CSLS-Industry Canada Workshop on
"Productivity Issues in a Canadian Context"

September 29th, 2000 Lord Elgin Hotel, Ottawa, Ontario

Investment and Productivity:
A Review

Session 3 "Investment and Productivity", 11:00-12:00

Ron Giammarino

University of British Columbia
Faculty of Commerce and Business Administration

First Draft Report, August 31, 2000

INTRODUCTION

Motivation for a conference on productivity is not hard to find today. Real incomes in Canada did not grow much in the 1990's and, after decades of catching up, they declined relative to the US in the last decade. Sharpe (1999) estimates that Canadian incomes were roughly 75% of US incomes in 1999. As figure 1 illustrates, Canada's relatively poor performance looks even worse when more countries are added to the comparison as other G7 nations continued to close the gap with the US while the same gap widened for Canada.

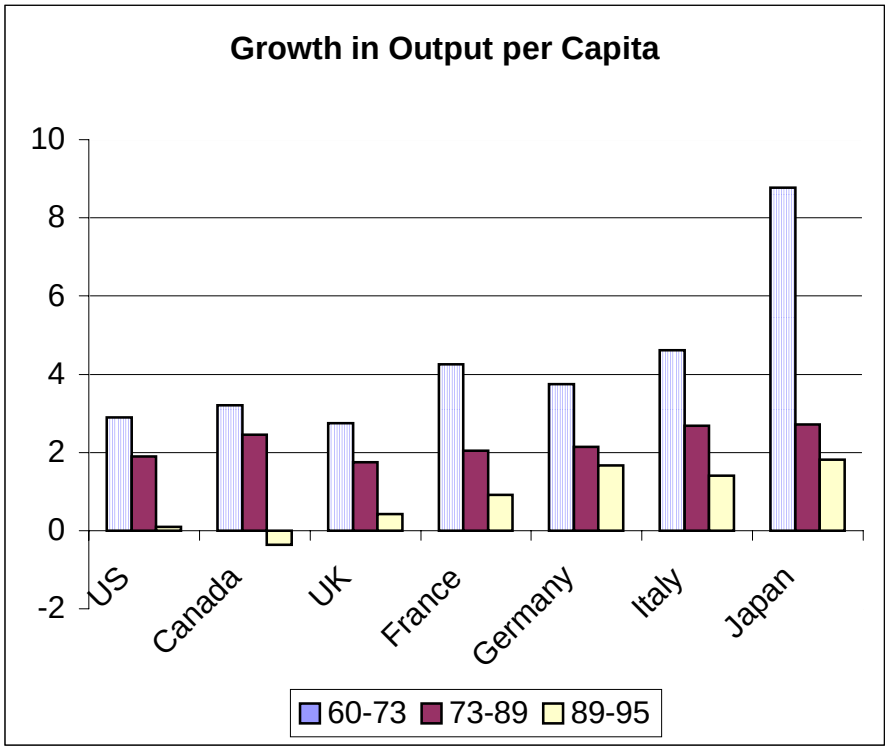
When real incomes fail to grow as expected it seems natural to look for levers that can raise productivity and the lever that draws the most attention is productivity. As Harris (1999) succinctly states it: "Over long periods of time productivity is the single most important determinate of a nations living standard or its level of real income." While absolute income levels should be the predominant concern, income relative to the US seems to be the benchmark that causes the most concern in Canada. Sulzenko and Kalwarowsky (2000), for instance, use this view to provide a perspective on what is at stake: "Raising productivity offers Canada the largest upside potential (relative to increasing labor input). . .To illustrate, of the $7500 Canada-US per capita income gap, a full $6200 is accounted for by Canada's significantly lower level of productivity while only $1300 stems from the higher effective rate of employment in the United States."

This session of the CSLS conference relates to investment and productivity and here too motivation is not hard to find. In a recent summary of the evidence for G7 countries, Jorgensen and Yip (1999) state that "Investments in tangible assets and human capital now account for the predominant share of economic growth in the G7 countries and also explain the predominant share of international differences in output per capita." Stiroh (2000) concludes his overview of investment and productivity by stating that " . . . one conclusion appears universal – broadly defined investment is the crucial factor to increase productivity, generate economic growth, and raise living standards."

The claim that a strong link between investment and productivity exists is intuitively plausible: investment provides the tools with which economic agents produce output – the more tools they have to work with, the more they can produce. Moreover, the evidence as summarized by Jorgensen and Yip and by Stiroh, seems to imply a strong empirical confirmation of this intuition.

But while the intuition is compelling and supporting evidence exists, some doubts have been expressed. For instance Blomstrom, Lipsey and Zejan (1996) allow the possibility that the link between investment and growth actually goes the other way (i.e. growth leads to investment) and provide evidence to support this alternative. In addition, Power (1998) examines plant level data and concludes " . . . there is virtually no observable relationship between investment and productivity or productivity growth." In line with this contradictory empirical evidence is a supporting intuition: While investment improves productivity, capital market imperfections keep firms from investing until they generate sufficient internal resources to pay for the capital. In other words, despite the existence of capital markets, some firms act as if the markets did not exist and invest when they can afford to do so in a cash flow sense. So, while investment may increase productivity, some of the contradictory evidence results from the fact that investment follows increases in cash flow.

Figure 1:Source Jorenson and Yip (1999)



Thus the current state of knowledge leaves a number of questions unanswered. How strong is the link between investment and productivity/growth? To the extent that there is a link, does it imply a role for government in improving welfare? Even with widespread support of the view that there is a link, the extent to which policy can work through this link is, not surprisingly, subject to debate. On the one hand are those who view investment as a channel for producing externalities that is not internalized by market prices. In this world, government policy directed at subsidizing private returns will increase welfare. On the other are those who feel markets, left to their own devices, produce investment levels that efficiently reflect the preferences of savers and investors. A third view, related to the first, is that investment decisions are driven largely by capital market imperfections. In this view, investment options can only be exercised when capital market imperfections are over come or when companies generate enough internal financing to support the investment. Overcoming imperfections in turn requires the development of institutions, specialized contracts, and/or more efficient governance mechanisms.

This paper presents a review of some of what is known about investment and productivity. The discussion rests heavily on "A Survey of the Relationship between Investment and Productivity" by Kevin J. Stiroh and ??? by Timothy Sargent. These are the two studies that will make up the section on Investment and Productivity in a forthcoming volume on Productivity published by the Center for the Study of Living Standards (CSLS). Stiroh very usefully casts his survey in light of the distinction between the neoclassical models, where returns to investment are captured by the private agents making the investment, and the endogenous growth literature where some of the returns are not captured by investors.

In addition to providing an overview of work in this area, I will identify a number of research areas that have either not been explored or have not been related to the issue of investment and productivity directly. Finally, I will present some thoughts on research issues that need to be addressed and policy questions that are outstanding.

What do we mean by Productivity

Linking investment to productivity requires that we be clear about what we mean by both of these terms. Sulzenko and Kalwarowsky (2000) follows common practice by defining productivity as "the efficiency with which people, capital, resources, and ideas are combined in the economy." It is difficult to disagree with this as a guiding principal yet implementation requires a more specific definition of inputs, outputs and efficiency.

Construction of a productivity measure starts at the most general level with a ratio of output per unit of input. The ideal output measure would be some index of the satisfaction or utility achieved by participants in the economy.

Measuring output is a complex problem. The approach taken in most of the literature is to consider some measure of realized physical production in the economy. A problem can arise with this focus if care is not taken to distinguish ex-ante efficiency from ex post efficiency. Investment decisions usually involve time and uncertainty and an efficient decision can lead to unfortunate outcomes over long horizons.

Irving Fisher's famous Fisher Separation shows that ex ante efficiency requires that the timing of cash flows relative to individual preferences, as reflected in market

prices, is the appropriate measure of efficiency. While preferences are not observable, market values typically are and efficiency requires that the market value of ownership of an investment opportunity should be maximized. Since ownership of investment opportunities usually resides in a corporation, maximization of market value of the firm is the widely accepted measure of ex-ante efficiency in the field of corporate finance. Fisher's original idea is easily extended to include risk and translates operationally into the Net Present Value rule.

It is nevertheless true that if we examine realized output over a long enough period and if agents have rational expectations, we can evaluate the ex-ante efficiency of the investment decisions, albeit imperfectly. Complex adjustments of the observations are, however, required. For example a particular level of output Y relative to some level of input I may be generated by an ex-ante efficient decision one period but not the next if the market required return has changed. Demographic changes, changes in technology, or shocks to wealth can cause risk free rates and risk premia to change over time. The attempts to construct constant quality indexes of capital reflect this concern by adjusting the measured input but additional work in this area is called for.

THE NEOCLASSICAL APPROACH

The output measure widely used in the macroeconomics literature is GDP but there has long been dissatisfaction with this measure. As a result, the development of new measures of economic and social well being has become a growth industry with little evidence that there will ultimately be widespread agreement on a particular index. Sharpe (1999) reviews this literature and the relationship between GDP and other measures of welfare. Though not all measures track GDP they are all related to a substantial part of GDP. Hence, GDP is commonly used as the output measure in these studies.

A commonly used method of relating output to investment and labor is through the neoclassical model

$$Y = Y(S, L, O)$$

where Y is the flow of output over some time period, and S and L are a flow of capital and labor inputs over that same period. Typically, the flow of capital inputs is simply proxied by some quality adjusted stock of capital, K, in place at the time. Investment is

related to output growth by being defined as the rate of change of the capital stock over that period of time. L is the labor input, typically measured hours of work supplied (the number of hours worked can differ from this) or number of employed people. O refers to other factors. A common interpretation of empirical estimates of O is that it captures technological advancement but it will also reflect such factors as cost shocks or measurement errors such as changes in interest rates or risk premia that are not included in the measure of capital services.

Specific technological assumptions are captured by a production function, F(K,L), that relates physical inputs of capital (proxied by the capital stock) and labor services to output. *Multifactor productivity* is defined as an index, A, of output to a weighted sum of inputs.

$$A \equiv \frac{Y(S,L,O)}{F(K,L)}$$

For a specific technology, output can now be related to capital, labor and other factors as captured by A.

$$Y = A * F(K,L)$$

Rather than deal in levels of output, most researchers are interested in explaining growth in output per capita, or per employed worker or per hour worked. The result is the following familiar transformation of the neoclassical model

$$\Delta \ln y = v_k \Delta \ln k + v_l \Delta \ln l + \Delta \ln A \qquad (1)$$

where lower case letters indicate aggregate amounts divided by the measure of labor supply.

Equation (1) is presented in Stiroh who emphasises its importance to research in the area. “The appealing simplicity and intuition of this neoclassical framework has made it the backbone of applied and theoretical work on productivity and economic growth”.

There seem to be two common uses of the shorthand term ‘productivity’ that are captured in this relationship. Often, as for instance in Stiroh’s paper, productivity seems to refer to labor productivity, the left hand side of equation (1). In other cases, as for instance in Jorgensen and Yip (1999), productivity is used to refer to the Solow residual,

A. Unless other wise indicated, we will use productivity to refer to the growth in output per unit of labor input.

The relationship of productivity and capital is clearly set out in (1) where the coefficient *v*k captures the relationship between capital input and productivity. Under the usual neoclassical assumptions of competitive markets and decreasing returns to scale, however, there is little room for this equation to explain increases in standards of living. All increases in productivity come exogenously from increases in multifactor productivity.

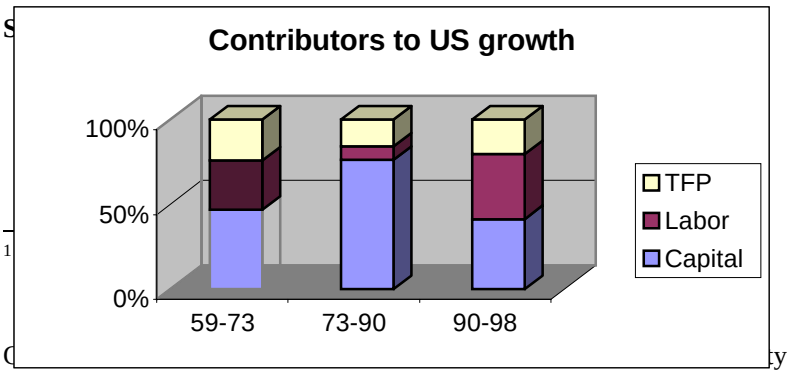
Stiroh surveys the stylized facts that have been documented in the literature with the aid of the neoclassical lens. These findings include the following.

DEFINING AND MEASURING INVESTMENT IS IMPORTANT

At a general level investment is defined as " . . . the commitment of current resources in the expectation of future returns."[1] While seemingly straight forward, this definition is in fact ambiguous and the work surveyed by Stiroh shows that the explanatory power of capital depends on the specific way in which investment is empirically defined.

Solow (1957) defined investment broadly and found that it had little explanatory power. In that early study, almost 90% of output was related to technological progress. As a result, broader based characterizations of investment were developed and found to explain a greater component of productivity. For instance, in a very recent study Jorgenson and Stiroh (2000) use 57 different types of private investment in their study of US productivity. As shown in Figure 2, with these finer measures, investment accounts for about 48% of productivity growth, labor accounts for 34% while only 18% is explained by total factor productivity.

Figure 2: US Growth Components



Jorgensen and Griliches (1967) initiated a line of research intended to deal with the heterogeneity of capital. This approach produces constant quality indexes for both labor and capital that explicitly adjust for a number of differences. An important difference is the user cost of capital of the asset. As mentioned above, the standard microeconomic assumption is that corporate managers make investments in order to maximize the market value of the firm. That is, the manager solves the following problem in evaluating an investment opportunity

$$\max_{I} \; V = \sum_{t=0}^{Ti} \frac{y_{it}(I, L)}{(1 + r_{it})^{t}} - p_{ai}(I)$$

where V is the net present value (NPV) of the investment opportunity, y(I,L) is the technology that converts an investment quantity, I, and labor input into output, r is the user cost of capital, Ti is the life of the investment project, and Pai(I) is the cost of the investment decision. It is important to note that each project is associated with a requried rate of return that reflects the timing and risk of the cash flows. Consequently, productivity, the ratio of output, y, to capital and/or labor, will be consistent with a project specific required rate of return.

As a result, when evaluating the aggregate contribution of capital to output, each unit of investment should be adjusted by the required return on that unit to reflect the required returns. Jorgenson and Yip (1999) discuss the procedure by which this is done as well as the appropriateness of using the required return versus the market value, V, of the asset. By taking this approach and adding other complexities such as the depreciation rate and the tax treatment of investment, constant quality indexes are computed.

HUMAN CAPITAL

Clearly similar issues arise in the recognition of labor input. In fact, training and education are conceptually consistent with the notions of investment outlined above. One of the primary differences is the ability (or inability) that agents have in writing contracts and the impediments that this imposes on creating a market for this investment.

The research surveyed by Stiroh finds that heterogeneous human capital seems to be reasonably consistent with the data, that international differences in human capital

investment helps to explain some of the international differences in productivity, and that investment in human capital provides returns to the investor.

RESEARCH AND DEVELOPMENT

Research and Development is another type of investment that, like human capital, has characteristics that make it the center of special attention.

From a conceptual point of view, one of the main problems is the difficulty with which agents assess the risk and return from an R&D project. It is often claimed that R&D investment is not recognized by the financial market participants who are increasingly driven by short term 'bottom line' investments. Somewhat surprisingly, however, most studies of the market's reaction to R&D expenditures by firms support the alternative hypothesis that the market does recognize the long run benefits of R&D investment. [2] It must be recognized, however, that this evidence relates to firms that have access to capital markets. The difficulty faced by investors trying to evaluate R&D investments may result in a capital market gap in which firms with good projects cannot obtain financing at all.[3]

A related empirical issue is measuring the returns to research and development. It has been noted, for example, that the return to R&D is often in the form of product quality and that this return will only be recognized if the analysis includes a careful quality adjustment.

Despite all of this, Stiroh concludes his survey with the observation that the conventional wisdom at this time is that R&D investment does significantly help explain cross sectional differences in productivity.

TRENDS and ISSUES:

Figure 3 presents evidence from Kirova and Lipsey (1997) as reported in Stiroh on broadly defined capital levels per worker in Canada, US, UK, and Italy. Figure 4 from the same source illustrates the same figures normalized by the investment level in the US and Figure 5, based on Jorgensen and Yip (1999) illustrates growth in investment per

[2] Evidence on R&D investment and market values is reviewed in Giammarino (1997).
[3] The impact of asymmetric information on the investment process will be discussed in greater detail below.

capita for the same countries. These figures indicate that quality adjusted investment levels in Canada relative to other countries has not fallen dramatically.

Figures 6, reports labor productivity growth as a percentage of US productivity for the same countries and here Canada's performance is relatively poor as Canada's gap relative to the US has actually increased slightly while other countries have closed the gap. Figures 7 presents labor productivity growth while 8 provides total factor productivity growth. These figures both reflect the widely documented and discussed world wide productivity slowdown that began in the mid 1970's. They also provide further evidence of a relative productivity slowdown in Canada as labor productivity growth and total factor productivity growth have both lagged almost all other countries in all years reported.

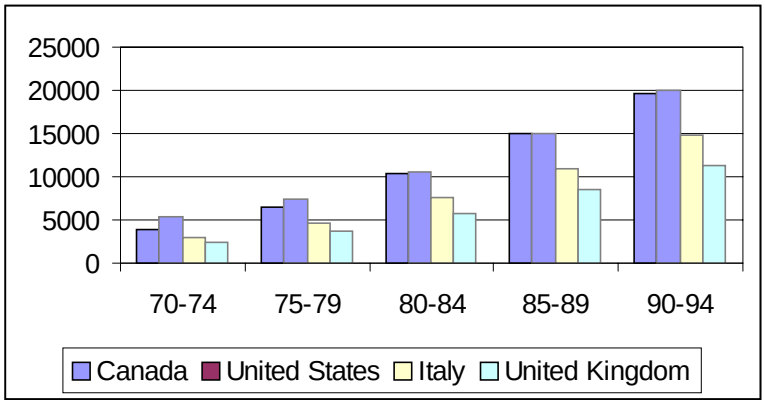


Figure 3: Per Capita Capital Formation

Source: Kirova and Lipsey (1997) as reported in Stiroh

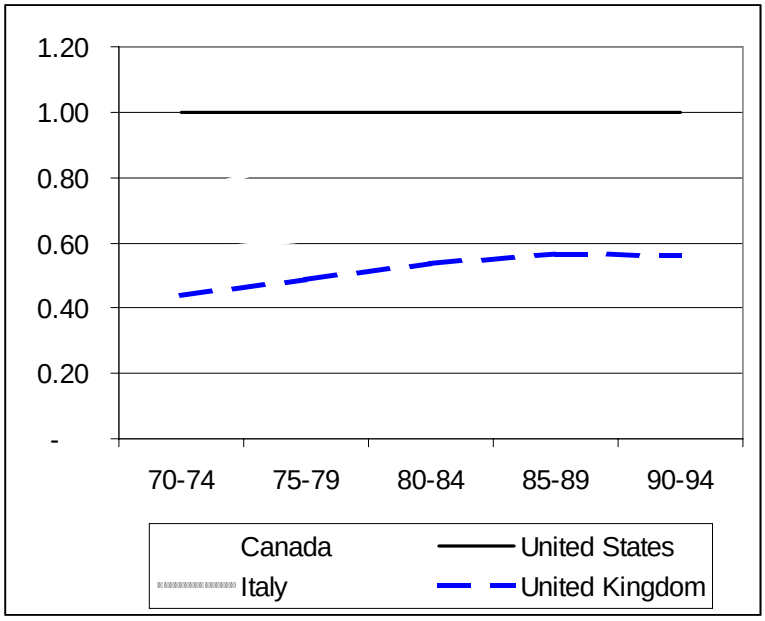


Figure 4: Growth in Per Capita Capital Formation

Source: Kirova and Lipsey (1997) as reported in Stiroh

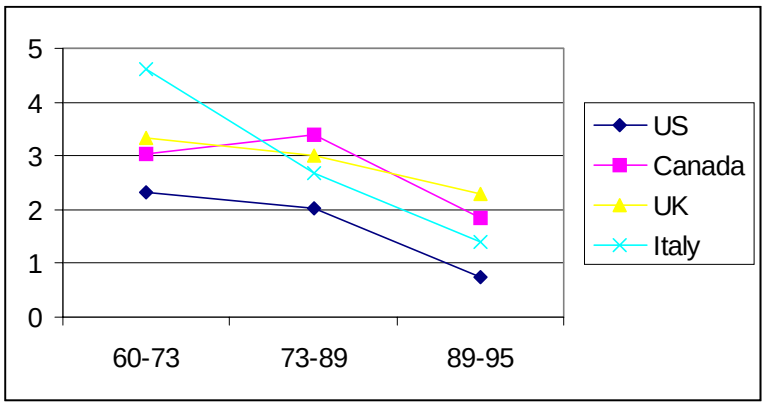


Figure 5: Growth in per capita capital input

Source: Jorgensen and Yip (2000)

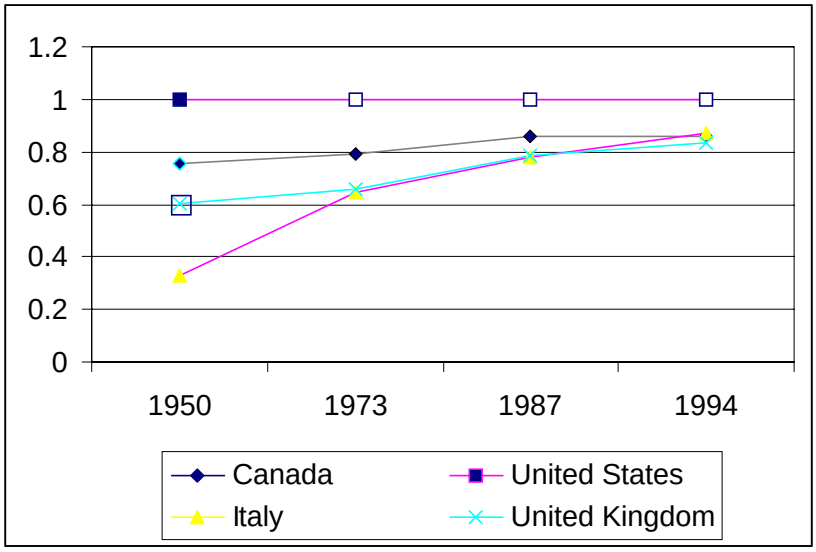


Figure 6: Labor productivity growth trends relative to the US.

Source: Van Ark as reported in Stiroh

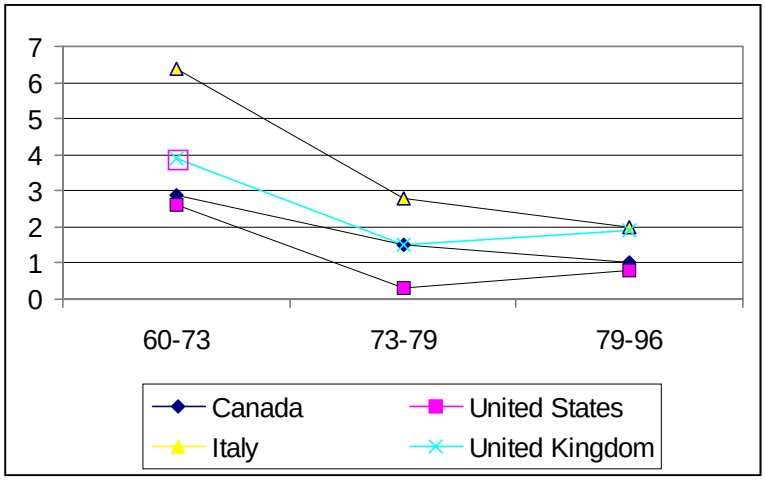


Figure 7: Growth in Labor Productivity, Source: Centre for the study of living standards.

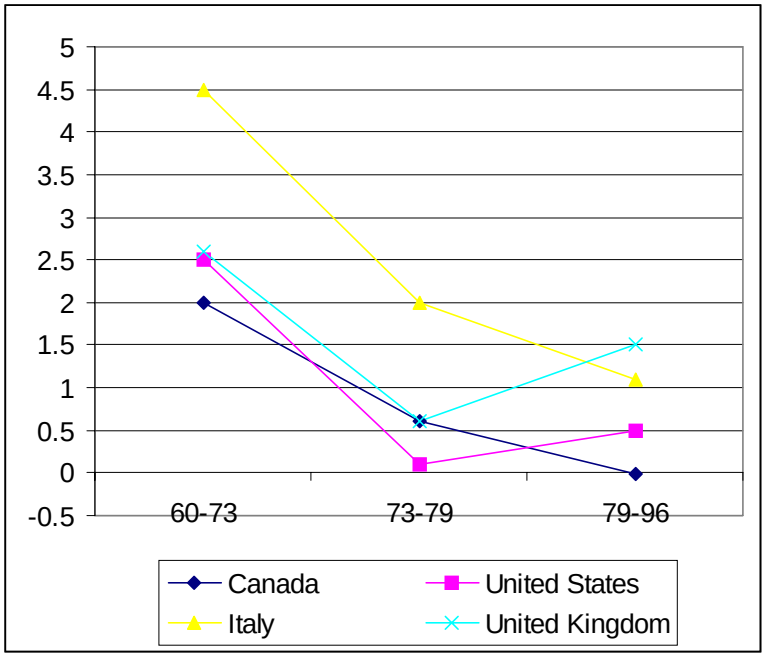


Figure 8: Growth in Total Factor Productivity

Source: Centre for the Study of Living Standards, 1998

In summary, investment is widely recognized as an important contributor to labor productivity yet its link to productivity in Canada is not clear. Per capita capital formation in Canada has not lagged other countries dramatically, yet productivity, both in terms of labor productivity and total factor productivity has fallen relative to other countries.

THE SPECIAL ROLE OF EQUIPMENT INVESTMENT

Investment in Machinery and Equipment has been the subject of special attention for some time but is gaining more attention of late. This attention is related to the fact that investment in equipment at one location or firm may enhance the productivity elsewhere. This has the potential of providing a more detailed explanation of total factor productivity and of identifying a role for government.

Long ago Arrow (1962) suggested that the productivity of any factor of production may be an increasing function of the level of investment in the economy. The notion was that investment contributed to portable learning by doing. Recently, the work of DeLong and Summers (1991) has placed the issue in the spotlight and generated considerable debate. They find a strong statistical relationship between investment in machinery and

equipment and economic growth. Based on data that covers the 1960 - 1985 period, they find that each percentage of GDP that is invested in machinery and equipment is associated with a one third of a percentage point per year increase in subsequent GDP growth. They also estimate that the social return to equipment investment in a well functioning market is on the order of 30%. To the extent that unpriced externalities exists, a case for government intervention can be made. Stiroh reviews recent research in this area and concludes that, while more research is needed, evidence presented so far " . . . suggests that investment in equipment primarily affects growth through the traditional, neoclassical channels. That is investment leads to capital deepening and labor productivity but not to total factor productivity.

THE MANUFACTURING SECTOR

Although the relatively poor productivity performance noted above is a cause for concern, there has been an even larger relative productivity slowdown in manufacturing. Figure 9 reflects data provided by Stiroh on relative labor productivity in manufacturing.

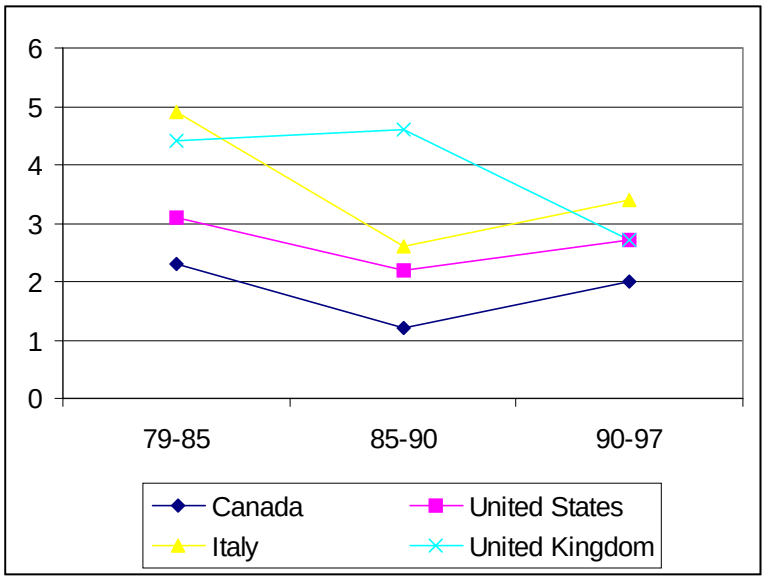


Figure 9: Labor Productivity in Manufacturing

SOURCE: Stiroh (2000)

Figure 10 is based on a more recent study that examines only Canadian US productivity differences by Rao, Ahmen an Kaptein-Russell (2000) shows that the relative decline is getting worse. They examine the role of investment in explaining the

productivity differences in the manufacturing sector and report a number of important findings.

In terms of within country results, they find that the differences in productivity *levels* across manufacturing sectors is highly correlated with machinery and equipment (M&E) and construction investment in both countries. Moreover they find that labor productivity in both countries is also highly correlated with M&E investment intensity. In contrast, however, they find either small or no correlation between investment intensity and *growth* in productivity.

They also study the productivity gap between Canada and the US and find that this gap is positively correlated with investment intensity gap between the two countries. They go on to consider the possibility that the investment intensities differ because of different industrial compositions but find no evidence to support this.

CAPITAL MARKET IMPERFECTIONS

The neoclassical model of the firm and of investment decisions is based on the usual perfect markets assumptions. This approach is in sharp contrast to much of corporate finance that takes examines imperfections due to taxes, transaction costs, incentive contracting problems, and asymmetric information. Asymmetric information and adverse selection have been the focus of an investment literature[4], identified with Fazzari, Hubbard and Petersen (1988) that has grown rapidly. Somewhat surprisingly, this literature has received relatively little attention in the productivity literature.

The starting point of this literature is the idea, first put in a finance context by Myers and Majluf (1984) that firms may prefer not to invest in valuable investments if the market does not know the quality of their firm as well as the managers themselves do. That is, firms that need external financing to exercise investment options trade off the net present value of the investment with the 'dilution' that results from the fact that they are 'pooled' with other quality types by the market.

This simple idea is able to explain the widely documented fact that firms that announce new equity issues usually see the price of their existing shares fall. In terms of

[4] See Hubbard 1998 for a recent survey of this literature.

investment theory, this insight has two important implications, often referred to as the pecking order hypothesis. First, firms prefer to use internal financing – in some sense it costs less because it is not subject to informational problems. Second, firms prefer to finance with secured loans if assets have verifiable values, essentially for the same reason.

Researchers have tested these implications by examining the extent to which investment decisions increase with internal cash flows and net worth, which is taken as a proxy for collateralizable assets.

Stiroh takes the view that, while this literature is interesting, it is focused on explaining investment levels and does not provide insight to the investment productivity link. It seems, however, that there are a number of links that could be developed.

For instance, our understanding of the productivity/investment link has improved considerably due to the development of constant quality indexes. These constant quality indexes do reflect the user cost of capital. Clearly the effective cost of capital would be affected by the adverse selection identified above

In addition, the existence of capital market imperfections implies that investment will take place when a valuable opportunity arrives ***and*** the firm has sufficient internal financing or collateralizable assets in place. Since this is more likely during busy segments of the business cycle, there is a cyclical element to investment and therefore productivity. Related to this is the fact that investment in a cash constrained firm is more likely to take place after a period of growth. Indeed. Blomstom, Lipsey and Zejan (1996) find evidence to support the hypothesis that investment follows growth rather than the other way around.

CONCLUSIONS AND RESEARCH AGENDA

To be completed after the Sargent paper is received.

BIBLIOGRAPHY

- Sharpe, Andrew, “A survey of Indicators of Economic and Social Well-being”, Centre for the Study of Living Standards, July 22, 1999.
- Sulzenko, Anrdei and James Kalwarowsky, “A Policy Challenge for a Higher Standard of Living, ISUMA, Spring 2000.
- Richard G. Harris, “Determinants of Canadian Productivity Growth: Issues and Perspectives, Industry Canada Discussion Paper Number 8, 1999.