CHAPTER 3. INNOVATION AND ECONOMIC GROWTH

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Abstract

This paper illustrates why technological innovation is considered as a major force in economic growth and focuses on some of the most distinctive features of innovation in the highly industrialized economies of the OECD area. In particular it attempts to examine a primary feature, the "uncertainty" that dominates the search for new technologies, with several cases drawing on American experience. It also touches on the impact of technological innovation and how it is transforming the tourism business model.

Technological innovation, a major force for economic growth

It is taken as axiomatic that innovative activity has been the single most important component of long-term economic growth. This paper begins by drawing on the findings of a very influential paper published by my colleague at Stanford, Prof. Moses Abramovitz, in the mid-1950s[4].

In the most fundamental sense, there are only two ways of increasing the output of the economy: (1) you can increase the number of inputs that go into the productive process, or (2) if you are clever, you can think of new ways in which you can get more output from the same number of inputs. If you are an economist you are bound to be curious as to which has been more important – and to what extent. Essentially what Abramovitz did was to measure the growth in output of the American economy between 1870 and 1950. Then he measured the growth in inputs (of capital and labor) in the same time period. He made what he thought were reasonable assumptions about the growth in a unit of labor and how much growth in a unit of capital should add to the output of the economy. It turned out that the measured growth of inputs (i.*e.*, in capital and labor) between 1870 and 1950 could only account for about 15% of the actual growth in the output of the economy. In a statistical sense, then, there was an unexplained residual of no less than 85%.

4. ABRAMOVITZ, M. (1956) *Resources and output trends in the United States since 1870.*

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Surprisingly enough, no economist had ever undertaken this exercise before - partly because it was only after the Second World War that reasonably accurate estimates of inputs and outputs for the American economy, over an extensive period of time, became available. Now, in any statistical exercise in which you are trying to tease out the relative importance of some variable, and you find yourself with a residual of 85%, you know you are in big trouble! Yet a number of other economists in the late 1950s and 1960s undertook similar exercises, using different methodologies, different time periods, and different sectors of the economy, with roughly similar results – they found themselves left with a very large residual that could not be accounted for. Robert Solow[5], who later won a Nobel Prize in Economics, was one of those other economists who discovered a very large residual, using a very different methodology and different time period. As it happened, he got the same result for the size of the residual – 85%. It was precisely the size of this residual that persuaded most economists that technological innovation must have been a major force in the growth of output in highly industrialised economies.

Although it might be tempting to say that the 85% residual was a negative finding, negative findings can sometimes be extremely useful. In this case the large size of the residual served as a kind of "wake-up call" to the economics profession because most economists for the previous 200 years had been building models in which economic growth was treated as if it was primarily a matter of adding more inputs into the productive process, especially inputs of capital. The large residual told economists that they had to look elsewhere in order to account for economic growth.

So I am going to focus my attention on some of the most distinctive features of innovative activity in the world of the highly industrialised economies of the OECD countries, and I will draw, in several cases, on the American experience. Actually, I want to focus primarily on a single feature that dominates the search for new or improved technologies, and some of the consequences that flow from this feature. The key word is "uncertainty."

Dealing with uncertainties

It is easy to conclude that, in advanced high tech countries with large, powerful firms, uncertainties will no longer be a major concern. After all, in the United States today, there are more than 16 000 firms that currently operate their own industrial research labs, and there are at least 20 firms that have annual R&D budgets in excess

5. SOLOW Robert (1970) *Growth Theory: an Exposition.*

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of USD 1 billion. In fact the top 20 American firms spent a total of USD 54 billion on R&D in the year 2000. Surely, you might think, such firms are no longer preoccupied with nagging problems flowing from uncertainties and the attendant financial risks.

Now, if you thought this, you would be wrong, very wrong, and for two compelling reasons. The first reason, as I have already suggested, is that the conduct of R&D in the high tech sectors of OECD economies has become hugely expensive. The second reason is that the outcome of this R&D spending is fraught with financial risks that derive from a variety of sources. What are these sources?

- Expenditures on scientific research may simply fail to discover new scientific knowledge of any potential usefulness whatever.

- Even if new scientific knowledge does emerge from research findings at the scientific frontier, it may never lead to a new marketable product. Or, equally important, it may require such a long period of expenditures on new product design or development that business decision makers may conclude that the realization of a new product is likely to be unacceptably costly – *i.e.* unprofitable.

But even if research does eventually lead to a valuable new product concept, many further questions remain to be addressed:

- How well will the new product perform, not only technologically, but in economic terms? Will a high performance be attained, but only at a prohibitively high cost? The Concorde airplane was a simply magnificent achievement in terms of engineering design and speed, but it was also an unqualified financial disaster. It was calculated, when the Concorde project was begun, that 300 of the planes would need to be sold, merely in order to cover its development costs. In the event, only 16 were sold.

- How rapidly will performance improve and how rapidly is the cost of production likely to decline?

- How appropriable is the product for the innovating firm? By "appropriable" I mean, how great is the likelihood that the innovating firm will be able to capture any profits that might be generated by its innovation? This may depend on whether the innovation is patentable.

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If not patentable, how soon is it likely to be imitated by competing firms that spent none of their own money in inventing the product? [This is the "free rider" problem].

– It is possible that a government regulatory agency, or a court decision, may destroy expected profits through regulatory requirements or a judicial ruling. In the US pharmaceutical industry the Food and Drug Administration requires that new pharmaceutical products go through a protracted period of testing before they may be sold to the public. Many new pharmaceutical products must be tested for several years before they can be marketed – in some cases the testing period may be more than a decade, as in the cases of vaccines or new contraceptive technologies. Estimates of the cost of bringing a wholly new pharmaceutical product to market in the US now routinely exceed the USD 500 million marks.

  Additionally, almost everyone in Switzerland must be familiar with ABB's devastating financial losses due to its acquisition of an American firm called Combustion Engineering. It turned out that ABB eventually "inherited" (if that is the right word) the unexpected liabilities of its subsidiary. These liabilities resulted from the decision of an American court, in a gigantic class action suit, involving the potential damage to human health resulting from Combustion Engineering's extensive use of asbestos. The class action suit has already involved more than 200 000 claimants, with over 100 000 more claimants still waiting in line.

– Finally, how soon will a superior new product come along, either from a competitor or from the introduction of some entirely new technology? It is no paradox to say that one of the greatest uncertainties confronting new technologies is the invention of still newer technologies.

There is one further source of uncertainty that I feel obliged at least to insert here, even though it has nothing to do with innovation, and even though you are already painfully familiar with its consequences to tourism. That is, of course, the possibility of encountering acts of terrorism. Terrorism has already had a devastating impact on travel, especially travel by air as well as travel to countries (or areas) where the risks of terrorism are perceived to be high. No other industry is as vulnerable to terrorism as tourism.

Thus, it is fundamental to an understanding of the nature of innovation to recognize that uncertainties are still at the heart of innovative activities. The basic fact of life here is that it is extremely difficult to forecast how the market will respond to the introduction of some new technology. One obvious reason is that, in societies that have become as affluent as most of the OECD member countries, it is difficult in the extreme to anticipate how certain new products (or services) will fit in with consumer preferences and priorities.

A few examples of innovation

Let me expand on this point by citing for you an absurdly incorrect failure to anticipate consumer reactions, on the part of a group of people who were certainly both intelligent and well informed: the reporters and editorial staff of *The New York Times*. In 1939 the *New York Times* reported on the success of recent experiments that obviously foretold the arrival of a potentially fascinating new product: television. But the *New York Times* did not think that television had much of a future – at least not in the United States. This most prominent and influential of all American newspapers solemnly declared: "Television will never be a serious competitor for radio, because people must sit and keep their eyes glued on a screen; the average American family hasn't time for it."[6] How do you explain the complete failure to anticipate that TV was to become the most influential and widely-used household consumer good of the 20th century? Frankly, I don't know how to answer that question, but it has been characteristic of many of the most important innovations of the 20th century that no-one correctly forecast their future impact. Indeed, far from being unwilling to keep their eyes glued to a television screen, a disturbingly high percentage of American families seem to have very little time for anything else!

Suppose we now consider a much more recent innovation: the mobile phone. In 1983, when AT&T was being divested in an anti-trust suit, it was considering whether it should attempt to retain the frequencies that would be essential for the operation of mobile phones. AT&T therefore hired one of America's best-known consulting firms to forecast the likely number of American subscribers for mobile phones by the year 1999. The forecast that was eventually given to AT&T was that there might be as many as one million subscribers to mobile phones in 1999. In fact, the number of subscribers passed the 70 million mark in that year!

6. New York Times (1939) C*ommentary after television introduced to a broad spectrum of the American public at the World's Fair.*

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How can you account for what now appears (in retrospect, of course) to have been an absurd underestimate? Partly, there was a failure to appreciate the very large number of ways in which such phones would be useful. But the underestimate was also caused by neglect of another consideration that is important in accounting for the future demand for innovations. The fact is that most major innovations enter the world in a very primitive condition, and go through a long process of technical improvements and cost reduction. The airplane first left the ground in 1903. The initial flight was less than the length of a football field, and the airplane was not an innovation of great commercial significance until the late 1930s. Why not? It took fully one-third of a century because many thousands of design improvements were necessary before airplanes became sufficiently safe and reliable to become widely used by the general public. I suspect, if any of us had been present at that first flight in December 1903, we would not have left the scene with visions of regularly-scheduled flights crossing the Atlantic Ocean in six hours or so, with passengers in a reasonably comfortable state.

The situation with respect to the mobile phone in 1983 was, in some important respects, very similar. Those phones were primitive. They were so heavy and bulky that they hardly deserved to have been called “mobile.” The quality of voice transmission was extremely poor. And, most important, the original mobile phones of 1983 sold for around USD 3 000, compared with much less than USD 100 in the United States today.

Consider one other recent technology: the laser. In 1960 the laser was merely a fascinating scientific breakthrough of no obvious usefulness to anyone. But, as a result of the intense competitive pressures generated in market economies to develop and introduce new products, the laser came to serve as the platform for a bewildering variety of new applications. It has become the primary instrument of research in the science of chemistry. It is the instrument of choice in a wide range of surgical procedures. There are in fact five medical journals in English that deal entirely with the use of lasers in medical practice [dermatologists, ophthalmologists, surgeons, etc]. The laser is essential for the high quality reproduction of music in compact discs (CDs). Transactions at supermarket checkout counters have been speeded up by lasers that can “read” (*i.e.* scan) the bar codes on each item purchased. The best computer printers today make use of the laser. Lasers, together with optical fibers, have totally revolutionized the worldwide telecommunications system. Last, but surely not least, the US Food and Drug Administration has recently approved the laser as a much less painful substitute for the dentist’s drill.

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The behavior of lasers had been predicted, on a purely theoretical basis, by Einstein, using no more than a blackboard and a piece of chalk, as long ago as 1916. But it took over 40 years before scientists could actually create a laser beam (Light Amplification by Stimulated Emission of Radiation).

Finally, the *computer*. The first digital, electronic computer was operating at the University of Pennsylvania's school of engineering at the end of 1945, and a number of firms were already engaged in the manufacture and sale of computers by 1950. And yet, as late as 1956 Howard Aiken, a brilliant physics instructor at Harvard and one of the great pioneers in computer development, continued to conceive of the computer as no more than a highly specialized scientific instrument. In 1956, in testifying before a congressional committee he was still, obviously, thinking of the computer as no more than an instrument suitable for only a narrow range of scientific research purposes. Aiken stated in that congressional testimony: "...if it should ever turn out that the basic logics of a machine designed for the numerical solution of differential equations coincide with the logics of a machine intended to make bills for a department store, I would regard this as the most amazing coincidence that I have ever encountered."[7] That is, of course, precisely how it turned out, but it was hardly a coincidence. A technology that was originally invented for one specific purpose - the numerical solution of large sets of differential equations - could easily be reprogrammed to solve problems in entirely different contexts, such as the making out of bills for a department store. But it was obviously not obvious. Now, nothing could be further from my intention here than to hold Aiken up for ridicule. Quite the contrary, he was a brilliant scientist and inventor, and yet he hadn't the most elementary sense of the potential impact of the invention to which he had made very large contributions.

The impact of a technological innovation

The impact of a technological innovation will generally depend not only on its inventors, but also on the creativity of the eventual users of the new technology.

Consider the electrification of factories. So long as factories depended on steam as their primary power source, the organization and layout of activities on the factory floor had to be determined by proximity to a single power source: the steam engine. Each machine on the factory floor, in turn, drew upon this power source through a clumsy and extremely wasteful transmission system of leather belts and pulleys. The introduction of electricity, with separate electric motors attached to

7. AIKEN Howard (1956), *The Future of Automatic Computing Machinery.*

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each machine, allowed the layout of work to be organized in a far more flexible and efficient way, depending on the sequence of activities required by the needs of the production process rather than by the location of the steam engine. The parallels with the introduction of the computer are obvious. But it is also relevant to point out that economic historians have recently devoted a great deal of attention to the electrification of American factories. The consensus of their studies is that it took about 40 years – from the 1880s to the 1920s – before the application of electric power produced a measurable increase in factory productivity. And one could also make a plausible argument that the interface between people and computers is a far more complex one than the interface between people and electric power. In thinking about high tech innovation, we tend to be excessively preoccupied with the work of the scientists and engineers whose R&D activities have created the new technologies in the first place. This is a case of misplaced emphasis. The benefits that can be made to flow from lasers, microprocessors, computers and information technology generally will ultimately depend not only on its inventors, but also on the creativity of the potential users of the new technology.

Of course, it is also important to remember that the computer itself has been transformed since the giant mainframes were supplemented (and, to a considerable extent, replaced) by desktop personal computers. The result has been an explosion of new efficiency opportunities, insofar as data processing could now be carried out in ways, and in places, with a degree of flexibility that was not possible with mainframes alone.

Merely applying much greater computer speed to patterns of work that were designed for an older and slower technology, is likely to yield very little in the way of productivity improvement. Redesigning the work process is a very complex problem in its own right, and it necessarily takes a long time, as the early history of electricity amply demonstrates. The introduction of the PC has required the reorganization of long-standing business practices, along with the design of new, complex software, tailored specifically for the employees of the business firm. This, in turn, continues to require the application of managerial skills of a very high order of sophistication in determining how the patterns of work might be optimally redesigned in order to exploit the vastly expanded capabilities of the latest generation of computers.

Innovation in tourism

With respect to the tourism sector, what appears to be called for is an intimate familiarity with consumer needs and preferences in particular specialized markets,

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and a speedy and imaginative approach to how these needs might be catered to in a more efficient, but also a more attractive and user-friendly manner. But my uninformed speculation suggests that Information Technology, and the Internet and World Wide Web in particular, are going to transform the role of travel agents, and doubtless sharply reduce the size of the travel agent industry, unless this industry can identify a new bundle of services that can be provided to potential travelers. Any household with access to the Internet – and therefore access to Google – now has immediate access to detailed information about almost any conceivable location on the earth's surface as a possible candidate for a visit.

Needless to say, ticketing for airplane travel can also be arranged on the Internet, which also provides invaluable information about the various prices of airplane tickets. In fact, an American research company (Forrester) has recently calculated that travel is now the largest on-line business in the world. The Internet is obviously transforming the tourism business in many ways, and easy access to information is growing rapidly in each of the separate components of the industry, and making it increasingly competitive. The ultimate uncertainty is figuring out new ways of rendering the tourist industry at least minimally profitable. I am happy to leave this subject to your deliberations over the next two days.

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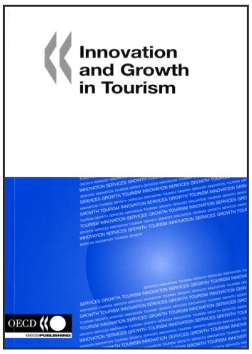

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