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THE IMPLICATIONS OF THE KNOWLEDGE-BASED ECONOMY FOR FUTURE SCIENCE AND TECHNOLOGY POLICIES

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Introduction

In the light of the developments which have occurred since the last Meeting of the Committee for Scientific and Technological Policy at Ministerial level held in March 1992, two themes are drawn to Ministers' attention in relation to the Committee's future activities:

- new growth theory and science and technology policies; and

- innovation performance and output indicators.

This background paper draws on the rapidly increasing academic literature, papers commissioned by Industry Canada, as well as work undertaken for the OECD.

Theme 1 - New Growth Theory and Science and Technology Policies

Economics has so far been unable to provide much understanding of the forces that drive long-term growth. At the heart of the old theory (neo-classical) is the production function, which says the output of the economy depends on the amount of production factors employed. It focuses on the traditional factors of labour, capital, materials and energy. It visualises that returns diminish as more capital is added to the economy, an effect which may be offset, however, by the flow of new technology. It sees technological progress, not investment, as the engine of growth. But it provides no convincing understanding of what technological progress is, and how it happens.

The new growth theory, as developed by such economists as Romer, Grossman, Helpman and Lipsey, adds the knowledge base as another factor of production. It sees the source of sustained growth to be the accumulation of knowledge, as reflected in more efficient methods of production and organisation, and in new and better goods and services. It recognises that knowledge can raise the return on investment; and that knowledge, like capital, has to be paid for by foregoing current consumption. It admits the possibility of a virtuous circle, in which investment spurs knowledge and knowledge spurs investment. In this view, a sustained increase in investment can permanently raise a country's growth rate, a result rejected by the old theory. The new theory recognises that new knowledge frequently spills over from the developing firm or industry to others, with new ideas often used repeatedly at little extra cost to other users. This spillover effect eases the constraint usually placed on growth by the scarcity of capital.

The strength of the new growth theory is in its better fit with real economies and its clearer grasp of the role of technological progress and how it happens. As *The Economist* (January 4, 1992) noted: "...it is to be hoped that its biggest effect will be to reorder the economic policy agenda." The new theory suggests governments can influence economic growth by the care and feeding of the knowledge base, which is the well-spring of innovation. To think in terms of long-term growth, rather than their more usual concentration on the business cycle, governments will need to focus even greater attention on issues such as access to international knowledge, education, investment, research and development, trade reform and intellectual property rights, in order to increase their capacity to innovate and stimulate technological progress.

Emphasis in the new growth theory on technological change rather than pure capital accumulation as the driving source of growth, draws attention to the role of ideas. Ideas are partly appropriable, at least for a limited time, as well as unlikely to be subject to the law of diminishing returns as knowledge accumulates. The central message is, therefore, fundamentally positive, as Lipsey and Beckar point out: "Current understanding of the economics of ideas seems to indicate that there are no boundaries to real-income-creating, sustainable growth." In effect, the new growth theory's focus on technological progress differs substantially from the pessimistic prediction of the prevailing neo-classical growth model, where technological progress is seen only as a constantly rising efficiency of available inputs.

The new growth theory highlights the role of innovation and technological progress. It draws attention to the need to focus public policy on the effective functioning of all the components of a national system of innovation - the network of institutions, public and private, whose activities initiate, import, modify and diffuse new technologies, and whose interactions influence the innovative performance of national firms.

As an outcome of the 1992 Ministerial meeting, the CSTP has several relevant activities building on the new growth theory, through the Working Group on Innovation and Technology Policy. For instance, David and Foray, in their 1994 work for the OECD, extend our understanding of technological progress and the ways in which private and public organisations effectively interact in the production and distribution of knowledge, as well as forming learning systems for scientific and technological knowledge, both codified and tacit knowledge. They take a "systems-theoretic" approach in examining the relationship between a society's knowledge-base and its capacity to generate and utilise economically beneficial innovations. They develop the idea of learning profiles, in which the key organising concept is the "distribution power" of an innovation system, which means its capability to ensure timely access by innovators to the relevant stocks of knowledge. A "distribution-oriented innovation system" is thus an organisational mode of innovation that is able to support the various steps of the process of technological advance. This approach shifts the relative emphasis of policy away from the importance of research and the creation of knowledge, towards an enhanced role for the effective and rapid diffusion of knowledge and innovation.

DSTI is also in the process of implementing a multi-country work plan for pilot case studies on National Innovation Systems. It is preparing guidelines and a check list for the case studies of items to be measured. It suggests the "distribution power" of an innovation system can be characterised by four families of indicators:

– the stock of knowledge;

– the forms of knowledge sharing and transfer;

– the effectiveness of knowledge sharing and transfer; and

– the economic impact of knowledge sharing and transfer.

Economics now has something significant to say about long-term economic growth. The effects on policy could be profound. But much remains to be learned, particularly about the role of institutions and the dynamics of technical advance. Three areas in which policies clearly play an important role in affecting output and productivity growth are:

- encouraging the accumulation of suitable human capital
- directly supporting R&D
- ensuring access to international knowledge and markets

Theme 2 - National Innovation Performance and Output Indicators

The past two decades have seen major changes in thinking about the foundations and scope of policies for innovation. These changes have been driven by several factors, including changes in our understanding of the nature and characteristics of innovation processes and their economic effects. There has been a rather fundamental rejection not only of the old growth theory and some of its tenets of production, but also of the primary innovation model - the linear model. These basic approaches have been central, however, both to the past rationale for policy and the choice of different types of statistics and indicators.

The extent and direction of innovation is greatly influenced by a country's institutional structure and system of incentives, or national innovation system. The study of national systems of innovation shows that they behave differently and confer, as a consequence, different comparative advantages on countries. How the systems differ may well determine the evolutionary path of a country. Understanding how they work and may be changed beneficially may well be key to future wealth and job creation and quality of life. Such understanding requires better measures of innovation performance and output indicators.

Statistics are the material from which indicators are constructed. Science and technology indicators can be defined as a series of data designed to answer questions about the S&T system and its links with the economy and society. Countries now use S&T input indicators primarily. Those outputs which are measured are helpful only to a limited extent for policy formulation purposes.

Current use of science and technology indicators focuses heavily on research and development. These data are widely used, with the mistaken but frequent assumption that the input measure of research and development is a good indicator of output performance; such as trade performance. However, the OECD *Science and Technology Policy: Review and Outlook 1994*, for instance, found that there is no direct and systematic link between the R&D-intensity level of an industry and its trade performance, particularly its capacity to create surpluses. It also recognised that R&D intensity is a flow, rather than a stock, concept. Thus it fails to reflect accumulated R&D expenditures or the technology capital in a given industry. The limitation of R&D as an input and not an output indicator is somewhat mitigated by the fact it enjoys a very close relationship to such output indicators as patents and scientific papers.

The R&D measure, as with most existing science and technology indicators, tends to be most relevant to the linear model of innovation. Such indicators are not necessarily amenable to help answer questions posed by the broader system analyses, which provide greater insight into innovation and technological progress. The challenge is to combine statistics in order to build indicators to answer new questions, as well as to develop entirely new categories of indicators and data.

Most current indicators of science and technology activities, such as R&D expenditure, patents, publications, citations, and the number of graduates, are not adequate to describe the dynamic system of knowledge development and acquisition. New measurements are needed to capture the state of the distribution of knowledge between key institutions and interactions between the institutions forming the national system of innovation, and the extent of innovation and diffusion. Also needed is the ability to measure the ways in which innovations interact with existing technological systems and their relations with other nations' systems; and the effectiveness with which an economy is translating S&T into growth.

One big gap in indicators, which requires careful filling if we are to obtain a better understanding of the dynamics and forces at work, is that between what we know to be happening at the broad industry and economy-wide performance level, as opposed to the level of the individual firm.

Canada, as no doubt some other Member countries, has recognised the need to overhaul the data on science and technology. That overhaul must include the design of a framework within which to compile data. The framework does not yet exist. Its design must include measures of innovation and indicators by industry of the propensity of firms to innovate, as well as how the propensity indicators relate to financial, production and export performance by industry and size of firm. Such information would allow governments to monitor more readily the effectiveness of their innovation instruments and policies and to target future efforts for greater effectiveness.

Most of the discussion of measurement of national systems of innovation has so far taken place outside of statistical agencies. However, the comparative advantage of making measurement of the system of innovation part of an on-going statistical programme is that the results can be related directly to other socio-economic indicators which are used every day to judge government policies: GDP, employment, the consumer price index, and the balance of trade. To make the link between information on a national system of innovation and socio-economic indicators requires a new statistical structure.

NESTI is tentatively planning a 1995/96 workshop on indicators for the next millennium. NESTI deals with issues that go beyond the S&T system and straddle the boundaries between economic statistics, science and technology statistics and human resource statistics.

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