

## Theories of Productivity Growth and the Role of Government in Facilitating Productivity Growth

Erwin Diewert,<sup>1</sup>  
 Department of Economics,  
 The University of British Columbia,  
 Vancouver, Canada, V6T 1Z1.  
 email: [diewert@econ.ubc.ca](mailto:diewert@econ.ubc.ca) May, 2004.

Paper presented the New Zealand Treasury Workshop: Toward Higher Productivity Growth in New Zealand, Wellington New Zealand, July 28-29, 2004.

### Abstract:

The paper discusses sources of economic growth in section 2. One of the most important sources of growth is *productivity growth* and this topic is discussed in section 3. Since we define productivity growth as the rate of growth of outputs divided by the rate of growth of inputs, increasing returns to scale is one possible source of productivity growth. This topic is reviewed in section 4. Section 5 looks at other miscellaneous factors that might explain growth. Section 6 summarizes the factors that might help to explain Total Factor Productivity growth. Section 7 looks at possible roles for the government in facilitating growth and section 8 concludes.

### 1. Introduction

This paper was stimulated by a report by Winton Bates (2001), who examined the possible roles of government for the New Zealand economy. In particular, Bates examined the role of government in facilitating growth as well as in providing services. He then finished his review by asking how big should the optimal government be.

Following Bates, the discussion of *the optimal size of government* could be organized around 5 topics:

- The recent historical record on the size of governments.
- The determinants of economic growth.
- The role of government in facilitating growth.
- The role of government (in addition to facilitating growth).
- Given a consensus on the possible roles of government, how best can the government achieve society's goals; i.e., how can the role of government be optimized?

Bates' (2001) discussion of the first topic listed above (i.e., what is the relationship between the size of governments and economic growth) is excellent and I can add nothing to it. However, more can be said about the remaining 4 topics. In the present

---

<sup>1</sup> This paper is based on Diewert (2001). The author is indebted to the SSHRC of Canada for financial support and to Winton Bates, Richard Harris, Jon Kesselman, Denis Lawrence, Serge Nadeau, Alice Nakamura, William Nordhaus, Someshwar Rao, Kevin Stiroh and William Ziemba for helpful comments.

paper, we will focus on topics 2 and 3 listed by Bates. In particular, we will attempt to provide a more comprehensive discussion of *the determinants of economic growth* and *the possible roles of government*. Thus in section 2, we discuss the various determinants of growth. It turns out that one of the most important determinants of economic growth is the *growth of total factor productivity*; i.e., the growth of outputs that cannot be readily explained by the growth in inputs. We devote sections 3 and 4 below to this somewhat esoteric topic. Section 5 discusses other factors that might influence growth. Section 6 provides a summary of the various factors that determine productivity growth. In the light of the growth theories discussed in sections 2-6, section 7 then examines the role of government in facilitating growth.

Section 8 concludes.

## **2. The Determinants of Economic Growth: Primary Input Growth and Other Factors**

There are a variety of theories that attempt to explain why some countries grow faster than others.

In a fairly recent review of the New Zealand economy, Bates (2001) explains that the main determinants of output growth are *input growth* (the growth of capital and labour inputs) and the *growth of Total Factor Productivity* (TFP). Bates goes on to note the importance of resource discoveries as another factor that can help explain growth. Resource discoveries and the exploitation of resources are somewhat important in the New Zealand context with agriculture, forests, oil and gas and perhaps fishing all playing a role. Other important factors in determining growth rates are:

- Changes in the terms of trade<sup>2</sup>;
- Immigration and population growth (obviously these factors influence the growth of labour input);
- Changes in domestic savings rates (this influences investment and the growth of capital input);
- Openness of the economy to foreign investment;
- Changes in the educational composition of the labour force;
- National entrepreneurial capacity<sup>3</sup> and
- The role of government in facilitating competition and the development of efficient markets.<sup>4</sup>

---

<sup>2</sup> See Diewert and Morrison (1986), Morrison and Diewert (1990), Kohli (1990) and Fox and Kohli (1998) on how to measure this factor.

<sup>3</sup> Alfred Marshall (1898; 377) described some of the characteristics of entrepreneurial ability as follows: “The ideal manufacturer, for instance, if he makes goods not to meet special orders but for the general market, must, in his first role as merchant and organizer of production, have a thorough knowledge of *things* in his own trade. He must have the power of forecasting the broad movements of production and consumption, of seeing where there is an opportunity for supplying a new commodity that will meet a real want or improving the plan of producing an old commodity. He must be able to judge cautiously and undertake risks boldly; and he must of course understand the materials and machinery used in his trade.”

Bates (2001) has an excellent discussion of the importance of institutions, property rights and government policies on growth rates; I can add little on his discussion of these factors.<sup>5</sup> However, the other factors listed above are also important.

In addition to the growth of primary inputs, the main factor which “explains” output growth is an increase in the *Total Factor Productivity* of the economy:

“The finding that TFP is largely responsible for differences in per capita incomes and growth rates does not take us very far. It merely implies that something other than capital accumulation may be important, without identifying what it is. Solow referred to this residual as ‘technical change’ and used this as a shorthand to cover education of the labour force and any kind of shift in the production function.” Winton Bates (2001; 11).

TFP growth is output growth that cannot be directly explained by input growth.<sup>6</sup> Put another way, TFP growth is sometimes taken to be an upward shift in the private sector

---

<sup>4</sup> The development of efficient markets is a tricky business. Of course, there must be a legal system that will enforce contracts. But contracts are simply not able to deal with the complexities of real world transactions. Hence for markets to function efficiently, there must be *trust* among economic agents as they deal with one another, trust that they will not try to cheat each other and that each party to a transaction has faith that the other party will behave honorably as external conditions perhaps not originally envisioned change. As usual, Alfred Marshall (1898; 7) had some pertinent observations on this point: “Again, the modern era has undoubtedly given new openings for dishonesty in trade. The advance of knowledge has discovered new ways of making things appear other than they are, and has rendered possible many new forms of adulteration. The producer is now far removed from the ultimate consumer; and his wrong-doings are not visited with the prompt and sharp punishment which falls on the head of a person who, being bound to live and die in his native village, plays a dishonest trick on one of his neighbours. The opportunities for knavery are certainly more numerous than they were; but there is no reason for thinking that people avail themselves of a larger proportion of such opportunities than they used to do. On the contrary, modern methods of trade imply habits of trustfulness on the one side and a power of resisting temptation to dishonesty on the other, which do not exist among a backward people.” I do not agree with Marshall that some people are necessarily “backward”. It seems that most market economies when in the early stages of their development have problems with determining what are appropriate rules of the game but as they evolve, appropriate norms also evolve.

<sup>5</sup> Hicks (1969) had a nice discussion on how custom and command economies have historically evolved into market oriented economies. Alfred Marshall (1898; 24-25) noted how governments can hinder the development of market economies: “Until a few years ago complete and direct self government by the people was impossible in a great nation: it could exist only in towns or very small territories. Government was necessarily in the hands of the few, who looked upon themselves as privileged upper classes, and who treated the workers as lower classes. Consequently, the workers, even when permitted to manage their own local affairs, were often wanting in the courage, the self-reliance, and the habits of mental activity, which are required as the basis of business enterprise. And as a matter of fact both the central Government and the local magnates did interfere directly with the freedom of industry; prohibiting migration, and levying taxes and tolls of the most burdensome and vexatious character. Even those of the lower classes who were nominally free, were plundered by arbitrary fines and dues levied under all manner of excuses, by the partial administration of justice, and often by direct violence and open pillage.”

<sup>6</sup> Technically, TFP growth can be obtained by subtracting 1 from an output index divided by an input index; see Caves, Christensen and Diewert (1982), Diewert (1990) and Diewert and Nakamura (2003) for further discussion. Lipsey and Carlaw (2000) present a fairly devastating critique of the neoclassical production function approach to the measurement of TFP. However, I think that many of their criticisms of the TFP concept can be mitigated if we just define TFP as an output index divided by an input index. This

aggregate production function. Bates goes on to note that differences in TFP growth rates have been largely responsible for differences in growth rates and he provides a good review of the endogenous growth theories of Romer and others. However, there are other much older growth theories that might be relevant. In the following section, we provide a review of some of these older theories.

### 3. The Determinants of Economic Growth: Productivity Growth

How does the production function or production possibilities set of a country expand over time?<sup>7</sup> We think of the production possibilities set of a given firm as a given set of plans or operating procedures that are known to the management of the production unit. But where does this knowledge of the production possibilities set come from? And how does this knowledge expand over time; i.e., how does innovation and the expansion of society's feasible set of outputs occur?

Knowledge of the set of feasible input and output combinations that a business unit in a specific geographic location could use and produce during an accounting period comes from at least three sources: (i) operating manuals or other written (or computer accessible) materials that are available in the establishment; (ii) knowledge of production techniques that is embodied in employees and managers who work in the establishment and (iii) knowledge that is embedded in establishment machines. This provides a brief answer to the first question above.

Note that it may be difficult to separate a *shift* in the establishment production function (due to innovative activity) from a *movement along* a production function (due to a change in scale or to a change in input prices. This point was made by Hicks (1973; 120) many years ago:

“I have so far been telling the story in the conventional terms, of shifts in technology and switches within the technology; but, at the point we have reached, do not the ‘technology’ and the ‘technological frontier’ themselves become suspect? They are essential tools of static analysis; but in dynamic analysis, such as this, do we need them? ... The notion of a ‘technology’, as a collection of techniques, laid up in a library (or museum) to be taken down from their shelves as required, has been deservedly criticized; in itself it is a caricature of the inventive process .... Why should we not say that every change in technique is an invention, which may be large or small? It certainly partakes, to some degree, of the character of an invention; for it requires, for its application, some new knowledge, or some new expertise. There is no firm line, on the score of novelty, between shifts that change the technology and shifts that do not.”

---

focuses attention on the proper measurement of outputs and inputs and on the choice of functional forms for the indexes of output and input. Diewert (1997) noted that four distinct approaches to the index number functional form problem led to either the Fisher (1922) ideal index or the Törnqvist index as the preferred choice. We note that the index number approach to the measurement of TFP will summarize the *combined* effect of three separate effects: (i) technical progress (i.e., an outward expansion of the production possibilities set); (ii) increasing (or decreasing) returns to scale (a movement along the frontier of the production possibilities set) and (iii) increases in managerial or organizational efficiency (a movement towards the frontier of the production possibilities set).

<sup>7</sup> We follow Nordhaus (1969; 19) in viewing an innovation as the introduction of a new process or vector of input-output coefficients into the economy.

We turn now to our second question; i.e., how does the production possibilities set of a country expand over time? Put another way, *how does knowledge of new techniques of production (process innovations) and of new products (product innovations) get created?* Traditional production theory as is embedded in general equilibrium theory is silent on this point (even though many economists have noted that knowledge creation cannot be regarded as exogenous<sup>8</sup> and critics<sup>9</sup> have noted this deficiency of traditional production theory).

Obviously, specialized schools, universities and publicly supported research labs are a primary source of the creation of new knowledge but a considerable amount of innovative activity is undertaken by individual inventors and the research departments of private firms.

Arrow<sup>10</sup> and others<sup>11</sup> have attributed increases in productivity (more output for the same amount of input) to experience or the incidental effect of new investments. Arrow (1962; 155-157) explains his theory of innovation as follows:

---

<sup>8</sup> “Analysis of production functions over the last twelve years has suggested strongly that (a) a major proportion of the increase in per capita income cannot be explained by increases in the capital-labor ratio, and (b) production functions differ strongly among nations and indeed among regions ... An economist could just leave the analysis at that, asserting that the causes which determine the amount of technological knowledge at any one time and place lie as much outside his province as the tastes which determine consumption patterns. But in fact, we know that significant quantities of resources are being expended by profit-making institutions on research and development ... Hence, it is suggested, we must regard the body of technological knowledge as the result as well as the cause of economic changes”. Kenneth J. Arrow (1969; 29).

<sup>9</sup> “... the basic assumptions of economic theory are either of a kind that are unverifiable --such as that producers ‘maximise’ their profits or consumers ‘maximise’ their utility-- or of a kind that are directly contradicted by observation--for example, perfect competition, perfect divisibility, linear-homogeneous and continuously differentiable production functions, wholly impersonal market relations, exclusive role of prices in information flows and perfect knowledge of all relevant prices by all agents and perfect foresight. There is also the requirement of a constant and unchanging set of products (goods) and of a constant and unchanging set of processes of production (or production functions) over time .... The latest theoretical models, which attempt to construct an equilibrium path through time with all prices for all periods fully determined at the start under the assumption that everyone foresees future prices correctly to eternity, require far more fundamental ‘relaxations’ for their applicability than was thought to be involved in the original Walrasian scheme”. Nicholas Kaldor (1972; 1238-1239).

“Dynamic general equilibrium models with state contingent goods and convex production sets may be useful for some purposes, but the critics are right that there is something fundamental and important about the evolution of an economy that equilibrium models based on convex sets cannot capture”. Paul Romer (1994; 14).

<sup>10</sup> “Knowledge arises from deliberate seeking, but it also arises from observations incidental or other activities. Haavelmo, Kaldor and I ... have all stressed that the activities of production and investment may lead to increases in productivity without any identifiable allocation of resources to that end”. Kenneth J. Arrow (1969; 30).

“The Horndal iron works in Sweden had no new investment (and therefore presumably no significant change in its methods of production) for a period of 15 years, yet productivity (output per manhour) rose on the average close to 2% per annum. We find again steadily increasing performance which can only be imputed to learning from experience”. Kenneth J. Arrow (1969; 156).

<sup>11</sup> See Allen (1983) and the references in Arrow (1962; 156).

“I would like to suggest here an endogenous theory of the changes in knowledge which underlie intertemporal and international shifts in production functions. The acquisition of knowledge is what is usually termed ‘learning’ and we might perhaps pick up some clues from the many psychologists who have studied this phenomenon .... I advance the hypothesis here that technical change in general can be ascribed to experience, that it is the very activity of production which gives rise to problems for which favorable responses are selected over time ... . The first question is that of choosing the economic variable which represents ‘experience .... I therefore take instead cumulative gross investment (cumulative production of capital goods) as a index of experience”.

A somewhat similar theory of innovation was advanced by Allen (1983) which he called *collective invention*.<sup>12</sup> Allen explained his theory as follows:

“Thus, if a firm constructed a new plant of novel design and that plant proved to have lower costs than other plants, these facts were made available to other firms in the industry and to potential entrants. The next firm constructing a new plant could build on the experience of the first by introducing and extending the design change that had proved profitable .... Collective invention was thus like modern research and development in that firms (and not individual inventors) generated the new technical knowledge. However, collective invention differs from R & D since the firms did not allocate resources to invention—the new technical knowledge was a by-product of normal business operation--and the technical information produced was exploited by agents other than the firms that discovered it”. Robert C. Allen (1983; 2).

“As long as the rate of investment was high, the rate of experimentation and the discovery of new technical knowledge was also high. On the other hand, if the rate of investment fell for any reason, the rates of experimentation and invention fell with it”. Robert C. Allen (1983; 3).

Allen illustrated his theory using data on changes in the height and operating temperatures of blast furnaces in England between 1850 and 1875 and he summarized his results as follows:

“Increasing furnace height and blast temperature led to lower fuel consumption and costs. The first firms to build tall furnaces might have treated this knowledge as a trade secret, but they did not. This information was made available to other parties through two channels {informal disclosure and publication in the engineering literature”. Robert C. Allen (1983; 6-7).

Thus Allen modeled innovation as follows: as firms invested in new facilities, bolder firms undertook marginal changes in the design of their facilities or machines; successful design changes were then communicated to the industry as a whole through trade associations or formal publication in journals or magazines. It is interesting to note that Marshall advanced similar ideas many years ago.<sup>13</sup>

---

<sup>12</sup> “Who invents? Why do they invent? In attempting to answer these questions, economists have identified and studied three kinds of institutions—nonprofit institutions like universities and government agencies, firms that undertake research and development, and individual inventors. In this paper, it is proposed that a fourth inventive institution be recognized. This institution is called collective invention”. Robert C. Allen (1983; 1).

<sup>13</sup> “Again, it is to his interest also that the secrecy of business is on the whole diminishing, and that the most important improvements in method seldom remain secret for long after they have passed from the experimental stage. It is to his advantage that changes in manufacture depend less on mere rules of thumb and more on broad developments of scientific principle; and that many of these are made by students in the pursuit of knowledge for its own sake, and are promptly published in the general interest”. Alfred Marshall (1920; 285).

Arrow and Allen both saw *investment* as a key input into the innovation process. Many modern growth theorists have noted that improvements in total factor productivity are often associated with increased investment activity. This association has a structural basis for the following reasons:

- New scientific and engineering information is often embodied in new investment goods;
- If investment is stagnant or declining, then capital services into the economy are also declining and since the growth in labour and other primary inputs is generally small, the decline in capital input leads to an overall decline in inputs used by the economy and hence average fixed costs increase and there is a decline in the overall efficiency of the economy. We discuss the role of fixed costs and increasing returns to scale in more detail below.

The next batch of theories of innovation date back to the origins of economics. Adam Smith (1963; 8) observed that many inventions or innovations are made by workers who simply figure out better ways of accomplishing a task that they are presently engaged in<sup>14</sup>:

“I shall only observe, therefore, that the invention of all those machines by which labour is so much facilitated and abridged, seems to have been originally owing to the division of labour. Men are much more likely to discover easier and readier methods of attaining any object when the whole attention of their minds is directed towards that single object, than when it is dissipated among a great variety of things. But in consequence of the division of labour, the whole of every man's attention comes naturally to be directed towards some one very simple object. It is naturally to be expected, therefore, that some one or other of those who are employed in each particular branch of labour should soon find out easier and readier methods of performing their own particular work, whenever the nature of it admits of such improvement”<sup>15</sup>.

Smith also observed that many improvements in productivity result from the *specialization of labour*: a worker who is able to concentrate or specialize on one task will become more proficient at that single task due to: (i) improvements in dexterity or physical skill and (ii) the elimination of the fixed costs in going from one type of task to another:

“This great increase of the quantity of work, which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances; first, to the increase of dexterity in every particular workman; secondly, to the saving of the time which is commonly lost in passing from one species of work to another; and lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many”. Adam Smith (1963; 7).

---

<sup>14</sup> This is obviously related to Arrow's learning by doing theory of productivity improvements.

<sup>15</sup> Smith (1963; 8-9) illustrated this general statement by the following specific example:

“In the first fire-engines, a boy was constantly employed to open and shut alternately the communication between the boiler and the cylinder, according as the piston either ascended or descended. One of those boys, who loved to play with his companions, observed that, by tying a string from the handle of the valve which opened this communication to another part of the machine, the valve would open and shut without his assistance, and leave him at liberty to divert himself with his play-fellows. One of the greatest improvements that has been made upon this machine, since it was first invented, was in this manner the discovery of a boy who wanted to save his own labour”.

Note that Smith suggested a third productivity benefit due to the increased specialization of labour: *specialized routine operations by workers lend themselves to replacement by more efficient machines*. Marshall<sup>16</sup> and Young<sup>17</sup> made similar observations. These observations are still valid today; e.g., many clerical and lower level managerial jobs are being replaced by computers and other machines.<sup>18</sup>

Smith (1963; 14) also pointed out *that the division of labour was limited by the extent of the market*; i.e., as the scale of the establishment grows due to the growth of markets for its outputs, the possibility of using specialized labour (and capital!) inputs also grows. As a corollary to his general principle, Smith pointed out that cities had larger markets than small towns and hence would support a higher degree of specialization in labour markets:

“There are some sorts of industry, even of the lowest kind, which can be carried on no where but in a great town. A porter, for example, can find employment and subsistence in no other place. A village is by much too narrow a sphere for him; even an ordinary market town is scarce large enough to afford him constant occupation”. Adam Smith (1963; 14).

---

<sup>16</sup> “We are thus led to a general rule, the action of which is more prominent in some branches of manufacture than others, but which applies to all. It is, that any manufacturing operation that can be reduced to uniformity, so that exactly the same thing has to be done over and over again in the same way, is sure to be taken over sooner or later by machinery .... Thus the two movements of the improvement of machinery and the growing subdivision of labour have gone together and are in some measure connected”. Alfred Marshall (1920; 255).

<sup>17</sup> “It is generally agreed that Adam Smith, when he suggested that the division of labour leads to inventions because workmen engaged in specialised routine operations come to see better ways of accomplishing the same results, missed the main point. The important thing, of course, is that with the division of labour a group of complex processes is transformed into a succession of simpler processes, some of which, at least, lend themselves to the use of machinery. In the use of machinery and the adoption of indirect processes there is a further division of labour, the economies of which are again limited by the extent of the market. It would be wasteful to make a hammer to drive a single nail; it would be better to use whatever awkward implement lies conveniently at hand. It would be wasteful to furnish a factory with an elaborate equipment of specially constructed jigs, gauges, lathes, drills, presses and conveyors to build a hundred automobiles; it would be better to rely mostly upon tools and machines of standard types, so as to make a relatively larger use of directly-applied and a relatively smaller use of indirectly-applied labour. Mr. Ford's methods would be absurdly uneconomical if his output were very small, and would be unprofitable even if his output were what many other manufactures of automobiles would call large”. Allyn A. Young (1928; 530).

<sup>18</sup> Nakamura and Lawrence (1994; 248) have a nice analysis of some of the differences between machines and workers that might cause managers to substitute machines for workers: “The comparative advantages of using machine labour are readily apparent. Computers and computer controlled machines are consistent in their responses, time after time. Machines are not vulnerable to feelings of boredom, fears that technological change may render them obsolete, or inopportune promotion aspirations. They never get pregnant, ask for maternity leaves, file discrimination or harassment suits, object if they are not given training opportunities, demand to be paid time-and-a-half for overtime work, or strikes. When parts of machines wear out, they can be replaced (or the whole machine can be replaced) without concerns about Workers' Compensation or disability claims being filed. Machines may not always perform as desired, but this is never a consequence of hard-to-handle attitudes or substance abuse problems. Rather, straightforward methods of scientific and engineering inquiry can usually be relied on to solve the performance difficulties of mechanical devices. And machines never have to be monitored to prevent them from intentionally shirking or stealing”.

Hence smallness of the local market hinders specialization and the resulting increases in efficiency. *This point is extremely important for a small isolated economy like New Zealand.* Because of New Zealand's smallness and geographic distance from major markets, it is difficult for New Zealand to provide specialized exports of goods and services to the world market and to develop a large variety of specialized domestic inputs. Consider the following quotation from *The Economist*, December 2, 2000:

“New Zealand's small population and geographic isolation from large markets also limit its scope for exploiting economies of scale. As ‘the last bus stop on the planet’, New Zealand is at a disadvantage compared with other small economies such as Ireland or Finland. A circle with a radius of 2,200 kilometers centered on Wellington encompasses only 3.8 million people and a lot of seagulls. A circle of the same size centered on Helsinki would capture well over 300 million people. Even if New Zealand had the best economic policies in the world, its isolation would probably still constrain its growth rate.”

*The Economist* sums up its article on New Zealand's economy as follows:

“New Zealand's smallness and remoteness mattered less when it produced mainly for the British market and when people had less choice about where to work and invest. But in today's more integrated world it is a serious handicap. As the OECD points out in its report, to offset its natural disadvantages, New Zealand needs to have better economic policies than other countries, if it is to be an attractive location for investment and for skilled workers to live. As other countries, notably in continental Europe, continue to liberalise their own economies, New Zealand's policies are no longer so exceptional. By reversing its reforms now, New Zealand could snatch defeat from the jaws of victory.”

Alfred Marshall further refined Adam Smith's idea that a larger market allows for increases in specialization and hence increased output for the same amount of aggregate input by introducing the ideas of *internal and external economies of scale*. In the following section, we shall examine his ideas and those of others on this topic in more depth.

#### **4. Increasing Returns to Scale**

We may divide the economies arising from an increase in the scale of production of any kind of goods, into two classes--firstly, those dependent on the general development of the industry; and, secondly, those dependent on the resources of the individual houses of business engaged in it, on their organization and the efficiency of their management. We may call the former external economies, and the latter internal economies”. Alfred Marshall (1920; 266).

*Internal economies of scale* occur if output expansion leads to a less than proportional increase in the use of inputs; i.e., internal economies are equivalent to increasing returns to scale in more modern language. The increasing returns to scale phenomenon could be regarded as meaning that the production possibilities set of an establishment has a particular shape and hence it might appear that the increasing returns to scale phenomenon can be accommodated by traditional production theory. This is true once a business unit has actually run an establishment at a higher scale and has demonstrated that the technology works at the higher output levels, but the first successful demonstration of operating a technology at a higher scale has much the same character as

establishing the feasibility of an innovation.<sup>19</sup> In any case, the benefits due to a firm being able to increase its scale when its technology is subject to increasing returns to scale is entirely similar to a productivity improvement due to an innovation. Hence increasing returns to scale may help to “explain” where improvements in total factor productivity come from.

There appear to be *six main sources of internal economies of scale*:

- (1) *Simple Indivisibilities*; i.e., most labour and capital inputs cannot be purchased in fractional amounts and all capital inputs have upper and lower limits on their capacities.<sup>20</sup> Thus a tiny firm will generally have higher costs than larger firms because it cannot purchase its inputs in small enough amounts.
- (2) *Multiple Stages of Production Indivisibilities*. This source of increasing returns to scale is an extension of the first source to deal with the complexities of multistage production. It is due to Babbage (1835; 212) and will be explained below.
- (3) *The Laws of Physics*; i.e., Kaldor<sup>21</sup> (and Marshall<sup>22</sup>) noted that the three dimensional nature of space leads to certain economies of scale.<sup>23</sup>
- (4) *The Laws of Geometry*. This source of increasing returns to scale was flagged by Lipsey (2000) and it is closely related to the previous source. We discuss some of Lipsey’s examples below.
- (5) *The Existence of Fixed Costs*; i.e., these are the efficiencies which result from averaging or amortizing fixed costs (a kind of indivisibility) over higher output levels. Before a machine yields a benefit from its operation, it may require the services of an operator who may have to be transported from one location to another<sup>24</sup> and the

---

<sup>19</sup> Allen (1983; 10) pointed out that increasing the height of blast furnaces eventually ran into diminishing returns: “These tall furnaces proved to be disasters”.

<sup>20</sup> For example, vehicles used to transport goods (trucks) cannot be constructed above and below certain capacities.

<sup>21</sup> “As was shown above, not all causes of increasing returns can be attributed to indivisibility of one kind or another and there is no reason to suppose that ‘economies of scale’ become inoperative above certain levels of production. There is first of all the steady and step-wise improvement in knowledge gained from experience--the so-called ‘dynamic economies of scale’ which have nothing to do with indivisibilities. But even in the field of ‘static’ or ‘reversible’ economies, there is the important group of cases which I described above as being due to the three dimensional nature of space--i.e., the fact that the capacity of, say, a pipeline can be quadrupled by doubling its diameter while the costs (in terms of labour and materials) are more nearly related to the diameter than to its capacity”. Nicholas Kaldor (1972; 1253).

<sup>22</sup> “A ship's carrying power varies as the cube of her dimensions, while the resistance offered by the water increases only a little faster than the square of her dimensions; so that a large ship requires less coal in proportion to its tonnage than a small one. It also requires less labour, especially that of navigation: while to passengers it offers greater safety and comfort, more choice of company and better professional attendance.” Alfred Marshall (1920; 290).

<sup>23</sup> For a more recent discussion of this topic, see Lipsey (2000).

<sup>24</sup> This example of a fixed cost is of course due to Adam Smith (1963; 7). A classic example of a returns to scale effect due to the existence of fixed costs is the square root inventory replenishment rule discovered by

machine may require a warming up period before production can begin. These are examples of fixed costs whose effect becomes relatively smaller the greater the length of time that the machine is continuously operated.

- (6) *The Law of Large Numbers*; i.e., these are efficiencies that result from the laws of probability theory. For example, consider a power plant that uses a number of identical engines. If the probabilities of engine failure are independently distributed, then having one set of spare parts on hand will generally be sufficient whether the plant has one engine or ten engines. Similarly, a large bank will not require as high a proportion of cash reserves to meet random demands as a small bank.<sup>25</sup> In a similar vein, a large property insurance company whose risks are geographically diversified faces a smaller probability of bankruptcy than a small insurance company,<sup>26</sup> etc.

The fact that machines have lower limits on their size and upper limits on their capacities means that for any single manufacturing process, there will generally be an output level and a machine that will minimize the average costs of production.<sup>27</sup> Babbage (1835) takes this observation one step further by considering how a factory or multistage manufacturing process could be arranged to produce the final output at minimum cost. To take a simple example, suppose a finally demanded product can be produced by two separate stages of production. Suppose that the average cost of production of the first stage can be minimized if 100 units are produced but the average cost of production of the second stage can only be minimized if 200 units are produced. Then obviously, the

---

the industrial engineers Green (1915) and Harris (1915; 48-52), and the economists Allais (1947; 238-241), Baumol (1952), Tobin (1956) and many others; see Whitin (1952; 503) (1957; 32 and 230) and Hadley and Whitin (1963; 3-4) for additional references to the literature.

<sup>25</sup> This application of probability theory to the determination of adequate bank reserves dates back to Edgeworth (1888; 122); for additional applications and references to the literature, see Whitin (1952; 506-511) (1957; 234-236) and Hadley and Whitin (1963; chapters 4-8). Edgeworth (1888; 124) also applied his statistical reasoning to the inventory stocking problem faced by a restaurant or club and noted that optimal inventory stocks are proportional to the square root of anticipated demands: "Suppose now the number of members in the club to be doubled or trebled, while their habits are unaltered. At first sight it might appear that the reserve of provisions which the manager requires should increase proportionately. But the corrected theory is that the ratio of the new reserve to the old should not be two or three but the square root of two or three".

<sup>26</sup> Hicks gave great importance to this factor. "The evolution of the institutions of the Mercantile Economy is largely a matter of finding ways of diminishing risks." John Hicks (1969; 48). "Neither of these methods would in fact be as powerful as they have proved to be, if it were not for the possibility of spreading risks, the so-called 'Law of Large Numbers' which is the basis of Insurance. We know that the medieval Italians were acquainted with insurance contracts; maritime insurance, insurance against the loss of a cargo in transit, was already possible in the fourteenth century. To undertake a single insurance of this type— involving a small but significant chance of a large loss, with no more than a moderate gain in the other event to set against it— would be intolerably risky; but it must soon have been observed that by combining a number of such risks, if they were reasonably independent of each other, the risk could be greatly reduced. If this had not been perceived, insurance could not have developed, as we know it did. We cannot tell at what point it was observed that the same principle applied to banking." John Hicks (1969; 79).

<sup>27</sup> If the demand for the output is large relative to the output level that minimizes average cost, then the optimal machine could in theory be replicated and the industry production function would exhibit approximate constant returns to scale for large industry outputs; see Samuelson (1967) and Diewert (1981) for arguments along these lines.

overall unit cost of production can only be minimized if we produce 200 units (or a multiple of 200 units using a replication argument). Thus the threshold level of output that is necessary to achieve overall economies of scale in producing a product that is manufactured in multiple stages will generally be higher than a simple average of the efficient threshold levels of output for each stage. Babbage<sup>28</sup> expressed this very subtle principle as follows:

*“When the number of processes into which it is most advantageous to divide it, are ascertained, then all factories which do not employ a direct multiple of this latter number, will produce the article at a greater cost. This principle ought always to be kept in view in great establishments, although it is quite impossible, even with the best division of the labour, to attend to it rigidly in practice. ... But it is quite certain that no individual, nor in the case of pin-making could any five individuals, ever hope to compete with an extensive establishment. Hence arises one cause of the great size of manufacturing establishments, which have increased with the progress of civilization.”* Charles Babbage (1835; 212-213).

Babbage also noted that the growth of large factories facilitated the division of labour:

*“Perhaps the most important principle on which the economy of a manufacture depends, is the division of labour amongst the persons who perform the work. The first application of this principle must have been made in a very early stage of society; for it must have soon been apparent, that a larger number of comforts and conveniences could be acquired by each individual, if one man restricted his occupation to the art of making bows, another to that of building houses, a third boats, and so on. This division of labour into trades was not, however, the result of an opinion that the general riches of the community would be increased by such an arrangement; but it must have arisen from the circumstance of each individual so employed discovering that he himself could thus make a greater profit of his labour than by pursuing more varied occupations. Society must have made considerable advances before this principle could be carried into the workshop; for it is only in countries which have attained a high degree of civilization, and in articles in which there is a great competition amongst the producers, that the most perfect system of the division of labour is to be observed.”* Charles Babbage (1835; 169).

Babbage then went on to give a list of principles which would lead to the most perfect system of the division of labour in factories:

1. *Of the time required for learning.* It will be readily admitted that the portion of time occupied in the acquisition of any art will depend on the difficulty of its execution; and that the greater number of distinct processes, the longer will be the time which the apprentice must employ in acquiring it. ...
2. *Of waste of materials in learning.* A certain quantity of material will, in all cases, be consumed unprofitably, or spoiled by every person who learns an art; and as he applies himself to each new process, he will waste some of the raw material, or of the partly manufactured commodity. But if each man commit this waste in acquiring successively every process, the quantity of waste will be much greater than if each person confine his attention to one process; in this view of the subject, therefore, the division of labour will diminish the price of production.
3. Another advantage resulting from the division of labour is, *the saving of that portion of time which is always lost in changing from one occupation to another.* ...

---

<sup>28</sup> Babbage (1835) in his preface explains how he came to be the world’s first industrial engineer (or management consultant): “The present volume may be considered as one of the consequences that have resulted from the Calculating-Engine, the construction of which I have been so long superintending. Having been induced, during the last ten years, to visit a considerable number of workshops and factories, both in England and on the Continent, for the purpose of endeavouring to make myself acquainted with the various resources of mechanical art, I was insensibly led to apply to them those principles of generalization to which my other pursuits had naturally given rise.”

4. *Change of tools.* The employment of different tools in the successive processes is another cause of the loss of time in changing from one operation to another. If these tools are simple and the change of tools is not frequent, the loss of time is not considerable; but in many processes of the arts the tools are of great delicacy, requiring accurate adjustment every time they are used; and in many cases the time employed in adjusting bears a large proportion to that employed in using the tool. The sliding-rest, the dividing and the drilling-engine, are of this kind; ...

5. *Skill acquired by frequent repetition of the same processes.* The constant repetition of the same process necessarily produces in the workman a degree of excellence and rapidity in his particular department, which is never possessed by a person who is obliged to execute many different processes. ...

6. *The division of labour suggests the contrivance of tools and machinery to execute its processes.* When each process, by which any article is produced, is the sole occupation of one individual, his whole attention being devoted to a very limited and simple operation, improvements in the form of his tools, or in the mode of using them, are much more likely to occur to his mind, than if it were distracted by a greater variety of circumstances. Such an improvement in the tool is generally the first step towards a machine.” Charles Babbage (1835; 170-174).

The above observations on the effects of an increasing division of labour reducing unit costs owe much to Adam Smith but it can be seen that Babbage put his own spin on Smith’s observations.<sup>29</sup> Babbage concludes his discussion on the division of labour by deriving a *seventh new principle*:

*“That the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided.”* Charles Babbage (1835; 175-176).

Babbage (1835; 176-186) illustrated his new principle by describing in great detail the mechanics of making pins, which could be broken down into a number of distinct processes, each of which had its own labour requirements (of different skills). He found that the unit cost of a pin made by a single worker (who necessarily must be the most skilled) would exceed the unit cost of a pin made using his new principle by a considerable margin:

*“The pins would therefore cost, in making, three times and three quarters as much as they now do by the application of the division of labour.”* Charles Babbage (1835; 186).

Finally, Babbage (1835; 212-213) tied the above material on the mechanics of making pins into his multiple processes principle of optimum production, (2) above, in our list of six sources of returns to scale.

We note that industrial engineering, operations research and management science have developed mathematical techniques that enable the business unit to achieve internal economies of scale with respect to many of the six factors listed above.

We turn now to Lipsey’s (2000) discussion of *geometry* as a source of increasing returns to scale. His first example is extremely simple and has to do with the mechanics of pasturing horses:

---

<sup>29</sup> Babbage (1835; 175) explicitly acknowledges the contributions of Smith.

“This example is chosen because its transparency allows the issues to be easily identified. It concerns a firm that is in the business of pasturing other people’s horses. One square unit of fenced space is required to accommodate one horse. The grass is free and the only production cost is the fence, which is continuously variable. When the firm wishes to pasture more horses, it increases the size of its one fenced field.” Richard G. Lipsey (2000, 3).

Thus if  $L$  is the length of fence used by the firm, its costs are proportional to  $L$  but its output is proportional to  $L^2$ . Thus the firm’s unit cost will be proportional to  $1/L$  and hence we have decreasing unit costs and increasing returns to scale. Lipsey stresses that the source of the increasing returns has nothing to do with indivisibilities:

“There are *no indivisibilities* in this example. The physical nature of the capital good is unchanged and the area of the pasture is a continuous variable. The neoclassical production function, defined in terms of inputs of service flows, displays constant returns to scale. Yet there are scale economies. These are rooted in the geometry of our three-dimensional world. The fenced area increases with the square of the length of the fence, while the cost increases linearly with the length of the fence.” Richard G. Lipsey (2000, 4).

Lipsey<sup>30</sup> gives several additional examples of scale effects that arise from geometrical relations:

“The geometrical relation governing any container typically makes the amount of material used, and hence its cost (given constant prices of the materials with which it is made), proportional to *one dimension less* than the service output, giving increasing returns to scale over the whole range of output (at least with respect to the inputs of materials). This holds for more than just storage. Blast furnaces, ships, and steam engines are a few examples of the myriad technologies that show such geometrical scale effects. Costs of construction also often increase less than in proportion to the increase in the capacity of any container. Consider just one example. The capacity of a closed cubic container of sides  $s$  is  $s^3$ . The amount of welding required is proportional to the total length of the seams, which is  $12s$ . The amount of material required for construction is  $6s^2$ . So material required per unit of capacity is  $6/s$  while [per unit volume] welding cost is  $12/s^2$ . Not only are both of these rates falling as the capital good is reconfigured to increase its capacity, they fall at different rates.” Richard G. Lipsey (2000, 6).

We turn now to a discussion of Marshall’s *external economies of scale*. Two examples are:

- reduced prices for inputs due to bulk purchasing<sup>31</sup> and
- the large scale of a business unit can translate into a large demand for inputs and this in turn can encourage specialized suppliers to come into existence.<sup>32</sup> Thus external

<sup>30</sup> Lipsey (2000) also gives many examples of scale effects that arise from physical laws and from indivisibilities.

<sup>31</sup> Bulk purchasing means that the supplying firm may be able to achieve internal economies of scale and thus can offer lower selling prices.

<sup>32</sup> This observation is of course due to Adam Smith as we have seen. Krugman summarizes Marshall's elaboration of Smith as follows: “It was Alfred Marshall who presented the basic classic economic analysis of the phenomenon. (Actually, it was the observation of industry localization that underlay Marshall’s concept of external economies, which makes the modern neglect of the subject even more surprising). Marshall (1920) identified three distinct reasons for localization. First by concentrating a number of firms in an industry in the same place, an industrial center allows a pooled market for workers with specialized skills; this pooled market benefits both workers and firms .... Second, an industrial center allows provision of nontraded [i.e., non internationally traded] inputs specific to an industry in greater variety and at lower

economies of scale reflect favorable changes in the environment facing the expanding business unit (lower input prices and new intermediate input suppliers).

Another way of explaining the second example is that a large demander of intermediate or primary inputs may facilitate the specialization of suppliers, leading to lower unit input prices for the large demander.

In the following section, we list some related factors that help to explain TFP growth.

## 5. Other Factors that Might Explain Growth

What is the underlying cause of both internal and external economies? It seems that Adam Smith (1963; 14) had the answer to this question: *growth of the market*. Some of the obvious *factors that facilitate growth of the market* are:

- transportation and infrastructure improvements<sup>33</sup>;
- population growth<sup>34</sup>;
- reduction in trade barriers<sup>35</sup>;
- reduction of taxes on commodities, labour services and capital<sup>36</sup>;

cost .... Finally, because information flows locally more easily than over great distances, an industrial center generates what we would now call technological spillovers ....” Paul Krugman (1991; 36-37).

<sup>33</sup> Adam Smith (1963; 15) was well aware of this factor: “As by means of water-carriage a more extensive market is opened to every sort of industry than what land-carriage alone can afford it, so it is upon the sea-coast, and along the banks of navigable rivers, that industry of every kind naturally begins to subdivide and improve itself, and it is frequently not till a long time after that those improvements extend themselves to the inland parts of the country”.

<sup>34</sup> “... every increase in [population] is likely for the time to be accompanied by a more than proportionate increase in their power of obtaining material goods. For it enables them to secure the many various economies of specialized skill and specialized machinery, of localized industries and production on a large scale: it enables them to have increased facilities of communication of all kinds; while the very closeness of their neighbourhood diminishes the expense of time and effort involved in every sort of traffic between them, and gives them new opportunities of getting social enjoyments and the comforts and luxuries of culture in every form. No doubt deduction must be made for the growing difficulty of finding solitude and quiet and even fresh air: but there is in most cases some balance of good.” Alfred Marshall (1920; 320-321). Perhaps Marshall could be considered the first environmentalist!

<sup>35</sup> As tariffs were reduced in the years following World War II, trade between countries grew faster than GDP growth. The North American Free Trade agreement led to a 75% increase in trade between Canada and the U.S. in 5 years.

<sup>36</sup> Bates (2001) has an instructive example showing how high rates of labour taxation can cause taxpayers to allocate their time to doing various domestic chores like mowing the lawn instead of contracting specialized service providers. Thus high taxes inhibit the formation of specialized markets. A Canadian economist, William Watson (1999) explains the problem as follows: “I spent Labour Day, fittingly, at work. ... I was scraping my front porch and filling the holes with wood filler, in preparation for painting it ... Objectively speaking, the reason I found myself scraping and patching was taxes. My comparative advantage, as we economists say, is typing, not hand tools. I should really be paying someone else to paint the front porch. The reason I don’t is taxes. Taxes mean I have to pay roughly four times what the job is worth. First, because my marginal rate is 50 plus per cent, I have to earn twice as much in pre-tax income as a painter would charge me. And, depending on the painter’s income tax rate and GST status, he has to charge me close to twice what he wants in after-tax income. Two times two being four (even in Tax-land), to pay for the job, I end up having to earn four times what the folks I would hire think their time is worth.”

- the provision of personal security and the security of property rights<sup>37</sup>;
- improvements in advertising and the transmission of information about products<sup>38</sup>;
- improvements in communications<sup>39</sup>; and
- growth of physical and human capital.

The role of population growth in facilitating the growth of the market should take into account the growth of *rural versus urban* population since it is the growth of population in the *cities* of a country that leads to the growth of specialized markets. Thus for the first 60 or 70 years of the past century, growth in the cities of most advanced economies was fueled not only by higher rates of natural population growth than prevail now but urban growth was also fueled by migration of workers from the farm to the city. These within country population shifts helped fuel the productivity boom in the previous century that fell off after the first OPEC price shock in 1973.<sup>40</sup>

The previous paragraph makes the point that an economy's productivity will be improved if workers are shifted from lower productivity jobs in agriculture to higher productivity jobs in manufacturing and services. However, the same point applies to shifts of workers from lower to higher productivity establishments *within an industry*. John Haltiwanger (2000; 16) sums up recent research in this area as follows:

“In this study we have focused on the contribution of the reallocation of activity across individual producers in accounting for aggregate productivity growth. A growing body of empirical analysis reveals striking patterns in the behaviour of establishment-level reallocation and productivity. First, there is a large ongoing pace of reallocation of outputs and inputs across establishments in market economies. Second, the pace of reallocation varies secularly, cyclically and by industry. Third, there are large and persistent productivity differentials across establishments in the same industry even in well functioning market economies. Fourth, entering establishments tend to have higher productivity than exiting establishments. Large productivity differentials and substantial reallocation are the necessary ingredients for an important role for reallocation in aggregate productivity growth. The emerging evidence suggests that the process of economic growth at the micro level is incredibly noisy and complex - there is a vast amount of churning as businesses and workers seek to find the best methods, products, locations and matches. This churning is an inevitable and vital component of economic growth. However, a number of conceptual and measurement issues remain. We don't have a clear understanding of the sources of within and between-country variation in the nature and magnitude of this churning, we don't have a clear understanding of the sources of within-industry heterogeneity in productivity levels and growth rates, and in turn we don't have a clear

---

<sup>37</sup> Bates' (2001; Chapter 2) discussion on this topic is more than adequate. Obviously physical intimidation and corruption is not conducive to economic growth in a country. Corruption acts like an uncertain tax on investments and hence will deter investment.

<sup>38</sup> Advertising makes potential purchasers aware of new products and thus stimulates market growth. A particularly effective recent innovation in this area is use of targeted mailing and email lists.

<sup>39</sup> Particularly important today are the improvements in telecommunications technology (fax machines, the internet, etc.). The recent growth in business to business provision of services over the internet should make it possible for New Zealanders to compete in international services markets. Communications improvements were also important in Marshall's time: “Meanwhile an increase in the aggregate scale of production of course increases those economies, which do not directly depend on the size of individual houses of business. The most important of these result from the growth of correlated branches of industry which mutually assist one another, perhaps being concentrated in the same localities, but anyhow availing themselves of the modern facilities for communication offered by steam transport, by the telegraph and by the printing-press”. Alfred Marshall (1920; 317).

<sup>40</sup> See Diewert and Fox (1999; 255-257) for the falloff in OECD country TFP growth after 1973.

understanding of all of this variation for within and between-country outcomes like economic growth. A key obstacle for current work is that the requisite data development is still in early stages.”

Harberger (1998) makes many of the same points as Haltiwanger in his Presidential Address to the American Economic Association. The available evidence indicates that establishments in the same industry differ tremendously in their efficiency and it can take long periods of time before these inefficient establishments are driven out of business. This indicates a potentially large role for business consultants or governments to bring a knowledge of best practice techniques to the attention of the inefficient establishments.<sup>41</sup> There is another important role for government and that is to facilitate the reallocation of resources from inefficient establishments to efficient ones. Thus other things being equal, it is likely that a highly regulated economy will not do as well as one where it is easy to set up new businesses and to hire (and fire) workers.<sup>42</sup>

As Bates explains in his Chapter 3, it is well known that tariffs and taxes have excess burdens associated with them. As long as these taxes and tariffs are not *increased*, they should not affect growth *rates* (in theory); they should only affect the *level* of economic activity. However, Feldstein, hints at a possible dynamic effect of high taxes on labour supply:

“The relevant distortion to labour supply is not just the effect of tax rates on participation rates and hours but also their effect on education, occupational choice, effort, location, and all the other aspects of behavior that affect the short-run and long-run productivity and income of the individual.” Martin Feldstein (1996; 22).

Thus high or increasing marginal rates of taxation on labour income can discourage individuals from using their after tax income to invest in higher education or specialized training courses, given that any increases in earnings might be taxed at very high rates.<sup>43</sup> This has the effect of hindering the growth of specialized labour markets and will divert effort into untaxed leisure or inefficient home production.

We return to our analysis of factors that might explain Total Factor Productivity growth. One such factor is of course the creation of *new* scientific and engineering knowledge. The creation of new knowledge is fairly well understood and will not be discussed here. However, what is perhaps most relevant for New Zealand is *not* the *initial creation* of the new knowledge but its *diffusion* to the local establishment level. The fact that a new

---

<sup>41</sup> Often this can be accomplished by benchmarking exercises where similar establishments are compared. See Zeitsch and Lawrence (1996) and Diewert and Nakamura (1999).

<sup>42</sup> However, on social grounds (and even on efficiency grounds) it would be desirable to have an effective unemployment insurance scheme that would offer laid off workers temporary income support as they searched for new jobs. What is not desirable is a scheme that discourages interregional labour mobility or a scheme that encourages seasonal workers to stay in seasonal jobs. See Nakamura and Diewert (2000) on recent reforms to the Canadian Employment Insurance scheme. The recent great expansion in internet job market companies should also improve the efficiency of labour markets.

<sup>43</sup> If there is progressive income taxation and variable labour supply, then investments in education can push the individual into a higher tax bracket. Under these conditions, we can expect a fair amount of excess burden; see for example Driffill and Rosen (1983) or Dupor, Lochner, Taber and Wittekind (1996). This literature is reviewed by Kesselman (1997; 47-49).

product or production process has been developed somewhere in the world is of little significance to a local establishment that could use the innovation if the original knowledge is not transmitted or diffused to the establishment. Some of the factors that facilitate the rapid diffusion of new (and old) knowledge into a local market area are:

- access to public libraries and university libraries<sup>44</sup>;
- access to newspapers, periodicals, journals, magazines, how to do it books, etc.<sup>45</sup>;
- memberships in trade associations, industry associations, professional societies, etc.<sup>46</sup>;
- access to international meetings and trade fairs where knowledge can be transmitted on a face to face basis<sup>47</sup> (adequate local transportation infrastructure will facilitate this access<sup>48</sup>);
- access to good schooling and specialized training programs<sup>49</sup>;
- access to specialized consulting services<sup>50</sup> and product information and
- access to telecommunications services<sup>51</sup> (i.e., having good local telecommunications infrastructure).

---

<sup>44</sup> It is here where basic information on science and engineering can be obtained: “Let us then look at those elements of the wealth of a nation which are commonly ignored when estimating the wealth of the individuals composing it .... Scientific knowledge indeed, wherever discovered, soon becomes the property of the whole civilized world, and may be considered as cosmopolitan rather than as specially national wealth. The same is true of mechanical inventions and of many other improvements in the arts of production....” Alfred Marshall (1920; 59).

<sup>45</sup> “For External economies are constantly growing in importance relatively to Internal in all matters of Trade-knowledge: newspapers, and trade and technical publications of all kinds are perpetually scouting for him and bringing him much of the knowledge he wants--knowledge which a little while ago would have been beyond the reach of anyone who could not afford to have well-paid agents in many distant places .... Although therefore the small manufacturer can seldom be in the front of the race of progress, he need not be far from it, if he has the time and the ability for availing himself of the modern facilities for obtaining knowledge”. Alfred Marshall (1920; 284-285).

<sup>46</sup> “But perhaps a greater though less conspicuous hindrance to the rise of the working man is the growing complexity of business. The head of a business has now to think of many things which he never used to trouble himself in earlier days; and these are just the kind of difficulties for which the training of the workshop affords the least preparation. Against this must be set the rapid improvement of the education of the working man not only at school, but what is more important, in after life by newspapers, and from the work of co-operative societies and trades-unions, and in the other ways”. Alfred Marshall (1920; 308-309).

<sup>47</sup> “While mass media play a major role in alerting individuals to the possibility of an innovation, it seems to be personal contact that is most relevant in leading to its adoption. Thus, the diffusion of an innovation becomes a process formally akin to the spread of an infectious disease”. Kenneth J. Arrow (1969; 33).

<sup>48</sup> Having an easily accessible local airport that has direct flights to many international destinations seems to be important in this respect.

<sup>49</sup> “Other things being equal, one person has more real wealth in its broadest sense than another, if the place in which the former lives has a better climate, better roads, better water, more wholesome drainage; and again better newspapers, books and places of amusement and instructions”. Alfred Marshall (1920; 58-59).

<sup>50</sup> Several companies provide *benchmarking services*; i.e., the performance of a given production unit is compared to peer group units that face similar operating conditions. If inefficiency is revealed, then the given unit can attempt to duplicate the techniques used by the most efficient units; see for example Zeitsch and Lawrence (1996). For references to the early history of benchmarking (which has its origins in the early industrial engineering literature), see Diewert and Nakamura (1999). This last study shows vast differences in the efficiency of diesel electric power plants around the world.

The point that we are trying to make here is that New Zealand does not *necessarily* have to devote a high percentage of its resources to primary research and development (i.e., to the creation of new products and processes): it need only have easy access to the sources of new knowledge.<sup>52</sup>

My colleague, Jon Kesselman, in a private communication notes that the above paragraph may be a serious oversimplification as he indicates below:

“Even if a nation has *access* to all of these ways of getting information, it seems to me that the most critical factor is whether there are large numbers of well-educated, well-trained, and motivated, creative, and able individuals actually at work in industry. Having low-cost access to all of these informational resources will do an economy no good if there are not sufficient numbers of workers to seek, absorb, integrate, and apply the ideas. Moreover, the creation of new products, new industrial processes, and new business management and marketing techniques relies on having large numbers of these energetic, able, creative workers. If a nation’s workers are always imitating what is the well-documented ‘best technique’ in other countries, they will be well behind the curve of the best technology that is actually in development and in the earlier stages of application in the world’s leading companies. Don’t the big economic rents come from those who develop the new products and processes first? If they are able to patent, trademark, or otherwise keep some proprietary ownership of their discoveries, then they can either keep the gains to themselves or earn the royalties from others who wish to use their discoveries. Given today’s fast changing technology and new products, firms that start producing the goods or implementing the new processes one or two years after they were first developed are entering only when the ‘invention’ has become a ‘commodity’ with much lower economic returns.”

It should be noted that expending resources on the development of new products is not necessarily productive. Paul Romer noted that there are costs associated with expenditures on developing new products and processes:

“Every real economy is presented with an almost incomprehensible number of new goods that can be introduced. Some of these goods are like good Z in Figure 3. They would increase utility. Many others, perhaps the great majority of all possible new goods, would not be worth introducing. The fixed costs are too high and the benefits too low. Out of the enormous set of possible new goods, a very small number are somehow selected and introduced.” Paul Romer (1994; 14).

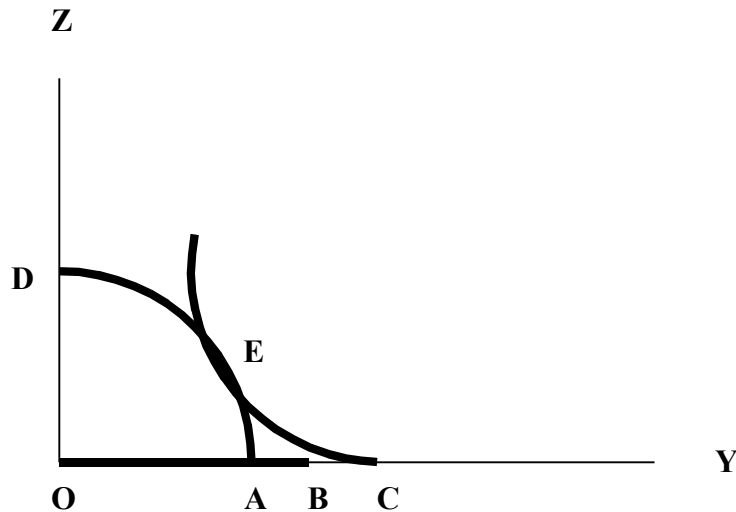
We have reproduced the essence of Romer’s (1994; 13) Figure 3 below. There are two commodities in the economy: “old” commodities Y and a new commodity Z. The production possibilities set for the “old” economy before the introduction of the new commodity is the line segment OB. The fixed costs of developing the new commodity are equal to the line segment AB. Once these fixed costs have been paid, the production possibilities set for the new economy is the set enclosed by the production frontier DA, which is tangent to an indifference curve at the point E. Note that the introduction of the new commodity in this particular case has led to a higher utility level (OC in terms of old goods) than the utility level achieved by the economy before the introduction of the new

---

<sup>51</sup> It seems likely that internet services will eventually be substitutes for most of the knowledge transmission activities listed above.

<sup>52</sup> Japan might be an example of a country that focuses on using and commercializing basic research that has been done offshore.

commodity, OB. However, if the fixed costs of developing the new commodity, AB, were greater than the benefit AC, then it would not pay to introduce the new commodity.



The main point to note about Romer's observation is this: it is by no means certain that all expenditures on the development of new processes and products are beneficial.

We conclude our survey of causal factors that might help to explain total factor productivity growth by discussing the role of *macroeconomic stability*. The main factors here are stable fiscal policy, stable exchange rates, stable prices and stable interest rates. Macroeconomic stability by itself is not a main driver of productivity growth. However, a lack of stability often has strong *negative effects* on the rate of TFP growth. In particular, it appears that high or variable rates of inflation may have a such a negative effect. Diewert and Fox (1999) identified *two mechanisms* that may cause high inflation to drive down TFP growth rates:

- Usually business income tax systems are not indexed to take into account the effects of inflation. Under these circumstances, even moderate inflation can lead to effective tax rates that diminish the real capital of businesses.
- Because many multiproduct firms did not know how to adjust depreciation allowances and user costs of capital for the effects of inflation, they were unable to properly price their products. As the capital intensity of advanced economies increased during the past century (and as firms greatly expanded the variety of products being produced), these effects of these pricing mistakes became relatively larger.<sup>53</sup>

<sup>53</sup> Diewert and Fox (1999) argue that the increase in inflation that started with the first oil shock in 1973 in most OECD economies and lasted until the early 1990's is the only major factor that changed abruptly that could perhaps explain the pronounced drop in TFP that hit virtually all OECD countries during that period.

Of course, under conditions of high and variable inflation, it becomes very difficult to determine the current real interest rate and to forecast future real interest rates. This increased uncertainty leads to incorrect investment decisions and a loss of efficiency for the economy. This is a *third mechanism* by which inflation translates into a loss of productive efficiency.

In the following section, we attempt to summarize our rather diffuse discussion in this section.

## 6. A Summary of the Factors Explaining Productivity Growth

The previous sections gave an overview of factors that might explain variations in the growth of Total Factor Productivity, which in turn is the main driver of growth in per capita incomes. In summary, factors that will tend to *augment* TFP growth are:<sup>54</sup>

- Rapid *investment growth* (in reproducible or physical capital).<sup>55</sup>
- Rapid growth in *investments in education, training and human capital*.
- Rapid *growth in primary inputs* will tend to lead to an even more rapid growth of output due to *increasing returns to scale in production*. The main drivers of increasing returns to scale are: the existence of indivisibilities; the laws of geometry and physics; the existence of fixed costs and the laws of statistics.
- Increases in TFP are associated with *increased specialization*, which in turn is driven by growth in the size of the market. In brief: big tends to be better!
- *Improvements in the functioning of markets*, which could occur in a variety of ways, including: (i) improvements in personal security; (ii) improvements in property rights; (iii) reductions in trade barriers; (iv) improvements in telecommunications (in particular, the growth of internet driven markets) and (v) improvements in transportation and infrastructure.
- *Access to new knowledge* about the development of new commodities and processes. Recall our discussion about the importance of business consultants, trade associations and benchmarking to diffuse knowledge about best practices.

Factors which will tend to *reduce* the growth of Total Factor Productivity (in addition to the negative of the above factors) are:

---

<sup>54</sup> Harris (2001; 5) has the following list of factors that explain growth in what he calls the *modern macroeconomic growth perspective*: A. *Supply Side Growth Factors*: (1) Primary inputs (labour, resources); (2) Reproducible capital goods (physical and human capital); (3) Technology, management and the knowledge base; (4) Allocative efficiency of markets and external spillovers; (5) International comparative advantage; (6) Terms of trade; and (7) Public policy. B. *Demand Side Factors*: (1) External market access; (2) The global business cycle; and (3) Domestic macroeconomic policy. It can be seen that our list of explanatory factors is not all that different.

<sup>55</sup> Harris (2001) characterizes productivity growth as being driven by three main factors: “The outcome of these studies, and of a host of other country-specific studies, has led to what I would call a consensus view on the three main correlates of national productivity growth — let's call them the Big 3. They are, respectively, investment in machinery and equipment, human capital development, and openness to trade and investment. In the literally hundreds of studies that have been done these three variables show up as robustly and highly correlated with productivity growth or growth in per capita GDP.”

- *High taxes.* In theory, this factor should just have one time level effects on economic efficiency but it is likely that high taxes have dynamic effects as well, tending to reduce investments in physical and human capital and retarding the formation of specialized markets.<sup>56</sup>
- *High inflation.* High or unpredictable rates of inflation tend to increase uncertainty about the real interest rate and future prices and hence lead to a misallocation of investment and a reduction in productive efficiency.

We turn now to a discussion of the role of government in optimizing growth.

## 7. The Role of Government in Facilitating Growth.

Immediately above, we listed 6 factors that will tend to increase TFP growth and 2 factors that will tend to decrease it. Let us look at each of these factors in turn and see what possibilities there are for the government to optimize any of these factors.

### (1) *Rapid investment growth (in reproducible or physical capital).*

Low rates of business income taxation are the key here. This leads to an argument for *smaller* government.

### (2) *Rapid growth in investments in education, training and human capital.*

To optimize this factor, the government should aim for low rates of taxation on labour earnings in order to encourage individuals to invest in their human capital. Given the difficulties that individuals have in accessing capital markets in order to finance investments in education and training, there is also an argument for the government to subsidize these human capital investments. Hence the first argument implies a *smaller* government while the second argument implies a *larger* one.

### (3) *Rapid growth in primary inputs.*

Low rates of taxation on business income will tend to encourage investment in physical capital while low rates of taxation on labour earnings and consumption will tend to encourage the growth of labour input. These are arguments for *smaller* government. There are other policies that the government can implement that can encourage primary input growth without much in the way of budgetary implications. Perhaps the most important of these policies might be to encourage immigration. Immigrants with large

---

<sup>56</sup> In addition to the extensive literature cited by Bates (2001) on the statistical relationships between taxation and growth rates, there are two more recent studies that could be cited. Kneller, Bleaney and Gemmell (1999) find that capital taxation is more damaging to growth than taxes on consumption or labour as does Kesselman (2000; 47-57). Kesselman (2000; 55) sums up his reading of the literature on this topic as follows: "What can be learned from the economic studies and comparative international experience is that taxing 'smarter' is more important than taxing less when promoting economic growth. Either shifting the total revenue mix toward greater reliance on indirect taxes on goods and services or on payroll-type taxes, or reforming the personal tax base to be more consumption oriented and less reliant on savings and capital incomes, would pay significant economic dividends."

endowments of human and physical capital are particularly desirable as are immigrant groups who historically have had high labour force participation rates or high propensities to invest in physical and human capital. Another set of policies that might encourage primary input growth but are not necessarily very costly are associated with the exploitation of natural resources. In particular, the subsidization of tree planting comes to mind.<sup>57</sup>

(4) *Increased specialization and growth of the market.*

Lower taxes on business and labour income should facilitate increased specialization. This is another argument for *smaller* government. The government should also explore possible free trade agreements with other Pacific Rim countries to improve its access to overseas markets. The budgetary implications of this policy are small.

(5) *Improvements in the functioning of markets.*

This factor includes: (i) improvements in personal security; (ii) improvements in property rights; (iii) reductions in trade barriers; (iv) improvements in telecommunications (in particular, the growth of internet driven markets) and (v) improvements in transportation and infrastructure. There is little that the New Zealand government could do in areas (i) to (iii) above. However, an argument could be made for additional infrastructure investments (or subsidies) to be made by the government in areas (iv) and (v) above. This leads to an argument for a *larger* government.

(6) *Access to new knowledge about the development of new commodities and processes.*

Obviously, New Zealand is too small for its higher education sector to be a major player in the development of new knowledge. However, one could still make an argument for subsidizing Universities for two reasons:

- Some Universities in relatively isolated locations have still managed to be incubators for high tech firms. The University of Waterloo in Canada comes to mind as do the University of British Columbia in Vancouver and the University of Alberta in Edmonton. Thus it may make sense to subsidize engineering, science, medicine and business departments in particular.<sup>58</sup>
- In order to transfer knowledge from abroad, it is necessary that New Zealanders have access to higher education in order to facilitate the diffusion and transfer processes.

The above considerations lead to an argument for a *larger* government. In addition to subsidizing higher education, there are some other things the New Zealand government

---

<sup>57</sup> Poor resource management can of course negatively impact long run growth. The management of the cod fishery on the east coast of Canada has led to a complete shutdown of the fishery!

<sup>58</sup> Of course, science departments also require good mathematics departments, engineering departments require science departments and business schools require good economics departments. All faculties need their students to have some skills in English and of course, it is always good for science and engineering students to have some access to the arts and humanities.

could do to facilitate knowledge transfers that do not have large budgetary implications. In particular, the government could publicize *benchmarking* to the New Zealand business community so that the performance of New Zealand businesses could be compared to their peers offshore. Benchmarking of government enterprises and regulated enterprises should also be encouraged.

(7) *High taxes.*

We have discussed this factor already. Without taking into account to what purpose additional tax revenue would be used, it appears that growth is enhanced by having lower taxes in high tax and spending jurisdictions.

(8) *High inflation.*

As discussed above, economic growth will tend to be larger if the inflation rate is low and stable. New Zealand has already achieved this so all that is needed is more of the same. This growth factor has no implications for the size of government.

Summing up, a detailed study of each growth factor would have to be undertaken to determine the optimal level of government expenditure in each of the various areas. However, a number of policies which would not require much government expenditure were mentioned above and should perhaps be considered.

There is one other role for government which should be mentioned explicitly at this point. An important role for government in encouraging growth is to create a transparent institutional environment which neither rewards nor tolerates rent seeking behaviour. In particular, business subsidies that are targeted to friends of the government or that are awarded on an almost random basis invites the diversion of resources from productive activity to wasteful rent seeking. In addition, the creation of an unlevel playing field will induce a loss of productive efficiency and slower productivity growth. Related to this point is the necessity for the government to create a transparent and effective system of business regulation. One need not look further than at the recent Californian energy crisis, which was created by a regulatory environment that did not encourage long term investment in power plants.

## **8. Conclusion**

We augmented Winton Bates' (2001) review of the role and size of government by considering in some detail the ancient theories of Adam Smith, Charles Babbage and Alfred Marshall that might help to explain economic growth. With these theories in mind, we then considered the role of government in facilitating growth.

We conclude our review of Bates by noting that it is also possible to do some fine tuning on the *tax collection* side of government as well as on the *expenditure* side. As Bates (2001; 52) notes, the deadweight loss associated with a particular tax rises roughly as the square of the tax rate and is roughly proportional to the sum of the relevant magnitudes of

the elasticities of supply and demand. Unfortunately, this means that for the government to set tax rates so as to minimize deadweight losses, a knowledge of elasticities of supply and demand is required. This knowledge is not easy to obtain. There are very few optimal tax studies that actually estimate empirically elasticities of supply and demand<sup>59</sup>. However, from the limited empirical evidence that is available, it appears that the marginal excess burden of taxing capital is higher than the marginal excess burdens of taxing labour or consumption. If this were true, then it would be desirable for New Zealand to have a system of business income taxation that is at least as favourable as its major trading partners. For some recent papers on this topic, see Mintz (1999) Harris (1999)<sup>60</sup>, Kesselman (2000) and Walsh (2000).

Our overall conclusion is that the exact determinants of TFP growth are still not *precisely* known but, broadly speaking, the most important factors are probably known to us and are summarized in section 6 above. Section 7 looks at the possible role of governments in improving TFP growth. It is likely that at least some of the suggestions made in this section may be helpful in improving New Zealand's TFP growth.

## References

- Allais, M. (1947), *Economie et Intérêt*, Paris: Imprimerie Nationale.
- Allen, R.C. (1983), "Collective Invention", *Journal of Economic Behavior and Organization* 4, 1-24.
- Arrow, K.J. (1962), "The Economic Implications of Learning by Doing", *The Review of Economic Studies* 29, 155-173.
- Arrow, K.J. (1969), "Classificatory Notes on the Production and Transmission of Technological Knowledge", *American Economic Review* 59 (May), 29-35.
- Babbage, C. (1835), *On the Economy of Machinery and Manufactures*, Fourth Edition, reprinted by A. M. Kelley, New York, 1965.

---

<sup>59</sup> In addition to the work of Diewert and Lawrence (1994) (2002) noted by Bates, there is the work of Jorgenson and Yun (1986) (1990) (1991).

<sup>60</sup> Harris (1999; 9) raises an important point in the context of the discussion of whether government debt or taxes should be reduced in a surplus situation: "In balancing these concerns however one needs to factor in the impact of tax cuts on economic growth and output. Even ignoring dynamic effects, given a marginal excess burden of 30 cents on each dollar of revenue, at the margin a *permanent* tax reduction today and forever of \$1 will raise real output *permanently* by 30 cents. In the presence of a fiscal surplus, the choice to reduce taxes will be growth enhancing, while debt reduction will not immediately increase the size of the economic pie. Debt reduction pushes the growth benefits into the future. ... The point is that with a current tax system which is generating a large fiscal surplus and a substantial MEB from current levels of taxation, an output maximizing strategy would be to reduce taxes rather than to reduce the debt." The main counter argument that one could make against this Harris critique is that the debt reduction strategy might be intergenerationally "fairer" since the current generation ran up the debt, a point that Harris (1999; 10) recognizes.

- Baumol, W.J. (1952), "The Transactions Demand For Cash: An Inventory Theoretic Approach", *Quarterly Journal of Economics* 66, 545-556.
- Bates, W. (2001), *How Much Government? The effects of high government spending on economic performance*, New Zealand Business Roundtable, Wellington, August 2001.
- Caves, D., L.R. Christensen and W.E. Diewert (1982), "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity", *Econometrica* 50, 1392-1414.
- Diewert, W.E. (1981), "The Comparative Statics of Industry Long Run Equilibrium", *The Canadian Journal of Economics* 14, 78-92.
- Diewert, W.E. (1990), "The Measurement of Productivity", *Bulletin of Economic Research* 44:3, 163-198.
- Diewert, W.E. (1997), "Commentary on Mathew D. Shapiro and David W. Wilcox: Alternative Strategies for Aggregating Price in the CPI", *The Federal Reserve Bank of St. Louis Review*, Vol. 79:3, (May/June), 127-137.
- Diewert, W.E. (2001), "Productivity Growth and the Role of Government", Discussion Paper No. 01-13, Department of Economics, The University of British Columbia, Vancouver, Canada, V6T 1Z1. <http://www.econ.ubc.ca/discpapers/dp0113.pdf>
- Diewert, W.E. and K.J. Fox (1999), "Can Measurement Error Explain the Productivity Paradox?", *Canadian Journal of Economics* 32, 251-280. Also available at: <http://web.arts.ubc.ca/econ/diewert/hmpgddie.htm>
- Diewert, W.E. and D. Lawrence, (1994), *The Marginal Costs of Taxation in New Zealand*, Report prepared for the New Zealand Business Roundtable by Swan Consultants, Canberra.
- Diewert, W.E. and D. Lawrence, (2002), "The Deadweight Costs of Capital Taxation in Australia", pp. 103-167 in *Efficiency in the Public Sector*, Kevin J. Fox (ed.), Boston: Kluwer Academic Publishers.
- Diewert, W.E. and C.J. Morrison (1986), "Adjusting Output and Productivity Indexes for Changes in the Terms of Trade", *Economic Journal* 96, 659-679.
- Diewert, W.E. and A.O. Nakamura (1999), "Benchmarking and the Measurement of Best Practice Efficiency: An Electricity Generation Application", *Canadian Journal of Economics* 32, 570-588.
- Diewert, W.E. and A.O. Nakamura (2003), "Index Number Concepts, Measures and Decompositions of Productivity Growth", *Journal of Productivity Analysis* 19, 127-159.

- Driffill, E.J. and H.S. Rosen (1983), "Taxation and Excess Burden: A Life Cycle Perspective", *International Economic Review* 24, 671-683.
- Dupor, B., L. Lochner, C. Taber, and M.B. Wittekind (1996), "Some Effects of Taxes on Schooling and Training", *American Economic Review* 86 (May), 340-346.
- Edgeworth, F.Y. (1888), "The Mathematical Theory of Banking", *Journal of the Royal Statistical Society* 51, 113-127.
- Feldstein, M. (1996), "How Big Should Government Be?", Working Paper 5868, National Bureau of Economic Research, Cambridge, Massachusetts.
- Fisher, I. (1922), *The Making of Index Numbers*, Boston: Houghton-Mifflin.
- Fox, K.J. and U. Kohli (1998), "GDP Growth, Terms of Trade Effects and Total Factor Productivity", *The Journal of International Trade and Economic Development* 7:1, 87-110.
- Green, J.B. (1915), "The Perpetual Inventory in Practical Stores Operation", *The Engineering Magazine* 48, 879-888.
- Hadley, G. and T.M. Whitin (1963), *Analysis of Inventory Systems*, Englewood Cliffs, N.J.: Prentice-Hall.
- Haltiwanger, J. (2000), "Aggregate Growth: What Have we Learned from Microeconomic Evidence?" Economics Department Working Paper No. 267, Paris: OECD.
- Harberger, Arnold (1998), "A Vision of the Growth Process," *American Economic Review* 88, 1-32.
- Harris, F.W. (1915), *Operations and Cost*, Chicago: A.W. Shaw Company.
- Harris, R.G. (1999), "Making a Case for Tax Cuts", paper prepared for the Business Council on National Issues *Global Agenda Initiative*.
- Harris, R.G. (2001), "Determinants of Canadian Productivity Growth: Issues and Prospects", Forthcoming in *Productivity Issues in a Canadian Context*, A. Sharpe and S. Rao (eds.), Montreal: McGill-Queen's Press.
- Hicks, J. (1969), *A Theory of Economic History*, London: Oxford university Press.
- Hicks, J. (1973), *Capital and Time: A Neo-Austrian Theory*, London: Oxford University Press.

- Jorgenson, D.W. and K.-Y. Yun (1986), "Tax Policy and Capital Allocation", *Scandinavian Journal of Economics* 88, 355-377.
- Jorgenson, D.W. and K.-Y. Yun (1990), "Tax Reform and US Economic Growth", *Journal of Political Economy* 98(5), S151-S193.
- Jorgenson, D.W. and K.-Y. Yun (1991), *Tax Reform and the Cost of Capital*, Oxford: Clarendon Press.
- Kaldor, N. (1972), "The Irrelevance of Equilibrium Economics", *The Economic Journal* 82, 1237-1255.
- Kesselman, J.R. (1997), *General Payroll Taxes: Economics, Politics and Design*, Canadian Tax Paper No. 101, Toronto: The Canadian Tax Foundation.
- Kesselman, J.R. (2000), "Flat Taxes, Dual Taxes, Smart Taxes: Making the Best Choices", *Policy Matters*, Volume 1, no. 7, Montreal: The Institute for Research On Public Policy. Email: [irpp@irpp.org](mailto:irpp@irpp.org)
- Kohli, U. (1990), "Growth Accounting in the Open Economy: Parametric and Nonparametric Estimates", *Journal of Economic and Social Measurement* 16, 125-136.
- Kneller, R., M.F. Bleaney and N. Gemmell (1999), "Fiscal Policy and Growth: Evidence from OECD Countries", *Journal of Public Economics* 74:2, 171-190.
- Krugman, P. (1991), *Geography and Trade*, Cambridge, MA: The MIT Press.
- Lipsey, R.G. (2000), "Economies of Scale in Theory and Practice", unpublished paper available at: <http://www.sfu.ca/~rlipsey/res.html>
- Lipsey, R.G. and K. Carlaw (2000), "What does Total Factor Productivity Measure?", unpublished paper available at: <http://www.sfu.ca/~rlipsey/res.html>
- Marshall, A. (1898), *Principles of Economics*, Fourth Edition (first edition 1890, eighth edition 1920), London: The Macmillan Co.
- Mintz, J.M. (1999), *Why Canada Must Undertake Business Tax Reform Soon*, Backgrounder, Toronto: C.D. Howe Institute.
- Morrison, C. and W.E. Diewert (1990), "Productivity Growth and Changes in the Terms of Trade in Japan and the United States", pp. 201-227 in *Productivity Growth in Japan and the United States*, C.R. Hulten (ed.), University of Chicago Press, Chicago.

- Nakamura, A.O. and W.E. Diewert (2000), "Insurance for the Unemployed: Canadian Reforms and their Relevance for the United States", pp. 217-247 in *Long-Term Unemployment and Reemployment Policies*, L.J. Bassi and S.A. Woodbury (eds.), Stamford Connecticut: JAI Press.
- Nakamura, A.O. and P. Lawrence (1994), "Education, Training and Prosperity", John Deutsch Institute for the Study of Economic Policy (March), 235-279.
- Nordhaus, W.D. (1969), "Theory of Innovations: An Economic Theory of Technological Change", *American Economic Review* 59 (May), 18-28.
- Romer, P. (1994), "New Goods, Old Theory and the Welfare Costs of Trade Restrictions", *Journal of Development Economics* 43, 5-38.
- Samuelson, P.A. (1967), "The Monopolistic Competition Revolution", In *Monopolistic Competition Theory: Studies in Impact*, R.E. Kuenne (ed.), New York: John Wiley.
- Smith, A. (1963), *The Wealth of Nations*, Volume 1 (first published in 1776), Homewood, Illinois: Richard D. Irwin.
- The Economist* (2000), "New Zealand's Economy", London, December 2.
- Tobin, J. (1956), "The Interest Elasticity of Transactions Demand for Cash", *The Review of Economics and Statistics* 38, 241-247.
- Walsh, B. (2000), "The Role of Tax Policy in Ireland's Economic Renaissance", *Canadian Tax Journal* 48:3, 658-673.
- Watson, W. (1999), "Labour Day, From the Front Porch", *Financial Post*, Toronto, Canada, September 8.
- Whitin, T.M. (1952), "Inventory Control in Theory and Practice", *Quarterly Journal of Economics* 66, 502-521.
- Whitin, T.M. (1957), *The Theory of Inventory Management*, Second edition, Princeton, N.J.: Princeton University Press.
- Young, A.A. (1928), "Increasing Returns and Economic Progress", *Economic Journal* 38, 527-542.
- Zeitsch, J. and D. Lawrence (1996), "Decomposing Economic Inefficiency in Base-Load Power Plants", *The Journal of Productivity Analysis* 7, 359-378.