-century village.
- The quality of consumption was changed. For example, factory-made leather shoes, no matter how crude, were much superior to wooden clogs. To take a more modern example, today's child who goes to see her friend the dentist is in a much better situation than her grandmother who went as a child to see her pain-generating enemy, the dentist of 60 years ago. Yet whether a doubling of GDP takes the form of twice as much of the same or of new things that enhance the quality of life, the statistics are the same.

Is There an Alternative?

Can we raise the living standards of the poorer nations without further economic growth in the advanced nations?[16] The answer is no, although some proponents of stopping growth believe that we can do so by using one or the other of two types of redistribution policies: transferring large amounts of income from the industrialized world to the LDCs, or moving much production to the Third World. Unfortunately, neither approach would work.

The first strategy — for production to remain in its present locations with the income generated by it being redistributed to the LDCs through international redistribution of income — would require enormous increases in the tax loads that citizens in advanced countries already find excessive. The 50 percent increase in the current tax bite that might be

16 This section relies heavily on Lipsey (1991).

enough to make some dent in Third World poverty would surely be politically and economically unfeasible. On the one hand, even the quite modest redistributions that are currently undertaken within one country run into serious incentive problems when people react to taxes that they regard as excessive. On the other hand, serious incentive (and self-respect) problems arise when people live indefinitely on money that is transferred to them from others who earn it. So the *massive* international redistributions of income required to raise living standards of the LDCs to, say, half the current US poverty level would be quite unfeasible.

The second strategy would redistribute production to the LDCs, thus transferring much of the current level of resource utilization to them. Of course, economic development does something like this by allowing poor countries to expand production and incomes without, however, requiring advanced countries to lower theirs. But analysts who wish to stop growth and help the poorer countries advocate relocating the *existing level of production* from the industrialized countries to the LDCs. Such a shift would pose even more impressive difficulties than redistributing income. How would production be wound down in the advanced countries? Western workers would not voluntarily agree to reduce their incomes to the poverty level in order to allow production to be transferred to the LDCs. Furthermore, the *efficiency of resource use* is much lower in most of the LDCs than it is in the advanced industrial countries (which is why some countries are poor and some are not). So the world GDP that would be generated by a constant level of resource use would shrink as a result of this transfer. (A fall of 50 percent is probably an underestimate of the loss.) Such an enormous transfer of production to regions with neither the infrastructure to support it nor the human capital to drive it could be attempted (I would not say accomplished) only by using the full battery of techniques of the command economy. It is hard to see how the fate of the Eastern European countries could fail to be repeated, but on a much grander scale, as the whole world came under command techniques for allocating resources.

I hope I have said enough to show the serious problems inherent in proposals to solve the world's poverty problems through redistribution either of existing incomes or of existing resource use. It seems not overly extreme to label these ideas as *romantic utopianism* — utopianism far less realistic than the early versions of communism.

I hasten to add that nothing I say here is intended to stop those who would urge people voluntarily to limit their consumption, adopt simpler lifestyles, and give generous assistance to the LDCs. The burden of my argument is that the redistributive alternative is unrealistic as the major contribution to solving the pressing problems of Third World poverty and that to assume otherwise is to divert attention from the search for feasible solutions.

Neglecting the Power of Technological Change

I would not have spent time on these impossible romantic ideas about redistribution were they not influential in persuading some people that it would be possible to stop technological change and abandon the idea of sustainable growth without condemning the world's many poor countries to perpetual poverty. In fact, the *only* alternative to permanent poverty of the LDCs is continual economic growth through innovations that produce new products using new and less polluting technologies, which is the way charted by the Brundtland report for sustainable growth (World Commission on Environment and Development 1987). I hasten to add that I agree with Thomas Kierans (1988; 1990), who insists that sustainable development means sustainable *economic* development in which there is no command and control approach to the environment; rather, the system is *incentivized* to produce technologies that are both economically efficient and environmentally friendly.

As I describe below, market-based environmental protection policies are available to those countries that wish to use them. The really serious problem is to get the poorer developing countries, such as China, Indonesia, Brazil, and India, to give up their old ways. Signing unenforceable agreements for the richer countries to use such policies while the others continue old practices is not a solution (although it was done at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro — where none of the countries I mentioned was a signatory).

Unfortunately, too many commentators think only of today's commodities and today's technologies. They do not see the possibilities of raising living standards and dealing with pollution through technological advance. Critics who advocate stopping growth and then redistributing either income or resource use often treat the solution of further growth with scorn. For example, David Suzuki, an internationally known Canadian conservationist, says in a newspaper article:

> Sadly, the Brundtland report...[accepted] the preposterous notion that continued economic growth in industrialized countries is critical for the Third World, and projected yet another round of economic growth that could lead to a fivefold increase in global wealth. *Can you imagine having and using five times as much of everything?*....[T]he human intellect cannot endlessly find new resources or create alternatives because the Earth is finite. (Suzuki 1991, D6, italics added.)

Like Dr. Suzuki today, our Victorian ancestors could not have imagined what to do with five times as much of all of the goods that they knew about. Although we do not have five times as many horse carriages, penny farthing bicycles, or gas lamps, we do have *ten* times as much market value of consumption as they had (measured in constant dollars), and going back to even twice the purchasing power that they had would mean returning to what we now regard as the poverty level.

Looking backward to see vast gains from past increases in total consumption while looking forward to perceive little gain from future increases in total consumption seems paradoxical. The explanation lies in *new* products and *new* processes. The Victorians could not have imagined the list of goods and services that we take for granted, any more than they could have imagined the clean, automated, computer-controlled factory of 1996. We can be thankful that no earlier-day antigrowth advocate was able to persuade the Victorians to stop growth because they could not imagine what to do with five times as many units of the products that they knew about.

Our grandchildren will have available to them many products and processes that we are now just beginning to dream about. The list may include biotechnology that feeds 12 billion people with relative ease; medical advances such as surgery that is unintrusive, robotized (now used in hip replacement), and performed by remote control (making the best surgeons' services available throughout the world); self-monitoring kits that feed the information into individuals' personal computers and warn them quickly when their bodies are acting strangely; superconductivity that makes power available throughout the world at negligible transport cost; commonplace e-mail friendship and experience sharing among children of different cultures, religions, races, and colors; and, sooner or later, an environmentally friendly replacement for fossil fuels.

Sustainability Policies

Markets are valuable coordinating mechanisms because market prices convey information about relative national scarcities without anyone having to calculate them.[17] Plentiful resources have low prices, and very scarce resources have high prices. This dichotomy leads profit-seeking firms to make lavish use of plentiful resources and be frugal in their use of very scarce resources. As a result, no firm would ever engage in such wasteful activities as using $3 worth of resources to recover $1 worth. Yet many public policies do just that, and it is an important job to persuade environmentalists of the need for economically rational policies that really will succeed in achieving their stated environmental goals.

Policy Solutions to Market Failure

Just as it is important to understand why markets typically work well as signaling devices, it is also important to understand that they do not always perform this function well or at all. Ever since the great English student of market failures, A.C. Pigou, pointed the way early in this century, economists have studied how and why markets sometimes fail to reflect people's values and how public policies can correct for these failures.

Two major causes of market failure are externalities and common property resources. Externalities occur when people other than those making a transaction are affected by it while its makers have no incentive to take these third-party effects into account. Common property resources, such as fishing grounds, have long been understood to encourage overexploitation. Since no user owns the resource, none has an individual incentive to conserve it.

Solutions to these and other problems of market failure take two main forms: command and market incentives. Economists favor market-based solutions because they are more flexible and usually produce *any*

17 This section relies heavily on Lipsey (1990).

given result at lower cost than that required by command solutions. I consider just one example, which I quote from a previous article.

> [A country has] an important export industry that is the source of some undesirable air pollution caused by smokestack emissions. The industry contains many firms, operating many plants of different vintages. The expenditure required to reduce a ton of smoke emissions differs greatly among the plants.
>
> The government wishes to reduce the industry's smoke emissions by one-half. The most extreme command solution would require that each plant cut its emissions to an amount equal to one-half of the current industry average. In this case, much money would be spent on reducing emissions from those plants where the cost of reducing emissions is large, while less would be spent on plants where the cost...is low.
>
> Now assume that instead...the government issues transferable rights to pollute, equal in total to one-half the industry's present amount of pollution. It either sells, or gives, these rights to firms in the first instance, and the rights are then salable among firms. The price of the right to emit a ton of pollution will tend, in this example, to equal the industry's average cost of removing a ton of pollution. Firms whose costs of removing pollution are less than the industry average, and hence less than the price of the pollution right, will clean up. Firms whose costs of cleaning up exceed the industry average, and hence exceed the price of the pollution right, will buy the rights and continue to pollute. The outcome is that the government's pollution-abatement targets will be met at the lowest possible cost to the industry.
>
> Compared with the command solution, which calls for the same [reduced] smoke emissions from all plants, this market-based solution is preferable to each firm's employees (because it minimizes employment losses), to its customers (because it minimizes the increase in the product's price), to its owners (because it minimizes the reduction in profits), and to the whole society (because it minimizes both the amount of scarce resources used in achieving any given amount of pollution abatement and the loss of international competitiveness due to the raising of export prices to cover the abatement costs). (Lipsey 1990, 121–123.)

Opposition

Environmentalists frequently oppose market-based solutions. A few of the most important reasons for this opposition are worth emphasizing because maintaining sustainable growth requires effective environmental policies.

Fear That Markets Are Not Efficient. Environmentalists often doubt the efficiency of markets. Some do not understand economists' reasoning as to why markets can be — and often are — efficient in their use of resources. Others understand the economists' case but reject it. For the most part, they simply insist that markets fall short of perfect efficiency. Few bother to complete the argument by trying to demonstrate that command-type allocation by government will be more effective in achieving agreed goals.

Dislike of Self-Interest Incentives. One of the greatest insights economists have had is that people respond to self-interest incentives and that, in the long term, such incentives dominate behavior in ordinary matters. Economists who point to the voluminous evidence of the importance of self-interest incentives are often accused of ignoring "higher" motives, such as social duty, self-sacrifice, and compassion. As I understand the evidence, however, motives such as altruism and devotion to a cause higher than one's own self-interest often do exert strong influences on human behavior. Such higher motives are powerful at some times and in some situations, but they do not govern many people's behavior in the course of ordinary living. If we want to understand how people behave in the aftermath of a flood or during a battle, we need to take account of motives in addition to self-interest; if we want to understand how people behave day after day in their buying and selling, we need little other than a theory of the self-interested responses to market incentives.

Many environmentalists feel that to rely on the motive of self-interest in respect to pollution and conservation is to degrade matters of life and death. Such people must be persuaded that an enormous weight of evidence shows that, although altruism can sometimes be important or even dominant, it cannot be relied on to guide the myriad day-to-day decisions that ordinary people must make to guide their economic affairs. Control of the environment requires influencing this mass of small decisions, as well as a few large ones, and the appeal to self-interest is the only currently known way to induce the continual behavior that is required. Once this point is accepted, what remains is to choose between relying on the self-interest of fear of penalties that the command approach uses and the self-interest of pursuit of gain involved in market-based approaches.

A Mystical View of Resources. Many environmentalists have a somewhat mystical view of resources as being above mere monetary calculation and believe that they should thus be treated in special ways. It is hard to argue rationally with religious positions. One can only point out that the use of the mystical view to justify departing from market solutions (and from solutions based on calculations of market failures, which are measured in terms of failure to provide maximum economic value) ensures that measured material living standards will be lowered. If that outcome is understood — and accepted — as the price of regarding resources as mystical entities, then so be it![18]

The Economics of Ideas

Ever since the science of economics began, the landscape of models has been dominated by diminishing returns to the accumulation of one factor and constant returns to scale. Ideas, however, are not like goods. If I have an idea, I can use it and so can everyone else, whereas if I use a machine, no one else can use it at the same time. In technical language, goods are rivalrous while ideas are not.[19]

Thus, the accumulation of ideas, with labor constant, is not subject to decreasing returns as is the accumulation of capital, with ideas (technological knowledge) constant. Investment need not be subject to decreasing returns, as long as it embodies new technological knowl-

18 I have no space here to discuss, as I did in Lipsey (1990), why groups other than environmentalists, often including firms, sometimes oppose market-based solutions.

19 Some people seek to equate ideas and human capital. As Romer has frequently pointed out, however, the two are significantly different in that human capital is rivalrous (if I visit a firm and use my skills to help it today, I cannot simultaneously visit some other firm and use my skills to help it), while ideas are not (once an idea is developed, everyone can use it simultaneously).

edge. Instead, with ideas as the key factor in growth, it is seen that incomes can go on growing forever.

The usual diminishing returns argument — that people use the best ideas first and then go on to less productive ones — does not apply to technological change. Some case, albeit a rather weak one, can be made for the diminishing returns argument within the latter stages of one general purpose technology, such as steam or the printing press. But in the shift from one GPT to another, there is no reason to expect diminishing returns because there is no reason to believe that the increment to total output coming from a succession of totally new ways of doing things will decrease over time. For example, the increment in going from the waterwheel to the steam engine was obviously less than the increment in going from steampower to electricity. Going from water to steam was going from one mechanical source of energy to another; the move was potent in its possibilities, but they paled by comparison with the horizons opened up when society went from steam to electricity, from a mechanical to an electronic form of power. *In the realm of fundamental new ideas, neither theory nor evidence supports the view of the diminishing economic returns to the accumulation of knowledge over the long term.* (Notice, as earlier observed, that the neoclassical model would cover the shift from water to steam and from steam to electricity in one macro production function, $GDP = AF(K,H,L)$, although it is hard to know what it means to say when the experiences under such diverse technologies are expressed by a single relation between inputs of labor and physical and human capital.) As I say elsewhere:

> Economic analysis will no doubt be used in the future to analyse many dismal economic events, and there will be many. But the days when the underlying basis of the subject justified the title "dismal science" are over. The modern title should become "the optimistic science" — not because economics predicts inevitable growth or the arrival of universal bliss, but because its underlying structure, altered to incorporate the economics of knowledge, implies no limit to real-income-creating, sustainable growth, operating in a basically market-organized society. If we cannot achieve sustained and sustainable economic growth, the fault dear Brutus must lie with ourselves, not with some iron-clad economic law that dictates failure before we start. (Lipsey 1994, 351.)

Conclusion

So sustainable growth is key to raising living standards throughout the world (to say nothing of creating and preserving freedom and democracy). Thus, technological change must continue on its present path of producing new and improved products with new methods that use fewer and fewer resources per unit of output. This approach will require a strong, market-oriented economy as well as public policy measures that nudge technological changes in the right direction and strong measures based on market incentives that correct for market failures caused by externalities and common property resources.

The Speed of Technological Change

Although a qualitative characteristic is hard to measure quantitatively, there can be little doubt that the pace of change is accelerating. The distance from the neolithic agricultural revolution to the invention of writing was measured in millennia. The distances between the use of oral communication in the Carolingian period to the use of written script in the Middle Ages, from the widespread use of waterwheels to the First Industrial Revolution, and from the invention of the efficient three-masted sailing ship to its replacement by the iron steamship were all measured in centuries. The distances between the first human-powered factories of the early Industrial Revolution, their mechanization through waterpower, the replacement of water by steam, and its replacement by electricity were all measured in decades. Current product cycles suggest that the movement from one technologically based product to another is increasingly being measured in *years*.

One important development is the change in the relation between science and technology. Until the middle of the nineteenth century, technology was developed by practical artisans, and scientists tried to explain why technology worked. Since the late nineteenth century and increasingly in the twentieth, however, science has often led technology. Today, discoveries in the laboratory are often transformed in a short time into marketable products. The older connection from practical results to theoretical issues is still there, but equally important today is the reverse link running from scientific discoveries to practical technologies.

Another important development accelerating change has been the institutionalization of research and development. Late in the nineteenth century, practical innovators set up R&D laboratories, and slowly these led to an institutional structure whose *raison d'être* was technological change. Change was no longer on the outside pushing in against the established forces of stability. Instead, the institutionalized forces of change were now resisted by the outside conservative forces who were hurt by change. Resist they did, sometimes with significant results, as when British unions in the 1960s and 1970s opposed a series of technological advances that would have cut costs in printing, transportation, and some key areas of manufacturing. Such successful resistances are now reduced to rearguard actions of limited scope and duration.

The new GPT that is transforming our society is an information technology. Just as the spread of literacy through fast printing presses and the organization of universal education in the West were important to the innovative industrial society of the nineteenth century and to the institutionalization of technological change, the spread of computer literacy is the key to the explosion of today's knowledge. A well-stocked medieval library might have contained 80 books, whose duplication represented lifetimes of work. A nineteenth-century printing press could print a book in a matter of hours. Today, the saving of a book on a floppy disk consumes seconds. As one commentator recently put it:

> [T]he message-carrying capacity of fibre optic systems is doubling every 18 to 24 months....At today's [1990] modem speeds, it would take 19 centuries to transmit the entire contents of the National Library in Ottawa to anywhere else in the world, by the turn of the century, you will be able to do it in minutes. (Ferchat 1991, 22.)

Throughout history, new GPTs have arrived episodically, causing in their turn episodic bouts of deep structural adjustment. Once the facilitating structure had become more or less fully adapted to the new technology, a period of secular boom followed. During this latter period, a stream of further product and process innovations would slowly exploit the full potential of the new GPT.

The current accelerating pace of technological change could upset this long-established sequence. It is conceivable that each new GPT could follow so fast on the introduction of the one that it replaces that deep structural adjustments, such as those that we have lived through over the past 20 or so years, would become endemic rather than episodic. In these circumstances, the facilitating structure would never solidify into a stable pattern that was reasonably well adjusted to prevailing technologies.

A shift from episodic DSAs followed by secular booms to more or less continuous DSAs would have profound effects on the way we live and how we react to economic and political situations. It would be analogous to moving from a Canadian experience of inflation to the worst Latin American experience. We would adjust by building much more flexibility into the facilitating structure, but the learning process would be costly and the new regime in all probability would be less preferable than the present one.

The Future of Poverty

Poverty has been greatly altered by technological change. Westerners on today's poverty line have purchasing power close to the average income of a hundred years ago, an amount enjoyed by only the wealthy three centuries ago. No one wants to be poor; no one envies them. But the poor celebrating welfare Wednesday, with its crowded bars and busy taxis, are a long way from the poor of 1700, wandering homeless with rags for shoes, beset with loathsome diseases, unable to see properly from eye disorders, and knowing little material enjoyment other than the occasional pint of beer bought with money begged from passersby. Inhabitants of eighteenth-century poor houses fared a little better, but they were still far, far below today's poverty line. Furthermore, the poor were a much larger proportion of the population then than they are today.

Not surprisingly, however, the poor do not wake up every morning thankful that they are so much better off than they would be if they had lived a century or two ago. (Even if they did, they would probably not realize that the difference is mainly due to the differences between the technologies in use then and now.) Instead, they are quite naturally and acutely aware that they do not have what the more affluent members of their own society have here and now. The poor will always be with us, in the sense of people at the bottom end of the income distribution.

Also, those who are comparatively poor because they cannot cope due to heredity or traumas in earlier life will always be present. No amount of wealth will ever remove this “dropout” end of the income distribution. It should not be beyond human wit, however, to design systems that do not destroy self-reliance but that do take the worst stings out of poverty (whether the reasons for it are avoidable or unavoidable) and that alleviate some of the harm done to children by their parents’ poverty. Clearly, the welfare system introduced after World War II failed in many ways, mainly because its founders did not anticipate the long-term reactions to the economic incentives that they set up. Currently, society is retrenching on all social safety net measures; I hope that a counterreaction will soon set in and that, armed with what they have learned, policymakers will do better when they try again.

In the meantime, everyone should recognize that poverty in the West now means something very different from what it means in other places today and what it meant here a hundred or more years ago. Also to be recognized, as Sarlo (1996) documents in detail, is that many of today’s antipoverty advocates overstate the problem. Small pockets of poverty do exist, but its scale is lower than ever before, lower than it is today in most places outside of the West, and lower than some current lurid accounts make it seem.

Also to be noted is that prosperous countries such as the United States have many problems — urban blight, black poverty, racial and sexual discrimination, and the enormous population of prison dwellers in jails — that are neither caused nor can be removed by technological change. The war on drugs, for example, is a self-inflicted disaster that has done incomparable harm both to producing countries such as Columbia and to consuming countries and that would exist, given current misguided policies, whether technologies were those of the nineteenth, twentieth, or twenty-first century.

The comparison between past and present poverty reveals the power of further growth to alleviate poverty in the future. Just as today’s poverty-line dweller looks rich compared to the person who lived 200 years ago in the same relative position in the income scale, the poverty-line dweller of 200 years from now would look like a wealthy person if he or she could be seen through the eyes of his or her twentieth-century counterpart.

The Future of Work

One reliable way to make a fortune is to use some new economic development as the villain in a disaster scenario. The date for disaster must be not so close that the prognosticator will be discredited before he has made his millions, but not so far away as to be of little current concern to readers. In the 1930s, people made fortunes predicting that the world had run out of technological ideas. In this view, there would not be enough opportunities to employ in new investment the money people wished to save, and this lack would create a tendency toward permanent depression. This "secular stagnation thesis," which is now seen to be groundless, influenced governments and the public and was solemnly taught to a generation of undergraduates. In the 1960s, the doomsday predictors argued that technological change was destroying jobs for the unskilled, who would become permanently unemployed. In the 1980s, pundits claimed that technological change was creating *too many* jobs for the unskilled — a surfeit of "bad jobs," causing low incomes for many workers. Today they say that work itself will disappear for all too many would-be workers.

And so it goes, with one disaster scenario succeeding another in a history that goes well back before the 1930s where I took up the story. The only uncertainty lies in the specific details of the scenarios that will occupy people's attention in forthcoming decades.

Although no one can foretell the future, a few things are clear enough.

- Predictions of apocalyptic disaster are as old as civilization.
- Technological change dramatically alters the nature of work and has done so for at least five millennia.
- Whatever else technological change is doing, it is not destroying jobs in general. In Canada, the total number of jobs increased from 9.7 million in 1975 to 11.7 million in 1985 to 13.5 million in 1995.
- The number of jobs for the better educated has been increasing, while the number for those with low educational levels has been falling. Recent research demonstrates this transition. The empirical data for Canada show that people with some level of postsecondary education enjoyed 53 to 76 percent employment growth during the 1980–89 period; people with less than high school education expe-

rienced negative employment growth over the same period. The required solution is more human capital and more remuneration for that capital — in short, more "good jobs" and fewer "bad jobs." Meanwhile, the worrying thing is that many of today's youth do not seem to have heard the message. A young person in the West who drops out of education today can enter only a declining part of the job market, one in which wages will be held down by globalized competition with the masses of unskilled workers throughout the less-developed part of the world.

- Pundits almost always put an unfavorable twist on novelty. The loss of high-paying, relatively low-skilled jobs for men on assembly lines is sad, but their replacement by part-time or flexible-hours work at home (made possible by the modern ICT Revolution) will be a boon for many. Furthermore, the personal initiative required for this new type of work is typically much more than was required on the assembly line. Far from turning the entire Western labor force into hamburger flippers, the ICT Revolution is producing many new opportunities for creative, skilled work. There will, however, continue to be a bifurcation between the "knows" and the "know nots" that can be alleviated only when the bulk of youths understand that there is little future in the types of unskilled work available to the uneducated.

Since no one can predict the future, writers are free to conjecture that a collapse of overall employment opportunities is latent in the new technologies. They may be right. Set against this possibility, however, are several powerful considerations. First, in the past, every new technology destroyed fewer jobs than it created. Second, there is no current evidence that net job creation has come to a halt. Third, there is nothing known about the new technologies to suggest that they will be net destroyers of jobs (although they are certainly destroying the pattern of past employment).

Policy Implications

Although the technological change that lies at the heart of economic growth is treated as exogenous in many economic theories, the evidence leaves little doubt that this change is largely endogenous in that it responds to economic incentives.[20] Given that much of R&D is a costly expenditure undertaken by firms in pursuit of profits, this point should not be surprising. In *Inside the Black Box*, Nathan Rosenberg (1982) substantiates this view with much evidence and also (see in particular chap. 7) makes the case that pure science responds significantly but in less obvious ways to economic incentives.

Some Basic Considerations

Since endogenous technological change lies at the heart of economic growth, governments cannot avoid influencing growth. Every government policy, including those related to education, competition, and income redistribution, will have some influence on the amount, location, and direction of technological change. A monograph would be needed to do this topic justice. Here I have space only to give the flavor of what is implied.

Understand and Accept Change. In the 1950s and 1960s, my colleagues and I at the London School of Economics (where I taught from 1955 to 1963) sent out countless foreign students who thought that all their countries needed to do was to copy existing Western technology. By the time that imitation had been done, much of the technology was obsolete. As I have already observed, the secret of the West's success is not one particular technology but a socioeconomic system that encourages continual experimentation and change and that restricts the power of vested interests to slow or even stop this change — as can happen all too easily.

Keep Regulation Flexible. Technological change turns yesterday's natural monopoly into today's fiercely competitive industry. The communications industry is a modern case in point. Yet Canada still gives the post office a legal monopoly over delivery of first-class mail and sets significant restraints on the firms that are allowed to compete with it on some of its other services (courier companies, for example). These regulations,

20 This section draws on Lipsey (forthcoming) and Lipsey and Carlaw (1996a; 1996b).

which were set up when the transmission of hard copy over space was a natural monopoly, make no sense in the days of faxes, e-mail, modems, satellite transmissions, and the massive capacity of transmission systems based on fiber optics. Service would be better, faster and cheaper if the government allowed open competition (including competition for subsidies for service in remote areas that was desired in the national interest but could not be provided profitably by private firms).

One can make a Schumpeterian case for abandoning all forms of regulation of natural monopolies: the higher the profits earned by any current natural monopoly, the greater the incentive for creative destruction — that is, the invention of new technologies that compete with it. In the very long run over which technology changes in response to economic incentives, there are no natural monopolies. If, however, current natural monopolies are to be controlled in the interests of social justice, then the regulations need to be flexible enough not to inhibit the invention of new technologies that will replace the old. Legislators also need to be aware of the need to alter controls when some new technology has destroyed the naturalness of a monopoly against which the public was being protected. As the pace of technological change increases, this need for policy flexibility is increasing, along with the harm that is done by inflexibility.

Encourage Created Assets. Many of the new technologies are knowledge based in the sense that human capital is the most important resource they require. As a result, today's national competitive advantages depend more on acquired resources than on resources inherited from nature. Fifty years ago neither Singapore nor Taiwan nor South Korea had any obvious natural advantages in the industrial activities at which they now excel.

Because of the importance of created assets, today's knowledge-intensive firms are footloose. They can quickly move from one location to another where labor is cheaper, taxes are lower, or R&D subsidies higher. Governments can no longer be sure of attracting and holding new firms with temporary assistance. Often, firms will enter a jurisdiction, take advantage of setup benefits, and then leave once these are exhausted. (Consider , for example, what happened with Mexico's earlier development policies.) By the same token, governments must not assume that established firms are securely attached to their home country. If local conditions, including regulations, taxes, and union pay scales, become unfavorable, firms may move. Sometimes such moves are imperceptible because they take the form not of the transfer of head offices but of foreign acquisitions and greenfield foreign direct investment (FDI). Like Northern Telecom, that Canadian success story, a national champion can stay apparently domiciled at home while evolving an increasing foreign and diminishing local presence.

Governments have a responsibility to help in the creation of human capital and to create the conditions in which physical capital will work effectively and its owners prosper. In today's knowledge-intensive world, functional illiteracy and innumeracy among the bottom quarter or third of the Canadian work force is particularly worrisome and may condemn those workers to either Third-World pay scales, state-subsidized employment, or a life of unemployment on social security.

The trade schools established by Bismarck were long a source of competitive advantage to Germany in that all students who did not go on to higher education received a good training in some trade. Yet in another demonstration that nothing is permanent, this German policy seems no longer to be the success story that it was. In the rapidly altering economic structure, the ability to adapt quickly is becoming more important than in-depth training in one trade. In the past, the United States and Germany have been adept at developing academic departments that mirrored the needs of technology (Nelson 1993). The United Kingdom and Canada have been less good at fostering institutional links between the private sector and academic research and training (although the University of Waterloo has shown other Canadian universities the way).

Be Aware of the Importance of FDI. In the modern globalizing world, foreign direct investment has become increasingly important. Firms that wish to sell in major foreign markets often need a manufacturing presence in those markets. The hostility to FDI that many countries, including Canada, manifested in the 1970s and early 1980s has been replaced by a welcome mat as countries compete ever more intensely to attract high-quality investment. No country that wishes to be a part of today's globalized trading system and growth engine can afford the luxury of being hostile to foreign investment — or of restricting the freedom of its homegrown firms to invest abroad.

Science and Technology Policies

Two models of policies with respect to technology are competing in the world today. One advocates a basically *laissez-faire* approach in which the government sets the right macro policies, such as a free exchange rate, a stable price level, and a reasonable budget balance, provides appropriate micro incentives, such as protection of private property and good patent laws, and then leaves it to the private sector to generate technological change unassisted. The other accepts the market-oriented economy, with market tests as the ultimate arbitrator of success or failure, but advocates substantial, coordinated government assistance to encourage technological change in a way that is systematically oriented toward innovation and growth. Two myths abound about this conflict of approaches.

First, although many economists advocate the first approach in Canada, the United States, and the United Kingdom and much of the folklore there accepts its existence, the facts are otherwise. In spite of the myth that the United States is the last bastion of pure *laissez faire*, the US government has given substantial assistance to technological change over the years, much of it successful. Public money directly funded valuable research in the aeronautics industry, particularly between the two world wars, helping to develop such research tools as the wind tunnel and such generic products as retractable landing gear. Procurement since World War II has been extremely important to several industries. For example, it helped to finance the development of the airframe for the Boeing 707 and the engines for the 747. It also created the university research base for the software industry and established the standards that assisted in its success — a successful piece of private sector industry creation by the public sector. (For more detail, see Lipsey and Carlaw 1996a.) Indeed, virtually all industrialized countries have micro, technology-oriented policies. In an unpublished paper given at the Six-Country Program Conference in Ghent, Belgium, in April 1996, it was reported that about 1,500 such policies were currently in use in the European Union, while my own research for a monograph commissioned by Investment Canada has located more than a hundred such policies currently in use in Canada.

Second, although many Western economists, particularly in Canada and the United States, believe that government will always fail if it tries to play an active role in the micro process of technological change, and others, particularly in continental Europe, believe the contrary, case studies, such as those reported in Lipsey and Carlaw (1996a), show that neither view is tenable. Some such policies have met with notable success, while many others have been dismal failures. This fact suggests that the real issue is not to write polemics supporting either extreme view but to isolate the conditions that increase the chances of success in proactive micro policies and diminish the chances of failure.

Research and Development. The accepted case for R&D assistance comes from Arrow (1962), who argues that, because technological advance confers large externalities in the form of benefits that the originators cannot co-opt, R&D will be underproduced in market economies. The externalities arise from the complex complementarities that exist among technologies in any modern economy (because few, if any, technologies work in isolation). In the neoclassical growth model, which is without microeconomic structure, R&D has a single marginal product. Thus, providing it with general support, such as generous tax relief, will give the necessary additional incentive. A microeconomic analysis suggests, however, that externalities vary enormously across technologies, as do the abilities of innovators to capture any given proportion of the value that they create. The implication is that, in principle at least, a more focused, micro-based set of technology encouraging policies would be preferable to blanket support for all R&D whether needed or not.

Diffusion of Technology. In the neoclassical model, knowledge diffuses instantly so that all that matters for growth is the first successful innovation of any new technology. This is not reality. In fact, technologies seldom end their lives in the form in which they were born. Instead, as they diffuse through the economy, they are altered and improved, fuzzing the distinction between invention, innovation, and diffusion. Also, learning about what is already known is a costly, time-consuming process with heavy fixed costs that can be burdensome even for a large firm and impossibly high for a small one. Therefore, there is a place for diffusion policies, such as exist in Canada's successful Industrial Research and Assistance Program (IRAP). IRAP, among other things, assists small firms to discover the existence of relevant technologies that are in use elsewhere and to adapt them to their own use. This approach makes no sense in an unstructured neoclassical or other aggregate model, but it is quite sensible in a model with a structure that comprehends the known facts about technological change and diffusion.

Precompetitive R&D. R&D can be roughly divided into precompetitive, which is not legally appropriable, and competitive, which is. In some cases, firms cannot keep the results of precompetitive research secret long enough to develop competitive products; then, there is too little R&D because incentives are lacking. In other cases, secrecy is possible, and there can be excessive and duplicative R&D as a group of firms all race for the same precompetitive result. Governments in several countries have found various ways to assist precompetitive R&D. Probably the most successful approach has been that of Japan's Ministry of International Trade and Industry (MITI). It does not try to pick winners bureaucratically, as do some European programs. Instead, its officials spend as much time as necessary consulting with industry to locate the next promising technological push. It then offers assistance to firms, which finance much of the R&D themselves. Even more important, MITI creates a climate in which firms are willing to share their precompetitive R&D results, thus avoiding the twin inefficiencies of too much or too little precompetitive R&D. The picking of winners bureaucratically is usually a route to error. In the MITI model, however, firms and the public body cooperate to identify likely winners that the private sector is willing to back with its own R&D money. The government assists by providing some monetary support and by creating a situation in which all firms share the results and then start the competitive R&D race on equal footing. This model has worked well, at least in some institutional settings.

Adjustment Policies

For a combination of accidental and policy-induced reasons, the structural adjustments that occurred in the United States in the 1980s (for example, the emergence of the rust belt) were postponed in Canada until the 1990s, and when they came, a new reality-distorting myth blamed them on the Canada-US Free Trade Agreement. Although the avoidance of adjustment seemed a good thing in Canada in the 1980s, it is less clear from today's perspective that it was beneficial for the United States to have a decade's head start on the structural adjustments that both countries had to experience.

In the United States, the adjustments caused widening inequalities in income distribution. A typical rust belt worker caught in the transition might have seen his wage fall from US$22 per hour to US$12, after which his wife went to work as well. But 15 years later, if family values, the work ethic, and a respect for education persevered, their children may well be taking meaningful, good-paying jobs in the new economy.

In Canada, the tax subsidy system prevented any growing inequalities in disposable income (although pretax earned income reacted much as it did in the United States once the structural adjustment began). The dependency ratio soared, however, and much less geographical movement of labor occurred, in response to the Canadian policy that everyone has a right to be supported in the place of his or her choice, whether or not employment is available. The reader must judge which society provides better opportunities for its young and a better chance of meeting the goal of raising the absolute incomes of everyone able and willing to work (rather than the goal of narrowing relative inequalities).

Education

The Canadian political rhetoric is "jobs, jobs, jobs." Yet it is not government that creates jobs in normal times,[21] although it may reallocate them by spending tax money in ways that differ from private spending. Anyone who fosters the myth that government can create jobs is urging

21 It may do so temporarily in times of severe depression if its fiscal situation permits a large run up in the debt.

the public to ignore the real issue, which is how to create the circumstances under which private sector firms can create jobs (instead of fleeing to more industry-friendly jurisdictions) and the labor force can fill them. *Creating* more jobs requires an environment of reasonable taxes, regulations, and labor laws. *Filling* jobs is something government could do more about — by education, education, education.

What is needed from the education system, particularly in a time of rapid change, is something that children, parents, and local advisors typically know more about than federal or provincial bureaucrats. Today is a time of great uncertainty about technological and structural change and about the required responses of the educational system. For any innovating system, experience from other times and places suggests the benefits of diverse experiments (with commitment of only the minimum expenditure of resources needed to try each one). It also suggests caution in allowing established forces — in this case, government education departments and teachers' unions — to manage the very changes that may have to jar, upset, or even overthrow the ensconced order. Identifying and carrying out diverse experiments without worrying about incentives to resist change is not something that a state-directed monolith does well, whether it is a nationalized steel industry or a provincial department of education.

A market-driven system in which parents received vouchers to use in any school of their choice would accomplish many things. It would encourage much-needed experimentation, prevent whole generations of students from being harmed by one experiment (which might subsequently be judged a failure), give parents and children the freedom to opt out of or into any educational experiment that seemed respectively either silly or promising, and break the current monopoly of the state bureaucracies and the teachers' unions over the creation of the most valuable asset a nation has, appropriately educated citizens. Yet touching faith that a centralized state bureaucracy can best determine the course of educational experiment under conditions of extreme uncertainty prevents the application of what has been learned about most other economic activities: the best way to encourage valuable technological advance is through the diversity of a decentralized market — in other words, through consumer-oriented experiments carried out by many people, which will be ruthlessly cut off as soon as consumers come to regard them as failures.

In making this last point, I stress that neither everyone nor even the majority need approve of any one educational experiment. It can sometimes be carried out with just one classroom full of students willing to give it a try. Recall the point made earlier about how much more experiment resistant the political decisionmaking process is than the market process. Despite today's understanding of the value of placing most technological experimentation within the decentralized market, education remains in the centralized political system — and at just the time when experimentation and innovation are needed more in education than almost anywhere else in the economy.

Capital Growth

A very different worry in these transitional times is how to get back on the track of a higher overall growth rate. Thinking based on a neoclassical growth model centers on aggregate saving and aggregate investment: encourage saving, keep real interest rates low (even at the cost of some inflation risk), and encourage the growth of human capital (for example, by keeping children in school longer)

To a student of technological change, this advice is incomplete at best and misleading at worst. For example, in the neoclassical approach, a dollar's worth of human capital makes the same marginal contribution to growth no matter where it is invested. From a microtechnology viewpoint, however, each dollar's worth of human capital (measured at values determined by current inputs) has a different value depending on the type of skills involved and their application. It is far more important to induce experimentation and innovation in education and to increase the ability of parents and children to select from among the currently available (albeit limited) range of choice than it is to allocate more taxpayers' money to education and then let the educational establishment decide how it should be spent.

Similar remarks apply to investment. More of the same is seldom as important as the same total value in a technologically new form. As I observed earlier, government should avoid policies that unduly restrict investment since that is the vehicle by which new technologies become embodied in the structure. But encouraging investment is not enough. The ability to stay at or near the technological leading edge matters at least as much. Of course, most of the new technologies Canadians use are developed everywhere, so excessive attention should not be paid to *Canadian* technology. But since being at or near the leading edge of technology is important for retaining a competitive position in world production, making Canada attractive to firms engaged in R&D, domestic or foreign owned, is critical.

Danger lurks here. Economists know all too well how to reduce the rate of technological progress. The stagnation of the Canadian economy could be achieved quite easily by some relatively small changes in several economic policies that even now make Canada compare unfavorably to some other jurisdictions. Current growth policy should direct serious attention to reducing the unfavorable policy settings and improving the environment for technologically progressive firms.

Conclusion

One of my major policy themes in this essay is that, although policy analysts may not know how to create the optimal conditions for growth, they do know how to create bad ones. Given freedom to control the standard economic policy levers, I could create zero growth, 20 percent unemployment, and 100 percent inflation without straining my intellect. In brief, economists know a lot about what to avoid. Without my summarizing them again, the alert reader can surely amass a list of a dozen or more things *not* to do, including creating conditions that restrict opportunities for innovations in education.

Political Implications

The deep structural adjustments required by major changes in today's general purpose technologies extend to the policy structure shown in Figure 1 and include both expansions and contractions of overall political power, as well as reallocations of that power among various levels of government.[22]

22 This section is based on Lipsey (forthcoming).

Alterations of Power

The globalization brought about by the ICT Revolution has reduced government power in some traditional areas of macroeconomic control. To some extent, governments have discovered limitations to the power of their macroeconomic policies, limitations that were probably always there but were not appreciated until revealed by decades of experience. Furthermore, although markets have always punished unsustainable policies, such as seriously large budget deficits, the moment of reckoning often comes much faster in today's globalized financial markets than it once did. Sophisticated communications and vast amounts of short-term capital in the hands of transnational corporations make it impossible for governments to control international capital movements in the ways that they routinely did from 1945 to 1970, the era of fixed exchange rates. (Indeed, the globalization of capital markets had a lot to do with the breakdown of the Bretton Woods system of fixed exchange rates.)

Governments face growing difficulties in dictating what their citizens will see and hear. Policies to restrict information flows are becoming less and less viable whether their purpose is to support a repressive dictatorship or to encourage local cultural industries. Access to the Internet provides a massive hole in the information-restricting barriers that the governments of many countries, such as Singapore and China, have tried to erect. Attempts to control pornography on the Internet show what difficulties arise when established policies meet new technologies. The policy administered by the Canadian Radio-television and Telecommunications Commission is in a state of disarray caused by new, more open means of communication, including satellite transmissions that can be received on dishes of steadily diminishing size and hence detectability.

At the level of microeconomic policy, the developments are more mixed. I observed earlier that the assets that confer today's national competitive advantages tend to be both created and highly mobile. That fact severely restricts any individual government's ability to follow policies that affect the values of these assets and that differ markedly from policies followed by other governments. Although this statement takes little space to make, its effects in limiting policy independence are profound.

In other areas of microeconomic control, governments have gained power. For example, computers have made it possible to collect and cross-reference masses of data about individual citizens and firms. The technology exists today to locate any inconsistent statements given to two different government authorities, and this possibility may soon be realized unless it is controlled by political means. Developments in genetics may also increase government power in many areas. For example, genetic screening to discover the predisposition of various groups to various afflictions may assist government health services. Analogous developments promise breakthroughs in crime prevention and detection. Traffic control will see massive changes in the next decade as it becomes possible to track cars through urban streets and to monitor speed with technologies vastly more advanced than following speeders with police cruisers. And so on.

Those who emphasize the loss of national power tend to concentrate on the broad macroeconomic issues, such as tariffs, exchange rates, and fiscal stabilization policies. Yet when one looks at micro areas, where a large amount of both national and local government activity occurs, modern technologies are giving governments a wide range of increasing powers.

Reallocations of Power

Today's technologies and resulting deep structural adjustment are also encouraging the reallocation of some of the powers of national governments. Some are tending to move upward to supranational bodies and others downward to more local levels of government. On the one hand, globalization is requiring that many issues involving trade and investment be supervised at the international level. The importance to most countries of a relatively free flow of international trade has led them to transfer power over trade restrictions to supranational bodies such as the WTO (the successor to the General Agreement on Tariffs and Trade — the GATT), the European Union, the North American Free Trade Agreement, and a host of other trade-liberalizing arrangements. Furthermore, the interrelation of trade and investment brought about by the ICT Revolution has caused modern trade-liberalizing agreements to be expanded to include measures to ensure the free flow and national treatment of foreign investment.

Because of the globalization of trade and investment, policies with respect to such matters as labor practices, industrial competition, R&D support, subsidies, and intellectual property protection, which were formerly thought to be of purely domestic interest, now affect international flows of trade, FDI, and factors of production. Concern over the international impact of these "domestic" measures gives rise to what Ostry (1990) calls "systems frictions." In response, trade-liberalizing arrangements are now working toward "deep integration," in which the sources of systems frictions are subject to agreed international control, which implies major transfers of power from national to supranational levels of government.

Pulling in the other direction, growing consciousness of regional identities and the decline of broad identification with the nation-state, which are also related to the globalization caused by the ICT Revolution, are causing pressures for the devolution of some powers to lower levels of authority.

Provided that acceptable allocations of powers are achieved, there is no need to find these two kinds of pressure contradictory. If these authorities maintain common markets (or at least modern free trade areas), there is little reason to oppose the devolving of considerable power over cultural and community matters to provincial and municipal authorities — although the process of altering the power structure will often be conflict ridden.

Determining an appropriate allocation of functions among local, national, and international levels of government — which implies willingness to pass some power upward to supranational authorities and some downward to state and local authorities — is one of the most important tasks currently facing modern national governments. It is not something that can be done once and for all. A future set of deep structural adjustments, in response to some future revolutions in general purpose technologies, may require some different shifts, such as a transfer of major powers back to the national level.

Part III

Conclusion

Drawbacks and Benefits

When I explain how technological change has transformed our lives for the better over the centuries and millennia, I risk appearing to believe that all economic growth and technological change is beneficial without drawbacks. Of course, life is more complex than that. So I cannot conclude without commenting on some qualifications and the tradeoffs involved.

The Immediate Pain of Change

My first qualification concerns the costs of growth. Because everyone has gained from past growth, it is sometimes assumed that everyone will gain from current growth. Commentators of this persuasion often read lectures to those who are hurt by growth, saying in one way or another: "This may seem like pain now, but it is all for your own good in the end." If "in the end" means in the lifetimes of their children and grandchildren, this suggestion is probably correct; if it means over the rest of a particular individual's life, the advice may well be wrong.

An important characteristic of growth-inducing technological change is that the price is usually confined to the present generation while the benefits extend to all future generations. Everyone in the West today, from richest to poorest, is better off for the adoption of waterpower that mechanized European manufacturing about a thousand years ago and set the West off on a trajectory that differed from that of either China or the Islamic countries. But the thousands of eleventh-century fullers who lost their jobs when fulling was mechanized undoubtedly would have been better off if that technological event had never occurred — at least in their working lifetimes. Change raises average living standards, but it upsets established ways. Some people lose jobs, some lose businesses, some find their skills made obsolete. Of those that are hurt, some adjust, but for many it is too late; they pay the price of change, and they would have been better off if change had stopped just before its adverse affects reached them.

So it has been, and as far as I can see, so it always will be. Everyone has cause to be thankful for technological change and economic growth that took place over the past centuries and millennia; members of today's generation are the beneficiaries of these advances while the costs were born by their ancestors. In contrast, the technological change and economic growth that is taking place in the present has many costs to be set against its undoubted benefits. It raises material living standards on average, but it also causes much upset and sometimes leaves behind large pockets of lowered living standards and broken lives.

Undesirable Technologies

My second qualification concerns specific technologies of which people disapprove. While a minority would vote to stop growth before it adversely affects them, almost no one would choose to return to the technology of any previous century while being in an unchanged position in the relative income scale. Many people, however, would prefer to eliminate some selection of today's technological marvels.

Of course, if everyone were agreed that some specific technology was undesirable, everyone, acting through the economic or political system, could eliminate it. The economic power of consumers to say no is absolute. If *no one* wants the product of some technology, that product will not be sold and its production will end. If the technology is more behind the scenes and thus not subject to this type of consumer power, then a democratic political system will act because it seldom fails to respond to unanimously held desires or even strong majorities. (For example, the use of the advanced technology of whale hunting was brought under international control even though the desire to do so was by no means unanimous.)

The selective elimination of certain technologies is an entertaining dream, but its practical application founders on the fact that people's lists of what should go would differ greatly. Some would eliminate television, but the great majority clearly would not. Some would prefer to do without freeways, but given the choice, most drive on them rather than on two-lane back roads. Some would eliminate Walt Disney's mutilation of English classics such as *Winnie the Pooh*. But they can read the original to their children, while the majority show that they prefer that Disney cartoon and many others of its sort to the available alternatives.

Basic Societal Changes

My third qualification concerns what technological change has done to our broader culture. While accepting most modern products, many mourn some of the social behavior patterns that technological change has destroyed. It would not be difficult to give a long and compelling list; I confine myself to three important illustrations.

Children are ready to learn skills and use them in useful work long before modern urban society allows them to do so. In the farms of the past (and to some extent even those of today), boys and girls worked beside their parents from the age of five or six, learning an array of skills. By the time a boy was eight or nine, he would be driving the team of horses that pulled the plow — or the tractor, if he lived in a Western society. By the same age, a girl would be doing on her own many of the things done by farm women (the list varies, of course, with the society in which she happened to be born). Youths with intellectual interests are well catered for in modern society, but those whose interests and abilities are mainly manual have little opportunity to do meaningful work until they grow up. Should we wonder that gangs of idle, bored youths terrorize neighborhoods? In the past, these same youths and their younger brothers and sisters would have been sleeping long hours to recover from a day's work done at their parents' side.

Parents who have spent time with their children in remote parts of the world without modern technological trappings often become acutely aware of the family values that have been lost to today's technology. Without television, movies, radio, and ready-made games, family members are thrown together and put on their own resources for work and play. Imagination and skill get much more reign when games have to be invented than when they can be store-bought. People talk to each other and play verbal games when they cannot passively listen to and look at ready-made entertainment. Families spend much more time together as a unit when parents are not undertaking physically and emotionally draining work outside of the home, as modern technology requires.

Social and occupational mobility has been a great boon. Although the father who forces his son to follow in his footsteps, in spite of the young man's strong desire to do something else, is a rare modern tragedy, doing what one's parents did was standard behavior through most of history. Geographical mobility has facilitated occupational mobility, but it has also broken up the extended family that was typical of the past. In villages, one grew up with parents, grandparents, aunts and uncles, and a host of other relatives. From them one learned standards of social and economic behavior and to them one gave the respect that goes to older people whose learning is relevant. In a static or very slowly changing society, the wisdom of the elderly is valuable because their experience is relevant to current circumstances. In today's fast-changing society, experience from even 20 years ago may be obsolete, and what a child's grandparents learned when they were young is almost sure to be irrelevant to the problems faced by modern youth. So the loss of children's respect for their elders and of elders' feelings of power and relevance is, to a significant extent, a product of the pace of modern technological change.

A Positive Balance of Benefits

Of course, my list of qualifications could be prolonged if I had more space. Nonetheless, whatever the costs of modern technology, migrants the world over vote with their feet, showing that they prefer the higher living standards conferred by more modern technology to the lower living standards associated with older technologies. The pattern of immigration is almost exclusively from lower-income to higher-income countries: Mexicans go to the United States, Chinese come to Canada, and Bangladeshis go to Singapore, and not vice versa.

Yes, over the centuries, technology has transformed our ways of life, trebled our life expectancies, removed many sources of physical suffering and reduced the pain associated with the rest, opened our minds to the world and allowed us to travel so that our eyes can see it, made vastly easier the day-to-day work required by men and women around the home, greatly increased the time available for leisure,[23] entertained us in myriad new ways, and offered those who want it chances to ski down mountains, sail across oceans, and dive into the ocean depths. We take these minor and major advantages — and literally millions of others — for granted every day. They are easy to disparage — but only if we do not really think we might lose them.

23 This is true as long as one does not go further back in time than the neolithic agricultural revolution. Hunter gatherers typically enjoyed more leisure than any society since settled agricultural and urban life began.

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