Industry-level Productivity and International Competitiveness Between Canada and the United States

Industry Canada Research Publications Program

The Industry Canada Research Publications Program provides a forum for the analysis of key micro-economic challenges in the Canadian economy and contributes to an informed public debate on these issues. Under the direction of the Micro-Economic Policy Analysis Branch, the Program's research paper series features peer-reviewed analytical working papers and policy-related discussion papers written by specialists on micro-economic issues of broad importance.

EDITORS: DALE W. JORGENSON AND FRANK C. LEE

Industry-level Productivity and International Competitiveness Between Canada and the United States

Industry Canada Research Monograph

Canadian Cataloguing in Publication Data

Main entry under title :
Industry-Level Productivity and International Competitiveness Between Canada and the United States

"Industry Canada Research Monograph"
Text in English and French on inverted pages.
Title on added t.p.: La productivité au niveau de l'industrie et la compétitivité internationale au Canada et aux États-Unis.
Includes bibliographical references.
ISBN 0-662-65349-1
Cat. No. C21-26/1-2000

1. Industrial productivity — Canada.
2. Industrial productivity —United States.
3. Competition — Canada.
4. Competition — United States.
I. Jorgenson, Dale W., 1933- .
II. Lee, Frank C. (Frank Chung).
III. Canada. Industry Canada.

HC79.I52I52 2000	338.4'567'0971	C00-980453-6E

Published in March 2001

The list of titles available in the Research Publications Program and details on how to obtain copies can be found at the end of this document. Abstracts of research volumes and papers published in Industry Canada's various series, and the full text of our quarterly newsletter, *MICRO*, are available on *STRATEGIS*, the Department's online business information site, at http://strategis.gc.ca.

Comments should be addressed to:

Someshwar Rao
Director
Strategic Investment Analysis
Micro-Economic Policy Analysis
Industry Canada
5th Floor, West Tower
235 Queen Street
Ottawa, Ontario
K1A 0H5

Tel.: (613) 941-8187; Fax: (613) 991-1261; E-mail: rao.someshwar@ic.gc.ca

Table of Contents

Contributors

Wulong Gu
Industry Canada

Kuen Huang
Statistics Canada

Mun S. Ho
Harvard University

Dale W. Jorgenson
Harvard University

Peter Koumanakos
Statistics Canada

Richard Landry
Statistics Canada

Frank C. Lee
OECD (formerly of Industry Canada)

Jean-Pierre Maynard
Statistics Canada

Kevin J. Stiroh
Federal Reserve Bank of New York

Jianmin Tang
Industry Canada

Susanna Wood
Statistics Canada

Preface

THE PURPOSE OF THIS MONOGRAPH is to illuminate the economic interrelationships between Canada and the United States. In order to achieve this objective, we have presented detailed comparisons of productivity trends and levels of output, input, and productivity for individual industries in the two countries. These comparisons employ purchasing power parities for both outputs and inputs and use a common methodology. While the estimates are preliminary in character, they embody the best information currently available on the determinants of relative standards of living and economic growth in both countries.

This monograph reflects the views of the authors, but not necessarily those of Industry Canada or of the institutions the authors are affiliated with. We would like to express our appreciation to Statistics Canada, the U.S. Bureau of Labor Statistics (BLS) and the Bureau of Economic Analysis (BEA) for data accessibility and consultations. In particular, the authors are grateful to Katharine Kemp of Statistics Canada for providing bilateral commodity price data, and Bruce Grimm and Dave Wasshausen of the BEA for details on the BEA investment data and prices.

We are grateful to Bob Arnold of CBO for helpful comments and discussions of the CBO's results and methods. We thank Erwin Diewert (University of British Columbia), Steve Oliner (Federal Reserve Board), Dan Sichel (Federal Reserve Board), and seminar participants at the Federal Reserve Bank of New York for helpful comments and discussions on Chapter 2. Dave Fiore provided excellent research assistance for Chapter 2. We are also indebted to Erwin Diewert (University of British Columbia), RenJ Durand (Industry Canada), Rick Harris (Simon Fraser University), Jeremy Rudin (Finance Canada), Larry Rosenblum (U.S. Bureau of Labor Statistics) for their helpful comments on Chapters 3, 4 and 5. In addition, we thank Masahiro Kuroda (Keio University) and Kun-Young Yun (Yonsei University) for helpful discussions.

Last but not the least, we wish to thank Serge Nadeau and Someshwar Rao at Industry Canada for their unwavering support throughout the duration of the project. In addition, we also thank Denis Gauthier who supported this project at the inception. However, the authors are solely responsible for any remaining errors and omissions.

Introduction 1

Dale W. Jorgenson and Frank C. Lee

ONE OF THE PRINCIPAL ECONOMIC POLICY OBJECTIVES shared by Canada and the United States is maintaining high and growing standards of living. Both countries have been remarkably successful at this and stand at the top of the world rankings in terms of economic performance. The first objective of this monograph is to quantify the sources of economic growth at the industry level in Canada and the United States. The second objective is to assess the relative competitiveness of American and Canadian industries.

In Chapter 2, Jorgenson and Stiroh focus on the recent revival of U.S. economic growth. They attribute the rise in the rate of U.S. economic growth since 1995 to a surge of investment in computers, software, and communications equipment and to a jump in the growth rate of total factor productivity (TFP). Average labour productivity (ALP) grew 0.95 percent per year more rapidly during 1995-98 than during 1990-95. More rapid TFP growth contributed 0.72 percent per year, while capital deepening generated 0.34 percent per year. These increases offset a modest decline in the rate of improvement of labour quality as the pool of available workers was exhausted.

In Chapter 3, Wulong Gu, Frank Lee and Jianmin Tang also adopt the constant quality indices of capital and labour inputs used in Chapter 2 for each of the 122 industries studied in Canada. The extent of asset types is not as detailed as that in the United States. They only consider five asset types — machinery and equipment (M&E), building structures, engineering structures, land and inventories. However, on the labour input side, workers are cross-classified by two sexes, three employment classes, seven age groups and four educational groups, for a total of 168 types. At the aggregate level, the same framework is adopted by aggregating the capital stock across different asset types and hours worked across different types of workers.

The results show that the Canadian private business sector's output growth slowed down from an annual rate of 5.6 percent during 1961-73 to 3.3 percent during 1973-88, and to 1.5 percent during 1988-95. TFP growth accounted for about 46 percent of output growth during 1961-73, and for 22 percent and

26 percent, respectively, during 1973-88 and 1988-95. At the same time, over 80 percent of the slowdown in output growth observed from the first to the second period is attributable to the slowdown in TFP growth. On the other hand, over 80 percent of the slowdown in output growth from 1973-88 to 1988-95 originated from the slowdown in the growth of both capital and labour inputs. The slowdown in the growth of capital stock and hours worked was mainly responsible for the input growth slowdown between the last two periods.

For a majority of the 122 industries examined in this chapter, input growth was a dominant source of output growth during 1961-73 and 1973-88. However, during 1988-95, TFP growth accounted for more than half of output growth in slightly more than half of these industries, primarily because input growth slowed down more than productivity growth between 1973-88 and 1988-95.

In Chapter 4, Wulong Gu and Mun Ho compare output growth between Canada and the United States in 33 industries. They first aggregate capital input in both countries to four asset types (M&E, structures, land and inventories) so that the underlying data used in the study are comparable. The authors do not use the U.S. data that incorporate the latest benchmark revision in the U.S. National Income and Product Accounts for the purpose of comparing the United States with Canada. The extensive benchmark revisions made in the United States have not yet taken place in the Canadian National Income and Product Accounts.

The results show that average growth rates of output in Canada were higher than in the United States for almost all industries before 1988. After 1988, output growth in Canada has been slightly lower than in the United States. On the productivity side, there was a substantial catch-up by Canadian industries to the productivity levels of U.S. industries during the period 1961-73. After 1973, productivity in Canadian industries grew at a rate similar to that of U.S. industries. Input growth is identified as the dominant source of output growth at the sectoral level, with productivity growth contributing about 20 percent of output growth for both countries during the entire period.

In the last chapter, Frank Lee and Jianmin Tang focus on international competitiveness between Canadian and U.S. industries. They first construct Canada-U.S. bilateral purchasing power parities for outputs and inputs by industry using bilateral Canada-U.S. commodity price data following Jorgenson and

Kuroda (1995). In 1995, more than half of Canadian industries were more competitive than their U.S. counterparts. However, the competitive position of Canadian industries is threatened by higher capital input prices and lower TFP levels. Canada had higher capital input prices than the United States in 27 of the 33 industries, whereas Canada had lower TFP levels than the United States in 23 of the 33 industries. Unlike capital input prices, all Canadian industries had an advantage over their U.S. counterparts in terms of labour costs. Finally, most Canadian industries paid almost the same price for their intermediate inputs as their U.S. counterparts.

Raising the Speed Limit: U.S. Economic Growth in the Information Age

2

Dale W. Jorgenson and Kevin J. Stiroh

2.1 Introduction

THE CONTINUED STRENGTH AND VITALITY of the U.S. economy continues to astonish economic forecasters.[1] A consensus is now emerging that something fundamental has changed, with "new economy" proponents pointing to information technology as the causal factor behind the strong performance of the U.S. economy. In this view, technology is profoundly altering the nature of business, leading to permanently higher productivity growth throughout the economy. Sceptics argue that the recent success reflects a series of favourable, but temporary, shocks. This argument is buttressed by the perception that the U.S. economy behaves rather differently than envisioned by new economy advocates.[2]

While productivity growth, capital accumulation, and the impact of technology were topics once reserved for academic debates, the recent strong performance of the U.S. economy has moved them into popular discussion. The purpose of this paper is to employ well-tested and familiar methods to analyze important new information made available by the recent benchmark revision of the U.S. National Income and Product Accounts (NIPA). We document the case for raising the speed limit — for upward revision of intermediate-term projections of future growth to reflect the latest data and trends.

The late 1990s have been exceptional in comparison with the growth experience of the U.S. economy over the past quarter century. While growth rates in the 1990s have not yet returned to those of the golden age of the U.S. economy in the 1960s, the data nonetheless clearly reveal a remarkable transformation of economic activity. Rapid declines in the prices of computers and semiconductors are well known and carefully documented, and evidence is accumulating that similar declines are taking place in the prices of software and communications equipment. Unfortunately, the empirical record is seriously incomplete, so much remains to be done before definitive quantitative assessments can be made about the complete role of these high-tech assets.

Despite the limitations of the available data, the mechanisms underlying the structural transformation of the U.S. economy are readily apparent. As an illustration, consider the increasing role that computer hardware plays as a source of economic growth.[3] For the period 1959 to 1973, computer inputs contributed less than one-tenth of one percent to U.S. economic growth. Since 1973, however, the price of computers has fallen at historically unprecedented rates and firms and households have followed a basic principle of economics — they have substituted towards relatively cheaper inputs. Since 1995, the price decline of computers has accelerated, reaching nearly 28 percent per year from 1995 to 1998. In response, investment in computers has exploded and the contribution of computers to growth has increased more than five-fold to 0.46 percentage points per year in the late 1990s.[4] Software and communications equipment, two other information technology assets, contributed an additional 0.30 percentage points per year for 1995-98. Preliminary estimates through 1999 reveal further increases in these contributions for all three high-tech assets.

Next, consider the acceleration of average labour productivity (ALP) growth in the 1990s. After a 20-year slowdown dating from the early 1970s, ALP grew 2.4 percent per year for 1995-98, more than a percentage point faster than during 1990-95.[5] A detailed decomposition shows that capital deepening, the direct consequence of price-induced substitution and rapid investment, added 0.49 percentage points to ALP growth. Faster total factor productivity (TFP) growth contributed an additional 0.63 percentage points, largely reflecting technical change in the production of computers and the resulting acceleration in their price decline. Slowing labour quality growth retarded ALP growth by 0.12 percentage points, relative to the early 1990s, a consequence of the exhaustion of the pool of available workers.

Focusing more specifically on TFP growth, it recorded an anaemic 0.34 percent per year for 1973-95, but accelerated to 0.99 percent during 1995-98. After more than twenty years of sluggish TFP growth, four of the last five years have seen growth rates near 1 percent. It could be argued that this represents a new paradigm. According to this view, the diffusion of information technology improves business practices, generates spillovers, and raises productivity throughout the economy. If this trend is sustainable, it could revive the optimistic expectations of the 1960s and overcome the pessimism of *The Age of Diminished Expectations*, the title of Krugman's (1990) influential book.

A closer look at the data, however, shows that gains in TFP growth can be traced in substantial part to information technology industries, which produce computers, semi-conductors, and other high-tech gear. The evidence is equally clear that computer-using industries like finance, insurance, and real estate (FIRE) and services have continued to lag in productivity growth. Reconciliation of massive high-tech investment and relatively slow productivity growth in service industries remains an important task for proponents of the new economy vision.[6]

What does this imply for the future? The sustainability of growth in labour productivity is the key issue for future growth projections. For some purposes, the distinctions among capital accumulation and growth in labour quality and TFP may not matter, so long as ALP growth can be expected to continue. It is sustainable labour productivity gains, after all, that ultimately drive long-run growth and raise living standards.

In this respect, the recent experience provides grounds for caution, since much depends on productivity gains in high-tech industries. Ongoing technological gains in these industries have been a direct source of improvement in TFP growth, as well as an indirect source of more rapid capital deepening. The sustainability of growth, therefore, hinges critically on the pace of technological progress in these industries. As measured by relative price changes, progress has accelerated recently, as computer prices fell 28 percent per year during 1995-98 compared to 15 percent during 1990-95. Of course, there is no guarantee of continued productivity gains and price declines of this magnitude. Nonetheless, as long as high-tech industries maintain the ability to innovate and improve their productivity at rates comparable even to their long-term averages, relative prices will fall and the virtuous circle of an investment-led expansion will continue.[7]

Finally, we argue that rewards from new technology accrue to the direct participants; first, to the innovating industries producing high-tech assets and, second, to the industries that restructure to implement the latest information technology. There is no evidence of spillovers from production of information technology to the industries that use this technology. Indeed, many of the industries that use information technology most intensively, like FIRE and services, show high rates of substitution of information technology for other inputs and relatively low rates of productivity growth. In part, this may reflect problems in measuring the output of these industries, but the empirical record provides little support for the “new economy” picture of spillovers cascading from information technology producers onto users of this technology.[8]

The chapter is organized as follows. Section 2 describes our methodology for quantifying the sources of U.S. economic growth. We present results for the period 1959-1998, and focus on the "new economy" era of the late 1990s. Section 3 explores the implications of the recent experience for future growth, comparing our results to recent estimates produced by the Congressional Budget Office (CBO), the Council of Economic Advisors (CEA), and the Office of Management and Budget (OMB). Section 4 moves beyond the aggregate data and quantifies the productivity growth at the industry level. Using methodology introduced by Domar (1961), we consider the impact of information technology on aggregate productivity. Section 5 concludes.

2.2 The Recent U.S. Growth Experience

THE U.S. ECONOMY HAS UNDERGONE a remarkable transformation in recent years with growth in output, labour productivity, and total factor productivity all accelerating since the mid-1990s. This resurgence of growth has led to a widening debate about sources of economic growth and changes in the structure of the economy. "New economy" proponents trace the changes to developments in information technology, especially the rapid commercialization of the Internet, that are fundamentally changing economic activity. "Old economy" advocates focus on the lacklustre performance during the first half of the 1990s, the increase in labour force participation and rapid decline in unemployment since 1993, and the recent investment boom.

Our objective is to quantify the sources of the recent surge in U.S. economic growth, using new information made available by the benchmark revision of the U.S. National Income and Product Accounts (NIPA) released in October 1999 (BEA, 1999). We then consider the implications of our results for intermediate-term projections of U.S. economic growth. We give special attention to the rapid escalation of growth rates in the official projections, such as those estimated by the Congressional Budget Office and the Council of Economic Advisers. The CBO projections are particularly suitable for our purposes, since they are widely disseminated, well documented, and represent the "best practice." We do not focus on the issue of inflation and do not comment on potential implications for monetary policy.

2.2.1 Sources of Economic Growth

Our methodology is based on the production possibility frontier introduced by Jorgenson (1966) and employed by Jorgenson and Griliches (1967). This captures substitutions among outputs of investment and consumption goods, as well inputs of capital and labour. We identify *information technology* (IT) with investments in computers, software, and communications equipment, as well as consumption of computer and software as outputs. The service flows from these assets are also inputs. The aggregate production function employed by Solow (1957, 1960) and, more recently by Greenwood, Hercowitz, and Krusell (1997), is an alternative to our model. In this approach, a single output is expressed as a function of capital and labour inputs. This implicitly assumes, however, that investments in information technology are perfect substitutes for other outputs, so that relative prices do not change.

Our methodology is essential in order to capture two important facts about which there is general agreement. The first is that the prices of computers have declined drastically relative to the prices of other investment goods. The second is that this rate of decline has recently accelerated. In addition, estimates of investment in software, now available in the NIPA, are comparable to investment in hardware. The new data show that the price of software has fallen relative to the prices of other investment goods, but more slowly than the price of hardware. We examine the estimates of software investment in some detail in order to assess the role of software in recent economic growth. Finally, we consider investment in communications equipment, which shares many of the technological features of computer hardware.

2.2.1.a Production Possibility Frontier

Aggregate output Y_t consists of investment goods I_t and consumption goods C_t. These outputs are produced from aggregate input X_t, consisting of capital services K_t and labour services L_t. We represent productivity as a "Hicks-neutral" augmentation A_t of aggregate input:[9]

(1) $Y(I_t, C_t) = A_t \cdot X(K_t, L_t)$.

The outputs of investment and consumption goods and the inputs of capital and labour services are themselves aggregates, each with many subcomponents.

Under the assumptions of competitive product and factor markets, and constant returns to scale, growth accounting gives the share-weighted growth of outputs as the sum of the share-weighted growth of inputs and growth in *total factor productivity* (TFP):

$$(2) \qquad \overline{w}_{I,t}\Delta \ln I_t + \overline{w}_{C,t}\Delta \ln C_t = \overline{v}_{K,t}\Delta \ln K_t + \overline{v}_{L,t}\Delta \ln L_t + \Delta \ln A_t \,,$$

where $\overline{w}_{I,t}$ is investment's average share of nominal output, $\overline{w}_{C,t}$ is consumption's average share of nominal output, $\overline{v}_{K,t}$ is capital's average share of nominal income, $\overline{v}_{L,t}$ is labour's average share of nominal income, $\overline{w}_{I,t} + \overline{w}_{C,t} = \overline{v}_{K,t} + \overline{v}_{L,t} = 1$, and Δ refers to a first difference. Note that we reserve the term *total factor productivity* for the augmentation factor in Equation (1).

Equation (2) enables us to identify the contributions of outputs and inputs to economic growth. For example, we can quantify the contributions of different investments, such as computers, software, and communications equipment, to the growth of output by decomposing the growth of investment among its components. Similarly, we can quantify the contributions of different types of consumption, such as services from computers and software, by decomposing the growth of consumption. As shown in Jorgenson and Stiroh (1999), both computer investment and consumption of IT have made important contributions to U.S. economic growth in the 1990s. We also consider the contributions to output of software and communications equipment as distinct high-tech assets. Similarly, we decompose the contribution of capital input to isolate the impact of computers, software, and communications equipment on input growth.

Rearranging Equation (2) enables us to present results in terms of growth in *average labour productivity* (ALP), defined as $y_t = Y_t / H_t$, where Y_t is output, defined as an aggregate of consumption and investment goods; $k_t = K_t / H_t$ is the ratio of capital services to hours worked H_t:

$$(3) \qquad \Delta \ln y_t = \overline{v}_{K,t}\Delta \ln k_t + \overline{v}_{L,t}\left(\Delta \ln L_t - \Delta \ln H_t\right) + \Delta \ln A_t \,.$$

This gives the familiar allocation of ALP growth among three factors. The first is *capital deepening*, the growth in capital services per hour. Capital deepening makes workers more productive by providing more capital for each hour of work and raises the growth of ALP in proportion to the share of capital. The second term is the improvement in *labour quality*, defined as the difference between growth rates of labour input and hours worked. Reflecting the rising proportion of hours supplied by workers with higher marginal products, labour quality improvement raises ALP growth in proportion to labour's share. The third factor is *total factor productivity* (TFP) growth, which increases ALP growth on a point-for-point basis.

2.2.1.b Computers, software, and communications equipment

We now consider the impact of investment in computers, software, and communications equipment on economic growth. For this purpose, we must carefully distinguish the *use* of information technology and the *production* of information technology.[10] For example, computers themselves are the output of one industry (the computer-producing industry, as part of Commercial and Industrial Machinery), and computing services are inputs into other industries (computer-using industries, like Trade, FIRE, and Services).

Massive increases in computing power, like those experienced by the U.S. economy, therefore reflect two effects on growth. First, as the production of computers improves and becomes more efficient, more computing power is being produced from the same inputs. This raises overall productivity in the computer-producing industry and contributes to TFP growth in the economy as a whole. Labour productivity also grows at both the industry and aggregate levels.[11]

Second, the rapid accumulation of computers leads to input growth of computing power in computer-using industries. Since labour is working with more and better computer equipment, this investment increases labour productivity. If the contributions to output are captured by the effect of capital deepening, aggregate TFP growth is unaffected. As Baily and Gordon (1988) remark, "there is no shift in the user firm's production function (p.378)," and thus no gain in TFP. Increasing deployment of computers increases TFP only if there are spillovers from the production of computers to production in the computer-using industries, or if there are measurement problems associated with the new inputs.

We conclude that rapid growth in computing power affects aggregate output through both TFP growth and capital deepening. Progress in the technology of computer production contributes to growth in TFP and ALP at the aggregate level. The accumulation of computing power in computer-using industries reflects the substitution of computers for other inputs and leads to growth in ALP. In the absence of spillovers, this growth does not contribute to TFP growth.

The remainder of this section provides empirical estimates of the variables in Equations (1) through (3). We then employ Equations (2) and (3) to quantify the sources of growth of output and ALP over 1959-1998 and various sub-periods.

2.2.2 Output

Our output data are based on the most recent benchmark revision of the NIPA.[12] Real output, Y_t, is measured in chained 1996 dollars, and $P_{Y,t}$ is the corresponding implicit deflator. Our output concept is similar, but not identical, to one used in the Bureau of Labor Statistics (BLS) productivity program. Like the BLS, we exclude the government sector, but unlike the BLS we include imputations for the flow of services from consumers' durables (CD) and owner-occupied housing. These imputations are necessary to preserve comparability between durables and housing; they also enable us to capture the important impact of information technology on households.

Our estimate of current dollar private output in 1998 is $8,013B, including imputations of $740B that primarily reflect the services of consumers' durables.[13] Real output growth was 3.63 percent for the whole period, compared to 3.36 percent for the official GDP series. The difference reflects both our imputations and our exclusion of the government sector in the NIPA data. Table A.1 in Appendix A shows the current dollar value and corresponding price index for total output and IT assets — investment in computers, I_c, investment in software, I_s, investment in communications equipment, I_m, consumption of computers and software, C_c, and the imputed service flow from consumers' computers and software, D_c.

The most striking feature of these data is the enormous price decline of computer investment — 18 percent per year from 1960 to 1995 (Figure 2.1). Since 1995 this decline has accelerated to 27.6 percent per year. By contrast, the relative price of software has been flat for much of the period and only began to fall in the late 1980s. The price of communications equipment behaves similarly to the price of software, while consumption of computers and software shows a decline similar to that of computer investment. The top panel of Table 2.1 summarizes the growth rates of prices and quantities of major output categories for 1990-95 and for 1995-98.

In terms of current dollar output, investment in software is the largest IT asset, followed by investment in computers and communications equipment (Figure 2.2). While business investments in computers, software, and communications equipment are by far the largest categories, households have spent more than $20B per year on computers and software since 1995, generating a service flow of comparable magnitude.

2.2.3 Capital Stock and Capital Services

This section describes our capital estimates for the U.S. economy from 1959 to 1998.[14] We begin with investment data from the Bureau of Economic Analysis, estimate capital stocks using the perpetual inventory method, and aggregate capital stocks using rental prices as weights. This approach, originated by Jorgenson and Griliches (1967), is based on the identification of rental prices with marginal products of different types of capital. Our estimates of these prices incorporate differences in asset prices, service lives and depreciation rates, and the tax treatment of capital income.[15]

We refer to the difference between growth in capital services and capital stock as the growth in *capital quality*, $q_{K,t}$; this represents a substitution towards assets with higher marginal products.[16] For example, the shift toward IT increases the quality of capital, since computers, software, and communications equipment are assets with relatively high marginal products. Capital stock estimates, like those originally employed by Solow (1957), fail to account for this increase in quality.

We employ a broad definition of capital, including tangible assets such as equipment and structures, as well as consumers' durables, land, and inventories. We estimate a service flow from the installed stock of consumers' durables, which enters our measures of both output and input. It is essential to include this service flow, since a steadily rising proportion is associated with investments in IT by the household sector. In order to capture the impact of information technology on U.S. economic growth, investments by the business and household sectors as well as the services of the resulting capital stocks must be included.

Table 2.1

Average Growth Rates of Selected Outputs and Inputs

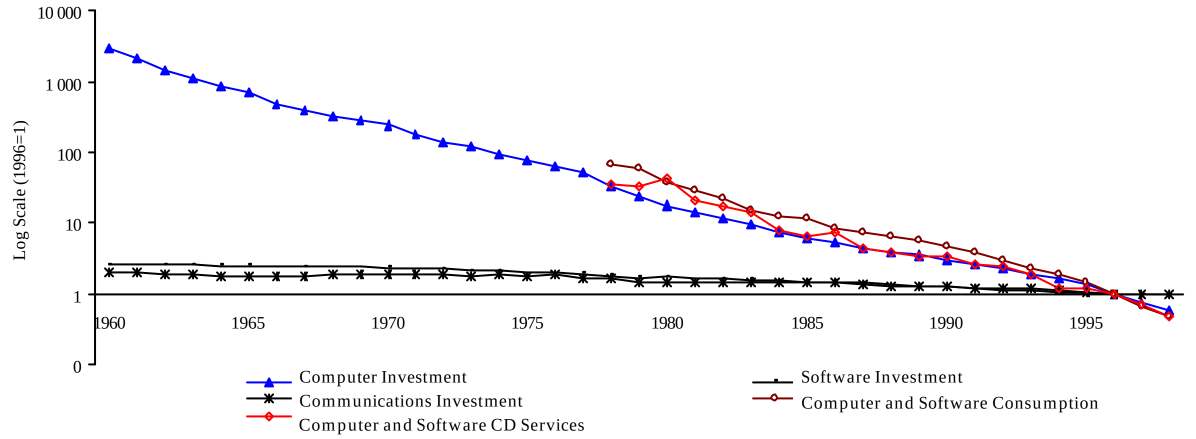
	1990-95		1995-98	
	Prices	**Quantities**	**Prices**	**Quantities**
	Outputs			
Private Domestic Output (Y)	1.70	2.74	1.37	4.73
Other (Y_n)	2.01	2.25	2.02	3.82
Computer and Software Consumption (C_c)	-21.50	38.67	-36.93	49.26
Computer Investment (I_c)	-14.59	24.89	-27.58	38.08
Software Investment (I_s)	-1.41	11.59	-2.16	15.18
Communications Investment (I_m)	-1.50	6.17	-1.73	12.79
Computer and Software CD Services (D_c)	-19.34	34.79	-28.62	44.57
	Inputs			
Total Capital Services (K)	0.60	2.83	2.54	4.80
Other (K_n)	1.00	1.78	4.20	2.91
Computer Capital (K_c)	-10.59	18.16	-20.09	34.10
Software Capital (K_s)	-2.07	13.22	-0.87	13.00
Communications Capital (K_m)	3.10	4.31	-7.09	7.80
Total Consumption Services (D)	1.98	2.91	-0.67	5.39
Non-Computer and Software (D_n)	2.55	2.07	0.54	3.73
Computer and Software CD Services (D_c)	-19.34	34.79	-28.62	44.57
Labour (L)	2.92	2.01	2.80	2.81

Note: CD refers to consumers' durable assets. All values are percentages.

Our estimate of capital stock is $26T in 1997, substantially larger than the $17.3T in fixed private capital estimated by the BEA (1998b). This difference reflects our inclusion of consumers’ durables, inventories, and land. Our estimates of capital stock for comparable categories of assets are quite similar to those of the BEA. Our estimate of fixed private capital in 1997, for example, is $16.8T, almost the same as that of the BEA. Similarly, our estimate of the stock of consumers' durables is $2.9T, while the BEA's estimate is $2.5T. The remaining discrepancies reflect our inclusion of land and inventories. Table B.1 in Appendix B lists the component assets and 1998 investment and stock values; Table B.2 presents the value of the capital stock from 1959 to 1998, as well as asset price indices for total capital and IT assets.

Figure 2.1

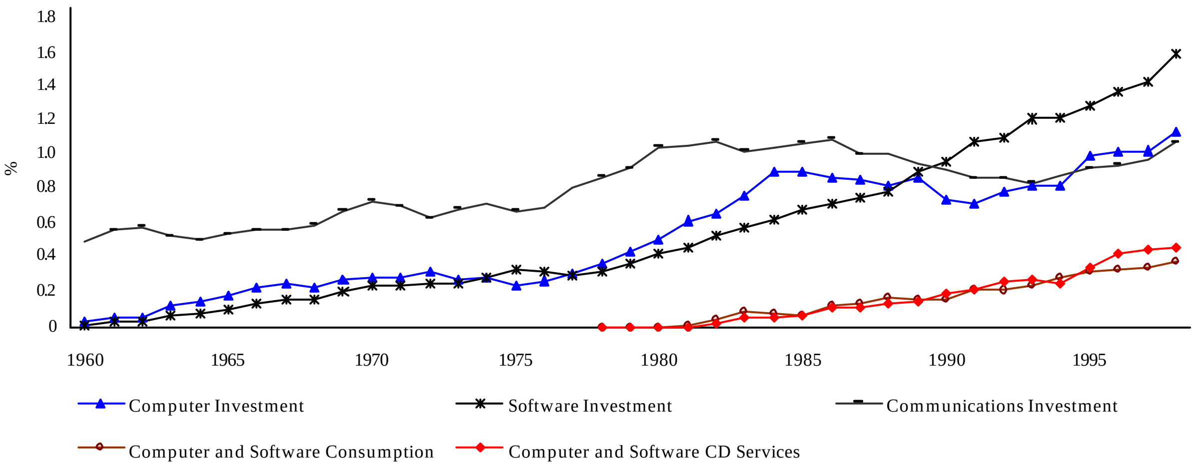
Relative Prices of Information Technology Outputs, 1960-98



Note: All price indices are relative to the output price index.

Figure 2.2

Output Shares of Information Technology, 1960-98



Note: Share of current dollar output.

The stocks of IT business assets (computers, software, and communications equipment), as well as consumers' purchases of computers and software, have grown dramatically in recent years, but remain relatively small. In 1998, combined IT assets accounted for only 3.4 percent of tangible capital, and 4.6 percent of reproducible, private assets.

We now move to estimates of capital service flows, where capital stocks of individual assets are aggregated using rental prices as weights. Table B.3 in Appendix B presents the current dollar service flows and corresponding price indices for 1959-98, and the second panel of Table 2.1 summarizes the growth rates of prices and quantities of inputs for 1990-95 and 1995-98.

There is a clear acceleration of growth of aggregate capital services from 2.8 percent per year for 1990-95 to 4.8 percent for 1995-98. It is largely due to a rapid growth in services from IT equipment and software, and reverses the trend toward slower capital growth through 1995. While information technology assets account for only 11.2 percent of the total, the service shares of these assets are much greater than the corresponding asset shares. In 1998, capital services were only 12.4 percent of capital stocks for tangible assets as a whole, but services were 40.0 percent of information technology stocks. This reflects the rapid price declines and high depreciation rates that enter into the rental prices of information technology.

Figure 2.3 highlights the rapid increase in the importance of IT assets, reflecting the accelerating pace of relative price declines. In the 1990s, the service price for computer hardware fell 14.2 percent per year, compared to an increase of 2.2 percent for non-information technology capital. As a direct consequence of this relative price change, computer services grew 24.1 percent, compared to only 3.6 percent for the services of non-IT capital during the 1990s. The current dollar share of services from computer hardware increased steadily and reached nearly 3.5 percent of all capital services in 1998 (Figure 2.3).[17]

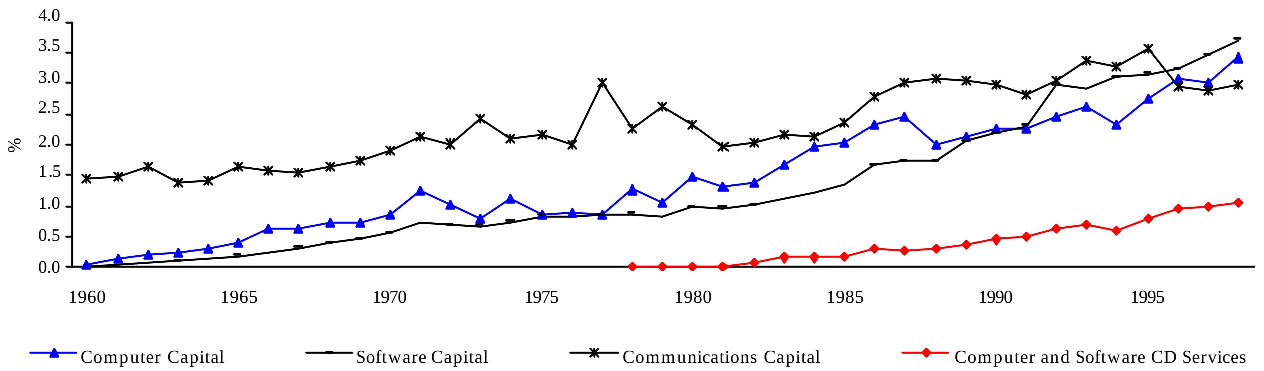
The rapid accumulation of software, however, appears to have different origins. The price of software investment has declined much more slowly (-1.7 percent per year for software versus -19.5 percent for computer hardware) from 1990 to 1998. These differences in investment prices lead to a much slower decline in service prices for software and computers, -1.6 percent versus -14.2 percent. Nonetheless, firms have been accumulating software quite rapidly, with real capital services growing 13.3 percent per year during the 1990s. While lower than the 24.1 percent growth recorded for computers, software growth is much more rapid than the growth of other forms of tangible capital. Complementarity between software and computers is one possible explanation. Firms respond to the decline in relative computer prices by accumulating computers and investing in complementary inputs like software to put the computers into operation.[18]

A competing explanation is that the official price indices used to deflate software investment omit a large part of true quality improvements. This would lead to a substantial overstatement of price inflation and a corresponding understatement of real investment, capital services, and economic growth. According to Moulton, Parker, and Seskin (1999), and Parker and Grimm (2000), only prices of pre-packaged software are calculated from constant-quality price deflators based on hedonic methods. Prices of business own-account software are based on input-cost indices, which implicitly assume no change in the productivity of computer programmers. Custom software prices are a weighted average of pre-packaged software and own-account software, with an arbitrary 75 percent weight given to business own-account software prices. Thus, the price deflators for nearly two-thirds of recent software investment are estimated under the maintained assumption of no gain in productivity.[19] If the quality of own-account and custom software is improving at a pace even remotely close to packaged software, this implies a large understatement of investment in software.

Although the price decline for communications equipment during the 1990s is comparable to that of software, as officially measured in the NIPA, investment has grown at a rate that is more in line with prices. However, there are also possible measurement biases in the pricing of communications equipment. The technology of switching equipment, for example, is similar to that of computers; investment in this category is deflated by a constant-quality price index developed by the BEA. Conventional price deflators are employed for transmission gear, such as fibre-optic cables, which also appear to be declining rapidly in price. This could lead to an underestimate of the rate of growth in communications equipment investment, capital stock, and capital services, as well as an overestimate of the rate of inflation.[20] We return to this issue at the end of Section 2.2.

Figure 2.3

Input Shares of Information Technology, 1960-98



Note: Share of current dollar capital and consumers' durable services.

2.2.4 Measuring Labour Services

This section describes our estimates of labour input for the U.S. economy from 1959 to 1998. We begin with individual data from the Census of Population for 1970, 1980, and 1990, as well as the annual Current Population Surveys. We estimate constant quality indices for labour input and its price to account for heterogeneity of the workforce across sexes, employment classes, age groups, and education levels. This follows the approach of Jorgenson, Gollop and Fraumeni (1987), whose estimates have been revised and updated by Ho and Jorgenson (1999).[21]

The distinction between labour input and labour hours is analogous to the distinction between capital services and capital stock. Growth in labour input reflects the increase in labour hours, as well as changes in the composition of hours worked as firms substitute among heterogeneous types of labour. We define the growth in labour quality as the difference between the growth in labour input and hours worked. Labour quality reflects the substitution of workers with high marginal products for those with low marginal products, while the growth in hours employed by Solow (1957) and others does not capture this substitution. Table C.1 in Appendix C presents our estimates of labour input, hours worked, and labour quality.

Our estimates show a value for labour expenditures of $4,546B in 1998, roughly 57 percent of the value of output. This share accurately includes private output and our imputations for capital services. If we exclude these imputations, labour's share rises to 62 percent, in line with conventional estimates. As shown in Table 2.1, the growth of the index of labour input, L_t, appropriate for our model of production in Equation (1) accelerated to 2.8 percent for 1995-98, from 2.0 percent for 1990-95. This is primarily due to the growth in the number of hours worked, which rose from 1.4 percent during 1990-95 to 2.4 percent during 1995-98, as the labour force participation increased and unemployment rates plummeted.[22]

The growth in labour quality decelerated in the late 1990s, from 0.65 percent during 1990-95 to 0.43 percent during 1995-98. This slowdown captures well-known underlying demographic trends in the composition of the workforce, as well as the exhaustion of the pool of available workers as unemployment rates steadily declined. Projections of future economic growth that omit labour quality, like those of the CBO discussed in Section 3, implicitly incorporate changes in labour quality into measured TFP growth. This reduces the reliability of projections of future economic growth. Fortunately, this is easily remedied by extrapolating demographic changes in the workforce in order to reflect foreseeable changes in the composition of workers by characteristics such as age, sex, and educational attainment.

2.2.5 Quantifying the Sources of Growth

Table 2.2 presents results of our growth accounting decomposition based on an extension of Equation (2) for the period 1959 to 1998 and various subperiods, as well as preliminary estimates through 1999. As in Jorgenson and Stiroh (1999), we decompose economic growth by both output and input categories in order to quantify the contribution of information technology (IT) to investment and consumption outputs, as well as capital and consumers' durable inputs. We extend our previous treatment of the outputs and inputs of computers by identifying software and communications equipment as distinct IT assets.

To quantify the sources of IT-related growth more explicitly, we employ an extended production possibility frontier:

(4) $Y(Y_n, C_c, I_c, I_s, I_m, D_c) = A \cdot X(K_n, K_c, K_s, K_m, D_n, D_c, L)$

where outputs include computer and software consumption, C_c, computer investment, I_c, software investment, I_s, telecommunications investment, I_m, the services of consumers' computers and software, D_c, and other outputs, Y_n. Inputs include the capital services of computers, K_c, software, K_s, telecommunications equipment, K_m, other capital assets, K_n, services of consumers' computers and software, D_c, other durables, D_n, and labour input, L.[23] As in Equation (1), total factor productivity is denoted by A and represents the ability to produce more output from the same inputs. Time subscripts have been dropped for convenience.

The corresponding extended growth accounting equation is:

(5) $$\overline{w}_{Y_n}\Delta\ln Y_n + \overline{w}_{C_c}\Delta\ln C_c + \overline{w}_{I_c}\Delta\ln I_c + \overline{w}_{I_s}\Delta\ln I_s + \overline{w}_{I_m}\Delta\ln I_m + \overline{w}_{D_c}\Delta\ln D_c = \overline{v}_{K_n}\Delta\ln K_n + \overline{v}_{K_c}\Delta\ln K_c + \overline{v}_{K_s}\Delta\ln K_s + \overline{v}_{K_m}\Delta\ln K_m + \overline{v}_{D_n}\Delta\ln D_n + \overline{v}_{D_c}\Delta\ln D_c + \overline{v}_{L}\Delta\ln L + \Delta\ln A$$

where $\overline{w}$ and $\overline{v}$ denote the average shares of nominal income for the subscripted variable $\overline{w}_{Yn} + \overline{w}_{Cc} + \overline{w}_{Ic} + \overline{w}_{Is} + \overline{w}_{\mathrm{Im}} + \overline{w}_{Dc} = \overline{v}_{Kn} + \overline{v}_{Kc} + \overline{v}_{Ks} + \overline{v}_{Km} + \overline{v}_{Dn} + \overline{v}_{Dc} + \overline{v}_{L} = 1$; we refer to a share-weighted growth rate as the *contribution* of an input or output.

2.2.5.a Output Growth

We first consider the sources of output growth for the entire period 1959 to 1998. Broadly defined capital services make the largest contribution to growth with 1.8 percentage points (1.3 percentage points from business capital and 0.5 from consumers' durable assets), labour services contribute 1.2 percentage points, and TFP growth is responsible for only 0.6 percentage points. Input growth is the source of nearly 80 percent of U.S. economic growth over the past 40 years, while TFP has accounted for approximately one-fifth. Figure 2.4 highlights this result by showing the relatively small contribution to growth of the TFP residual in each sub-period.

More than three-quarters of the contribution of broadly defined capital reflects the accumulation of capital stock, while increased labour hours account for slightly less than three-quarters of labour's contribution. The quality of both capital and labour have made important contributions, with 0.45 and 0.32 percentage points per year, respectively. Accounting for substitution among heterogeneous capital and labour inputs is therefore an important part of quantifying the sources of economic growth.

A look at the U.S. economy before and after 1973 reveals some familiar features of the historical record. After strong output and TFP growth in the 1960s and early 1970s, the U.S. economy slowed markedly through 1990, with annual output growth falling from 4.3 percent to 3.1 percent and annual TFP growth falling almost two-thirds of a percentage point from 1.0 percent to 0.3 percent. Growth in capital inputs also slowed, falling from 5.0 percent during 1959-73 to 3.8 percent during 1973-90, which contributed to a sluggish ALP growth of 2.9 percent during 1959-73 to 1.4 percent during 1973-90.

We now focus on the 1990s and highlight recent changes.[24] Relative to the early 1990s, output growth has increased by nearly 2.0 percentage points during 1995-98. The contribution of capital jumped by 1.0 percentage point, the contribution of labour rose by 0.4 percentage points, and TFP growth accelerated by 0.6 percentage points. ALP growth rose 1.0 percentage point. The rising contributions of capital and labour encompass several well-known trends in the late 1990s. Growth in hours worked accelerated as labour markets tightened, unemployment fell to a 30-year low, and labour force participation rates increased.[25] The contribution of capital reflects the investment boom of the late 1990s as businesses poured resources into plant and equipment, especially computers, software, and communications equipment.

The acceleration of TFP growth is perhaps the most remarkable feature of the data. After averaging only 0.34 percent per year from 1973 to 1995, the acceleration of TFP to 0.99 percent suggests massive improvements in technology and increases in the efficiency of production. While the resurgence of TFP growth in the 1990s has yet to surpass that recorded in the 1960s and early 1970s, more rapid TFP growth is critical for sustained higher rates of growth.

Figures 2.5 and 2.6 highlight the rising contributions of information technology (IT) outputs to U.S. economic growth. Figure 2.5 shows the breakdown between IT and non-IT outputs for the sub-periods from 1959 to 1998, while Figure 2.6 decomposes the contribution of IT outputs into the five components identified above. Although the role of IT has steadily increased, Figure 2.5 shows that the recent surge in investment and consumption nearly doubled the contribution to output of IT during 1995-98 relative to 1990-95. Figure 2.6 shows that computer investment is the largest single IT contributor in the late 1990s, and that consumption of computers and software is becoming increasingly important as a source of output growth.

Figures 2.7 and 2.8 present a similar decomposition of the role of IT as a production input, where the contribution is rising even more dramatically. Figure 2.7 shows that the capital and consumers' durable contribution from IT increased rapidly in the late 1990s, and now accounts for more than two-fifths of the total contribution to growth from broadly defined capital. Figure 2.8 shows that computer hardware is also the single largest IT contributor on the input side, which reflects the growing share and rapid growth rates of the late 1990s.

Table 2.2

Growth in U.S. Private Domestic Output and the Sources of Growth, 1959-99

						Preliminary*
	1959-98	**1959-73**	**1973-90**	**1990-95**	**1995-98**	**1995-99**
Growth in Private Domestic Output (Y)	3.630	4.325	3.126	2.740	4.729	4.763
Contribution of Selected Output Components						
Other (Y_n)	3.275	4.184	2.782	2.178	3.659	3.657
Computer and Software Consumption (C_c)	0.035	0.000	0.023	0.092	0.167	0.175
Computer Investment (I_c)	0.150	0.067	0.162	0.200	0.385	0.388
Software Investment (I_s)	0.074	0.025	0.075	0.128	0.208	0.212
Communications Investment (I_m)	0.060	0.048	0.061	0.053	0.122	0.128
Computer and Software CD Services (D_c)	0.036	0.000	0.023	0.089	0.187	0.204
Contribution of Capital Services (K)	1.260	1.436	1.157	0.908	1.611	1.727
Other (K_n)	0.936	1.261	0.807	0.509	0.857	0.923
Computers (K_c)	0.177	0.086	0.199	0.187	0.458	0.490
Software (K_s)	0.075	0.026	0.071	0.154	0.193	0.205
Communications (K_m)	0.073	0.062	0.080	0.058	0.104	0.109
Contribution of CD Services (D)	0.510	0.632	0.465	0.292	0.558	0.608
Other (D_n)	0.474	0.632	0.442	0.202	0.370	0.403
Computers and Software (D_c)	0.036	0.000	0.023	0.089	0.187	0.204
Contribution of Labour (L)	1.233	1.249	1.174	1.182	1.572	1.438
Aggregate Total Factor Productivity (TFP)	0.628	1.009	0.330	0.358	0.987	0.991
Growth of Capital and CD Services	4.212	4.985	3.847	2.851	4.935	5.286
Growth of Labour Input	2.130	2.141	2.035	2.014	2.810	2.575

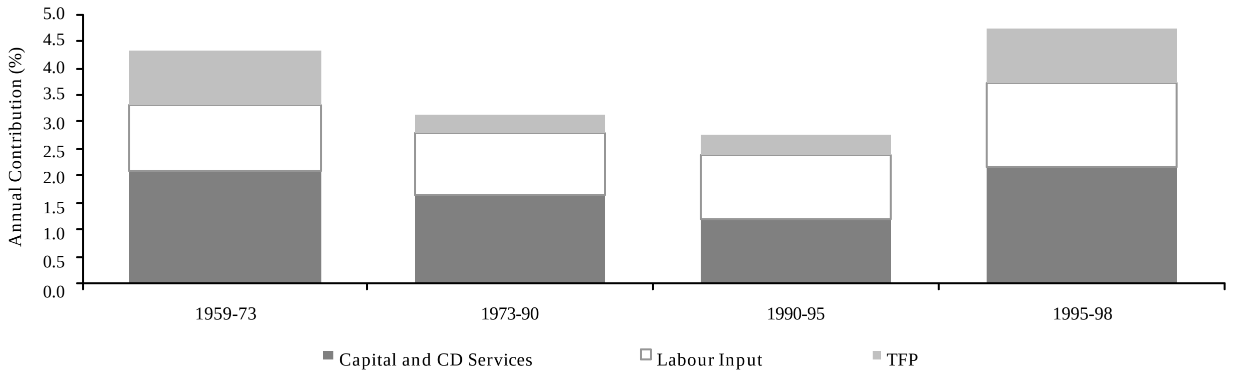
Table 2.2 (cont'd)

						Preliminary*
	1959-98	1959-73	1973-90	1990-95	1995-98	1995-99
Contribution of Capital and CD Quality	0.449	0.402	0.405	0.434	0.945	1.041
Contribution of Capital and CD Stock	1.320	1.664	1.217	0.765	1.225	1.293
Contribution of Labour Quality	0.315	0.447	0.200	0.370	0.253	0.248
Contribution of Labour Hours	0.918	0.802	0.974	0.812	1.319	1.190
Average Labour Productivity (*ALP*)	2.042	2.948	1.437	1.366	2.371	2.580

Note: The contribution of an output or an input is defined as the share-weighted, real growth rate. CD refers to consumers' durable assets. All values are percentages. 1995-99 results include preliminary estimates for 1999; see the Annex to this chapter for details on estimation and data sources.

Figure 2.4

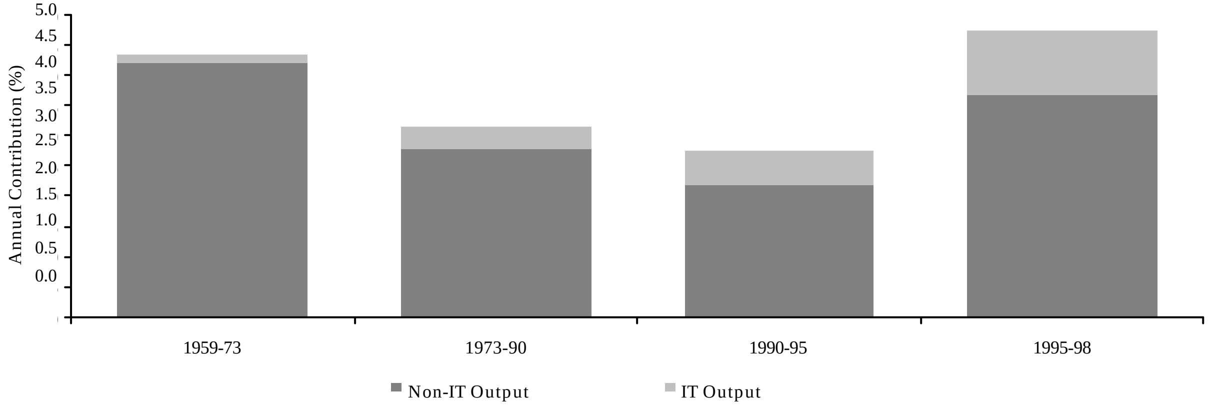
Sources of U.S. Economic Growth, 1959-98



Note: An inp ut's contribution is its average share-weighted, annual growth rate. TFP defined in Equation (2) in the text.

Figure 2.5

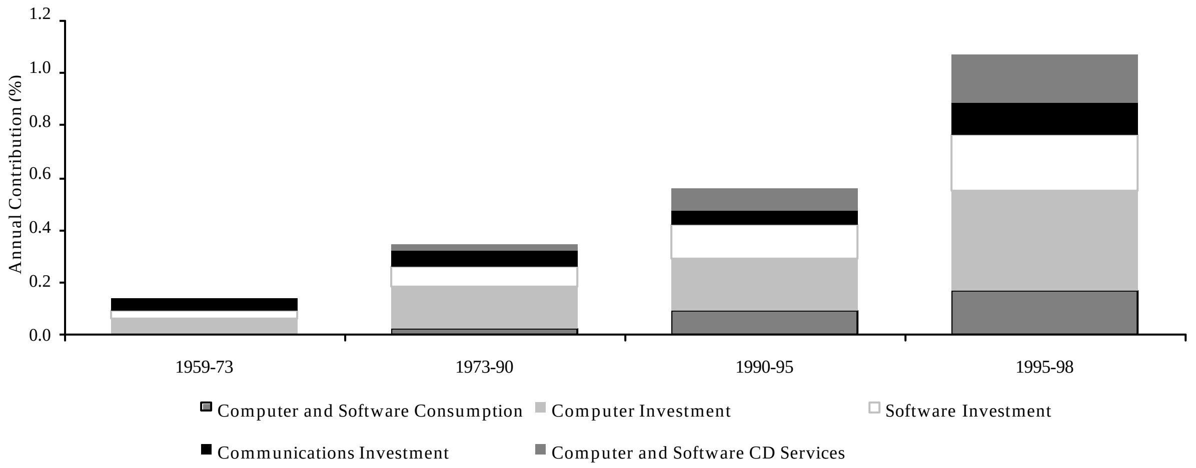
Contribution to Output of Information Technology, 1959-98



Note: The contribution of an output is its average share-weighted, annual growth rate.

Figure 2.6

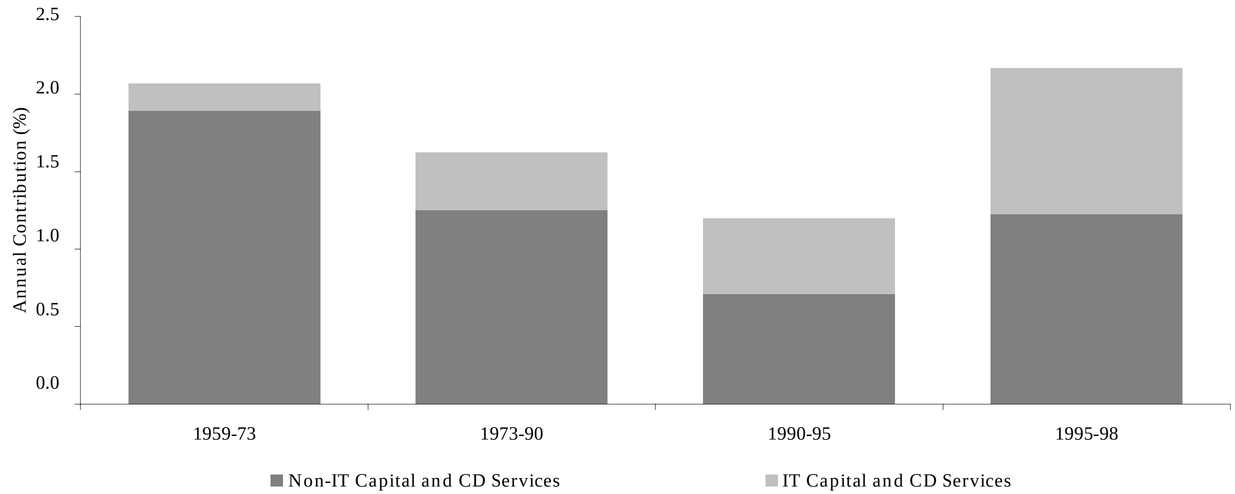
Contribution to Output of Information Technology Assets, 1959-98



Note: The contribution of an output is its average share-weighted, annual growth rate.

Figure 2.7

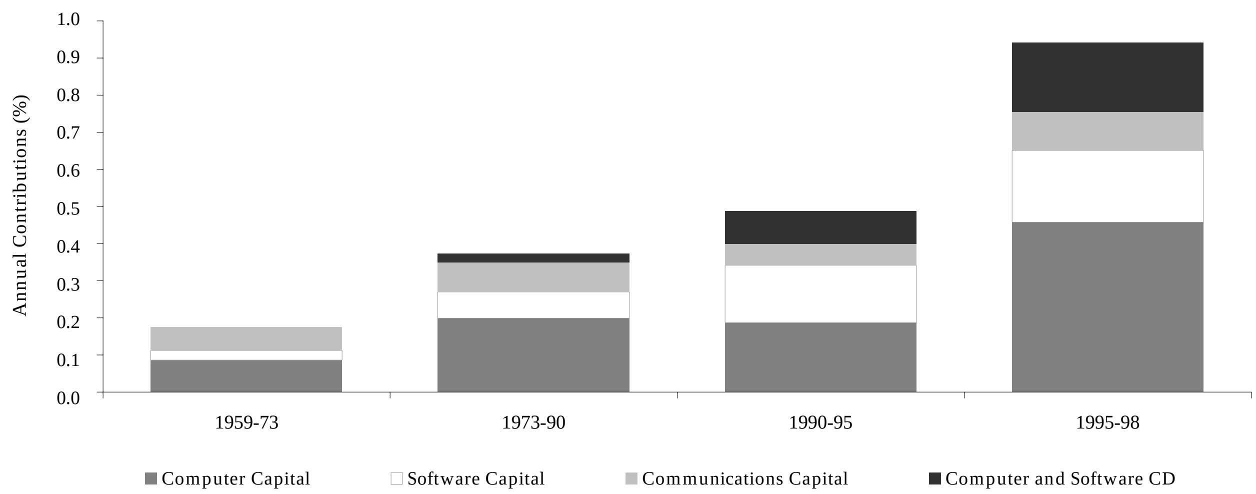
Input Contribution of Information Technology, 1959-98



Note: The contribution of an output is its average share-weighted, annual growth rate.

Figure 2.8

Input Contribution of Information Technology Assets, 1959-98



Note: The contribution of an output is its average share-weighted, annual growth rate.

The contribution of computers, software, and communications equipment offers a different picture from that presented by Jorgenson and Stiroh (1999) for both data and methodological reasons. First, the BEA benchmark revision has classified software as an investment good. While software is growing more slowly than computers, the substantial nominal share of software services has raised the contribution of information technology. Second, we have added communications equipment, also a slower growing component of capital services, with similar effects. Third, we now incorporate asset-specific revaluation terms in all rental price estimates. Since the acquisition prices of computers are steadily falling, asset-specific revaluation terms have raised the estimated service price and increased the share of computer services. Finally, we have modified our timing convention and now assume that capital services from individual assets are proportional to the average of the current and lagged stock. For assets with relatively short service lives like IT, this is a more reasonable assumption than in our earlier work, which assumed that it took a full year for new investment to become productive.[26]

This large increase in the contribution of computers and software to growth is consistent with recent estimates by Oliner and Sichel (2000), although their estimate of such contribution is somewhat larger. They report that computer hardware and software contributed 0.93 percentage points to growth during 1996-99, while communications contributed another 0.15. The discrepancy primarily reflects our broader output concept, which lowers the input share of these high-tech assets, and also minor differences in tax parameters and stock estimates. Whelan (1999) also reports a larger contribution to growth of 0.82 percentage points from computer hardware over 1996-98. The discrepancy also reflects our broader output concept. In addition, Whelan (1999) introduces a new methodology to account for retirement and support costs that generates a considerably larger capital stock and raises the input share and the contribution of computer capital to growth.

Despite differences in methodology and data sources among studies, a consensus is building that computers are having a substantial impact on economic growth.[27] What is driving the increase in the contributions of computers, software, and communications equipment? As we argued in Jorgenson and Stiroh (1999), price changes lead to substitution toward capital services with lower relative prices. Firms and consumers are responding to relative price changes.

Table 2.1 shows that the acquisition price of computer investment fell nearly 28 percent per year, the price of software fell 2.2 percent, and the price of communications equipment fell 1.7 percent during the period 1995-98, while other output prices rose 2.0 percent. In response to these price changes, firms accumulated computers, software, and communications equipment more rapidly than other forms of capital. Investment other than information technology actually declined as a proportion of the private domestic product. The story of household substitution toward computers and software is similar. These substitutions suggest that the gains from the computer revolution accrue to firms and households that are adept at restructuring activities to respond to these relative price changes.

2.2.5.b Average Labour Productivity Growth

To provide a different perspective on the sources of economic growth we can look at ALP growth. By simple arithmetic, output growth equals the sum of the growth in hours of work and the growth in labour productivity.[28] Table 2.3 shows the output breakdown between growth in hours worked and ALP for the same periods as in Table 2.2. For the entire period 1959-1998, ALP growth was the predominant determinant of output growth, increasing just over 2 percent per year over 1959-98, while the number of hours increased about 1.6 percent per year. We then examine the changing importance of the factors determining ALP growth. As shown in Equation (3), ALP growth depends on a capital deepening effect, a labour quality effect, and a TFP effect.

Table 2.3

The Sources of ALP Growth, 1959-98

Variable	1959-98	1959-73	1973-90	1990-95	1995-98
Growth of Private Domestic Output (*Y*)	3.630	4.325	3.126	2.740	4.729
Growth in Hours Worked (*H*)	1.588	1.377	1.689	1.374	2.358
Growth in ALP (*Y/H*)	2.042	2.948	1.437	1.366	2.371
Contribution of Capital Deepening to ALP	1.100	1.492	0.908	0.637	1.131
Contribution of Labour Quality to ALP	0.315	0.447	0.200	0.370	0.253
Contribution of TFP to ALP	0.628	1.009	0.330	0.358	0.987

Note: Contributions to ALP are defined in Equation (3). All values are percentages.

Figure 2.9 plots the importance of each factor, revealing the well-known productivity slowdown of the 1970s and 1980s, and highlighting the acceleration of labour productivity growth in the late 1990s. The slowdown through 1990 reflects a lesser capital deepening, declining labour quality growth, and decelerating growth in TFP. The growth of ALP slipped further during the early 1990s with the serious slump in capital deepening only partly offset by a revival in the growth of labour quality and an uptick in TFP growth. Slow growth in hours worked combined with a slow ALP growth during 1990-95 to produce a further slide in the growth of output. This stands out from previous cyclical recoveries during the post-war period, when output growth accelerated during the recovery, powered by a more rapid growth in hours worked and ALP.

For the most recent period of 1995-98, strong output growth reflects growth in labour hours and ALP almost equally. Comparing 1990-95 to 1995-98, output growth accelerated by nearly 2.0 percentage points due to a 1.0 percentage point increase in hours worked, and a 1.0 percentage point increase in ALP growth.[29] Figure 2.9 shows that the acceleration in ALP growth is due to rapid capital deepening from the investment boom, as well as faster TFP growth. Capital deepening contributed 0.49 percentage points to the acceleration in ALP growth, while acceleration in TFP growth added 0.63 percentage points. Growth in labour quality slowed somewhat as growth in hours worked accelerated. This reflects the falling unemployment rate and a tightening of labour markets as more workers with relatively low marginal products were drawn into the workforce. Oliner and Sichel (2000) also show a decline in the contribution of labour quality to growth in the late 1990s, from 0.44 during 1991-95 to 0.31 during 1996-99.

Our decomposition also sheds some light on the hypothesis advanced by Gordon (1999b), who argues that the vast majority of recent ALP gains are due to the production of IT, particularly computers, rather than to the use of IT. As we have already pointed out, more efficient IT production generates aggregate TFP growth as more computing power is produced from the same inputs, while IT use affects ALP growth via capital deepening. In recent years, the acceleration of TFP growth was a slightly more important factor in the acceleration of ALP growth than capital deepening. Efficiency gains in computer production are an important part of aggregate TFP growth, as Gordon's results on ALP suggest. We return to this issue in greater detail below.

Figure 2.9

Sources of U.S. Labour Productivity Growth, 1959-98

Note: Annual contributions are defined in Equation (3) in the text.

2.2.5.c Total Factor Productivity Growth

Finally, we consider the remarkable performance of U.S. TFP growth in recent years. After maintaining an average rate of 0.33 percent for the period 1973-90, TFP growth rose to 0.36 percent during 1990-95 and then vaulted to 0.99 percent per year during 1995-98. This jump is a major source of growth in output and ALP for the U.S. economy (Figures 2.4 and 2.9). While TFP growth in the 1990s has yet to attain the peaks recorded for some periods in the golden age of the 1960s and early 1970s, the recent acceleration suggests that the U.S. economy may be recovering from the anaemic productivity growth of the past two decades. Of course, caution is warranted until more historical experience is available.

As early as Domar (1961), economists have utilized a multi-industry model of the economy to trace aggregate productivity growth to its sources at the level of individual industries. Jorgenson, Gollop, and Fraumeni (1987), and Jorgenson (1990) have employed this model to identify industry-level sources of growth. More recently, Gullickson and Harper (1999), and Jorgenson and Stiroh (2000) have used the model for similar purposes. We postpone more detailed consideration of these sources of TFP growth until we have examined the impact of alternative price deflators on our decomposition of growth.

2.2.6 Alternative Growth Accounting Estimates

Tables 2.1 through 2.3 and Figures 2.1 through 2.9 report our primary results using the official data published in the NIPA. As we have already noted, however, there is reason to believe that the rates of inflation in official price indices for certain high-tech assets, notably software and telecommunications equipment, may be overstated. Moulton, Parker, and Seskin (1999), and Parker and Grimm (2000), for example, report that only the pre-packaged segment of software investment is deflated with a constant-quality deflator. Own-account software is deflated with an input cost index and custom software is deflated with a weighted average of the pre-packaged and own-account deflator. Similarly, BEA reports that in the communications equipment category, only telephone switching equipment is deflated with a constant-quality, hedonic price deflator.

This subsection incorporates alternative price series for software and communications equipment and examines the impact on the estimates of U.S. economic growth and its sources. Table 2.4 presents growth accounting results under three different scenarios. The Base case repeats the estimates from Table 2.2, which are based on official NIPA price data. Two additional cases, Moderate Price Decline and Rapid Price Decline, incorporate price series for software and communications equipment that show faster price declines and correspondingly more rapid real investment growth.[30]

The Moderate Price Decline case assumes that pre-packaged software prices are appropriate for all types of private software investment, including custom and business own-account software. Since the index for pre-packaged software is based on explicit quality adjustments, it falls much faster than the prices of custom and own-account software, -10.1 percent vs. 0.4 percent and 4.1 percent, respectively, for the full period 1959-98 according to Parker and Grimm (2000). For communications equipment, the data are more limited and we assume prices fell 10.7 percent per year throughout the entire period. This estimate is the average annual "smoothed" decline for digital switching equipment over 1985-96, as reported by Grimm (1997). While this series may not be appropriate for all types of communications equipment, it exploits the best available information.

The Rapid Price Decline case assumes that software prices fell 16 percent per year during 1959-98, the rate of quality-adjusted price decline reported by Brynjolfsson and Kemerer (1996) for microcomputer spreadsheets over 1987-92. This is a slightly faster rate of decline than the -15 percent estimated by Gandal (1994) for 1986-91, and considerably faster than the 3 percent annual decline for word processors, spreadsheets, and databases reported by Oliner and Sichel (1994) for 1987-93. For communications equipment, we used estimates from the most recent period from Grimm (1997), who reports a decline of 17.9 percent per year over 1992-96.

While this exercise necessarily involves some arbitrary choices, the estimates incorporate the limited data now available and provide a valuable perspective on the crucial importance of accounting for quality changes in the prices of investment goods. Comparisons among the three cases are also useful for suggesting the range of uncertainty currently confronting analysts of U.S. economic growth.

Before discussing the empirical results, it is worthwhile to emphasize that a more rapid price decline for information technology has two direct effects on the sources of growth, and one indirect effect. The alternative investment deflators raise real output growth by reallocating nominal growth away from prices towards quantities. This also increases the growth rate of capital stock, since there are larger investment quantities in each year. More rapid price declines also give greater weight to capital services from information technology.

The counter-balancing effects of increased output and increased input growth lead to an indirect effect on measured TFP growth. Depending on the relative shares of high-tech assets in investment and capital services, the TFP residual will either increase if the output effect dominates or decrease if the effect on capital services dominates.[31] Following Solow (1957, 1960), Greenwood, Hercowitz, and Krusell (1997) we omit the output effect and attribute the input effect to "investment-specific" (embodied) technical change. This must be carefully distinguished from the effects of industry-level productivity growth on TFP growth, discussed in Section 4.

Table 2.4 reports growth accounting results from these three scenarios: Base case, Moderate Price Decline, and Rapid Price Decline. The results are not surprising; the more rapid the price decline for software and communications equipment, the faster the rate of growth of output and capital services. Relative to the Base case, output growth increases by 0.16 percentage points per year over 1995-98 in the Moderate Price Decline case and by 0.34 percentage points in the Rapid Price Decline case. Capital input growth shows slightly larger increases across the three cases. Clearly, constant-quality price indices for information technology are essential to further progress in understanding the impact on growth of high-tech investment.

The acceleration of output and input growth reflects the increased contributions from IT, and determines the effect on the TFP residual. In particular, the contribution of software to output for 1995-98 increases from 0.21 percentage points in the Base case to 0.29 percentage points in the Moderate Price Decline case, and to 0.40 percentage points in the Rapid Price Decline case. Similarly, the capital services contribution for software increases from 0.19 to 0.29 and to 0.45 percentage points. The contribution of communications equipment shows similar changes. Residual TFP growth fell slightly during the 1990s, as the input effect outweighed the output effect, due to the large capital services shares of IT.

Table 2.4

Growth in U.S. Private Domestic Output and the Sources of Growth, 1959-99

	Base Case				Moderate Price Decline				Rapid Price Decline			
	1959 -73	**1973 -90**	**1990 -95**	**1995 -98**	**1959 -73**	**1973 -90**	**1990 -95**	**1995 -98**	**1959 -73**	**1973 -90**	**1990 -95**	**1995 -98**
Growth in Private Domestic Output (*Y*)	4.33	3.13	2.74	4.73	4.35	3.30	2.90	4.89	4.36	3.38	3.03	5.07
Contribution of Selected Output Components												
Other (Y_n)	4.18	2.78	2.18	3.66	4.12	2.76	2.17	3.66	4.08	2.75	2.16	3.66
Computer and Software Consumption (C_c)	0.00	0.02	0.09	0.17	0.00	0.02	0.09	0.17	0.00	0.02	0.09	0.17
Computer Investment (I_c)	0.07	0.16	0.20	0.39	0.07	0.16	0.20	0.39	0.07	0.16	0.20	0.39
Software Investment (I_s)	0.03	0.08	0.13	0.21	0.04	0.14	0.22	0.29	0.05	0.17	0.29	0.40
Communications Equipment Investment (I_m)	0.05	0.06	0.05	0.12	0.12	0.19	0.13	0.21	0.16	0.25	0.19	0.27
Computer and Software CD Services (D_c)	0.00	0.02	0.09	0.19	0.00	0.02	0.09	0.19	0.00	0.02	0.09	0.19
Contribution of Capital Services (*K*)	1.44	1.16	0.91	1.61	1.54	1.39	1.15	1.83	1.61	1.51	1.32	2.09
Other (K_n)	1.26	0.81	0.51	0.86	1.25	0.80	0.51	0.86	1.25	0.79	0.51	0.85
Computers (K_c)	0.09	0.20	0.19	0.46	0.09	0.20	0.19	0.46	0.09	0.20	0.19	0.46
Software (K_s)	0.03	0.07	0.15	0.19	0.05	0.15	0.28	0.29	0.06	0.18	0.36	0.45
Communications Equipment (K_m)	0.06	0.08	0.06	0.10	0.16	0.25	0.18	0.23	0.22	0.34	0.27	0.33
Contribution of CD Services (*D*)	0.63	0.47	0.29	0.56	0.63	0.46	0.29	0.56	0.63	0.46	0.29	0.56
Non-Computers and Software (D_n)	0.63	0.44	0.20	0.37	0.63	0.44	0.20	0.37	0.63	0.44	0.20	0.37
Computers and Software (D_c)	0.00	0.02	0.09	0.19	0.00	0.02	0.09	0.19	0.00	0.02	0.09	0.19
Contribution of Labour (*L*)	1.25	1.17	1.18	1.57	1.25	1.17	1.18	1.57	1.25	1.18	1.18	1.57
Aggregate Total Factor Productivity (*TFP*)	1.01	0.33	0.36	0.99	0.94	0.27	0.27	0.93	0.88	0.22	0.23	0.85

Table 2.4 (cont'd)

	Base Case				Moderate Price Decline				Rapid Price Decline			
	1959 -73	**1973 -90**	**1990 -95**	**1995 -98**	**1959 -73**	**1973 -90**	**1990 -95**	**1995 -98**	**1959 -73**	**1973 -90**	**1990 -95**	**1995 -98**
Growth of Capital and CD Services	4.99	3.85	2.85	4.94	5.24	4.40	3.43	5.44	5.41	4.70	3.84	6.02
Growth of Labour Input	2.14	2.04	2.01	2.81	2.14	2.04	2.01	2.81	2.14	2.04	2.01	2.81
Contribution of Capital and CD Quality	0.40	0.41	0.43	0.95	0.48	0.59	0.63	1.11	0.54	0.70	0.78	1.34
Contribution of Capital and CD Stock	1.66	1.22	0.77	1.23	1.68	1.26	0.82	1.28	1.69	1.27	0.84	1.31
Contribution of Labour Quality	0.45	0.20	0.37	0.25	0.45	0.20	0.37	0.25	0.45	0.20	0.37	0.25
Contribution of Labour Hours	0.80	0.97	0.81	1.32	0.80	0.97	0.81	1.32	0.80	0.98	0.81	1.32
Average Labour Productivity (*ALP*)	2.95	1.44	1.37	2.37	2.98	1.61	1.52	2.53	2.99	1.69	1.65	2.72

Note: The Base case uses official NIPA price data. The Moderate Price Decline case uses the pre-packaged software deflator for all software and annual price changes of -10.7 percent for communications equipment. The Rapid Price Decline case uses annual price changes of -16 percent for software and -17.9 percent for communications equipment. See text for details and sources. A contribution is defined as the share-weighted, real growth rate. CD refers to consumers' durable assets. All values are percentages.

This exercise illustrates the sensitivity of the sources of growth to alternative information technology price indices. We do not propose to argue the two alternative cases are more nearly correct than the Base case with the official prices from NIPA. Given the paucity of quality-adjusted price data on high-tech equipment, we simply do not know. Rather, we have tried to highlight the importance of correctly measuring prices and quantities to understand the dynamic forces driving economic growth in the United States. As high-tech assets continue to proliferate through the economy and other investment goods become increasingly dependent on electronic components, these measurement issues will become increasingly important. While the task that lies ahead of us will be onerous, the creation of quality-adjusted price indices for all high-tech assets deserves top priority.

2.2.7 Decomposition of TFP Growth

We next consider the role of high-tech industries as a source of TFP growth. As discussed above, the production of high-tech investment goods has made an important contribution to aggregate growth. CEA (2000), for example, allocates 0.39 percentage points of aggregate TFP growth to computer production, while Oliner and Sichel (2000) allocate 0.47 percentage points to the production of computers and computer-related semi-conductors for the period 1995-99.[32]

We employ a methodology based on the price "dual" approach to measurement of productivity at the industry level. Anticipating our complete industry analysis presented in Section 4, below, it is worthwhile to spell out the decomposition of TFP growth by industry. Using the Domar approach to aggregation, industry-level productivity growth is weighted by the ratio of the gross output of each industry to aggregate value-added in order to estimate the industry contribution to aggregate TFP growth. In the dual approach, the rate of productivity growth is measured as the decline in the price of output, plus a weighted average of the growth rates of input prices.

In the case of computer production, this expression is dominated by two terms; namely, the price of computers and the price of semi-conductors, a primary intermediate input to the computer-producing industry. If semi-conductor industry output is used only as an intermediate good to produce computers, then its contribution to the productivity growth of the computer industry, weighted by computer industry output, precisely cancels its independent contribution to aggregate TFP growth.[33] This independent contribution from the semi-conductor industry, based on the complete Domar weighting scheme, is the value of semi-conductor output divided by aggregate value added, multiplied by the rate of price decline in semi-conductors.

In Table 2.5, we report details of our TFP decomposition for the three alternative cases described above for 1990-95 and 1995-98 and summarize the IT vs. non-IT comparison in Figure 2.10. In our Base case, using official NIPA data, we estimate that the production of information technology accounts for 0.44 percentage points in 1995-98, compared to 0.25 percentage points in 1990-95. This reflects the accelerating relative price changes due to a radical shortening of the product cycle of semi-conductors.[34]

As we have already noted, the estimates of price declines for high-tech investments in our Base case calculations may be conservative; in fact, these estimates may be *very* conservative. Consider the Moderate Price Decline case, which reflects only part of the data we would require for constant-quality estimates of the information technology price declines. This boosts the contribution of information technology to TFP growth to 0.64 percentage points, an increase of 0.20 percentage points for 1995-98. Proceeding to what may appear to be the outer limit of plausibility, but still consistent with the available evidence, we can consider the Rapid Price Decline case. The contribution of information technology to TFP growth is now a robust 0.86 percentage points, accounting for all of TFP growth during 1995-98.

As a final observation from the TFP decomposition, we note that the acceleration of TFP in the late 1990s does not appear to be entirely located within IT-producing industries. While the actual growth rates vary considerably across our three alternative cases, non-IT TFP growth increased markedly in each case when the early 1990s are compared to the late 1990s. This runs counter to the conclusion of Gordon (1999b), who reports that the entire acceleration of labour productivity growth in the late 1990s reflects gains in IT-production. This divergence likely reflects Gordon's detrending procedure, which attributes a sizeable portion of the recent productivity growth to cyclical factors, as well as his focus on labour productivity and our focus on TFP growth.

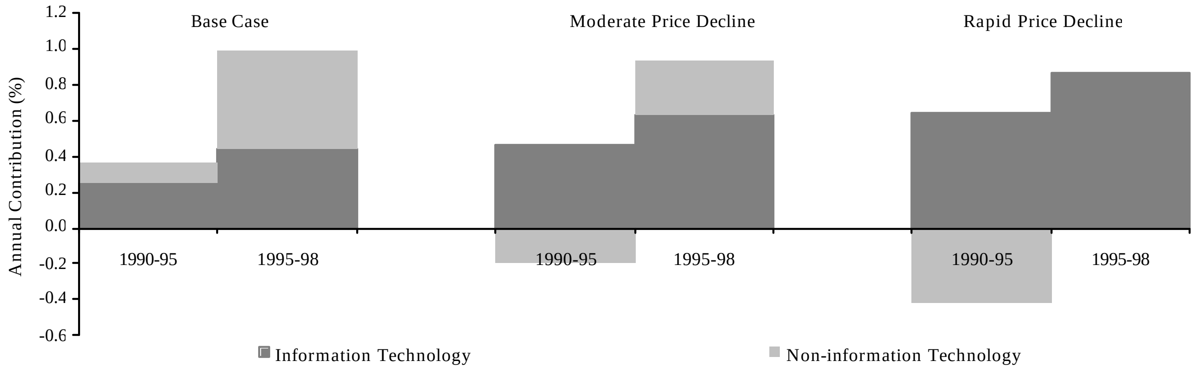
Table 2.5
Information Technology Decomposition of TFP Growth for Alternative Deflation Cases, 1990-98

	Base Case		Moderate Price Decline		Rapid Price Decline	
	1990-95	**1995-98**	**1990-95**	**1995-98**	**1990-95**	**1995-98**
Aggregate TFP Growth	0.36	0.99	0.27	0.93	0.23	0.85
	TFP Contribution					
Information Technology	0.25	0.44	0.46	0.64	0.64	0.86
Computers	0.16	0.32	0.16	0.32	0.16	0.32
Software	0.05	0.08	0.17	0.18	0.28	0.34
Communications Equipment	0.04	0.04	0.13	0.13	0.21	0.20
Non-information Technology	0.11	0.55	-0.19	0.29	-0.41	-0.01
	Relative Price Change					
Computers	-16.6	-29.6	-16.6	-29.6	-16.6	-29.6
Software	-3.4	-4.2	-11.3	-9.7	-18.0	-18.0
Communications Equipment	-3.5	-3.8	-12.7	-12.7	-19.9	-19.9
	Average Nominal Share					
Computers	0.96	1.09	0.96	1.09	0.96	1.09
Software	1.54	1.88	1.54	1.88	1.54	1.88
Communications Equipment	1.05	1.02	1.05	1.02	1.05	1.02

Note: The Base case uses official NIPA price data. The Moderate Price Decline case uses the pre-packaged software deflator for all software and -10.7 percent for communications equipment. The Rapid Price Decline case uses -16 percent for software and -17.9 percent for communications equipment. See the text for details and sources. A TFP contribution is defined as the share-weighted growth rate of relative prices.

Figure 2.10

TFP Decomposition for Alternative Deflation Cases



Note: The annual contribution of information technology is the share-weighted decline in relative prices.

This acceleration of non-IT TFP growth could also be interpreted as evidence of a "new economy." If these productivity gains do indeed reflect spillovers from IT into non-IT industries, this would provide some missing evidence for the new economy side. Alternatively, this could reflect technological progress in non-IT industries that is entirely independent of the IT revolution. Differentiation between these two hypotheses is impossible at the aggregate level, and requires detailed industry data for the most recent period of 1995-98. Without this data, identification problems prevent us from drawing firm conclusions about the sources and implications of the acceleration of TFP in non-IT industries.

2.3 Setting the Speed Limit

WE NOW CONSIDER THE SUSTAINABILITY of recent U.S. growth trends over longer time horizons. Rapid output growth is highly desirable, of course, but cannot continue indefinitely if it is fuelled by a falling unemployment rate and higher labour force participation. Output growth driven by continuing TFP improvements, on the other hand, is more likely to persist. The sustainability of growth has clear implications for government policies. Since economic growth affects tax revenues, potential government expenditures and the long-term viability of programs like Social Security and Medicare, it is closely monitored by government agencies. This section examines the impact of the recent success of the U.S. economy on official growth forecasts.

2.3.1 A Brief Review of Forecast Methodologies

The importance of economic growth for the U.S. government is evident in the considerable effort expended on projecting future growth. No fewer than five government agencies — the Congressional Budget Office (CBO), the Social Security Administration (SSA), the Office of Management and Budget (OMB), the Council of Economic Advisors (CEA), and the General Accounting Office (GAO) — report estimates of future growth for internal use or public discussion. This section briefly discusses the methodologies employed by these agencies.[35]

All forecasts are based on models that rest securely on neoclassical foundations. While the details and assumptions vary, all employ an aggregate production model similar to Equation (1), either explicitly or implicitly. In addition, they all incorporate demographic projections from the SSA as the basic building block for labour supply estimates. The CBO (1995, 1997, 1999a, 1999b, 2000) and the GAO (1995, 1996) employ an aggregate production function and describe the role of labour growth, capital accumulation, and technical progress explicitly. On the other hand, the SSA (1992, 1996), the OMB (1997, 2000), and the CEA (2000) employ a simplified relationship where output growth equals the sum of the growth in hours worked and labour productivity. Projections over longer time horizons are driven by aggregate supply with relatively little attention paid to business cycle fluctuations and aggregate demand effects.

Given the common framework and source data, it is not surprising that the projections are quite similar. Reporting on estimates released in 1997, Stiroh (1998b) finds that the SSA and the GAO projections of per capita GDP in 2025 were virtually identical, while that of the CBO was about 9 percent higher due to economic feedback effects from the improving government budget situation. More recently, the CBO (2000) projects real GDP growth of 2.8 percent and the OMB (2000) projects 2.7 percent for the period 1999-2010, while the CEA (2000) reports 2.8 percent for 1999-2007. Although the timing is slightly different — the CBO projects faster growth than the OMB earlier in the period and the CEA reports projections only through 2007 — the estimates are virtually identical. All three projections identify the recent investment boom as a contributor to rising labour productivity and capital deepening and as a source of continuing economic growth. We now consider the CBO projections in greater detail.

2.3.2 CBO's Growth Projections

The CBO utilizes a sophisticated and detailed, multi-sector growth model of the U.S. economy.[36] The core of this model is a two-factor production function for the non-farm business sector, with CBO projections based on labour force growth, national savings and investment, and exogenous TFP growth. Production function parameters are calibrated to historical data, using a Cobb-Douglas model:

$$(6) \qquad Y = A \cdot H^{0.7} \cdot K^{0.3}$$

where Y is potential output, H is potential hours worked, K is capital input, and A is potential total factor productivity.[37]

The CBO projects hours worked on the basis of demographic trends, with separate estimates for different age and sex classifications. These estimates incorporate the SSA estimates of population growth, as well as internal CBO projections of labour force participation and hours worked for the different categories. However, the CBO does not use this demographic detail to identify changes in labour quality. Capital input is measured as the service flow from four types of capital stocks — producers' durable equipment excluding computers, non-residential structures, and inventories. Stocks are estimated by the perpetual inventory method and weighted by rental prices, thereby incorporating some changes in capital quality. TFP growth is projected on the basis of recent historical trends, with labour quality growth implicitly included in CBO's estimate of TFP growth.

Turning to the most recent CBO projections, reported in CBO (2000), we focus on the non-farm business sector, which drives the GDP projections and is based on the most detailed growth model. Table 2.6 summarizes the CBO's growth rate estimates for the 1980s and 1990s, and projections for 1999-2010. We also present estimates from the BLS (2000) and our results.[38] The CBO projects potential GDP growth of 3.1 percent for 1999-2010, up slightly from 3.0 percent in the 1980s and 2.9 percent in the 1990s. The CBO expects actual GDP growth to be somewhat slower at 2.8 percent, as the economy moves to a sustainable, long-run growth rate. Acceleration in potential GDP growth reflects faster capital accumulation and TFP growth, partly offset by slower growth in hours worked. Projected GDP growth is 0.4 percent higher than earlier estimates (CBO, 1999b) due to an upward revision in capital growth (0.1 percent), slightly more rapid growth in hours worked (0.1 percent), and faster TFP growth, reflecting the benchmark revisions of NIPA, and other technical changes (0.2 percent).[39] The CBO's estimates for the non-farm business sector show strong potential output growth of 3.5 percent for 1999-2010. While projected output growth is in line with the experience of the 1990s and somewhat faster than the 1980s, there are significant differences in the underlying sources. Most important, the CBO projects an increasing role for capital accumulation and TFP growth over the next decade, while the growth in the number of hours worked will slow. This implies that future output growth will be driven by ALP growth, rather than the growth in hours worked.

Table 2.6
Growth Rates of Output, Inputs, and Total Factor Productivity, Comparison of the BLS, the CBO, and Jorgenson-Stiroh

	BLS	CBO						Jorgenson-Stiroh	
	Non-farm Business	Overall Economy			Non-farm Business				
	1990-99	1980-90	1990-99	1999-2010	1980-90	1990-99	1999-2010	1980-90	1990-98
Real Output	3.74	3.0	2.9	3.1	3.2	3.4	3.5	3.48	3.55
Labour Input								2.14	2.34
Hours Worked	1.68	1.6	1.2	1.1	1.6	1.5	1.2	1.81	1.76
Labour Quality								0.33	0.58
Capital Input					3.6	3.6	4.4	3.57	3.68
TFP - not adjusted for labour quality					0.9	1.2	1.4	0.91	0.97
TFP - adjusted for labour quality								0.73	0.63
ALP	2.06	1.4	1.7	1.9	1.5	1.9	2.3	1.67	1.79

Note: The CBO estimates refer to "potential" series that are adjusted for business cycle effects. Growth rates do not exactly match those of Table 2.5 since discrete growth rates are used here for consistency with CBO's methodology. Hours worked for CBO Overall Economy refers to potential labour force.

The CBO projects that potential non-farm business ALP growth for 1999-2010 will rise to 2.3 percent, powered by capital deepening (3.2 percent) and TFP growth (1.4 percent). This represents a marked jump in ALP growth, relative to the rate of 1.5 percent recorded in the 1980s and of 1.9 percent recorded in the 1990s. In considering whether the recent acceleration in ALP growth represents a trend break, the CBO "gives considerable weight to the possibility that the experience of the past few years represents such a break (CBO, 2000, p. 43)." This assumption appears plausible given recent events, and low unemployment and high labour force participation make growth in hours worked a less likely source of future growth. Falling investment prices for information technology make capital deepening economically attractive, while the recent acceleration in TFP growth gives further grounds for optimistic projections.

As the investment boom continues and firms substitute more information technology in their production, the CBO has steadily revised its projected growth rates of capital upward. It is worthwhile to note just how much the role of capital accumulation has grown in successive CBO projections, rising from a projected growth rate of 3.6 percent in January 1999 (CBO, 1999a) to 4.1 percent in July 1999 (CBO, 1999b), to 4.4 percent in January 2000 (CBO, 2000). This reflects the inclusion of relatively fast-growing software investment in the benchmark revision of NIPA, but also extrapolates recent investment patterns.

Similarly, the CBO has raised its projected rate of TFP growth in successive estimates — from 1.0 percent in January 1999 to 1.1 percent in July 1999, to 1.4 percent in January 2000.[40] These upward revisions reflect methodological changes in the way the CBO accounts for the rapid price declines in investment, particularly computers, which added 0.2 percent. The CBO adjustments for the benchmark revision of NIPA contributed another 0.1 percent.

Table 2.6 also reports our own estimates of growth for roughly comparable periods. While the time periods are not precisely identical, our results are similar to CBO's. We estimate slightly faster growth during the 1980s, due to rapidly growing consumers' durable services, but slightly lower rates of capital accumulation due to our broader measure of capital. Our growth of hours worked is higher, since we omit the cyclical adjustments made by the CBO to develop their potential series.[41] Finally, our TFP growth rates are considerably lower, due to our labour quality adjustments and inclusion of consumers' durables. If we were to drop the labour quality adjustment, our estimate would rise to 1.0 percent per year from 1990 to 1998, compared to 1.2 percent for the CBO over 1990-99. The remaining difference reflects the fact that we do not include the rapid TFP growth of 1999, but do include the services of consumers' durables, which involve no growth in TFP.

2.3.3 Evaluating the CBO' s Projections

Evaluating the CBO's growth projections requires an assessment of their estimates of the growth of capital, labour, and TFP. It is important to emphasize that this is not intended as a criticism of the CBO, but rather a description of "best practice" in the difficult area of growth projections. We also point out that comparisons between our estimates and the CBO's estimates are not exactly due to our broader output concept and our focus on actual data series, as opposed the potential series that are the focus of the CBO.

We begin with the CBO's projections for potential labour input. These data, based on the hours worked from the BLS and SSA demographic projections, show a decline in the growth of hours worked from 1.5 percent in the 1990s to 1.2 percent for the period 1999-2010. This slowdown reflects familiar demographic changes associated with the aging of the U.S. population. However, the CBO does not explicitly estimate labour quality, so that labour composition changes are included in the CBO's estimates of TFP growth and essentially held con stant.

We estimate growth in labour quality of 0.57 percent per year for 1990-98, while our projections based on demographic trends yield a growth rate of only 0.32 percent for the 1998-2010 period. Assuming the CBO's labour share of 0.70, this implies a decline in the contribution from labour quality to growth of about 0.18 percentage points per year over CBO's projection horizon. Since this labour quality effect is implicitly incorporated into the CBO's TFP estimates, we conclude that their TFP projections are overstated by this 0.18 percentage points decline in the labour quality contribution.

TFP growth is perhaps the most problematic issue in long-term projections. Based on the recent experience of the U.S. economy, it appears reasonable to expect strong future productivity performance. As discussed above and shown in Table 2.2, TFP growth has increased markedly during the period 1995-98. However, extrapolation of this experience runs the risk of assuming that a temporary productivity spurt is a permanent change in trend.

Second, the recent acceleration of TFP growth is due in considerable part to the surge in productivity growth in IT-producing industries. This makes the economy particularly vulnerable to slowing productivity growth in these industries. Computer prices have declined at extraordinary rates in recent years and it is far from obvious that this can continue. However, acceleration in the rate of decline reflects the change in the product cycle for semi-conductors, which has shifted from three years to two years and may be permanent.

We conclude that the CBO's projection of TFP growth is optimistic in assuming a continuation of recent productivity trends, but nonetheless reasonable. However, we reduce this projection by only 0.18 percent per year to reflect the decline in labour quality growth, resulting in projected TFP growth of 1.22 percent per year. To obtain a projection of labour input growth we add labour quality growth of 0.32 percent per year to the CBO's projection of growth in hours worked of 1.2 percent per year. Multiplying a labour input growth of 1.52 percent per year by the CBO labour share of 0.7, we obtain a contribution of labour input of 1.06 percent.

The CBO's projected annual growth of capital input of 4.4 percent is higher than in any other decade, and 0.8 percent higher than in the 1990s.[42] This projection extrapolates recent increases in the relative importance of computers, software, and communications equipment. Continuing rapid capital accumulation is also predicated on the persistence of high rates of decline in asset prices, resulting from rapid productivity growth in the IT producing sectors. Any attenuation in this rate of decline would produce a double whammy — less TFP growth in IT-producing industries and reduced capital deepening elsewhere.

Relative to historical trends, the CBO's capital input growth projection of 4.4 percent seems out of line with the projected growth of potential output of 3.5 percent. During the 1980s, capital growth exceeded potential output growth by 0.4 percent, according to their estimates, or 0.1 percent in our estimates. In the 1990s, capital growth exceeded output growth by only 0.2 percent, again according to their estimates, and 0.1 percent in our estimates. This difference jumps to 0.9 percent for the period covered by the CBO's projections, that is 1999-2010.

Revising the growth of capital input downward to reflect the difference of 0.2 percent between the growth of output and the growth of capital input during the period 1995-98 would reduce the CBO's projected output growth to 3.35 percent per year. This is the sum of the projected growth of TFP of 1.22 percent per year, the contribution of labour input of 1.06 percent per year, and the contribution of capital input of 1.07 percent per year. This is a very modest reduction in output growth from the CBO's projection of 3.5 percent per year that can be attributed to the omission of a projected decline in labour quality growth.

We conclude that the CBO's projections are consistent with the evidence presented, as well as with our own analysis of recent trends. We must emphasize, however, that any slowdown of the technical progress in information technology could have a major impact on potential growth. Working through both output and input channels, the U.S. economy has become highly dependent on information technology as the driving force behind continued growth. Should productivity growth in these industries falter, the projections we have reviewed could be overly optimistic.

2.4 Industry Productivity

WE HAVE EXPLORED THE SOURCES of U.S. economic growth at the aggregate level and demonstrated that accelerated TFP growth is an important contributor to the recent growth resurgence. Aggregate TFP gains — the ability to produce more output from the same inputs — reflects the evolution of the production structure at the plant or firm level in response to technological changes, managerial choices, and economic shocks. These firm- and industry-level changes then cumulate to determine aggregate TFP growth. We now turn our attention to industry data to trace aggregate TFP growth to its sources in the productivity growth of individual industries, as well as the reallocations of output and inputs among industries.

Our approach utilizes the framework of Jorgenson, Gollop, and Fraumeni (1987) for quantifying the sources of economic growth in U.S. industries. The industry definitions and data sources have been brought up-to-date. The methodology of Jorgenson, Gollop, and Fraumeni for aggregating over industries is based on Domar's (1961) approach to aggregation. Jorgenson and Stiroh (2000) have presented summary data from our work; other recent studies of industry-level productivity growth include BLS (1999), Corrado and Slifman (1999), and Gullickson and Harper (1999). The remainder of this section summarizes our methodology and discusses the results.

2.4.1 Methodology

As with the aggregate production model discussed in Section 2, we begin with an industry-level production model for each industry. A crucial distinction, however, is that industry output Q_i is measured using a "gross output" concept, which includes output sold to final demand as well as output sold to other industries as intermediate goods. Similarly, inputs include all production inputs, including capital services K_i and labour services L_i, as well as intermediate inputs, energy E_i and materials M_i, purchased from other industries.[43] Our model is based on the industry production function:

$$(7) \qquad Q_i = A_i \cdot X_i(K_i, L_i, E_i, M_i)$$

where time subscripts have been suppressed for clarity.

We can derive a growth accounting equation similar to Equation (2) for each industry in order to measure the sources of economic growth for individual industries. The key difference is the use of gross output and an explicit accounting of the contribution to growth of intermediate inputs purchased from other industries. This yields:

$$(8) \qquad \Delta \ln Q_i = \overline{w}_{K_i} \Delta \ln K_i + \overline{w}_{L_i} \Delta \ln L_i + \overline{w}_{E_i} \Delta \ln E_i + \overline{w}_{M_i} \Delta \ln M_i + \Delta \ln A_i$$

where $\overline{w}_i$ is the average share of the subscripted input in the ith industry, and the assumptions of constant returns to scale and competitive markets imply that $\overline{w}_{K_i} + \overline{w}_{L_i} + \overline{w}_{E_i} + \overline{w}_{M_i} = 1$.

The augmentation factor $\Delta \ln A_i$ represents the growth in output not explained by input growth and is conceptually analogous to the TFP concept used above in the aggregate accounts. It represents efficiency gains, technological progress, scale economies, and measurement errors that allow more measured gross output to be produced from the same set of measured inputs. We refer to this term as *industry productivity* or simply *productivity* to distinguish it from TFP, which is estimated from a value-added concept of output.[44]

Domar (1961) first developed an internally consistent methodology that linked industry-level productivity growth in Equation (8) with aggregate TFP growth in Equation (2). He showed that aggregate TFP growth can be expressed as a weighted average of industry productivity growth:

$$(9) \qquad \Delta \ln A = \sum_{i=1}^{37} \overline{w}_i \cdot \Delta \ln A_i, \quad \overline{w}_i = \frac{1}{2}\left(\frac{P_{i,t} \cdot Q_{i,t}}{P_{Y,t} \cdot Y_t} + \frac{P_{i,t-1} \cdot Q_{i,t-1}}{P_{Y,t-1} \cdot Y_{t-1}} \right)$$

where $\overline{w}_i$ is the "Domar weight", $P_i{\cdot}Q_i$ is current dollar gross output in sector i, and $P_Y{\cdot}Y$ is current dollar aggregate value-added. This simplified version of the aggregation formula given by Jorgenson, Gollop, and Fraumeni (1987), excludes re-allocations of value added, capital input, and labour input by sector. Jorgenson and Stiroh (2000) show that these terms are negligible for the period 1958-96, which is consistent with the results of Jorgenson, Gollop, and Fraumeni (1987), and Jorgenson (1990) for periods of similar duration.

Domar weights have the notable feature of not summing up to unity. This reflects the different output concepts used at the aggregate and industry levels in Equations (1) and (7), respectively. At the aggregate level, only primary inputs are included, while both primary and intermediate inputs are included in the industry production functions. For the typical industry, gross output considerably exceeds value added, so the sum of gross output across industries exceeds the sum of value added. This weighting methodology implies that economy-wide TFP growth can grow faster than productivity in any industry, since productivity gains are magnified as they work their way through the production process.[45]

In addition to providing an internally consistent aggregation framework, industry-level gross output allows an explicit role for intermediate goods as a source of industry growth. For example, Triplett (1996) shows that a substantial portion of the price declines in computer output can be traced to steep price declines in semi-conductors, the major intermediate input in the computer-producing industry. Price declines in semi-conductors reflect technological progress — Moore's law in action. This should be measured as productivity growth in the industry that produces semi-conductors. By correctly accounting for the quantity and quality of intermediate inputs, the gross output concept allows aggregate TFP gains to be correctly allocated among industries.

2.4.2 Data Sources

Our primary data include a set of inter-industry transactions accounts developed by the Employment Projections Office of the BLS. The data cover a relatively short time period from 1977 to 1995. We linked the BLS estimates to industry-level estimates back to 1958, described by Stiroh (1998a), and extrapolated to 1996 using current BLS and BEA industry data.[46] This generated a time series from 1958 to 1996 for 37 industries, at roughly the two-digit Standard Industrial Classification (SIC) level, including Private Households and General Government.[47] Table 2.7 lists the 37 industries, the relative size in terms of 1996 value added and gross output, and the underlying SIC codes for each industry.

Before proceeding to the empirical results, we should point out two limitations of this industry-level analysis. Due to the long lag in obtaining detailed inter-industry transactions, investment, and output data by industry, our industry data are not consistent with the BEA benchmark revision of NIPA published in December 1999; they correspond to the NIPA produced by the BEA in November 1997. As a consequence, they are not directly comparable to the aggregate data described in Tables 2.1 through 2.6. Since the impact of the benchmark revision was to raise output and aggregate TFP growth, it is not surprising that the industry data show slower output and productivity growth. In addition, our estimates of rental prices for all assets in this industry analysis are based on the industry-wide asset revaluation terms, as in Stiroh (1998a). They are not directly comparable to the aggregate data on capital input, where asset-specific revaluation terms are included in the rental price estimates. The use of industry-wide revaluation terms tends to reduce the growth in capital services since assets with falling relative prices, such as computers, have large service prices and rapid accumulation rates.

Table 2.7
1996 Value Added and Gross Output by Industry

Industry	SIC Codes	Value Added	Gross Output
Agriculture	01-02, 07-09	133.3	292.2
Metal Mining	10	8.8	10.7
Coal Mining	11-12	14.7	21.1
Petroleum and Gas	13	57.4	83.3
Non-metallic Mining	14	10.5	17.0
Construction	15-17	336.0	685.5
Food Products	20	147.2	447.6
Tobacco Products	21	26.7	32.7
Textile Mill Products	22	19.9	58.9
Apparel and Textiles	23	40.7	98.5
Lumber and Wood	24	34.2	106.7
Furniture and Fixtures	25	23.4	54.5
Paper Products	26	68.3	161.0
Printing and Publishing	27	113.5	195.6
Chemical Products	28	184.0	371.2
Petroleum Refining	29	44.7	184.3
Rubber and Plastic	30	64.1	148.9
Leather Products	31	3.4	8.1
Stone, Clay, and Glass	32	40.4	79.1
Primary Metals	33	57.6	182.1
Fabricated Metals	34	98.4	208.8
Industrial Machinery and Equipment	35	177.8	370.5
Electronic and Electric Equipment	36	161.9	320.4
Motor Vehicles	371	84.9	341.6
Other Transportation Equipment	372-379	68.0	143.8
Instruments	38	81.3	150.0
Miscellaneous Manufacturing	39	24.8	49.3
Transport and Warehouse	40-47	258.6	487.7
Electric Utilities	491, 493	111.8	186.7
Gas Utilities	492, 493, 496	32.9	57.9
Trade	50-59	1,201.2	1,606.4
FIRE	60-67	857.8	1,405.1
Services	70-87, 494-495	1,551.9	2,542.8
Government Enterprises		95.2	220.2
Private Households	88	1,248.4	1,248.4
General Government		1,028.1	1,028.1

Note: All values are in current dollars. Value added refers to payments to capital and labour. Gross output includes payments for intermediate inputs.

2.4.3 Empirical Results

2.4.3.a Sources of Industry Growth

Table 2.8 reports estimates of the components of Equation (8) for the period 1958-96. For each industry, we show output growth, the contribution of each input (defined as the nominal share-weighted growth rate of the input), and productivity growth. We also report average labour productivity (ALP) growth, defined as real gross output per hour worked, and the Domar weights calculated from Equation (9). We focus the discussion of our results on industry productivity and ALP growth.

Industry productivity growth was the highest in two high-tech industries, Industrial Machinery and Equipment, and Electronic and Electric Equipment, at 1.5 percent and 2.0 percent per year, respectively. Industrial Machinery includes the production of computer equipment (SIC no. 357) and Electronic Equipment includes the production of semi-conductors (SIC no. 3674) and communications equipment (SIC no. 366). The enormous technological progress in the production of these high-tech capital goods has generated falling prices and productivity growth, and fuelled the substitution towards information technology.

An important feature of the data is that productivity growth can be isolated for industries that produce intermediate goods, for example, Electronic and Electric Equipment.[48] Consider the contrast between computer production and semi-conductor production. Computers are part of final demand, sold as consumption and investment goods, and can be identified in the aggregate data, as was done in Table 2.2. Semi-conductors, on the other hand, do not appear at the aggregate level, since they are sold almost entirely as an input to computers, telecommunications equipment, and an increasingly broad range of other products such as machine tools, automobiles, and virtually all recent vintages of appliances. Nonetheless, improved semi-conductor production is an important source of aggregate TFP growth since it is ultimately responsible for the lower prices and improved quality of goods like computers produced for final demand.

The enormous price declines in computer equipment and the prominent role of investment in computers in the GDP accounts have led Gordon (1999b), Whelan (1999), and others to emphasize technological progress in the production of computers. Triplett (1996), however, quantifies the role of semi-conductors as an intermediate input and estimates that falling semi-conductor prices may account for virtually all of the relative price decline in computer equipment. He concludes, "productivity in the computer industry palls beside the enormous increases in productivity in the semi-conductor industry (Triplett, 1996, p. 137)."[49]

The decline in the prices of semi-conductors is reflected in the prices of intermediate input into the computer industry, effectively moving productivity away from computers and toward semi-conductor production. Building on this observation, Oliner and Sichel (2000) present a model that includes 3 sectors — semi-conductor production, computer production, and other goods — and shows that productivity in the semi-conductors sector is substantially more important than productivity in the computer sector. Our complete industry framework with Domar aggregation over all industries captures the contributions of productivity growth from all industries.

The impact of intermediate inputs can be seen in Table 2.8 in the large contribution of material inputs in the Industrial Machinery industry. Since a substantial portion of these inputs consists of semi-conductors purchased from the Electronic Equipment industry, productivity gains that lower the prices of semi-conductors increase the flow of intermediate inputs into the Industrial Machinery industry. By correctly accounting for these inputs, industry productivity growth in the Industrial Machinery industry falls, and we can rightly allocate technological progress to the Electronic Equipment industry, which produces semi-conductors. While this type of industry reallocation does not affect aggregate productivity growth, it is important to identify the sources of productivity growth and allocate the latter among industries in order to assess the sustainability of the recent acceleration in productivity.

The two high-tech industries also show high rates of average labour productivity (ALP) growth, respectively 3.1 and 4.1 percent per year. This reflects an underlying relationship similar to Equation (3) for the aggregate data, where industry ALP growth reflects industry productivity growth, labour quality growth, and increases in input intensity, including increases in capital as well as intermediate inputs per hour worked. As implied by Table 2.8, these industries showed rapid accumulation of capital and intermediate inputs, which raised ALP growth above productivity growth. It is also worthwhile to note that Communications, another high-tech industry, shows an ALP growth much faster than industry productivity growth due to the rapid accumulation of inputs, notably intermediate materials. These results highlight the crucial importance of accounting for all inputs when examining the sources of industry growth.

Table 2.8
Sources of U.S. Economic Growth by Industry, 1958-96

Industry	Output Growth	Contributions of Inputs				Productivity Growth	ALP Growth	Domar Weight
		Capital	Labour	Energy	Materials			
Agriculture	1.70	0.19	-0.13	-0.04	0.51	1.17	3.21	0.062
Metal Mining	0.78	0.73	-0.07	-0.07	-0.26	0.44	0.99	0.003
Coal Mining	2.35	0.82	0.00	0.06	0.63	0.84	2.32	0.005
Petroleum and Gas	0.43	0.61	-0.01	0.06	0.20	-0.44	0.88	0.022
Non-metallic Mining	1.62	0.59	0.18	0.06	0.34	0.46	1.52	0.003
Construction	1.43	0.07	0.87	0.02	0.91	-0.44	-0.38	0.113
Food Products	2.20	0.21	0.18	0.00	1.27	0.54	1.59	0.076
Tobacco Products	0.43	0.59	0.05	0.00	-0.01	-0.20	0.88	0.004
Textile Mill Products	2.23	0.12	0.02	0.01	0.86	1.23	2.54	0.013
Apparel and Textiles	2.03	0.24	0.17	0.00	0.82	0.80	2.01	0.022
Lumber and Wood	2.24	0.21	0.33	0.02	1.70	-0.02	1.55	0.015
Furniture and Fixtures	2.91	0.31	0.58	0.02	1.44	0.56	1.78	0.007
Paper Products	2.89	0.50	0.40	0.05	1.51	0.42	1.96	0.022
Printing and Publishing	2.51	0.55	1.20	0.02	1.19	-0.44	0.14	0.024
Chemical Products	3.47	0.74	0.47	0.09	1.58	0.58	2.02	0.048
Petroleum Refining	2.21	0.44	0.24	0.49	0.71	0.33	0.80	0.033
Rubber and Plastic	5.17	0.47	1.16	0.08	2.43	1.04	1.94	0.016
Leather Products	-2.06	-0.11	-1.13	-0.02	-1.08	0.28	2.08	0.004
Stone, Clay, and Glass	1.86	0.26	0.37	0.00	0.82	0.41	1.30	0.014
Primary Metals	1.14	0.13	0.05	-0.03	0.77	0.22	1.51	0.040

Table 2.8 (cont'd)

Industry	Output Growth	Contributions of Inputs: Capital	Labour	Energy	Materials	Productivity Growth	ALP Growth	Domar Weight
Fabricated Metals	2.28	0.26	0.28	0.00	1.09	0.65	1.88	0.035
Industrial Machinery and Equipment	4.79	0.52	0.75	0.02	2.04	1.46	3.15	0.048
Electronic and Electric Equipment	5.46	0.76	0.65	0.03	2.04	1.98	4.08	0.036
Motor Vehicles	3.61	0.28	0.29	0.02	2.78	0.24	2.28	0.043
Other Transportation Equipment	1.31	0.23	0.37	0.00	0.52	0.18	1.00	0.027
Instruments	5.23	0.65	1.44	0.03	1.99	1.12	2.57	0.017
Miscellaneous Manufacturing	2.53	0.34	0.41	0.00	0.95	0.82	2.08	0.008
Transport and Warehouse	3.25	0.20	0.72	0.12	1.34	0.86	1.74	0.061
Communications	5.00	1.62	0.53	0.02	1.95	0.88	3.93	0.033
Electric Utilities	3.22	1.01	0.20	0.67	0.83	0.51	2.52	0.026
Gas Utilities	0.56	0.66	-0.04	0.14	0.05	-0.24	0.94	0.016
Trade	3.66	0.62	0.83	0.04	1.19	0.98	2.49	0.195
FIRE	3.42	1.14	0.94	0.00	1.52	-0.18	0.66	0.131
Services	4.34	0.84	1.70	0.07	1.92	-0.19	0.92	0.208
Government Enterprises	2.86	1.24	1.08	0.23	0.83	-0.52	0.49	0.022
Private Households	3.50	3.55	-0.06	0.00	0.00	0.00	5.98	0.137
General Government	1.35	0.60	0.75	0.00	0.00	0.00	0.46	0.131

Note: Output growth is the average annual growth in real gross output. The contributions of inputs are defined as the average, share-weighted growth of the individual input. Productivity growth is defined in Equation (8). ALP growth is the growth in average labour productivity. The Domar weight is the average ratio of industry gross output to aggregate value added, as defined in Equation (9). All numbers except Domar weights are percentages.

Productivity growth in information technology provides a final perspective on the conclusions of Greenwood, Hercowitz, and Krusell (1997), and Hercowitz (1998). They argue that some 60 percent of post-war U.S. growth can be attributed to investment-specific (embodied) productivity growth, which they distinguish from input accumulation and (disembodied) productivity growth. They note that the relative price of equipment in the United States has fallen 3 percent per year, which they interpret as evidence of technical change that affects capital goods, but not consumption goods. Our decomposition, however, reveals that declines in the prices of investment goods are the consequence of improvements in industry (disembodied) productivity. The Domar aggregation shows how these improvements contribute directly to aggregate TFP growth. There is no separate role for investment-specific technical change.

Other industries that show relatively strong productivity growth include Agriculture, Textile Mill Products, Rubber and Plastic, Instruments, and Trade. All of these industries recorded productivity growth in the 1.0 percent per year range, and ALP growth in the 2 to 3 percent range. Industries with the slowest productivity growth include Petroleum and Gas, Construction, Printing and Publishing, and Government Enterprises, all of which showed a decline in productivity of nearly 0.5 percent per year.

It is worth emphasizing that 9 industries showed negative productivity growth over the entire period, a counter-intuitive result if we were to interpret productivity growth solely as technological progress. It is difficult to envision technology steadily worsening for a period of nearly 40 years as implied by these estimates. The perplexing phenomenon of negative technical progress was a primary motivation for the work of Corrado and Slifman (1999), and Gullickson and Harper (1999), who suggest persistent measurement problems as a plausible explanation. Corrado and Slifman (1999) conclude, "a more likely statistical explanation for the implausible productivity, profitability, and price trends... is that they reflect problems in measuring prices (p. 331)." If prices are systematically overstated because quality change is not accurately measured, then output and productivity are correspondingly understated. We do not pursue this idea here, but simply point out that measurement problems are considered a reasonable explanation by some statistical agencies.[50]

An alternative interpretation for negative productivity growth is the possibility of declines in efficiency that have no association with technology. These might include lower quality of management and a worsening of industrial organization as barriers to entry are raised. This appears to be a plausible explanation, given the widespread occurrence of negative productivity growth for extended periods of time. Until more careful research linking firm- and plant-level productivity to industry productivity estimates has been done, it would be premature to leap to the conclusion that estimates of economic performance should be adjusted so as to eliminate negative productivity growth rates, wherever they occur.

Low productivity growth rates are surprising in light of the fact that many of the affected industries are heavy investors in information technology. Stiroh (1998a), for example, reports that nearly 80 percent of computer investment in the early 1990s was in three service-related industries: Trade, FIRE, and Services. Triplett (1999) reports a high concentration in service industries using the BEA's capital use survey. The apparent combination of slow productivity growth and heavy computer-use remains an important obstacle for new economy proponents who argue that the use of information technology is fundamentally changing business practices and raising productivity throughout the U.S. economy.

2.4.3.b Comparison with Other Results

Before proceeding to the Domar aggregation results, it is useful to compare these results to those of three other recent studies — BLS (1999), Corrado and Slifman (1999), and Gullickson and Harper (1999). BLS (1999) reports industry productivity growth ("industry multifactor productivity" in their terminology) for 19 manufacturing industries over 1949-96. Corrado and Slifman (1999) report estimates of ALP growth for selected one- and two-digit SIC industries over the period 1977-97. Gullickson and Harper (1999) report industry productivity growth for certain one- and two-digit SIC industries based on two output series for the period 1947-92. Similar to BLS (1999), Gullickson and Harper use a "sectoral output" concept estimated by the Employment Projections staff at the BLS; also, for 1977-92, they use the BEA's gross output series, "adjusted for consistency."[51] Note that none of these studies reflect the BEA benchmark revision of NIPA.

Differences in time periods, industry classifications, and methodologies make a definitive reconciliation with our results impossible. For example, the BLS (1999) reports detailed manufacturing industries; Corrado and Slifman (1999) use a value-added concept, the BEA's "gross product originating," for output; Gullickson and Harper (1999) use the same data sources as we do, but make different adjustments for consistency and do not account for labour quality growth. Nonetheless, it is useful to compare broad trends over similar time periods to assess the robustness of our findings.

We first consider the ALP estimates produced by Corrado and Slifman (1999). We can compare similar time periods, but there are relatively few overlapping industries since our industry breakdown focuses on manufacturing industries, while they provide details primarily for service industries. For comparable industries, however, the results are quite similar. For 7 industries with comparable definitions, 5 show differences in ALP growth of less than 0.25 percent when we compare our estimates for 1977-96 to Corrado and Slifman's estimates for 1977-97 (Corrado and Slifman, 1999, Table 2.2).[52] Our ALP growth rates for Communication and Trade are below theirs by 1.3 percent and 0.4 percent, respectively, for these periods.

For the majority of industries, our productivity estimates for 1977-92 are similar to those of Gullickson and Harper (1999). The range of discrepancies is somewhat greater due to the difficulty of linking the various data sets needed to estimate intermediate inputs and industry productivity growth. For 7 of the 11 comparable industries, productivity differences are below 0.5 percent, while we found larger discrepancies for Metal Mining, Coal Mining, Petroleum and Gas, and Services.[53] Similar differences can also be seen in Gullickson and Harper's comparison of productivity growth estimated from the BLS and BEA gross output series, where they find differences of 0.5 percentage points or more in 17 out of 40 industries and aggregates. Methodological differences, such as the inclusion of labour quality growth in our estimates of labour input growth, contribute to this divergence, as do different methods of linking data sets.

Neither Corrado and Slifman (1999) nor Gullickson and Harper (1999) break out ALP growth or industry productivity growth among detailed manufacturing industries. To gauge these results, we have compared our manufacturing results to the manufacturing industry estimates produced by the BLS (1999). For the 18 industries that are comparable, 10 showed productivity differences of less than 0.25 percent for 1979-96; 2 showed differences varying between 0.25 percent and 0.5 percent; the remaining 6 industries, Textile

Mills, Lumber and Wood, Petroleum Refining, Leather, Stone, Clay and Glass, and Instruments, showed differences greater than 0.5 percent.[54]

2.4.3.c Domar Aggregation

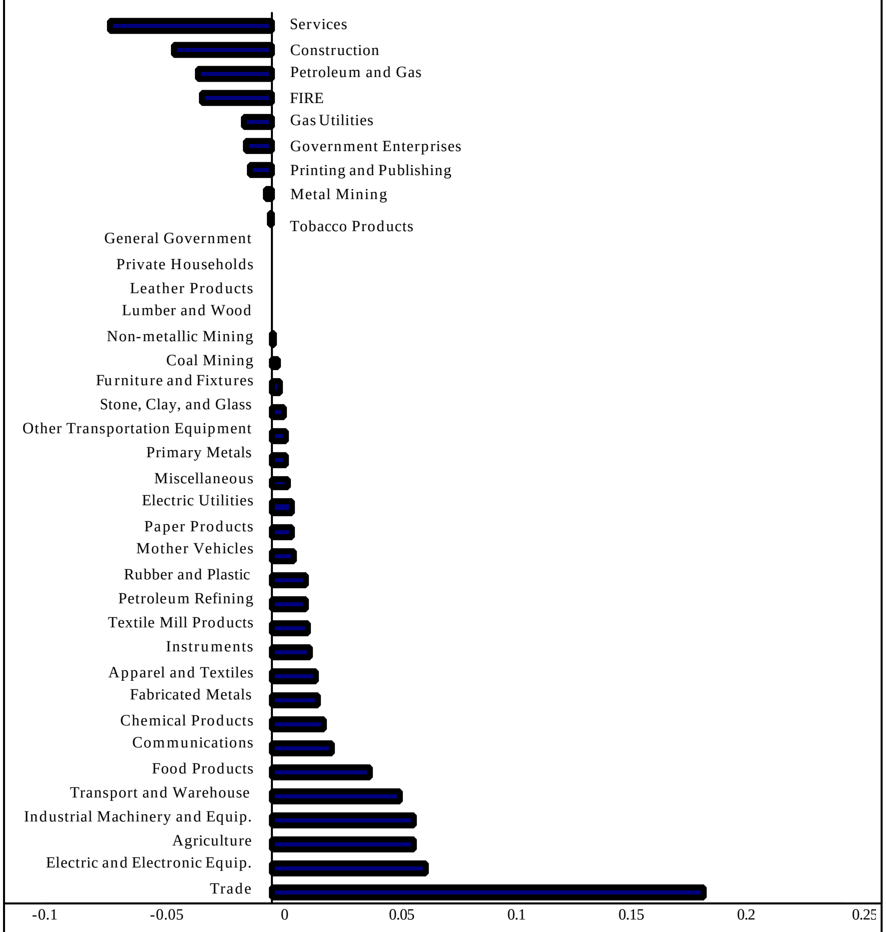
We now turn to the aggregation of industry productivity growth described by Equation (9). This is not directly comparable to our estimates of aggregate productivity, due to different vintages of data and a broader definition of output. Nonetheless, it is useful to quantify an industry's contribution to aggregate TFP growth and to trace aggregate productivity growth back to its sources at the level of the individual industry. These results update the earlier estimates of Jorgenson, Gollop, and Fraumeni (1987). Gordon (1999b) presents a similar decomposition of ALP growth, although he focuses exclusively on the contribution of computer production.

Figure 2.11 presents our estimates of each industry's contribution to aggregate TFP growth for the period 1958-96. This follows Equation (9) by weighting industry productivity growth by the "Domar weight," defined as industry gross output divided by aggregate value added. Summing across industries gives an estimate of aggregate TFP growth of 0.48 for 1958-96. This is lower than the number implied by Table 2.2 for two reasons. First, the data are prior to the BEA benchmark revision, which raised output and TFP growth. Second, the estimates reflect a broader output concept that includes Government Enterprises, which we estimate as having negative industry productivity growth, and General Government, which has zero productivity growth by definition. The estimate is consistent, however, with the estimates produced by Ho, Jorgenson, and Stiroh (1999), and Jorgenson and Stiroh (1999), which are based on the same vintage of data.

The most striking feature of Figure 2.11 is the wide range of industry contributions. Trade, Industrial Machinery, and Electronic Equipment make the largest contributions, although for different reasons. Trade has solid, but not exceptionally strong productivity growth of almost 1 percent per year; it makes the largest contribution due to its large relative size. Trade receives a Domar weight of nearly 0.20. Industrial Machinery and Electronic Equipment, on the other hand, make important contributions due to their rapid productivity growth, 1.5 percent and 2.0 percent, respectively, in spite of their relative small size, with Domar weights of 0.05 and 0.04, respectively. The contribution of an industry to aggregate productivity growth depends on both productivity performance and relative size.

Figure 2.11

Industry Contributions to Aggregate Total Factor Productivity Growth, 1958-96



Note: Each industry's contribution is calculated as the product of industry productivity growth and the industry Domar weight, averaged for 1958-96.

Figure 2.11 also highlights the impact of the 9 industries that experienced negative productivity growth over this period. Again, both performance and relative size matter. The Services industry makes a negative contribution of 0.07 due to its large weight and productivity growth of –0.19 percent. Construction, on the other hand, shows even slower industry productivity growth, –0.44 percent per year, but makes a smaller negative contribution, since it is much smaller than Services. We can also do a "thought experiment" similar to Corrado and Slifman (1999) and Gullickson and Harper (1999), and imagine that productivity growth is zero in these 9 industries rather than negative. By zeroing out the negative contributions, we find that aggregate TFP growth would have been 0.22 percent higher, an increase of nearly half.[55] Clearly, negative productivity growth in these industries is an important part of the aggregate productivity story.

Finally, these data enable us to provide some new perspective on an argument made by Gordon (1999b), who decomposes trend-adjusted ALP growth into a portion due to computer production and a residual portion for the rest of the economy.[56] He finds that the former accounts for virtually all of the productivity acceleration since 1997. While we cannot comment directly on his empirical estimates since our industry data end in 1996 and we examine TFP growth rather than ALP growth, we can point to an important qualification to his argument. The U.S. economy is made up of industries with both positive and negative productivity growth rates, so that comparing one industry to the aggregate of all others necessarily involves aggregation over off-setting productivity trends. The fact that this aggregate does not show net productivity growth does not entail the absence of gains in productivity in any of the component industries, since such gains could be offset by declines in other industries.

Consider our results for 1958-96 and the importance of the negative contributions. The 5 industries with the largest, positive contributions — Trade, Electronic Equipment, Agriculture, Industrial Machinery, and Transport — cumulatively account for a sum across all industries of about 0.5 percent per year. Nonetheless, we find sizeable productivity growth in some of the remaining industries that are offset by negative contributions in others. This logic and the prevalence of negative productivity growth rates at the industry level, in BLS (1999), Corrado and Slifman (1999), and Gullickson and Harper (1999), suggest that a similar argument could hold for ALP and for the most recent period. This raises the question of whether off-setting productivity growth rates are responsible for Gordon's finding that there is "no productivity growth in the 99 percent of the economy located outside the sector which manufactures computer hardware (Gordon, 1999b, p. 1)." Assessing the breadth of recent productivity gains and identifying the sources of productivity growth at the industry level remains an important task for future research.

2.5 Conclusion

THE PERFORMANCE OF THE U.S. ECONOMY in the late 1990s has been nothing short of phenomenal. After a quarter century of economic malaise, accelerating total factor productivity growth and capital deepening have led to a remarkable growth resurgence. The pessimism of the famous Solow (1987) paradox, that we see computers everywhere but in the productivity statistics, has given way to optimism about the information age. Productivity statistics, beginning in 1995, have begun to reveal a clearly discernible impact of information technology. Both labour productivity and TFP growth have jumped to rates not seen for such an extended period of time since the 1960s. While a substantial portion of these gains can be attributed to computers, there is growing evidence of similar contributions from software and communications equipment — each equal in importance to computers.

The forces shaping the information economy originate in the rapid progress of semi-conductor technology — Moore's Law at work. These gains are driving down the relative prices of computers, software, and communications equipment, and inducing massive investments in these assets by firms and households. Technological progress and the induced capital deepening are the primary factors behind accelerating output growth in recent years. The sustainability of recent growth trends, therefore, hinges to a large degree on the prospects for continuing progress, especially in the production of semiconductors. While this seems plausible, perhaps even likely, the contribution of high-tech assets to the stronger growth remains subject to considerable uncertainty, owing to incomplete information on the price trends of these assets.

The vibrant performance of the U.S. economy has not gone unnoticed. Forecasters have had to raise their projected growth rates, and raise them again. The moderate speed limits set by Blinder (1997) and Krugman (1997), reflecting the best evidence available only a few years ago, have given way to the optimism of the ordinarily conservative community of official forecasters.

Our review of the evidence now available suggests that the official forecasters are relying very heavily on a continuation of the acceleration in U.S. economic growth since 1995.

What are the risks associated with the optimistic view of future U.S. economic growth in the information age? Upward revision of growth projections seems a reasonable response as evidence accumulates of a possible break in trend productivity growth. Nonetheless, caution is warranted until productivity patterns have been observed for a longer time period. Should the pace of technological progress in high-tech industries diminish, economic growth would take a double hit— slower total factor productivity growth in key industries that produce high-tech equipment and slower capital accumulation in others that invest in and use high-tech equipment. Both factors have made important contributions to the recent success of the U.S. economy, so that any slowdown would reduce future growth potential.

At the same time, we must emphasize that the uncertainty surrounding intermediate-term projections has become much greater as a consequence of widening gaps in our knowledge, rather than changes in the volatility of economic activity. The excellent research that underlies estimates of prices and quantities of computer investment in NIPA has provided much needed illumination of the impact of information technology. But this is only part of the contribution of information technology to economic growth and, in fact, may not be the largest. As the role of technology continues to increase, ignorance of the most basic empirical facts about the information economy will plague researchers as well as forecasters. The uncertainties about past and future economic growth will not be resolved quickly. This is, of course, a guarantee that the lively economic debate now unfolding will continue for the foreseeable future.

The first priority for empirical research must be the construction of constant-quality price indices for a wider variety of high-tech assets. These assets are becoming increasingly important in the U.S. economy, but only a small portion have constant-quality price deflators that can translate the improved production characteristics into accurate measures of investment and output. This echoes the earlier findings of Gordon (1990), who reported that official price measures substantially overstate price changes for capital goods. In fact, Gordon identified computers and communications equipment as two assets with the largest overstatements, together with aircraft, which we have not included.[57] Much remains to be done to complete Gordon's program aimed at implementing constant-quality price deflators for all components of investment in NIPA.

The second priority for research is to decompose the sources of economic growth at the industry level. Fortunately, the required methodology is well established and increasingly familiar. Domar aggregation over industries underlies the back-of-the-envelope calculations of the contribution of information technology to economic growth outlined in Section 3, as well as the more careful and comprehensive view of the contributions of industry-level productivity that we have presented in Section 4. This view will require considerable refinement to discriminate among alternative perspectives on the rapidly unfolding information economy. However, the evidence already available is informative on the most important issue. This is the "new economy" view that the impact of information technology is like *phlogiston*, an invisible substance that spills over in every kind of economic activity and reveals its presence by increases in industry-level productivity growth across the U.S. economy. This view is simply inconsistent with the empirical evidence.

Our results suggest that while technology is clearly the driving force in the resurgence of growth, familiar economic principles can be applied. Productivity growth in the production of information technology is responsible for a sizeable part of the recent spurt in TFP growth and can be identified with price declines for high-tech assets and semi-conductors. This has induced an eruption of investment in these assets that is responsible for capital deepening in the industries that use information technology. Information technology provides a dramatic illustration of economic incentives at work! However, there is no corresponding eruption of industry-level productivity growth in these sectors that would herald the arrival of phlogiston-like spillovers from production in the information technology industries.

Many of the goods and services produced with high-tech capital may not be adequately measured, as suggested in the already classic paper of Griliches (1994). This may help to explain the surprisingly low productivity growth in many of the high-tech intensive, service industries. If the official data are understating both real investment in high-tech assets and the real consumption of commodities produced with these assets, the under-estimation of U.S. economic performance may be far more serious than we have suggested. Only as the statistical agencies continue their slow progress towards improved data and implementation of state-of-the-art methodology will this murky picture become more transparent.

Notes

1 Labour productivity growth in the business sector averaged 2.7 percent over 1995-99, the four fastest annual growth rates in the 1990s, except for a temporary jump of 4.3 percent in 1992 as the economy exited recession (BLS, 2000).

2 Stiroh (1999) critiques alternative new economy views; Triplett (1999) examines data issues in the new economy debate; and Gordon (1999b) provides an often-cited rebuttal of the new economy thesis.

3 Our work on computers builds on the path-breaking research of Oliner and Sichel (1994, 2000), Sichel (1997, 1999), and our own earlier results, reported in Jorgenson and Stiroh (1995, 1999, 2000), and Stiroh (1998a). Other valuable work on computers includes Haimowitz (1998), Kiley (1999), and Whelan (1999). Gordon (1999a) provides a historical perspective on the sources of U.S. economic growth, and Brynjolfsson and Yang (1996) review the micro evidence on computers and productivity.

4 See Baily and Gordon (1988), Stiroh (1998a), Jorgenson and Stiroh (1999), and Department of Commerce (1999) for earlier discussions of relative price changes and input substitution in the high-tech sectors.

5 BLS (2000) estimates for the business sector show a similar increase from 1.6 percent over 1990-95 to 2.6 percent over 1995-98. See CEA (2000, p. 35) for a comparison of productivity growth at various points in the economic expansions of the 1960s, 1980s, and 1990s.

6 See Gullickson and Harper (1999), Jorgenson and Stiroh (2000), and Section 4, below, for industry-level analyses.

7 There is no consensus, however, on the fact that technical progress in computer and semi-conductor production is slowing. According to Fisher (2000), chip processing speed continues to increase rapidly. Moreover, the product cycle is accelerating as new processors are brought to market more quickly.

8 See Dean (1999) and Gullickson and Harper (1999) for the BLS perspective on measurement errors; Triplett and Bosworth (2000) provide an overview of the measurement of output in the service industries.

9 It would be a straightforward change to make technology labour-augmenting or "Harrod-neutral," so that the production possibility frontier could be written: $Y(I, C) = X(K,AL)$. Also, there is no need to assume that inputs and outputs are separable, but this simplifies our notation.

10 Baily and Gordon (1988), Griliches (1992), Stiroh (1998a), Jorgenson and Stiroh (1999), Whelan (1999), and Oliner and Sichel (2000) discuss the impact of investment in computers from these two perspectives.

11 Triplett (1996) points out that much of the decline in computer prices reflects falling semi-conductor prices. If all inputs are correctly measured for quality change, therefore, much of the TFP gains in computer production are rightly pushed back to TFP gains in semi-conductor production since semi-conductors are a major intermediate input in the production of computers. See Flamm (1993) for early estimates of semi-conductor prices. We address this question further in Section 4.

12 See Appendix A for details on our source data and methodology for estimating output.

13 Current dollar NIPA GDP in 1998 was $8,759.9B. Our estimate of $8,013B differs due to total imputations ($740B), exclusion of general government and government enterprise sectors ($972B and $128B, respectively), and exclusion of certain retail taxes ($376B).

14 See Appendix B for details on the theory, source data, and methodology for estimating capital services.

15 Jorgenson (1996) provides a recent discussion of our model of capital as a factor of production. The BLS (1983) describes the version of this model employed in the official productivity statistics. Hulten (2000) provides a review of the specific features of this methodology for measuring capital input and the link to economic theory.

16 More precisely, growth in capital quality is defined as the difference between the growth in capital services and the growth in the average of the current and lagged stock of capital. Appendix B provides further details. We use a geometric depreciation rate for all reproducible assets, so that our estimates are not identical to the wealth estimates published by the BEA (1998b).

17 Tevlin and Whelan (1999) provide empirical support for this explanation, reporting that computer investment is particularly sensitive to the cost of capital, so that the rapid drop in service prices can be expected to trigger a large investment response.

18 An econometric model of the responsiveness of different types of capital services to own- and cross-price effects could be used to test for complementarity, but this is beyond the scope of the paper.

19 According to Parker and Grimm (2000), the total software investment of $123.4B includes $35.7B in pre-packaged software, $42.3B in custom software, and $45.4B in own-account software in 1998. Applying the weighting conventions employed by the BEA, this implies that $46.3B = $35.7B + 0.25 * $42.3B, or 38 percent of the total software investment, is deflated with explicit quality adjustments.

20 Grimm (1997) presents hedonic estimates for digital telephone switches and reports average price declines of more than 10 percent per year from 1985 to 1996.

21 Appendix C provides details on the source data and methodo logy.

22 By comparison, the BLS (2000) reports growth in business hours of 1.2 percent over 1990-95 and 2.3 percent over 1995-98. The slight discrepancies reflect our methods of estimating hours worked by the self-employed, as well as minor differences in the scope of our output measures.

23 Note that we have broken broadly defined capital into tangible capital services, *K*, and consumers' durables services, *D*.

24 Table 2.2 also presents preliminary results for the more recent period of 1995-99, where the 1999 values are based on the estimation procedure described in the Annex to this chapter, rather than on the detailed model described above. The results for 1995-98 and 1995-99 are quite similar; we focus our discussion on the period 1995-98.

25 See Katz and Krueger (1999) for explanations of the strong performance of the U.S. labour market, including demographic shifts toward a more mature labour force, a rise in the prison age population, improved efficiency of labour markets, and the "weak backbone hypothesis" of worker restraint.

26 We are indebted to Dan Sichel for very helpful discussions of this timing convention.

27 Oliner and Sichel (2000) provide a detailed comparison of the results across several studies of computers and economic growth.

28 See Krugman (1997) and Blinder (1997) for a discussion of the usefulness of this relationship.

29 The BLS (2000) shows similar trends for the business sector with the growth in hours worked increasing from 1.2 percent during 1990-95 to 2.3 percent during 1995-98, while ALP increased from 1.58 percent to 2.63 percent.

30 The notion that official price deflators for investment goods omit substantial quality improvements is hardly novel. The magisterial work of Gordon (1990) successfully quantified the overstatements of inflation rates in the prices of a wide array of investment goods, covering all producers' durable equipment in the NIPA.

31 This point was originally made by Jorgenson (1966); Hulten (2000) provides a recent review.

32 Gordon (1999a), Stiroh (1998a), and Whelan (1999) also provide estimates.

33 This calculation shows that the simplified model of Oliner and Sichel (2000) is a special case of the complete Domar weighting scheme used in Section 4.

34 Relative price changes in the Base case are taken from the investment prices presented in Table 2.5. Output shares are estimated based on final demand sales available from the BEA website for computers and from Parker and Grimm (2000) for software. Investment in communications equipment is from the NIPA, and we estimate other final demand components for communications equipment using ratios relative to final demand for computers. This is an approximation necessitated by the lack of complete data on final demand sales by commodity.

35 Stiroh (1998b) provides details and references to supporting documents.

36 The 5 sectors — non-farm business, farm, government, residential housing, and households, and non-profit institutions — follow the breakdown used in Table 1.7 of the NIPA.

37 See CBO (1995, 1997) for details on the underlying model and the adjustments for business cycle effects that lead to the potential series.

38 Note that the growth rates in Table 2.6 do not exactly match those of Table 2.2 due to differences in calculating growth rates. All growth rates in Table 2.6 follow the CBO's convention of calculating discrete growth rates as $g = [(X_t / X_0)^{1/t} - 1]*100$, while growth rates in Table 2.2 are calculated as $g = [\ln(X_t / X_0)/t]*100$.

39 See CBO (2000, p. 25 and p. 43) for details.

40 Earlier upward revisions to TFP growth primarily reflect "technical adjustment... for methodological changes to various price indices" and "increased TFP projections (CBO, 1999b, p. 3)."

41 See CBO (1995) for details on the methodology used for cyclical adjustments to derive the "potential" series.

42 These comparisons are from CBO (2000, Table 2-6).

43 This is analogous to the sectoral output concept used by the BLS. See Gullickson and Harper (1999), particularly pp. 49-53, for a review of the concepts and terminology used by the BLS.

44 The BLS refers to this concept as *multi-factor productivity* (MFP).

45 Jorgenson, Gollop, and Fraumeni (1987), particularly Chapter 2, provide details and earlier references; Gullickson and Harper (1999, p. 50) discuss how aggregate productivity can exceed industry productivity in the Domar weighting scheme.

46 We are grateful to Mun Ho for his extensive contribution to the construction of the industry data.

47 Appendix D provides details on the component data sources and linking procedures.

48 Our industry classification is too broad to isolate the role of semi-conductors.

49 This conclusion rests critically on the input share of semi-conductors in the computer industry. Triplett reports Census data estimates placing this share at 15 percent for 1978-94, but states that industry sources estimate this share to be closer to 45 percent. This has an important impact on his results. At one end of the spectrum, if no account is made for semi-conductor price declines, the relative productivity in computer equipment increases 9.1 percent over 1978-94. Assuming a 15 percent share for semi-conductors reduces this value to 9 percent; assuming a 45 percent share reduces it to 1 percent.

50 Dean (1999) summarizes the BLS view on this issue. McGuckin and Stiroh (2000) attempt to quantify the magnitude of the potential mismeasurement effects.

51 See Gullickson and Harper (1999), particularly pp. 55-56, for details.

52 These 5 industries are Agriculture, Construction, Transportation, FIRE and Services. Note that our estimates for 1977-1996 are not shown in Table 2.10.

53 The 7 other industries that are comparable are Agriculture, Non-metallic Mining, Construction, Transportation, Communications, Trade, and FIRE.

54 The 10 industries with small differences are Food Products, Apparel, Furniture and Fixtures, Paper Products, Printing and Publishing, Chemical Products, Primary Metals, Industrial and Commercial Machinery, Electronic and Electric Machinery, and Miscellaneous Manufacturing. The 2 industries with slightly larger differences are Rubber and Plastic, and Fabricated Metals.

55 This aggregate impact is smaller than that estimated by Gullickson and Harper (1999), partly because our shares differ due to the inclusion of a Household and Government industry. Also, as pointed out by Gullickson and Harper, a complete re-estimation would account for the change in intermediate inputs implied by the productivity adjustments.

56 Oliner and Sichel (2000) argue that Gordon's conclusion is weakened by the new NIPA data released in the benchmark revision, which allow a larger role for ALP growth outside of computer production.

57 Gordon (1990), Table 12.3, p. 539.

Annex:
Extrapolation for 1999

Table 2.2 presents primary growth accounting results through 1998 and preliminary estimates for 1999. The data through 1998 are based on the detailed methodology described in Appendices A-D; data for 1999 are extrapolated from currently available data and recent trends.

Our approach to extrapolating growth accounting results through 1999 was to estimate 1999 shares and growth rates for major categories like labour, capital, and information technology components, as well as the output growth. The 1999 labour share was estimated from 1995-98 data, growth in hours worked is from the BLS (2000), and labour quality growth comes from the projections described above. The 1999 growth rates of information technology output were taken from the NIPA, and shares were estimated from 1995-98 data. The 1999 growth rates of information technology inputs were estimated from recent investment data and the perpetual inventory method, and shares were estimated from 1995-98 data. The 1999 growth of other capital was estimates from NIPA investment data for broad categories like equipment and software, non-residential structures, residential structures, as well as consumers' durable purchases; the income share was calculated from the estimated labour share. Output growth was estimated from growth in the BLS business output and the BEA GDP, with adjustment made for different output concepts. Finally, TFP growth for 1999 was estimated as the difference in the estimated output growth and share-weighted input growth.

Economic and Productivity Growth in Canadian Industries

3

Wulong Gu, Frank C. Lee and Jianmin Tang

3.1 Introduction

THE PURPOSE OF THIS STUDY is to analyse the sources of output and labour productivity growth in the Canadian economy since 1961. The study also considers the sources of output growth in individual industries. We adopt the constant quality indices of capital and labour inputs introduced by Jorgenson and Griliches (1967), and later used extensively in Jorgenson (1995a, 1995b), Jorgenson, Gollop, and Fraumeni (1987), and Jorgenson and Yip (1999) to identify the sources of growth. This framework is similar to the one employed by the U.S. Bureau of Labor Statistics, but some minor differences still remain between the two.[1] At the industry level, we adjust for capital quality by aggregating capital stocks across different asset types, using the share of property income as the weight for each type. At the same time, we combine hours worked by each type of worker using its share of labour compensation to reflect labour quality. At the aggregate level, we apply the same framework by aggregating capital stocks across different asset types and hours worked across different types of workers. A number of studies have compared Canada's aggregate economic growth performance with that of its competitors based on this framework (Dougherty, 1992; Dougherty and Jorgenson, 1997; and Jorgenson and Yip, 1999). However, this is the first study where this framework is used to assess Canada's economic performance at the industry level.

Output growth in Canada's private business sector decreased from an average of 5.6 percent per year during the period 1961-73 to 3.3 percent during 1973-88 and 1.5 percent during 1988-95. The health and strength of the private business sector are directly related to the overall performance of Canada's gross domestic product (GDP) per capita. Growth in GDP per capita also slowed down over the entire period — from 3.6 percent per year during 1961-73 to 2.1 percent during 1973-88, and to a mere 0.3 percent during 1988-95. Based on our findings, about 46 percent of the private business sector's output growth over 1961-73, and 22 percent and 26 percent, respectively, over 1973-88 and 1988-95, are attributable to growth in quality-adjusted TFP. Over 80 percent of the slowdown in output growth between 1961-73 and 1973-88 is attributable to the slowdown in TFP growth; over the following interval (1973-88 to 1988-95), more than 80 percent of the slowdown in output growth is attributable to slower capital and labour input growth.

For most of the 122 industries examined in this study, input growth was a predominant source of output growth during 1961-73 and 1973-88. In the last period (1988-95), however, TFP growth accounted for more than 50 percent of output growth in slightly more than half of Canadian industries. This is due to the fact that, in 80 industries, the slowdown in input growth between 1973-88 and 1988-95 was greater than that of TFP growth.

In the next section, we briefly describe the methodology used, while in Section 3.3 we describe the data set. In Section 3.4, we analyse the sources of growth at the level of individual industries, and in Section 3.5 we present our findings for the private business sector. Section 3.6 outlines our conclusions.

3.2 Methodology

TO ANALYSE THE SOURCES OF GROWTH in the Canadian private business sector, we adopt the methodology described in Jorgenson, Gollop, and Fraumeni (1987), where the output $\{Q_{it}\}$ of each industry i is a function of capital inputs $\{K_{it}\}$, labour inputs $\{L_{it}\}$, intermediate inputs $\{M_{it}\}$, and time, t:

(1) $$Q_{it} = F\left(K_{it}, L_{it}, M_{it}, t\right).$$

Assuming constant returns to scale with a translog production function (see Christensen, Jorgenson, and Lau, 1973), the growth rate of output can be expressed as a weighted average of the growth rates of capital, labour, and intermediate inputs plus the average rate of productivity growth, or total factor productivity (TFP) growth $\{\overline{v}_{it}\}$:

(2) $$\ln Q_{it} - \ln Q_{it-1} = \overline{v}_{it}^{K}[\ln K_{it} - \ln K_{it-1}] + \overline{v}_{it}^{L}[\ln L_{it} - \ln L_{it-1}] + \overline{v}_{it}^{M}[\ln M_{it} - \ln M_{it-1}] + \overline{v}_{it}.$$

Weights are defined by the average shares of each component:

$$(3) \quad \bar{v}_{it}^{K} = \frac{1}{2}[v_{it}^{K} + v_{it-1}^{K}],\ \bar{v}_{it}^{L} = \frac{1}{2}[v_{it}^{L} + v_{it-1}^{L}],$$
$$\bar{v}_{it}^{M} = \frac{1}{2}[v_{it}^{M} + v_{it-1}^{M}],\ \bar{v}_{it} = \frac{1}{2}[v_{it} + v_{it-1}],$$

where, $v_{it} = \partial \ln Q_{it} / \partial t(K_{it}, L_{it}, M_{it}, t)$.

The shares of each component are given as:

$$(4) \quad v_{it}^{K} = \frac{P_{it}^{K} K_{it}}{P_{it} Q_{it}},\ v_{it}^{L} = \frac{P_{it}^{L} L_{it}}{P_{it} Q_{it}},\ v_{it}^{M} = \frac{P_{it}^{M} M_{it}}{P_{it} Q_{it}},$$

where $\{P_{it}\}$, $\{P_{it}^{K}\}$, $\{P_{it}^{L}\}$, and $\{P_{it}^{M}\}$ denote the prices of output and of capital, labour, and intermediate inputs, respectively.

We also assume that each sector's input (capital, labour, and intermediate inputs) is a translog function of its components and that each differs in its marginal productivity. We can express the growth rate of each input as the weighted average of the growth rates of individual components:

$$(5) \quad \ln X_{t}^{i} - \ln X_{t-1}^{i} = \sum_{j=1}^{m} \bar{v}_{jt}^{Xi} \left[\ln X_{jt}^{i} - \ln X_{jt-1}^{i}\right],\ X = \{K, L, M\},$$

where the weights are provided by the average shares of each component:

$$(6) \quad \bar{v}_{jt}^{Xi} = \frac{1}{2}[v_{jt}^{Xi} + v_{jt-1}^{Xi}],\ (j = 1,2, ..., m),\ X = \{K, L, M\},$$

and the shares of each component are defined as:

$$(7) \quad v_{jt}^{Xi} = \frac{P_{jt}^{Xi} X_{jt}^{i}}{\sum_{j=1}^{m} P_{jt}^{Xi} X_{jt}^{i}},\ (j = 1, 2, ..., m),\ X = \{K, L, M\}.$$

Note that the number of components, m, varies for each type of input, X.

In our analysis, we explicitly consider the quality components of capital and labour inputs for each industry. The above equations enable us to construct both quality and quantity indices for capital and labour inputs. The quality component can be measured as the ratio of the capital input, K_{it}, to the preceding period's capital stock, $A_{it\text{-}1}$:

(8) $$q_{it}^{K} = K_{it} / A_{it-1} .$$

Thus, q_{it}^{K} is expressed as:

(9) $$\ln q_{it}^{K} - \ln q_{it-1}^{K} = \sum_{j=1}^{p} \bar{v}_{jt}^{Ki} [\ln A_{jt-1}^{i} - \ln A_{jt-2}^{i}] - [\ln A_{it-1} - \ln A_{it-2}],$$

where A_i is an unweighted sum of different types of capital stock. The index therefore reflects changes in the composition of capital.

Similarly, the quality of the labour input can be defined as the ratio of the labour input, L_{it}, to hours worked, H_{it}:

(10) $$q_{it}^{L} = L_{it} / H_{it} .$$

Here, the quality index of the labour input is expressed as:

(11) $$\ln q_{it}^{L} - \ln q_{it-1}^{L} = \sum_{j=1}^{1} \bar{v}_{jt}^{Li} \left[\ln H_{jt}^{i} - \ln H_{jt-1}^{i}\right] - \left[\ln H_{it} - \ln H_{it-1}\right],$$

where H_i is an unweighted sum of its components.

3.3 Data

WE CONSTRUCT BOTH OUTPUT AND INPUT DATA for 122 industries (listed in Table 3.A1, in the Annex to this chapter) covering the period 1961 to 1995. Both prices and quantities of gross output and intermediate input (energy, materials, and services) are taken from Statistics Canada's KLEMS database.[2]

3.3.1 Capital Input Data

The prices and quantities of capital inputs are aggregated from five asset types — machinery and equipment, non-residential structures, engineering structures, inventories, and land — for the 122 industries. For depreciable assets (including machinery and equipment, building structures, and engineering structures), we use capital stock estimates from Statistics Canada's KLEMS database which uses a modified double-declining-balance rate (Statistics Canada, 1994a).[3] We then estimate inventory stocks and land using Statistics Canada data as explained below.

Our estimates of inventory stocks are mainly based on national and industry balance sheet data. We first estimate inventory stocks at current prices for the 122 industries, using industry balance sheet data and the Input-Output tables. For the period 1972-87, inventory stocks at current prices are set as the book value of inventory stocks from balance sheet data at the detailed level of industry aggregation (the three-digit 1970 Standard Industrial Classification). For the periods 1961-71 and 1988-95, net inventory investment at current prices is estimated from the Input-Output tables on inventory changes in finished goods and goods in progress, and in raw materials and goods purchased for resale. To obtain inventory stocks and inventory investment at constant prices, nominal inventory stocks and inventory investment are deflated by the average of the price deflators of raw materials and final output. The data on inventory stocks for the period 1972-87 are extrapolated to the periods 1961-71 and 1988-95 on the basis of the estimated net inventory investment data. Our final estimates of inventory stocks in current and constant dollars are all adjusted to national totals from the national balance sheet.

To estimate land input by industry, we first obtain estimates of total land in current dollars from 1961 to 1995 from the National Balance Sheet Accounts. We assume that the quantity of land remains constant and derive its price index. We then remove the real value of farm, residential, and government land from the real value of total land. The remaining non-agricultural, non-government land is allocated across 121 industries. For 1972-87, the allocation is based on Statistics Canada's Detailed Balance Sheet and Income and Earnings Statistics. The land estimates are then extrapolated based on the growth in the stock of non-residential structures by industry for the periods 1961-71 and 1987-95, always adjusting to the national total.

We then estimate the prices of capital services for five assets, based on property compensation data. Following Jorgenson and Yun (1991), we use the following expression to construct the rental price of depreciable assets for each industry i:[4]

$$(12) \qquad P_j^{Ki} = \frac{1 - e_j^i - tz_j^i}{1-t} P_j^{Ii} \left[(r_j - \pi_j^i) + (1 + \pi_j^i)\delta_j^i \right] + t_j^{pi} P_j^{Ii} \ ,$$

where: t is the combined federal and provincial corporate income tax rate; e_j^i is the rate of the investment tax credit; z_j^i is the present value of capital cost allowances on one dollar's worth of investment;[5] P_j^{Ii} is the price of new investment good j; r_j is the nominal rate of return on asset type j; $\pi_j^i = \left(P_{jt}^{Ii} - P_{jt-1}^{Ii}\right) / P_{jt-1}^{Ii}$ is the capital gain for asset j; δ_j^i is the depreciation rate for asset j; and t_j^{pi} is the property tax rate.

We use the following expression for the rental price of land and inventories since there is no investment tax credit, capital consumption allowance or economic depreciation:

$$(13) \qquad P_j^{Ki} = \left[\frac{r_j - \pi_j^i}{1-t} + t_j^{pi} \right] P_j^{Ii} \, .$$

We take into account the following three features of the corporate tax system in the calculation of rental prices: both federal and provincial corporate tax rates, small business tax deductions for Canadian-controlled private corporations, and tax credit provisions for manufacturing and processing.

To account for these features of the corporate tax system, we use the following data from Statistics Canada's industry balance sheet and income statement figures: the distribution of taxable income across ten provinces by industry for the periods 1961-87 and 1993-95, and total taxable income and small business deductions by industry for the period 1974-94. We then calculate average statutory corporate tax rates for each industry over the period 1961-95, using appropriate taxable income shares as weights. The income share weights are estimated for those years in which data are missing. For example, to estimate the shares of small business deductions in total taxable income over the period 1961-73, we assume that these shares were the same as in 1974. In 1976, to encourage investment, a credit was granted for new production facilities. Initially set at 5 percent for all industries, the rate was raised to 7 percent in 1979; regional variations with higher rates were also introduced. In 1989, the investment tax credits were discontinued, except in the Atlantic provinces.

Business property taxes in the rental price equations described above are levied mainly on land, engineering structures, and building structures, with machinery being exempt. To estimate property tax rates, we first obtain as the property tax base the nominal values of land and engineering and building structures for the 122 industries. We then divide the tax base into total taxes on production from the Input-Output tables to obtain the average property tax rates.

We determine the rates of return on assets by assuming that the nominal rate of return is the same for all assets (including land and inventories) within a given industry. We also assume that the sum of the values of capital services over all assets is equal to total capital compensation. We can then estimate the nominal rate of return on all assets within a given industry, and ultimately the rental price of capital for all assets within the industry.

Finally, we combine the price and quantity data on capital to construct an index of capital input, as explained in Section 3.2.

3.3.2 Labour Input Data

We construct labour input indices from the data on hours worked and labour compensation of workers, broken down by sex, employment status (three categories), age (seven categories), and education (four levels) in each industry, as shown in Table 3.1.[6]

We use various data sources to generate annual estimates of hours worked and labour compensation for 168 components of the workforce in each of the 122 industries. First, we obtain benchmark estimates of hours worked, compensation per hour, and total compensation for the census reference years (the year prior to the census)[7] from the population censuses of 1961, 1971, 1981, 1986, 1991, and 1996. Annual data on hours worked from the monthly Labour Force Survey (LFS) are used to estimate matrices of hours worked for the years between the census benchmarks. We then employ annual data on labour compensation from the Survey of Consumer Finance (SCF) to estimate compensation matrices between two successive censuses. For this purpose, we rely on the method of iterative proportional fitting (for details, see

Jorgenson, Gollop, and Fraumeni, 1987). A weighted average of two neighbouring benchmark matrices is used to initialize our method of proportional fitting. Data from the LFS and the SCF on hours worked and compensation by worker characteristics are used to control for the distribution of hours worked and labour compensation. All matrices of hours worked and labour compensation are then controlled to industry totals on hours worked and compensation by class of employment from Statistics Canada's labour productivity database.

Table 3.1

Classification of the Canadian Workforce

Worker Characteristics	Number of Categories	Type
Sex	2	Female; Male
Employment Status	3	Paid Employees; Self-employed; Unpaid Family Workers
Age	7	15-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	0-8 Years Grade School; Some or Completed High School; Some or Completed Post-Secondary School; University or Higher

We then combine the data on labour compensation per hour and on hours worked to construct an index of labour input, as described in Section 3.2.

3.4 Sectoral Output and TFP Growth

IN THIS SECTION, WE EXAMINE OUTPUT GROWTH in the 122 industries over the three periods 1961-73, 1973-88, and 1988-95. We then analyse growth in TFP, capital inputs, labour inputs, and intermediate inputs. Finally, the quality of capital and labour inputs is also discussed.

3.4.1 Growth in Output and TFP

Based on the framework introduced in Section 3.2, we can decompose the rate of output growth into the contributions of input and TFP growth. Note that in this paper total factor productivity refers to quality-adjusted TFP. We first compare output and TFP growth rates by industry for the three periods, as shown in Annex Table 3.A2. In a typical industry, growth in both output and TFP slowed down during the three periods. Output growth averaged 6.3 percent per year across 122 industries over 1961-73. That figure declined to 2.7 percent during 1973-88 and to 0.5 percent during 1988-95. TFP growth also slowed down — from 1.4 percent annually during 1961-73 to 0.6 percent over 1973-88 and 0.3 percent over 1988-95.

Table 3.2 summarizes the patterns of output and TFP growth by period. Output growth is negative for 1, 18, and 52 industries, respectively, over 1961-73, 1973-88, and 1988-95. While no industry suffered negative output growth over the entire period, 12 industries did so in the last two periods — other metal mines, iron mines, asbestos mines, distillery products, tobacco products, leather products, copper, wire products, small electrical appliances, major appliances, clay products, and hydraulic cement. At the same time, the number of industries with output growth exceeding 4 percent per year decreased from 97 to 35, and to 14 industries, respectively, over the three successive periods. Only 9 industries experienced growth in output at rates exceeding 4 percent in all three periods — vegetable oil mills, machine shops, motor vehicles, motor parts, communication equipment, office machines, plastics and synthetics, telecommunication carriers, and professional services. Thus the period 1961-73 stands out as one of expansion while the period 1988-95 is identified as one of widespread slowdown in output growth.

The slowdown in TFP growth also became more widespread over the course of the three periods. The number of industries experiencing negative TFP growth rose from 19 over 1961-73 to 37 over 1973-88, and to 51 over 1988-95. However, only 2 industries (urban transit systems and motion pictures) had negative TFP growth in all three periods, while 13 industries had negative TFP growth in the last two periods (including the biscuit, bread, and bakery industry, the sash, door, and other millwork industries, railroads, hydraulic cement, ready-mix concrete, storage, and broadcasting). Moreover, the number of industries with annual TFP growth rates in excess of 2 percent declined from 34 during 1961-73 to 14 in each of the two subsequent periods. Therefore, the number of industries that experienced negative output and TFP growth increased over the three periods. The number of industries enjoying relatively strong growth (higher than 2 percent per year) also declined over the three periods for output and over the first two periods for TFP.

Table 3.2
Classification of Industries by Annual Rate of Growth of Output and Productivity

	Number of Industries					
	Output			TFP		
Growth Rate	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95
< –2%	1	2	29	0	3	8
-2% to 0%	0	16	23	19	34	43
0% to 2%	6	36	34	69	71	57
2% to 4%	18	33	22	29	12	14
4% to 6%	39	23	6	3	1	0
> 6%	58	12	8	2	1	0

Although the slowdown in both output and TFP growth became widespread over the three periods, some industries did expand. In particular, 19 industries saw their output grow faster during 1973-88 than during 1961-73; similarly, 24 industries experienced faster output growth over 1988-95 than over 1973-88. However, only the vegetable oil and office machine industries posted faster output growth in both 1973-88 and 1988-95 relative to the immediately preceding period. On the TFP side, 40 industries experienced faster growth in the second period compared to the first, and 54 industries posted higher growth in the last period compared to the second. Seven industries posted faster TFP growth in each successive period—gold mines, fish products, copper, other rolled and cast metal products, stamped metal products, shipbuilding, and jewellery.

3.4.2 Input Growth and Its Contribution to Output Growth

Our next task is to attribute growth in output to the growth of three types of inputs. Annex Table 3.A3 presents the average annual growth rates of capital, labour, and intermediate inputs in each of the 122 industries and for each of the three periods. As described in Section 3.3, the data on capital input are generated for five asset types, and the labour input is comprised of 168 types of workers. The intermediate input is made up of three categories — energy, materials, and services. We first discuss the patterns of growth of the capital input, then those of labour and the intermediate input.

Table 3.3 ranks industries by pattern of input growth rate for each period. Considering the three periods in chronological order, 101, 46, and 39 industries, respectively, experienced annual rates of growth of the capital input in excess of 2 percent. The last period witnessed relatively weak growth in capital input, averaging 0.1 percent per year, while the first period recorded strong growth, averaging 4.7 percent annually. To gain a better understanding of the patterns of growth of the capital input by period, we narrow our focus to industries with annual growth rates higher than 6 percent and those with annual rates of decline higher than 2 percent. Over the three periods (1961-73, 1973-88, and 1988-95), 36, 14, and 12 industries, respectively, had a rate of growth of their capital input in excess of 6 percent. At the opposite end, during 1961-73 no industry had a negative capital input growth rate of 2 percent or more, but the situation changed in the two subsequent periods, when 7 and 42 industries underwent a decline in capital input growth over 1973-88 and 1988-95, respectively.

Among the 122 industries, 15 experienced an annual rate of growth of their capital input in excess of 8 percent over 1961-73; that number declined to 6 and 7 industries, respectively, during 1973-88 and 1988-95. Only professional business services had capital input growth in excess of 8 percent in all three periods. In 1973-88, capital input grew at a rate exceeding 8 percent in the following industries: motor vehicles, office machines, courier services, educational services, and laundries. In 1988-95, the following industries fell into that group: wooden boxes, platemaking, shipbuilding, miscellaneous transportation equipment, air transportation, and water systems. At the other end of the spectrum, no industry had an annual rate of decline in excess of 4 percent during 1961-73; only one industry, concrete products, fell into that category over 1973-88, but between 1988 and 1995, that number climbed to 18 and included 3 mining industries, 3 furniture-related industries, 2 steel manufacturing industries, and 5 metal products industries.

Table 3.3

Classification of Industries by Annual Rate of Growth of Three Input Categories

Growth Rate	Number of Industries								
	Capital Input			Labour Input			Intermediate Input		
	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95
< –2%	0	7	42	4	13	37	1	5	27
-2% to 0%	9	29	24	11	30	38	0	13	19
0% to 2%	12	40	17	24	33	31	7	21	31
2% to 4%	28	21	15	48	26	14	14	48	23
4% to 6%	37	11	12	21	17	2	40	16	14
> 6%	36	14	12	14	3	0	60	19	8

Annex Table 3.A3 and Table 3.3 show that quality-adjusted labour input growth also underwent a slowdown over the entire period 1961-95. In the three subperiods, 107, 79, and 47 industries, respectively, experienced annual rates of labour input growth greater than 2 percent. In a typical industry, labour input grew 3.0 percent annually over 1961-88 and 1.1 percent annually over 1973-88, while during 1988-95, labour input actually fell by 1.0 percent per year. To contrast the patterns of input growth among subperiods, we narrow our discussion to industries with annual rates of growth of the labour input greater than 6 percent or with negative growth rates of more than 2 percent. Over the first two periods (1961-73 and 1973-88), 14 and 3 industries, respectively, had annual labour input growth rates in excess of 6 percent; in the last period (1988-95), no industry saw its labour input grow at more than 6 percent per year. The number of industries with rates of decline of their labour input exceeding 2 percent rose from 4 in 1961-73 to 13 in 1973-88 and 37 in 1988-95.

Among the 122 industries, crude petroleum and natural gas, plastics and synthetic resins, carpets, trucks, motor vehicles, and miscellaneous transportation equipment recorded annual rates of labour input growth exceeding 8 percent over 1961-73, but no industry reached that level during 1973-88 or 1988-95. In contrast, the number of industries showing rapid declines in labour input growth increased over the three periods: only gold mines experienced a labour input decline in excess of 4 percent per year during 1961-73, but in the next period three industries (iron mines, asbestos mines, and record players) were in that category; over 1988-95, the number climbed to 18.

Table 3.3 shows that in the three periods, 114, 83, and 45 industries, respectively, experienced growth in intermediate inputs greater than 2 percent. As we saw with the other two inputs, the first period witnessed strong growth in intermediate inputs, averaging 6.2 percent annually, while the second period showed moderately strong growth at an annual average of 3.0 percent. In the last period, intermediate inputs grew at a relatively weak average rate of 0.9 percent per year. When the focus is narrowed on industries with annual rates of growth greater than 6 percent or those with a negative growth rate higher than 2 percent, we note that over the three periods, 60, 19, and 8 industries, respectively, had intermediate input growth rates in excess of 6 percent, but none suffered a decline in excess of 2 percent in any of the three periods.

During 1961-73, 15 industries recorded intermediate input growth in excess of 8 percent per year. That number declined to 6 industries over 1973-88 and 5 in 1988-95. Both crude petroleum and professional services saw their intermediate input growth exceed 8 percent annually in the first two periods, but in the last two periods, only the office machine industry experienced annual growth above 8 percent. Railroads, miscellaneous transportation equipment, communications equipment, office machines, and electrical power led the upward trend in intermediate input growth during the last period.

The output growth figures presented for each industry in Annex Table 3A.2 are the sum of the contributions of the three inputs (capital, labour, and intermediate inputs) and of TFP growth. The contribution of each input is measured as the product of the share of that input in the value of output, and of its growth rate. Table 3.4 compares TFP growth with the sum of the contributions of all three inputs to output growth. It shows that TFP growth was the predominant factor (accounting for more than 50 percent of output growth) in 13 and 32 industries, respectively, over 1961-73 and 1973-88. The importance of TFP growth increased dramatically in the period 1988-95, when 68 industries relied on this factor as their predominant source of output growth. The surge in the importance of TFP growth is mainly attributable to a dramatic slowdown in input growth over the period, particularly labour and intermediate inputs. By comparing the contribution of TFP growth with that of each of the three inputs, Table 3.5 provides further insight into these developments. The number of industries where intermediate inputs were the primary source of output growth declined from 93 during 1961-73 to 67 during 1973-88, and 39 during 1988-95. On the other hand, the contribution of TFP growth gained considerably in significance for a number of industries over the same periods: while it was the primary source of output growth in 17 industries over 1961-73, that number increased to 34 and 53, respectively, during 1973-88 and 1988-95. The contribution of capital input also became more important over the three periods, as this factor was the primary source of output growth in 6 industries during 1961-73, in 15 industries during 1973-88, and in 22 industries during 1988-95. The number of industries that relied on the contribution of the labour input as their primary source of expansion remained more or less constant throughout the three periods.

Table 3.4

Predominant Source of Output Growth Among 122 Industries

	Number of Industries		
	1961-73	**1973-88**	**1988-95**
Input Contribution	109	90	54
TFP Growth	13	32	68

Table 3.5

Primary Source of Output Growth in 122 Industries

	Number of Industries		
	1961-73	**1973-88**	**1988-95**
Capital Input Contribution	6	15	22
Labour Input Contribution	6	6	8
Intermediate Input Contribution	93	67	39
TFP Growth	17	34	53

3.4.3 Growth in the Quality of Capital and Labour Inputs

We can gain additional insight into the sources of output growth by analysing the implications of quality adjustments to capital and labour for TFP. Annex Tables 3.A4 and 3.A5 present findings on capital and labour quality growth, respectively, over the same three periods. They show that growth in capital input quality became progressively more important over the three periods. On average, quality grew at an annual rate of 0.8 percent during 1961-73, 0.9 percent during 1973-88, and 0.9 percent during 1988-95. Capital stock grew by 3.9 percent and 1.0 percent per year, respectively, in the first two periods, but declined by 0.8 percent annually in the last period.

Growth in capital input quality was a major source of capital input growth in 20 industries over the period 1961-73, in 54 industries over 1973-88, and in 76 industries over 1988-95. We reach similar conclusions with respect to labour quality in that this factor played an increasingly important role over time: growth in labour input quality was a predominant source of labour input growth in 20, 53, and 83 industries over the three successive periods.

Thus, for most industries, failure to incorporate quality change would result in attributing a greater share of output growth to TFP growth and a smaller share to input growth. In other words, if changes in capital and labour quality were omitted, TFP growth would be higher. In a typical industry, the omission of capital and labour quality would lead to overestimating TFP growth by 16 percent for the period 1961-73, by 22 percent for 1973-88, and by 44 percent for 1988-95.

3.5 Sources of Output and Labour Productivity Growth in the Private Business Sector

IN THIS SECTION, WE ANALYSE the sources of output and labour productivity growth in the Canadian private business sector. Our analysis is based on the premise that there exists an aggregate production function. As discussed in Jorgenson, Gollop, and Fraumeni (1987) and in Jorgenson (1995a, 1995b), this requires a number of restrictive assumptions, but it provides a useful framework for identifying the sources of economic growth in the aggregate economy. For the private business sector, the growth rate of TFP is the difference between the growth rate of value-added output and a weighted average of the growth rates of capital and labour inputs. Again, capital and labour have two components, quantity and quality, and they are broken down by the same components as the sectoral data described in Section 3.3.

Table 3.6 decomposes the sources of Canada's private business sector output growth over the three periods. In the first, output grew at 5.6 percent per year, with capital input contributing 1.2 percent annually, labour input 1.8 percent, and TFP 2.6 percent. However, there was a steady decline in the contributions of capital and labour inputs and of TFP growth over time, resulting in a slowdown of output growth. By 1988-95, private business sector output grew at only 1.5 percent per year, and the average contributions from the growth in capital and labour inputs, and from TFP had declined to 0.5, 0.6, and 0.4 percent, respectively. Moreover, the relative importance of

TFP growth declined over the three periods. The results show that TFP growth accounted for about 46 percent of output growth during 1961-73, but for only 22 percent and 26 percent, respectively, during 1973-88 and 1988-95. Capital input growth was responsible for 22 percent of output growth over 1961-73, and for about 32 percent in both 1973-88 and 1988-95.

Table 3.6

Sources of Output Growth in the Private Business Sector (%)

	1961-73	1973-88	1988-95
Output Growth	5.56	3.27	1.48
Contributions of Capital Inputs	1.22	1.06	0.49
Contribution of Capital Stock	0.85	0.73	0.27
Contribution of Capital Quality	0.38	0.33	0.22
Contributions of Labour Inputs	1.76	1.49	0.60
Contribution of Hours Worked	1.29	1.30	0.22
Contribution of Labour Quality	0.47	0.19	0.38
TFP Growth	2.58	0.72	0.39

Table 3.7 illustrates how the figures reported in Table 3.6 changed from one period to another. From 1961-73 to 1973-88, the slowdown in TFP growth accounted for over 80 percent of the slowdown in the private business sector's growth and thus was clearly the dominant factor behind that development. By contrast, over 80 percent of the slowdown in output growth from 1973-88 to 1988-95 stemmed from the slowdown in the growth of both capital and labour inputs, and more specifically, from the slowdown in the growth of the capital stock and hours worked.

We end this section with an analysis of labour productivity growth, since it is directly related to the overall standard of living, defined as GDP per capita. Table 3.8 presents a summary view of labour productivity growth over the period 1961-95; it shows that labour productivity slowed down significantly after the first period — from 3.6 percent per year during 1961-73 to 1.2 percent during 1973-88, remaining at about that rate over 1988-95. TFP growth accounted for 72, 61, and 36 percent of labour productivity growth in 1961-73, 1973-88, and 1988-95, respectively. The lower contribution of TFP growth in the last period was more or less offset by labour quality: although this factor accounted for only 16 percent of labour productivity growth during 1973-88, that contribution had risen to 34 percent in the last period. Table 3.9 indicates that 78 percent of the labour productivity growth slowdown from 1961-73 to

1973-88 was accounted for by the slowdown in TFP growth (from 2.6 percent per year during 1961-73 to 0.7 percent per year during 1973-88). The rest of the labour productivity growth slowdown is accounted for by the slowdown in capital intensity and labour quality. Although TFP growth continued to decline, this was offset by a rebound in the growth of capital intensity and labour quality that prevented labour productivity growth from further slipping behind. Capital and labour quality together accounted for 24 percent of labour productivity growth over 1961-73, 44 percent over 1973-88, and 54 percent over 1988-95.

Table 3.7

Changes in the Sources of Output Growth in the Private Business Sector (%)

	1973-88 Less 1961-73	**1988-95 Less 1973-88**
Output Growth	-2.29	-1.79
Contributions of Capital Inputs	-0.16	-0.57
Contribution of Capital Stock	-0.12	-0.45
Contribution of Capital Quality	-0.04	-0.12
Contributions of Labour Inputs	-0.27	-0.89
Contribution of Hours Worked	0.01	-1.07
Contribution of Labour Quality	-0.28	0.19
TFP Growth	-1.86	-0.33

Table 3.8

Sources of Labour Productivity Growth in the Private Business Sector (%)

	1961-73	**1973-88**	**1988-95**
Labour Productivity Growth	3.56	1.19	1.12
Contributions of Capital Input / Hour	0.51	0.28	0.34
Contribution of Capital Stock / Hour	0.13	-0.05	0.12
Contribution of Capital Quality	0.38	0.33	0.22
Contribution of Labour Quality	0.47	0.19	0.38
TFP Growth	2.58	0.72	0.39

Table 3.9
Changes in the Sources of Labour Productivity Growth in the Private Business Sector (%)

	1973-88 Less 1961-73	1988-95 Less 1973-88
Labour Productivity Growth	-2.37	-0.17
Contributions of Capital Input / Hour	-0.23	0.06
Capital Stock / Hour	-0.18	0.17
Capital Quality	-0.05	-0.11
Contribution of Labour Quality	-0.28	0.19
TFP Growth	-1.86	-0.33

3.6 Conclusion

THIS STUDY HAS SHOWN that adjusting capital and labour inputs for changes in capital and labour quality allows a better understanding of economic growth in Canada. By incorporating quality adjustments to capital and labour inputs into the analysis, we attribute a greater proportion of output growth and labour productivity growth to input growth and, correspondingly, a smaller proportion to TFP growth.

Our results show that output growth in the Canadian private business sector slowed down from 5.6 percent during 1961-73 to 3.3 percent during 1973-88 and 1.5 percent during 1988-95. TFP growth accounted for about 46 percent of output growth over 1961-73, and for 22 percent and 26 percent, respectively, over 1973-88 and 1988-95. At the same time, over 80 percent of the slowdown in output growth observed from the first to the second period is attributable to the slowdown in TFP growth. On the other hand, over 80 percent of the slowdown in output growth from 1973-88 to 1988-95 originated from the slowdown in the growth of both capital and labour inputs. The slowdown in the growth of capital stock and hours worked was mainly responsible for the slower input growth between the two periods.

Labour productivity growth in Canada's private business sector also decreased significantly after 1973 — from 3.6 percent to 1.2 percent annually between 1961-73 and 1973-88, remaining at about the latter rate over 1988-95. TFP growth accounted for 72, 61, and 36 percent, respectively, of labour productivity growth over the three successive periods. The lower contribution of TFP growth in the last period was more or less offset by labour quality, which had accounted for 16 percent of labour productivity growth during 1973-88, a contribution that rose to 34 percent in the last period. However, 78 percent of the slowdown in labour productivity growth between 1961-73 and 1973-88 was accounted for by the slower TFP growth. As with the decline in output growth, the rest of the labour productivity growth slowdown is attributable to slower growth in capital intensity and labour quality. Although TFP growth continued to decrease from 1973-88 to 1988-95, this was offset by a rebound in the growth of capital intensity and labour quality that prevented labour productivity growth from further slipping behind.

For a majority of the 122 industries covered in our study, input growth was a predominant source of output growth during 1961-73 and 1973-88. During 1988-95, however, TFP growth accounted for more than half of output growth in slightly more than half of those industries, primarily because input growth fell more than did productivity growth between 1973-88 and 1988-95.

This study serves as a first step towards understanding the sources of output and labour productivity growth in the Canadian economy. A number of refinements may prove fruitful in that respect. For example, capital input in our study is based on only five asset categories; it would undoubtedly be useful to develop these categories further, as this would help us better understand the sources of output and labour productivity growth in Canada. In addition, increasing the number of asset categories would make it possible to analyse the implications of investment in information technology for the Canadian economy.

Notes

1 At the industry level, the U.S. Bureau of Labor Statistics does not adjust for labour quality, and at the economy-wide level, it aggregates capital input over different asset types and industries.

2 Described in Johnson (1994).

3 A double-declining-balance depreciation rate is used in Statistics Canada's estimates of capital stock.

4 See Appendix E for a detailed description.

5 See Dougherty (1992) for the method of calculating the present value of capital cost allowances.

6 See Appendix F for a detailed analysis.

7 The micro-data file for the 1961 Census is not available. However, very detailed information on employment and earnings disaggregated for one, two, and three characteristics of labour input are published by Statistics Canada. We thus employed the method of iterative proportional fitting to estimate the matrices of hours worked and labour compensation for 1961.

Annex: Detailed Industry Tables

Table 3.A1

List of Industries

No.	Industries	Abbreviation
1.	Agricultural and Related Service Industries	Agric.
2.	Fishing and Trapping Industries	Fishing
3.	Logging and Forestry Industries	Logging
4.	Gold Mines	Gold
5.	Other Metal Mines	Oth. Mines
6.	Iron Mines	Iron Mines
7.	Asbestos Mines	Asbestos
8.	Other Non-metal Mines (Except Coal)	Non-metal Mines
9.	Salt Mines	Salt
10.	Coal Mines	Coal
11.	Crude Petroleum and Natural Gas Industries	Crude Pet. and Gas
12.	Quarry and Sand Pit Industries	Quarry
13.	Service Industries Incidental To Mineral Extraction	Oth. Mining
14.	Poultry, Meat and Meat Products Industries	Poultry
15.	Fish Products Industries	Fish Prod.
16.	Fruit and Vegetable Industries	Fruit
17.	Dairy Products Industries	Dairy
18.	Feed Industry, Cane and Beet Sugar Industry, Miscellaneous Food Products Industries	Feed
19.	Vegetable Oil Mills (Except Corn Oil)	Veg. Oil
20.	Biscuit Industry, Bread and Other Bakery Products Industries	Biscuit
21.	Soft Drink Industry	Soft Drink
22.	Distillery Products Industry	Distillery
23.	Brewery Products Industry	Brewery
24.	Wine Industry	Wine
25.	Tobacco Products Industries	Tobacco
26.	Rubber Products Industries	Rubber
27.	Plastic Products Industries	Plastic
28.	Leather Tanneries, Footwear Industry, Miscellaneous Leather and Allied Products Industries	Leather

Table 3.A1 (cont'd)

No.	Industries	Abbreviation
29.	Man-made Fibre Yarn and Woven Cloth Industries, Wool Yarn and Woven Cloth Industries	Fibre Yarn
30.	Broad Knitted Fabric Industry	Knitted Fabric
31.	Miscellaneous Textile Products Industries	Misc. Textile
32.	Carpet, Mat and Rug Industry	Carpet
33.	Clothing, Hosiery Industries	Clothing
34.	Sawmill, Planing Mill and Shingle Mill Products Industries	Sawmill
35.	Veneer and Plywood Industries	Veneer
36.	Sash, Door and Other Millwork Industries	Sash
37.	Wooden Box and Coffin Industries	Wooden Box
38.	Other Wood Industries	Oth. Wood
39.	Household Furniture Industries	House. Furn.
40.	Office Furniture Industries	Office Furn.
41.	Other Furniture and Fixture Industries	Oth. Furn.
42.	Pulp and Paper Industries	Pulp
43.	Asphalt Roofing Industry	Roofing
44.	Paper Box and Bag Industries	Paper Box
45.	Other Converted Paper Products Industries	Oth. Paper
46.	Printing and Publishing Industries	Printing
47.	Platemaking, Typesetting and Bindery Industries	Platemaking
48.	Primary Steel Industries	Primary Steel
49.	Steel Pipe and Tube Industry	Steel Pipe
50.	Iron Foundries	Iron
51.	Non-ferrous Metal Smelting and Refining Industries	Non-ferrous
52.	Aluminium Rolling, Casting and Extruding Industries	Aluminium
53.	Copper and Alloy Rolling, Casting and Extruding Industries	Copper
54.	Other Rolling, Casting and Extruding, Non-ferrous Metal Products Industries	Oth. Roll.
55.	Power Boiler and Structural Metal Industries	Power Boiler
56.	Ornamental and Architectural Metal Products Industries	Ornamental
57.	Stamped, Pressed and Coated Metal Products Industries	Stamped
58.	Wire and Wire Products Industries	Wire
59.	Hardware, Tool and Cutlery Industries	Hardware
60.	Heating Equipment Industry	Heating
61.	Machine Shop Industry	Machine Shop
62.	Other Metal Fabricating Industries	Oth. Metal
63.	Agricultural Implement Industry	Agr. Implement

Table 3.A1 (cont'd)

No.	Industries	Abbreviation
64.	Commercial Refrigeration and Air Conditioning Equipment Industries	Refrig.
65.	Other Machinery and Equipment Industries	Oth. M&E
66.	Aircraft and Aircraft Parts Industry	Aircraft
67.	Motor Vehicle Industry	Motor Veh.
68.	Truck and Bus Body and Trailer Industries	Truck
69.	Motor Vehicle Parts and Accessories Industries	Motor Parts
70.	Railroad Rolling Stock Industry	Railroad
71.	Shipbuilding and Repair Industry	Shipbuilding
72.	Miscellaneous Transportation Equipment Industries	Misc. Trans.
73.	Small Electrical Appliances Industry	Small Elec.
74.	Major Appliances Industries (Electric and Non-electric)	Major Appl.
75.	Other Electrical and Electronic Products Industries, Battery Industry	Oth. Elec.
76.	Record Player, Radio and Television Receiver Industries	Record Player
77.	Communications and Other Electronic Equipment Industries	Comm. Equip.
78.	Office, Store and Business Machine Industries	Office Machine
79.	Communications and Energy Wire and Cable Industries	Wire and Cable
80.	Clay Products Industries	Clay
81.	Hydraulic Cement Industry	Hydraulic
82.	Concrete Products Industries	Concrete
83.	Ready-mix Concrete Industry	Ready-mix
84.	Glass and Glass Products Industries	Glass
85.	Miscellaneous Non-metallic Mineral Products Industries	Misc. Non-met.
86.	Refined Petroleum and Coal Products Industries	Ref. Pet. and Coal
87.	Industrial Chemicals Industries N.E.C.	Oth. Ind. Chem.
88.	Chemical Products Industries N.E.C.	Oth. Chemical
89.	Plastic and Synthetic Resin Industry	Plastic and Syn.
90.	Pharmaceutical and Medicine Industry	Pharma.
91.	Paint and Varnish Industry	Paint
92.	Soap and Cleaning Compounds Industry	Soap
93.	Toilet Preparations Industry	Toilet
94.	Floor Tile, Linoleum and Coated Fabric Industries, Other Manufacturing Industries	Tile
95.	Jewellery and Precious Metal Industries	Jewellery
96.	Sporting Goods and Toy Industries	Sporting
97.	Sign and Display Industry	Sign
98.	Construction Industries	Construction

Table 3.A1 (cont'd)

No.	Industries	Abbreviation
99.	Air Transport and Related Services Industries	Air Trans.
100.	Railway Transport and Related Services Industries	Rail Trans.
101.	Water Transport and Related Services Industries	Water Trans.
102.	Truck Transport Industries	Truck Trans.
103.	Urban, Interurban and Rural Transit Systems Industries, Miscellaneous Transport Services	Urban Trans.
104.	Pipeline Transport Industries	Pipeline
105.	Storage and Warehousing Industries	Storage
106.	Telecommunication Broadcasting Industries	Broadcasting
107.	Telecommunication Carriers Industries	Tel. Carrier
108.	Postal and Courier Services Industries	Courier
109.	Electric Power Systems Industry	Electric Power
110.	Gas Distribution Systems Industry	Gas Dist.
111.	Water Systems and Other Utility Industries, N.E.C.	Water Sys.
112.	Wholesale Trade Industries	Wholesale
113.	Retail Trade Industries	Retail
114.	Finance and Real Estate Industries	Finance
115.	Insurance Industries	Insurance
116.	Professional Business Services, Advertising Services, Other Business Services	Professional
117.	Educational Services Industries, Private	Education
118.	Other Health and Social Services Industries	Oth. Health
119.	Accommodation and Food Services Industries	Accomod.
120.	Motion Picture and Video Industries, Other Amusement and Recreational Services	Motion Pic.
121.	Laundries and Cleaners, Other Personal Services Industries	Laundries
122.	Membership Organizations (Excluding Religious) and Other Services Industries	Membership

Table 3.A2

Annual Growth Rates, Output and TFP (%)

	Output Growth			TFP Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric.	3.49	3.84	2.17	2.12	1.22	1.35
2. Fishing	0.79	3.24	-2.26	-0.65	0.06	-2.40
3. Logging	3.99	2.33	1.97	1.59	1.46	-0.60
4. Gold	-6.68	5.85	2.32	-0.98	1.85	2.82
5. Oth. Mines	4.97	-0.70	-1.98	0.49	1.05	-0.70
6. Iron Mines	10.75	-1.90	-1.46	1.68	0.41	-0.27
7. Asbestos	3.69	-6.75	-3.48	-1.27	-2.57	0.77
8. Non-metal Mines	15.03	4.37	0.18	7.63	1.42	2.84
9. Salt	5.79	5.52	0.49	2.02	3.91	1.27
10. Coal	5.96	7.79	-0.39	2.44	3.82	3.12
11. Crude Pet. and Gas	10.50	0.41	3.78	3.51	-5.46	3.50
12. Quarry	5.69	3.48	-2.11	2.21	1.13	-3.37
13. Oth. Mining	5.62	5.54	1.79	-0.65	0.27	-0.26
14. Poultry	4.05	2.31	0.52	0.15	0.20	-0.38
15. Fish Prod.	2.96	2.51	-1.32	-0.61	0.19	1.29
16. Fruit	3.78	2.44	1.01	0.85	0.82	1.17
17. Dairy	1.99	1.23	-1.55	0.48	0.12	-0.63
18. Feed	3.60	1.89	2.45	0.88	-0.19	1.62
19. Veg. Oil	6.14	6.55	7.10	0.87	0.72	1.13
20. Biscuit	1.06	-0.95	0.71	0.94	-0.21	-0.32
21. Soft Drink	5.71	1.61	0.46	0.75	-0.21	0.35
22. Distillery	6.92	-2.03	-3.56	2.58	0.21	0.15
23. Brewery	4.78	1.45	0.22	1.94	-0.73	1.92
24. Wine	9.68	2.87	-2.92	2.54	1.44	-1.61

Table 3.A2 (cont'd)

	Output Growth			TFP Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
25. Tobacco	2.18	-1.10	-0.65	0.75	0.82	0.27
26. Rubber	7.59	1.52	4.35	1.20	0.72	3.18
27. Plastic	13.63	5.88	2.29	3.22	0.18	-0.10
28. Leather	0.88	-0.60	-6.18	0.59	1.09	-0.34
29. Fibre Yarn	4.62	0.26	-0.30	1.34	2.01	1.04
30. Knitted Fabric	10.04	1.79	1.09	2.16	2.73	1.27
31. Misc. Textile	5.80	2.70	-1.04	1.41	-0.10	0.70
32. Carpet	20.11	3.22	-4.26	3.86	1.46	-0.23
33. Clothing	4.58	1.41	-2.01	0.90	0.69	0.72
34. Sawmill	5.78	3.85	1.44	0.27	1.72	-1.05
35. Veneer	4.82	-0.36	0.16	0.64	1.05	-1.69
36. Sash	6.11	3.91	-2.22	0.66	-0.02	-0.64
37. Wooden Box	4.16	1.78	-1.25	0.43	0.54	-1.51
38. Oth. Wood	3.52	7.10	3.79	-1.06	1.36	1.29
39. House. Furn.	6.65	0.69	-3.67	1.53	-0.89	0.96
40. Office Furn.	8.51	6.27	-0.15	2.40	-0.24	0.90
41. Oth. Furn.	6.64	2.25	0.94	1.49	-0.65	1.91
42. Pulp	4.33	1.96	1.72	-0.15	0.19	-0.37
43. Roofing	2.78	4.00	-2.60	1.64	1.59	-0.10
44. Paper Box	5.38	1.16	0.78	1.05	0.03	0.39
45. Oth. Paper	6.57	1.68	1.07	0.96	-0.73	1.34
46. Printing	3.81	3.73	-2.23	0.46	0.52	-1.44
47. Platemaking	4.65	5.12	-3.67	1.06	1.25	-2.14
48. Primary Steel	6.81	0.83	-0.15	0.95	-0.50	1.22
49. Steel Pipe	5.07	2.78	2.59	1.87	0.56	2.69
50. Iron	6.34	0.20	2.22	1.56	1.08	1.54

Table 3.A2 (cont'd)

	Output Growth			TFP Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
51. Non-ferrous	3.41	1.53	2.85	0.15	0.81	0.26
52. Aluminium	7.61	3.16	1.15	1.72	0.49	-1.16
53. Copper	4.07	-1.54	-4.66	0.40	0.46	1.26
54. Oth. Roll.	5.87	3.22	-0.82	-0.05	0.14	1.73
55. Power Boiler	6.67	0.43	-0.58	1.88	0.54	-0.45
56. Ornamental	5.95	4.74	-3.06	-0.10	2.42	1.03
57. Stamped	6.51	3.57	-2.55	0.38	1.06	1.56
58. Wire	6.77	-0.27	-1.27	1.44	-0.18	0.86
59. Hardware	7.91	1.59	2.04	1.55	-0.46	1.56
60. Heating	2.93	1.63	1.01	1.39	0.18	2.11
61. Machine Shop	5.75	4.71	6.00	1.70	-0.01	3.29
62. Oth. Metal	7.09	-1.01	0.39	1.49	-0.34	0.71
63. Agr. Implement	7.51	-1.63	7.43	1.30	0.75	2.19
64. Refrig.	11.34	1.94	-1.30	1.93	0.93	0.85
65. Oth. M&E	8.60	2.86	2.62	1.27	0.22	0.24
66. Aircraft	0.20	5.17	2.10	0.40	-0.24	1.46
67. Motor Veh.	13.17	4.05	5.21	2.81	0.32	0.30
68. Truck	18.17	0.67	-1.27	1.70	0.35	0.10
69. Motor Parts	14.20	5.11	4.79	2.04	2.04	1.52
70. Railroad	11.89	-1.17	7.19	2.67	-1.55	-0.08
71. Shipbuilding	3.61	0.55	-6.38	-0.19	-0.18	0.06
72. Misc. Trans.	17.39	0.01	9.50	2.39	0.16	2.87
73. Small Elec.	9.71	-0.59	-6.88	3.67	0.87	1.09
74. Major Appl.	6.27	-0.27	-3.56	2.39	-0.32	1.76
75. Oth. Elec.	6.96	1.56	-3.38	2.18	0.50	-0.18
76. Record Player	9.39	1.16	-7.31	3.17	3.36	-1.58

Table 3.A2 (cont' d)

	Output Growth			TFP Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
77. Comm. Equip.	8.69	7.06	9.32	2.34	1.80	0.92
78. Office Machine	5.97	20.74	22.24	-0.33	7.00	3.99
79. Wire and Cable	5.52	1.45	-1.73	0.38	0.24	0.10
80. Clay	3.32	-1.31	-12.42	2.51	0.27	-6.16
81. Hydraulic	4.58	-0.29	-2.02	1.72	-0.28	-0.39
82. Concrete	5.88	0.51	-4.98	2.14	0.96	-1.45
83. Ready-mix	8.52	1.22	-3.30	0.77	-0.96	-0.67
84. Glass	6.85	2.04	-0.49	1.93	1.11	1.25
85. Misc. Non-met.	5.66	1.81	-2.37	2.14	0.49	-0.28
86. Ref. Pet and Coal	6.18	-0.12	1.32	0.75	0.18	0.34
87. Oth. Ind. Chem.	6.86	3.80	-0.29	1.32	1.11	1.58
88. Oth. Chemical	5.66	3.83	1.92	1.11	0.69	1.48
89. Plastic and Syn.	8.21	6.10	6.68	2.76	0.56	2.90
90. Pharma.	8.33	4.50	3.41	2.51	1.92	-0.57
91. Paint	4.59	2.20	-3.23	0.55	0.76	-2.49
92. Soap	3.89	4.09	-0.02	1.94	-0.13	2.00
93. Toilet	6.78	3.51	0.65	1.27	-0.08	2.44
94. Tile	6.09	1.90	0.11	1.79	-0.15	0.22
95. Jewellery	4.99	1.37	-3.20	-0.58	0.41	0.60
96. Sporting	7.36	2.33	3.93	1.36	0.84	1.77
97. Sign	4.38	3.87	-1.04	1.11	-1.29	1.17
98. Construction	4.09	2.76	-1.69	-0.05	0.76	-0.25
99. Air Trans.	8.81	4.30	0.13	1.68	0.06	-2.01
100. Rail Trans.	4.95	2.61	0.01	4.99	2.89	1.55
101. Water Trans.	6.02	0.21	-1.98	2.66	2.04	-1.14
102. Truck Trans.	6.16	4.68	3.80	1.50	1.10	0.84

Table 3.A2 (cont'd)

	Output Growth			TFP Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
103. Urban Trans.	4.65	2.68	0.82	-0.63	-0.21	-1.44
104. Pipeline	11.86	1.27	6.74	6.69	0.50	1.89
105. Storage	2.61	1.91	0.80	1.49	-1.10	-0.53
106. Broadcasting	9.43	5.25	3.43	2.29	-0.70	-0.94
107. Tel. Carrier	8.36	8.18	4.83	4.68	4.94	1.79
108. Courier	4.53	5.65	1.74	1.93	-0.03	-1.94
109. Electric Power	8.45	4.56	1.56	2.78	0.31	-1.95
110. Gas Dist.	8.23	3.20	1.39	4.71	-0.75	-2.13
111. Water Sys.	9.24	6.47	1.31	1.13	1.28	-1.71
112. Wholesale	6.38	4.84	2.93	1.82	2.13	-0.01
113. Retail	5.37	3.63	1.87	2.35	0.83	0.16
114. Finance	5.81	4.07	3.32	-1.08	-2.11	1.91
115. Insurance	2.06	5.15	2.91	-1.37	2.19	-0.42
116. Professional	8.88	7.20	4.18	0.47	-0.59	-1.40
117. Education	3.91	2.29	-3.23	-1.05	3.28	-5.89
118. Oth. Health	7.32	5.26	2.34	0.10	0.56	-0.36
119. Accomod.	4.43	2.79	0.90	-0.47	-1.76	0.39
120. Motion Pic.	5.40	6.29	2.85	-0.48	-0.35	-1.38
121. Laundries	0.69	1.98	0.32	0.08	0.93	-1.74
122. Membership	6.98	6.26	2.96	1.39	-0.67	-1.31
Average	6.34	2.71	0.53	1.39	0.58	0.30

Table 3.A3

Annual Growth Rates, Inputs (%)

	Capital Input			Labour Input			Intermediate Input		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric.	1.61	0.06	-3.13	-3.00	-0.04	0.04	4.64	4.60	1.98
2. Fishing	2.00	-0.47	3.42	-2.23	4.46	-6.49	3.88	5.44	1.70
3. Logging	1.98	-2.60	-0.99	-0.27	-0.97	0.12	5.19	2.89	4.48
4. Gold	4.03	-0.31	-4.10	-8.92	5.34	-0.37	-4.44	11.28	2.74
5. Oth. Mines	4.10	-0.24	-2.90	2.38	-3.14	-2.59	8.69	-0.02	1.58
6. Iron Mines	10.22	-1.52	-0.79	3.46	-4.77	-0.21	10.96	-1.86	-2.01
7. Asbestos	7.45	-1.23	-1.80	1.71	-6.66	-0.81	5.27	-4.62	-7.04
8. Non-metal Mines	4.94	2.74	-8.16	5.61	1.56	1.90	11.79	3.94	2.37
9. Salt	4.50	-0.14	-3.87	2.18	1.34	1.20	4.60	3.00	0.09
10. Coal	13.39	3.07	-11.66	-2.57	2.94	-1.09	7.15	7.56	0.68
11. Crude Pet. and Gas	6.43	5.12	-1.09	8.96	7.01	-1.29	8.86	9.02	3.83
12. Quarry	3.00	0.56	6.35	0.67	1.85	1.65	6.16	3.81	-2.58
13. Oth. Mining	8.84	2.92	-3.22	4.63	6.86	1.73	6.08	5.58	2.79
14. Poultry	3.80	0.83	0.15	1.69	0.43	1.03	4.23	2.39	0.93
15. Fish Prod.	6.63	1.40	-1.12	4.00	2.05	-4.70	3.40	2.56	-2.03
16. Fruit	5.71	0.74	0.38	0.72	-0.57	0.87	3.08	2.50	-0.60
17. Dairy	6.66	0.68	-0.18	-1.21	-0.65	-1.95	1.59	1.41	-0.87
18. Feed	1.26	3.70	-2.40	1.17	1.01	0.41	3.26	1.98	1.93
19. Veg. Oil	3.11	4.25	3.35	2.99	4.31	2.80	5.55	5.99	6.65
20. Biscuit	0.52	-1.90	4.73	-0.76	-1.53	-0.42	0.59	0.30	0.36
21. Soft Drink	4.16	-0.02	-1.71	1.27	-0.99	-0.95	7.27	3.26	0.83
22. Distillery	4.51	-3.22	-1.81	2.69	-1.80	-8.76	4.72	-1.74	-2.71
23. Brewery	3.72	-0.51	-3.26	1.30	2.06	-2.50	2.98	3.72	0.20
24. Wine	4.30	-0.91	-2.05	6.00	1.06	-3.32	8.57	2.26	-0.59

Table 3.A3 (cont'd)

	Capital Input			Labour Input			Intermediate Input		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
25. Tobacco	1.80	-1.54	-2.31	-0.63	-3.37	-1.82	1.76	-1.56	0.12
26. Rubber	6.78	-0.22	3.10	3.67	0.64	-0.84	7.63	1.10	3.01
27. Plastic	5.37	4.43	2.59	8.52	4.48	1.82	12.17	6.37	2.66
28. Leather	2.84	-0.91	-2.12	-1.79	-2.55	-6.21	1.31	-1.30	-6.19
29. Fibre Yarn	4.14	-2.44	-1.00	0.13	-3.46	-3.09	4.50	-0.84	-0.59
30. Knitted Fabric	6.53	-1.97	5.11	3.35	-3.66	-0.28	8.92	-0.14	-0.93
31. Misc. Textile	5.88	1.32	-0.57	2.39	2.64	-2.05	5.07	3.17	-1.85
32. Carpet	8.75	-1.84	-3.95	11.67	-0.90	-5.57	18.97	2.83	-3.70
33. Clothing	4.98	1.68	1.79	0.90	-0.55	-4.71	5.10	1.28	-2.47
34. Sawmill	10.49	0.79	0.39	2.94	0.10	0.87	6.11	3.06	3.42
35. Veneer	7.56	-2.54	1.88	2.52	-2.95	-0.26	4.70	-0.68	2.39
36. Sash	1.86	1.20	-3.47	4.11	3.79	-1.71	6.52	4.40	-1.48
37. Wooden Box	5.37	-1.13	17.46	1.29	-0.84	-2.11	5.10	2.63	2.15
38. Oth. Wood	7.23	6.14	2.25	2.95	2.47	0.47	5.00	7.21	4.30
39. House. Furn.	5.24	1.58	-4.43	3.56	0.79	-4.65	6.13	2.09	-4.57
40. Office Furn.	7.10	5.04	-6.11	2.83	4.67	-0.23	8.60	7.84	-0.23
41. Oth. Furn.	5.31	0.24	-6.78	3.21	2.68	-0.88	6.27	3.43	0.14
42. Pulp	6.03	0.94	4.07	1.64	0.01	-1.39	5.36	2.63	2.25
43. Roofing	2.61	1.98	0.91	-1.65	1.87	-5.69	2.02	2.70	-3.45
44. Paper Box	5.19	0.88	-0.61	2.88	-0.31	0.49	4.80	1.66	0.43
45. Oth. Paper	7.33	3.66	2.98	4.59	0.38	-0.83	5.81	3.14	-0.35
46. Printing	3.46	1.93	-1.11	2.01	2.24	-0.32	4.55	4.39	-1.12
47. Platemaking	-0.04	1.58	10.35	2.25	3.18	-2.09	6.29	5.74	-3.34
48. Primary Steel	4.72	1.32	-4.93	3.80	-0.28	-4.56	7.19	2.11	0.19
49. Steel Pipe	-1.43	6.22	-14.21	4.13	1.14	0.15	3.55	2.34	1.81
50. Iron	3.82	-1.41	-0.28	3.34	-1.96	-0.63	6.27	0.22	1.82

Table 3.A3 (cont'd)

	Capital Input			Labour Input			Intermediate Input		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
51. Non-ferrous	2.73	2.46	5.95	0.78	-0.34	-2.02	3.87	1.02	3.19
52. Aluminium	4.88	1.11	4.54	2.58	-0.19	1.05	6.78	3.30	2.37
53. Copper	-1.36	-1.69	-5.08	1.80	-1.88	-4.67	4.28	-2.13	-5.76
54. Oth. Roll.	3.39	2.33	0.42	5.32	2.40	-1.68	6.57	3.59	-3.32
55. Power Boiler	3.96	-3.05	-6.33	3.62	-0.26	-0.18	5.66	0.87	1.29
56. Ornamental	5.01	0.99	-6.72	2.92	2.36	-5.44	7.96	2.36	-3.06
57. Stamped	7.05	2.39	-14.73	3.48	1.44	-1.42	7.09	2.99	-3.15
58. Wire	2.24	0.36	-6.86	3.84	-1.21	-1.20	6.63	0.22	-1.60
59. Hardware	3.48	2.46	-0.83	6.38	1.49	1.19	7.06	2.44	0.28
60. Heating	2.11	-0.76	-2.33	-0.61	2.68	-1.42	2.49	1.26	-0.46
61. Machine Shop	5.44	-1.73	3.44	2.87	5.01	1.73	4.88	5.63	3.85
62. Oth. Metal	4.62	-0.29	-7.65	3.96	-1.40	0.54	6.86	-0.35	0.93
63. Agr. Implement	2.70	-3.10	3.46	3.09	-1.99	0.46	8.25	-2.55	7.43
64. Refrig.	4.80	1.34	-3.87	7.32	0.64	-2.14	11.45	0.88	-2.01
65. Oth. M&E	2.87	0.62	3.80	5.36	2.65	-0.12	9.78	3.25	3.26
66. Aircraft	-0.37	3.61	0.83	-0.19	4.07	-1.02	0.18	6.75	2.12
67. Motor Veh.	3.18	11.47	-0.16	6.24	0.64	0.64	12.06	4.16	5.62
68. Truck	11.62	5.52	-0.38	13.62	-0.56	-0.71	17.73	0.38	-1.68
69. Motor Parts	9.10	3.29	-0.90	9.82	2.65	2.37	13.89	3.75	4.40
70. Railroad	-1.27	6.56	2.74	5.48	0.66	0.78	11.07	-1.46	10.74
71. Shipbuilding	1.58	-0.76	18.22	1.41	-1.77	-6.57	6.17	2.07	-10.93
72. Misc. Trans.	10.20	-1.13	12.34	11.08	-0.30	-2.12	17.77	0.28	8.75
73. Small Elec.	2.76	0.18	-16.98	4.89	-2.92	-10.96	7.50	-0.91	-5.83
74. Major Appl.	5.49	1.93	-2.92	1.48	-1.84	-5.18	4.89	0.35	-5.65
75. Oth. Elec.	3.67	-0.54	-2.80	3.47	-0.24	-4.97	5.88	2.19	-2.47
76. Record Player	5.83	0.25	1.78	1.82	-7.59	-15.01	8.01	-0.47	-5.47

Table 3.A3 (cont'd)

	Capital Input			Labour Input			Intermediate Input		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
77. Comm. Equip.	6.48	3.82	7.62	4.17	2.51	-0.05	8.72	7.80	12.34
78. Office Machine	6.90	12.64	-0.28	2.86	3.75	-0.64	7.89	18.07	22.47
79. Wire and Cable	2.75	1.55	-2.50	3.00	-0.82	-2.88	6.23	1.75	-1.78
80. Clay	-1.38	1.55	-8.92	-0.27	-2.85	-5.18	2.84	-2.22	-8.36
81. Hydraulic	-0.28	1.17	-5.36	2.80	-2.10	-2.58	5.67	0.60	0.01
82. Concrete	4.35	-6.34	-2.96	2.23	0.07	-3.08	4.53	1.22	-4.27
83. Ready-mix	14.23	1.91	-3.96	6.13	1.47	-1.93	7.08	2.06	-3.14
84. Glass	8.95	-1.62	-2.17	2.69	0.40	-4.52	5.57	2.12	0.28
85. Misc. Non-met.	2.33	1.70	-1.76	2.18	0.10	-2.78	4.79	1.96	-1.88
86. Ref. Pet and Coal	3.48	1.35	-2.60	1.80	-0.58	-1.72	6.03	-0.25	1.18
87. Oth. Ind. Chem.	5.88	4.76	-3.31	1.55	0.20	-2.69	6.80	3.18	-0.75
88. Oth. Chemical	4.94	1.53	-2.03	2.10	1.25	0.88	5.31	4.02	1.15
89. Plastic and Syn.	1.71	2.10	-1.04	2.02	2.80	2.71	7.77	6.60	4.74
90. Pharma.	5.61	1.27	5.60	3.66	1.78	1.54	6.95	3.37	4.06
91. Paint	4.57	-0.06	0.60	1.46	-0.08	0.13	5.04	2.22	-1.52
92. Soap	4.13	5.02	-0.72	1.36	2.51	-2.01	1.57	4.58	-2.15
93. Toilet	3.11	3.12	-1.41	6.00	3.63	-3.67	6.01	3.84	-1.13
94. Tile	6.86	2.77	1.13	2.13	1.70	-1.01	5.22	2.14	0.13
95. Jewellery	9.82	-0.01	2.61	3.36	-0.62	-1.60	5.99	1.23	-4.40
96. Sporting	5.80	0.23	4.53	4.59	0.01	2.75	6.71	2.51	1.51
97. Sign	2.83	6.75	-1.55	2.70	4.11	-1.62	4.26	5.58	-2.70
98. Construction	1.04	0.84	0.99	2.65	1.81	-1.12	5.17	2.35	-1.90
99. Air Trans.	5.27	3.76	8.10	6.60	3.00	1.47	8.38	5.31	1.99
100. Rail Trans.	-0.38	0.75	-4.58	-1.53	-3.30	-2.36	2.65	2.26	0.11
101. Water Trans.	-0.35	-0.72	-2.39	-0.76	-0.80	-3.79	7.51	-2.67	1.87
102. Truck Trans.	2.68	1.17	2.00	2.39	3.37	4.00	7.39	4.25	2.53

Table 3.A3 (cont' d)

	Capital Input			Labour Input			Intermediate Input		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
103. Urban Trans.	4.99	4.30	0.68	3.23	2.27	2.65	7.64	3.50	2.25
104. Pipeline	4.39	0.31	6.06	3.84	5.01	3.77	9.62	0.14	0.53
105. Storage	2.14	6.50	-1.85	0.45	0.99	1.42	0.81	3.31	2.51
106. Broadcasting	7.48	5.54	7.71	4.60	4.93	-0.29	8.85	6.92	5.35
107. Tel. Carrier	3.52	2.68	4.54	3.39	1.88	-0.05	4.81	8.03	4.32
108. Courier	6.67	12.61	-2.45	2.91	4.61	2.66	2.30	8.88	5.06
109. Electric Power	5.91	4.73	2.51	3.44	3.39	1.57	7.86	3.94	8.76
110. Gas Dist.	4.51	4.41	3.07	1.07	2.91	3.60	3.10	3.14	5.64
111. Water Sys.	7.22	2.38	9.98	5.89	5.67	3.94	9.51	6.05	0.74
112. Wholesale	1.61	1.90	2.21	4.97	1.95	1.97	5.57	4.47	4.86
113. Retail	1.35	2.16	4.81	2.64	2.67	0.36	4.42	3.35	3.15
114. Finance	6.54	7.01	1.12	6.11	4.30	0.20	8.20	6.84	2.60
115. Insurance	5.48	3.98	4.76	0.60	0.52	2.28	4.46	4.20	3.18
116. Professional	8.03	10.73	16.86	7.58	6.82	4.29	10.87	8.49	6.70
117. Education	9.25	13.71	7.10	5.68	2.84	3.71	5.14	2.84	4.35
118. Oth. Health	8.01	2.03	0.37	7.53	4.96	3.30	6.06	6.24	2.68
119. Accomod.	7.25	7.76	3.26	4.13	4.73	-0.86	5.12	3.65	1.37
120. Motion Pic.	8.07	7.89	4.06	5.14	5.23	2.79	5.82	7.22	5.17
121. Laundries	2.14	-0.39	1.29	0.19	0.22	1.44	2.02	3.30	3.62
122. Membership	6.96	13.59	5.77	5.72	4.00	3.64	4.70	7.98	4.80
Average	4.71	1.96	0.10	3.00	1.06	-0.96	6.21	3.01	0.90

Table 3.A4

Annual Growth Rates, Capital Stock and Quality (%)

	Capital Stock Growth			Capital Quality Growth		
	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95
1. Agric.	0.17	0.06	-0.11	1.44	0.00	-3.03
2. Fishing	2.01	-0.59	3.39	-0.01	0.13	0.03
3. Logging	-0.04	-2.44	-2.46	2.02	-0.16	1.47
4. Gold	5.44	0.39	-4.01	-1.41	-0.70	-0.09
5. Oth. Mines	3.85	-1.08	-2.48	0.25	0.84	-0.42
6. Iron Mines	7.79	-2.17	0.37	2.42	0.65	-1.16
7. Asbestos	7.45	-2.70	-1.63	0.00	1.47	-0.16
8. Non-metal Mines	5.20	2.43	-7.88	-0.26	0.31	-0.28
9. Salt	4.26	0.06	-3.54	0.24	-0.20	-0.33
10. Coal	12.06	2.30	-11.40	1.33	0.77	-0.26
11. Crude Pet. and Gas	6.44	5.10	-1.11	-0.01	0.02	0.01
12. Quarry	2.50	1.08	7.27	0.49	-0.53	-0.92
13. Oth. Mining	7.49	3.01	-3.34	1.35	-0.09	0.11
14. Poultry	2.68	0.55	-0.30	1.12	0.28	0.45
15. Fish Prod.	3.10	0.88	-1.99	3.52	0.52	0.87
16. Fruit	5.90	0.16	0.41	-0.19	0.59	-0.03
17. Dairy	5.95	0.21	-0.54	0.71	0.47	0.37
18. Feed	4.26	3.95	-2.54	-3.00	-0.26	0.14
19. Veg. Oil	0.40	1.47	1.76	2.72	2.78	1.59
20. Biscuit	0.73	-1.52	4.63	-0.21	-0.38	0.11
21. Soft Drink	2.60	-0.48	-2.43	1.56	0.47	0.72
22. Distillery	4.08	-3.41	-1.14	0.43	0.19	-0.67
23. Brewery	2.18	-1.04	-3.27	1.54	0.53	0.01
24. Wine	3.48	-0.89	-2.28	0.81	-0.02	0.23

Table 3.A4 (cont'd)

	Capital Stock Growth			Capital Quality Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
25. Tobacco	1.41	-1.81	-2.28	0.39	0.27	-0.04
26. Rubber	6.23	-1.35	-2.48	0.56	1.12	5.58
27. Plastic	4.07	4.51	2.53	1.30	-0.08	0.06
28. Leather	1.42	-0.41	-0.90	1.42	-0.49	-1.22
29. Fibre Yarn	4.15	-2.20	-0.70	-0.01	-0.23	-0.30
30. Knitted Fabric	5.76	-1.45	3.03	0.77	-0.52	2.08
31. Misc. Textile	5.96	1.42	-0.91	-0.08	-0.10	0.34
32. Carpet	8.28	-1.13	-2.00	0.46	-0.71	-1.95
33. Clothing	4.89	2.06	1.83	0.09	-0.38	-0.04
34. Sawmill	9.76	1.58	-1.66	0.73	-0.79	2.05
35. Veneer	6.12	-2.22	0.19	1.44	-0.32	1.69
36. Sash	2.52	0.74	-4.89	-0.67	0.45	1.42
37. Wooden Box	4.20	-0.50	3.79	1.18	-0.63	13.66
38. Oth. Wood	6.22	5.28	-1.34	1.01	0.86	3.58
39. House. Furn.	5.49	2.38	-5.06	-0.25	-0.79	0.63
40. Office Furn.	7.41	5.27	-11.77	-0.30	-0.23	5.67
41. Oth. Furn.	4.13	-0.25	-8.35	1.18	0.49	1.57
42. Pulp	6.22	1.05	2.79	-0.20	-0.11	1.28
43. Roofing	1.64	1.41	1.06	0.97	0.57	-0.15
44. Paper Box	4.80	0.93	1.15	0.39	-0.04	-1.76
45. Oth. Paper	6.08	2.91	1.29	1.25	0.75	1.69
46. Printing	3.35	1.54	0.10	0.10	0.39	-1.20
47. Platemaking	1.88	0.98	8.54	-1.92	0.60	1.81
48. Primary Steel	4.05	-0.18	-4.72	0.67	1.50	-0.22
49. Steel Pipe	-1.08	3.67	-13.44	-0.35	2.55	-0.77
50. Iron	3.36	-2.55	-1.24	0.46	1.14	0.96

Table 3.A4 (cont' d)

	Capital Stock Growth			Capital Quality Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
51. Non-ferrous	2.95	0.99	4.67	-0.23	1.47	1.28
52. Aluminium	5.60	1.30	2.51	-0.73	-0.19	2.03
53. Copper	-2.02	-2.68	-4.81	0.66	0.99	-0.27
54. Oth. Roll.	2.94	1.66	-0.38	0.44	0.67	0.80
55. Power Boiler	2.47	-2.83	-6.76	1.48	-0.22	0.43
56. Ornamental	3.42	0.94	-7.51	1.60	0.05	0.79
57. Stamped	5.27	1.55	-14.36	1.78	0.85	-0.37
58. Wire	1.68	0.57	-11.26	0.55	-0.20	4.40
59. Hardware	2.69	2.74	-2.53	0.80	-0.29	1.70
60. Heating	1.23	-1.22	-2.57	0.88	0.46	0.24
61. Machine Shop	4.48	-0.73	-3.19	0.96	-1.01	6.63
62. Oth. Metal	3.74	-0.38	-8.91	0.88	0.09	1.26
63. Agr. Implement	4.63	-7.08	2.28	-1.93	3.98	1.19
64. Refrig.	4.10	0.24	-4.06	0.70	1.10	0.18
65. Oth. M&E	2.28	-0.08	2.86	0.60	0.70	0.94
66. Aircraft	1.56	3.93	0.95	-1.92	-0.32	-0.12
67. Motor Veh.	2.34	3.48	-4.56	0.84	7.99	4.40
68. Truck	11.06	5.09	4.88	0.56	0.43	-5.26
69. Motor Parts	7.47	2.03	0.24	1.64	1.25	-1.15
70. Railroad	-0.90	5.02	2.02	-0.37	1.54	0.73
71. Shipbuilding	4.70	-1.12	7.06	-3.12	0.36	11.16
72. Misc. Trans.	11.32	-2.99	11.67	-1.11	1.86	0.67
73. Small Elec.	0.51	-0.42	-22.00	2.25	0.60	5.02
74. Major Appl.	5.39	1.87	-3.85	0.10	0.06	0.93
75. Oth. Elec.	2.89	-0.83	-2.89	0.79	0.29	0.09
76. Record Player	3.88	-1.54	9.77	1.95	1.79	-7.99

Table 3.A4 (cont’d)

	Capital Stock Growth			Capital Quality Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
77. Comm. Equip.	5.61	2.97	10.49	0.87	0.86	-2.87
78. Office Machine	6.63	8.43	1.93	0.27	4.21	-2.21
79. Wire and Cable	2.96	2.61	-1.15	-0.20	-1.06	-1.35
80. Clay	-3.35	-0.35	-7.11	1.97	1.91	-1.82
81. Hydraulic	-1.11	1.24	-4.97	0.82	-0.07	-0.39
82. Concrete	4.57	-6.34	-3.58	-0.22	0.00	0.62
83. Ready-mix	12.00	0.79	-3.51	2.24	1.11	-0.45
84. Glass	8.02	-1.27	-1.73	0.93	-0.35	-0.44
85. Misc. Non-met.	1.93	1.36	-1.43	0.40	0.34	-0.33
86. Ref. Pet and Coal	-3.74	-2.99	-2.40	7.22	4.35	-0.20
87. Oth. Ind. Chem.	5.25	3.23	-3.16	0.63	1.53	-0.15
88. Oth. Chemical	3.62	1.06	-2.21	1.32	0.47	0.18
89. Plastic and Syn.	1.48	1.23	-1.37	0.23	0.87	0.33
90. Pharma.	4.21	0.83	5.26	1.40	0.45	0.34
91. Paint	3.66	-0.41	0.30	0.91	0.35	0.30
92. Soap	1.27	4.15	-1.62	2.86	0.87	0.91
93. Toilet	0.67	3.16	-1.34	2.45	-0.04	-0.08
94. Tile	6.01	2.20	0.93	0.85	0.57	0.20
95. Jewellery	10.12	-4.61	-14.41	-0.30	4.60	17.02
96. Sporting	7.16	0.05	3.17	-1.36	0.18	1.37
97. Sign	2.60	6.36	-1.66	0.23	0.40	0.10
98. Construction	-0.48	-0.13	-0.14	1.52	0.97	1.13
99. Air Trans.	5.27	3.40	8.06	0.00	0.36	0.04
100. Rail Trans.	-0.55	-0.32	-4.22	0.17	1.07	-0.36
101. Water Trans.	0.14	-0.74	-2.38	-0.50	0.01	-0.01
102. Truck Trans.	1.71	1.13	2.32	0.97	0.04	-0.33

Table 3.A4 (cont’d)

	Capital Stock Growth			Capital Quality Growth		
	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95
103. Urban Trans.	4.24	3.11	-0.88	0.75	1.20	1.56
104. Pipeline	3.99	-0.14	5.94	0.40	0.44	0.12
105. Storage	1.41	10.96	-5.22	0.73	-4.46	3.37
106. Broadcasting	5.22	5.09	6.01	2.26	0.45	1.70
107. Tel. Carrier	3.83	2.32	4.35	-0.30	0.35	0.19
108. Courier	4.28	3.53	-1.84	2.39	9.08	-0.61
109. Electric Power	5.18	4.25	2.45	0.73	0.48	0.06
110. Gas Dist.	3.99	3.81	2.78	0.52	0.61	0.29
111. Water Sys.	7.75	-0.83	9.79	-0.54	3.21	0.19
112. Wholesale	0.56	1.77	0.31	1.05	0.13	1.90
113. Retail	0.62	2.33	1.15	0.73	-0.17	3.66
114. Finance	4.99	3.16	1.01	1.55	3.85	0.10
115. Insurance	4.48	2.99	4.70	1.00	0.99	0.06
116. Professional	6.64	6.19	10.23	1.39	4.54	6.63
117. Education	2.82	2.72	5.39	6.43	10.99	1.71
118. Oth. Health	6.50	1.25	0.13	1.51	0.78	0.24
119. Accomod.	5.83	4.16	2.58	1.42	3.60	0.68
120. Motion Pic.	5.24	2.89	3.68	2.83	5.00	0.38
121. Laundries	3.61	0.53	0.39	-1.46	-0.91	0.90
122. Membership	-1.43	1.31	2.13	8.39	12.28	3.64
Average	3.93	1.02	-0.75	0.78	0.93	0.85

Table 3.A5

Annual Growth Rates Of Labour Quality (%)

	Hours Worked Growth			Labour Quality Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric.	-3.38	-0.59	-0.37	0.38	0.55	0.41
2. Fishing	-2.94	4.53	-7.15	0.71	-0.07	0.65
3. Logging	-0.81	-1.09	0.19	0.54	0.12	-0.07
4. Gold	-9.49	4.80	-0.14	0.57	0.54	-0.23
5. Oth. Mines	2.19	-3.31	-2.49	0.19	0.18	-0.09
6. Iron Mines	3.05	-4.89	-0.16	0.41	0.11	-0.06
7. Asbestos	1.22	-7.04	-1.10	0.48	0.38	0.29
8. Non-metal Mines	5.03	1.21	1.66	0.58	0.36	0.24
9. Salt	1.80	1.11	0.90	0.38	0.23	0.30
10. Coal	-3.35	2.59	-0.91	0.79	0.34	-0.18
11. Crude Pet. and Gas	8.89	6.73	-1.81	0.06	0.28	0.52
12. Quarry	0.18	1.74	1.51	0.49	0.11	0.13
13. Oth. Mining	4.45	6.53	1.64	0.18	0.33	0.08
14. Poultry	1.48	0.42	1.05	0.21	0.00	-0.02
15. Fish Prod.	3.96	2.05	-4.83	0.05	0.00	0.13
16. Fruit	0.66	-0.78	0.27	0.06	0.21	0.61
17. Dairy	-1.62	-0.74	-2.32	0.42	0.08	0.37
18. Feed	0.82	0.65	0.09	0.35	0.36	0.32
19. Veg. Oil	2.93	1.98	3.06	0.06	2.33	-0.25
20. Biscuit	-0.88	-1.89	-0.53	0.12	0.36	0.11
21. Soft Drink	0.13	-1.28	-1.35	1.14	0.29	0.40
22. Distillery	2.26	-3.22	-9.07	0.43	1.43	0.31
23. Brewery	1.12	1.77	-3.13	0.18	0.30	0.63
24. Wine	5.79	0.94	-3.33	0.21	0.12	0.00

Table 3.A5 (cont'd)

	Hours Worked Growth			Labour Quality Growth		
	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95
25. Tobacco	-1.44	-3.97	-2.59	0.80	0.60	0.78
26. Rubber	3.46	0.35	-0.92	0.21	0.29	0.08
27. Plastic	8.34	4.16	1.42	0.19	0.32	0.40
28. Leather	-1.71	-2.63	-6.63	-0.08	0.07	0.42
29. Fibre Yarn	-0.25	-4.49	-3.31	0.37	1.03	0.21
30. Knitted Fabric	3.00	-4.61	-0.89	0.36	0.96	0.61
31. Misc. Textile	2.17	2.23	-2.57	0.22	0.40	0.52
32. Carpet	11.17	-1.25	-6.26	0.50	0.35	0.70
33. Clothing	0.90	-0.54	-4.94	-0.01	-0.01	0.23
34. Sawmill	2.38	-0.18	0.71	0.56	0.28	0.17
35. Veneer	1.97	-3.22	-0.52	0.56	0.27	0.25
36. Sash	3.58	3.67	-1.85	0.53	0.11	0.14
37. Wooden Box	0.73	-1.26	-2.41	0.56	0.42	0.30
38. Oth. Wood	2.61	1.98	0.38	0.34	0.49	0.08
39. House. Furn.	3.33	0.54	-4.75	0.24	0.25	0.10
40. Office Furn.	2.59	4.77	-0.51	0.25	-0.09	0.28
41. Oth. Furn.	2.97	2.32	-1.42	0.24	0.35	0.54
42. Pulp	1.41	-0.22	-1.58	0.24	0.23	0.19
43. Roofing	-2.41	1.62	-6.70	0.76	0.25	1.02
44. Paper Box	2.38	-0.70	0.03	0.50	0.39	0.45
45. Oth. Paper	4.20	0.00	-1.22	0.39	0.38	0.40
46. Printing	1.77	2.20	-0.65	0.23	0.04	0.33
47. Platemaking	2.62	3.28	-2.52	-0.37	-0.11	0.43
48. Primary Steel	3.59	-0.56	-4.79	0.21	0.28	0.24
49. Steel Pipe	3.97	0.80	-0.17	0.16	0.34	0.32
50. Iron	2.96	-2.17	-0.94	0.38	0.21	0.31

Table 3.A5 (cont' d)

	Hours Worked Growth			Labour Quality Growth		
	1961-73	**1973-88**	**1988-95**	**1961-73**	**1973-88**	**1988-95**
51. Non-ferrous	0.36	-0.51	-2.16	0.42	0.17	0.14
52. Aluminium	2.02	-0.52	0.77	0.57	0.34	0.28
53. Copper	1.36	-2.11	-5.00	0.43	0.23	0.32
54. Oth. Roll	5.07	2.19	-1.98	0.25	0.21	0.30
55. Power Boiler	3.24	-0.47	-0.55	0.38	0.21	0.36
56. Ornamental	2.69	2.30	-5.90	0.23	0.07	0.46
57. Stamped	3.18	1.17	-1.78	0.29	0.27	0.36
58. Wire	3.57	-1.43	-1.76	0.27	0.22	0.56
59. Hardware	6.07	1.34	0.69	0.31	0.16	0.51
60. Heating	-0.82	2.07	-2.11	0.21	0.61	0.68
61. Machine Shop	2.52	4.81	1.49	0.35	0.20	0.24
62. Oth. Metal	3.66	-1.74	0.08	0.30	0.34	0.46
63. Agr. Implement	2.73	-2.14	0.61	0.36	0.15	-0.15
64. Refrig.	6.79	0.19	-2.45	0.53	0.44	0.31
65. Oth. MandE	5.06	2.49	-0.44	0.30	0.17	0.33
66. Aircraft	-0.82	3.89	-1.24	0.63	0.18	0.22
67. Motor Veh.	5.78	0.54	0.55	0.46	0.10	0.09
68. Truck	13.61	-0.73	-0.94	0.02	0.17	0.23
69. Motor Parts	9.70	2.53	1.90	0.12	0.12	0.47
70. Railroad	5.12	0.40	0.71	0.36	0.27	0.07
71. Shipbuilding	0.79	-2.01	-6.77	0.62	0.24	0.20
72. Misc. Trans.	10.59	-0.82	-1.94	0.49	0.51	-0.18
73. Small Elec.	4.77	-3.07	-11.44	0.12	0.16	0.48
74. Major Appl.	1.21	-2.01	-5.54	0.27	0.17	0.36
75. Oth. Elec.	3.40	-0.46	-5.49	0.08	0.21	0.53
76. Record Player	1.86	-7.95	-15.37	-0.04	0.36	0.37

Table 3.A5 (cont'd)

	Hours Worked Growth			Labour Quality Growth		
	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95
77. Comm. Equip.	4.00	2.19	-0.71	0.17	0.32	0.66
78. Office Machine	2.52	3.34	-1.17	0.34	0.42	0.53
79. Wire and Cable	2.60	-1.16	-3.15	0.39	0.35	0.27
80. Clay	-0.41	-3.10	-4.92	0.14	0.25	-0.26
81. Hydraulic	2.40	-2.54	-2.50	0.40	0.43	-0.08
82. Concrete	1.74	-0.17	-3.46	0.49	0.23	0.38
83. Ready-mix	5.67	1.29	-2.00	0.46	0.18	0.07
84. Glass	2.37	0.20	-4.71	0.32	0.20	0.19
85. Misc. Non-met.	1.80	-0.18	-3.04	0.38	0.29	0.26
86. Ref. Pet and Coal	1.50	-0.74	-2.39	0.31	0.16	0.67
87. Oth. Ind. Chem.	1.28	-0.17	-3.35	0.27	0.37	0.66
88. Oth. Chemical	1.84	0.87	0.22	0.26	0.38	0.66
89. Plastic and Syn.	1.64	2.29	2.22	0.39	0.51	0.49
90. Pharma.	3.36	1.59	1.06	0.30	0.19	0.48
91. Paint	1.16	-0.26	-0.26	0.30	0.18	0.39
92. Soap	1.03	2.31	-2.37	0.33	0.20	0.36
93. Toilet	4.63	3.28	-4.24	1.37	0.35	0.57
94. Tile	1.85	1.49	-1.69	0.28	0.21	0.67
95. Jewellery	3.22	-0.63	-1.53	0.14	0.01	-0.08
96. Sporting	4.36	-0.23	2.44	0.23	0.25	0.31
97. Sign	2.43	4.03	-1.61	0.27	0.09	-0.01
98. Construction	2.21	1.40	-1.31	0.44	0.41	0.19
99. Air Trans.	6.01	2.81	0.95	0.59	0.18	0.52
100. Rail Trans.	-1.93	-3.47	-2.44	0.40	0.17	0.08
101. Water Trans.	-1.18	-0.97	-3.71	0.42	0.18	-0.08
102. Truck Trans.	2.05	3.21	3.97	0.34	0.16	0.03

Table 3.A5 (cont'd)

	Hours Worked Growth			Labour Quality Growth		
	1961-73	1973-88	1988-95	1961-73	1973-88	1988-95
103. Urban Trans.	2.84	1.99	2.38	0.40	0.28	0.27
104. Pipeline	3.28	4.76	3.55	0.56	0.24	0.22
105. Storage	0.28	0.90	1.41	0.17	0.09	0.01
106. Broadcasting	4.02	4.82	-0.49	0.58	0.11	0.20
107. Tel. Carrier	2.85	1.50	-0.19	0.54	0.37	0.15
108. Courier	2.48	4.41	2.61	0.43	0.20	0.04
109. Electric Power	2.85	3.01	1.24	0.59	0.38	0.33
110. Gas Dist.	0.72	2.64	3.46	0.34	0.27	0.14
111. Water Sys.	5.40	5.52	3.90	0.49	0.15	0.04
112. Wholesale	4.64	1.81	1.55	0.33	0.14	0.42
113. Retail	2.34	2.56	0.30	0.30	0.10	0.06
114. Finance	5.97	4.18	-0.23	0.14	0.11	0.43
115. Insurance	0.89	0.42	1.96	-0.29	0.10	0.32
116. Professional	8.16	6.28	3.69	-0.58	0.53	0.60
117. Education	4.56	2.00	3.39	1.12	0.84	0.32
118. Oth. Health	8.02	6.17	3.87	-0.49	-1.21	-0.57
119. Accomod.	3.57	4.59	-1.02	0.56	0.14	0.16
120. Motion Pic.	4.57	5.14	2.64	0.57	0.08	0.15
121. Laundries	-0.89	0.37	0.99	1.08	-0.14	0.45
122. Membership	5.64	3.95	3.44	0.08	0.05	0.20
Average	2.65	0.79	-1.24	0.35	0.27	0.28

A Comparison of Industrial Productivity Growth in Canada and the United States

4

Wulong Gu and Mun S. Ho

4.1 Introduction

THE PURPOSE OF THIS STUDY is to provide a consistent international comparison of the patterns of growth in Canadian and U.S. industries. While much comparative work has been done with respect to sectoral (total factor) productivity[1] in the two countries, it has often been based on concepts that are not entirely comparable. Our approach here is to use methods and definitions that are almost identical for the two countries and, therefore, to provide a better sense of their relative productivity performance.

We find that during the 1961-73 period, Canadian industries were able to bring their productivity levels closer to U.S. levels and also had a higher rate of output growth. After 1973, however, output and productivity growth in the aggregate business sector slowed down in both countries. The productivity growth of the business sector was almost identical in the two countries during the 1973-95 period. As a result, the gap in productivity levels between the Canadian and U.S. private business sectors remained virtually unchanged after 1973.

Behind the overall trend in the growth of Canadian and U.S. industries, there is substantial variation across industrial sectors. The primary objective of this study is to characterize the patterns of growth for each of 33 industrial sectors in the two countries. We decompose the growth of industrial output into the contributions of capital, labour, and intermediate inputs, and productivity growth. We find that input growth was the predominant source of output growth for almost all industries in the two countries over the 1961-95 period. Productivity growth contributed, on average, only about 20 percent of industrial output growth in the two countries during this period.

Our methodology for making international comparisons of growth in output, input, and productivity is based on the economic theory of production. We use measures of labour and capital that take into account the changing composition of the labour force and capital stocks (relatively more educated and older workers, and relatively more equipment compared to structures).

We show that the rise in the quality[2] of labour and capital inputs plays a significant role in the economic growth of both countries.

The study is organized as follows. In Section 4.2, we outline the theoretical framework for making international comparisons. In Section 4.3, we present a brief discussion of the data used in the measurement of industrial output and input in the two countries. Our empirical findings about the patterns of growth in Canada and the United States are summarized in Section 4.4. Finally, we present our conclusions in Section 4.5.

4.2 Methodology

OUR METHODOLOGY FOR MODELING PRODUCTION follows that of Jorgenson, Gollop, and Fraumeni (1987) and we will merely summarize that approach here. One may view output as being produced with different types of labour, capital, and intermediate inputs. That is, one may write the production function as:

(1) $$Q_{it} = f(K^i_{1t}, K^i_{2t}, \ldots, K^i_{pt}, L^i_{1t}, L^i_{2t}, \ldots, L^i_{qt}, X^i_{1t}, X^i_{2t}, \ldots, X^i_{rt}, t),$$

where Q_{it} is the quantity of output for sector i in period t; K^i_{jt}, the various types of capital input (structures, high-tech equipment, low-tech equipment, etc.); and L^i_{jt} and M^i_{jt}, the various labour and intermediate inputs. The last argument, t, is an index of the level of technology. Such an approach would allow, for example, skilled and unskilled workers to have different elasticities of substitution with different types of capital equipment. However appealing such an approach may be, it is not practicable for a large number of inputs and we assume that the production function can be simplified to:

(2) $$Q_{it} = f(K_{it}, L_{it}, M_{it}, t),$$

with

(3) $$K_{it} = k(K^i_{1t}, K^i_{2t}, \ldots, K^i_{pt}), \quad L_{it} = l(L^i_{1t}, L^i_{2t}, \ldots, L^i_{qt}),$$

and $$M_{it} = m(M^i_{1t}, M^i_{2t}, \ldots, M^i_{rt}).$$

The requirements for such an aggregation process are well known and we refer the reader to Jorgenson, Gollop, and Fraumeni (1987).

We assume that technology is characterized by constant returns to scale and define the cost of capital (P^K_{it}) in such a way that the value of output is equal to the value of all inputs from the point of view of the producer. This is unlike approaches that do not impose such an equality and calculate the cost of capital by other methods (for example, Hall, 1988). Denoting the price of output to the producer by P_{it} we have:

(4) $$P_{it}Q_{it} = P^K_{it}K_{it} + P^L_{it}L_{it} + P^M_{it}M_{it} ,$$

where $P^K_{it}, P^L_{it}, P^M_{it},$ are the prices of the respective input aggregates· The term for labour, for example, represents total labour compensation paid by producer i,

(5) $$P^L_{it}L_{it} = P^{Li}_{1t}L^i_{1t} + P^{Li}_{2t}L^i_{2t} + \ldots + P^{Li}_{qt}L^i_{qt} ,$$

where P^L_{it} is the price of type j labour.

We describe the aggregation process (3) in detail below. For the time being, we concentrate on the production constraints described by Equations (2) and (4). To construct an index of productivity for each sector i, we assume that the production function (2) may be written in a Hicks-neutral[3] translog form: $\ln Q_{it} = a(t) + f(\ln K_{it}, \ln L_{it}, \ln M_{it})$.

Specifically, the translog index of the rate of growth of productivity is given by:

(6) $$\ln \frac{A_{it}}{A_{it-1}} = \ln \frac{Q_{it}}{Q_{it-1}} - \bar{v}^K_{it} \ln \frac{K_{it}}{K_{it-1}} - \bar{v}^L_{it} \ln \frac{L_{it}}{L_{it-1}} - \bar{v}^M_{it} \ln \frac{M_{it}}{M_{it-1}},$$

where A_{it} is the index of technology in sector i, and the weights are input value shares:

(7) $$\bar{v}^K_{it} = \tfrac{1}{2}(v^K_{it} + v^K_{it-1}); \quad v^K_{it} = \frac{P^K_{it}K_{it}}{P_{it}Q_{it}};$$

$$\bar{v}^L_{it} = \tfrac{1}{2}(v^L_{it} + v^L_{it-1}); \quad v^L_{it} = \frac{P^L_{it}L_{it}}{P_{it}Q_{it}}; \text{ and}$$

$$\overline{v}_{it}^{M} = \tfrac{1}{2}(v_{it}^{M} + v_{it-1}^{M}) \; ; \quad v_{it}^{M} = \frac{P_{it}^{M} M_{it}}{P_{it} Q_{it}} .$$

The advantages of a chain index like (6) over the fixed-weight indices are well known and we need not elaborate here. We now turn to the construction of the input aggregates.

In constructing the input aggregates for capital, labour, and intermediate inputs, we impose separability assumptions as alluded to in Equations (2) and (3) above. The construction of capital input aggregates is discussed in detail in Appendix E for Canada, and in Appendix B for the United States. The method for labour input is given in Appendix C for the United States, and in Appendix F for Canada, and we will merely summarize the main points here.

The capital input index for each sector is constructed in a way that recognizes the tradeoff between detail and tractability. We have chosen to build up from four components — structures, equipment, land, and inventories. Beginning with investment data, we use the perpetual inventory method to derive the various stocks of capital, A^{i}_{jt}. The stock of type j created at the end of period t-1 produce a flow of capital services K^{i}_{jt} in period t. We assume that the quantity of services is proportional to the stocks:

(8) $$K^{i}_{jt} = q^{K}_{j} A^{i}_{jt-1} .$$

Note that the proportionality constant, q^{K}_{j}, is independent of time, hence the term "constant quality index." These flows of services from the various types of capital inputs are then aggregated, using the rental costs of capital, P^{Ki}_{jt}, derived from sectoral value-added data. We express the total flow of capital input into sector i as a translog function of the components:

(9) $$\ln\frac{K_{it}}{K_{it-1}} = \sum_{j}\tfrac{1}{2}(v^{Ki}_{jt} + v^{Ki}_{jt-1})\ln\frac{K^{i}_{jt}}{K^{i}_{jt-1}} = \sum_{j}\tfrac{1}{2}(v^{Ki}_{jt} + v^{Ki}_{jt-1})\ln\frac{A^{i}_{jt}}{A^{i}_{jt-1}} ,$$

where the weights are the value shares of total capital input:

$$(10) \quad v_{jt}^{Ki} = \frac{P_{jt}^{Ki} K_{jt}^{i}}{P_{it}^{K} K_{it}}, \ (j = 1,2,\ldots,p),$$

$$\text{and } P_{it}^{K} K_{it} = P_{1t}^{Ki} K_{1t}^{i} + P_{2t}^{Ki} K_{2t}^{i} + \ldots + P_{pt}^{Ki} K_{pt}^{i}.$$

In our analysis, we separate the growth of capital inputs into the effect of capital accumulation and the effect of substitution among different types of physical assets. The contribution of substitution among components of aggregate capital, which Jorgenson calls the quality index of capital input, is measured as:

$$(11) \quad q_{it}^{K} = \frac{K_{it}}{A_{it-1}},$$

where the total capital stock A_{it} of sector i is defined as the unweighted sum of the individual stocks:

$$(12) \quad A_{it} = \sum_{j} A_{jt}^{i}.$$

The labour input is constructed in a similar manner. While it might be argued that various categories of labour are not perfect substitutes (for example, physicists for engineers), that level of detail is clearly not practical and we have chosen to divide the labour force into sex, age, educational attainment, and employment category, as shown in Tables 4.1 and 4.2. All workers in a particular category are assumed to earn the same wage and to have the same marginal product. As in Equation (8) above (for capital services), we assume that the flow of effective labour services from group j is proportional to the annual number of hours worked by all workers in j, $L^{i}_{jt}=q^{L}_{j} H^{i}_{jt}$, where j runs over all the cells cross-classified by the different categories of workers. For Canada, the total number of cells in each sector is q = 168. The total labour input into sector i is then the translog aggregate over j:

$$(13) \quad \ln\frac{L_{it}}{L_{it-1}} = \sum_{j} \tfrac{1}{2}(v_{jt}^{Li} + v_{jt-1}^{Li}) \ln\frac{L_{jt}^{i}}{L_{jt-1}^{i}} = \sum_{j} \tfrac{1}{2}(v_{jt}^{Li} + v_{jt-1}^{Li}) \ln\frac{H_{jt}^{i}}{H_{jt-1}^{i}},$$

where the weights are the value shares:

$$v_{jt}^{Li} = \frac{P_{jt}^{Li} L_{jt}^{i}}{\sum_k P_{kt}^{Li} L_{kt}^{i}}, \quad (j = 1,2,\ldots,q).$$

We also wish to decompose the increase in labour input into changes in hours worked and changes in the composition of workers. The measure for the changes in composition, also called quality of labour by Jorgenson, is given as:

$$(14) \quad q_{it}^{L} = \frac{L_{it}}{\sum_j H_{jt}^{i}}.$$

Finally, the intermediate input aggregate is defined similarly as a translog aggregate over the various commodities:[4]

$$(15) \quad \ln \frac{M_{it}}{M_{it-1}} = \sum_{j=1}^{r} \tfrac{1}{2}(v_{jt}^{Mi} + v_{jt-1}^{Mi}) \ln \frac{M_{jt}^{i}}{M_{jt-1}^{i}}.$$

Table 4.1

Classification of the Canadian Workforce

Worker Characteristics	Number of Categories	Type
Sex	2	Female; Male
Employment Category	3	Paid Employees; Self-employed; Unpaid Family Workers
Age	7	15-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	0-8 Years Grade School; Some or Completed High School; Some or Completed Post-secondary; University or Above

Table 4.2

Classification of the U.S. Workforce

Worker Characteristics	Number of Categories	Type
Sex	2	Female; Male
Employment Category	2	Paid Employees; Self-employed and Unpaid Family Workers
Age	7	16-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	6	0-8 Years Grade School; 1-3 Years High School; 4 Years High School; 1-3 Years College; 4 Years College; 5+ Years College

4.3 Data

THE STARTING POINT FOR IMPLEMENTING the above methodology is the production account of each industry in both countries (for details, see Jorgenson, Kuroda, and Nishimizu, 1987). This includes data on price and quantity indices of output, capital inputs, labour inputs, and intermediate inputs (including energy, materials, and services) for each industry.[5] The value of output in Equation (2) is defined from the point of view of the producer. This includes subsidies but excludes all indirect taxes on output as well as trade and transportation margins incurred in the delivery of output to other sectors.

Similarly, the value of inputs is defined from the producer-purchaser's point of view. The value of labour inputs includes all taxes levied on labour and all costs incurred in the employment of labour, such as insurance and other fringe benefits. The value of capital inputs includes all taxes levied on the ownership and utilization of capital, such as property taxes and corporate income taxes. The value of intermediate inputs includes all taxes, as well as trade and transportation margins associated with taking deliveries of intermediate inputs from other sectors.

4.3.1 Intermediate Input Data

For Canada, the industry production account is estimated from the annual input-output (I-O) tables (see Durand, 1998, on the transformation of annual input-output tables for productivity analysis). Production accounts were estimated for 122 industries in Canada and 35 industries in the United States. Accounts for these industries were then consolidated into a common set of 33 industries making up the private business sector for the purpose of this study.[6]

The industry production account for the United States is an update and modification of that found in Jorgenson, Gollop, and Fraumeni (1987). The I-O data for 1977-95 come from the U.S. Bureau of Labor Statistics (BLS) and were linked to the pre-1977 tables described in Jorgenson and Wilcoxen (1990).[7]

4.3.2 Labour Input Data

Price and quantity indices of labour inputs for each industry in both countries are measured on the basis of labour compensation and hours worked, disaggregated by sex, age, educational attainment, and employment category.[8] To ensure the comparability of labour input measures between Canada and the United States, we employed a similar classification scheme for the workforce in the two countries, as shown in Tables 4.1 and 4.2. We have seven age groups and four to six educational levels.[9] Due to the different methods of estimating compensation, we also divided workers into employees and self-employed or unpaid family workers,[10] giving a total of 168 cells.

For the United States, the data are derived from the decennial Census of the Population, supplemented by the annual Demographic Surveys.[11] The data set consists of the number of workers, their annual weeks worked, their average hours per week, and their wage rates, for each cell. Compensation rates for each cell are calculated so that the totals of each industry match those of the National Income Accounts.

For Canada, the data are derived from the Census of Population, supplemented by the annual Surveys of Consumer Finance and the monthly Labour Force Surveys. The data set includes hours worked and labour compensation for each type of worker, cross-classified by sex, age, educational attainment, employment category, and industry. The estimates of hours worked and labour compensation for each industry are adjusted to official measures of hours worked and compensation produced by Statistics Canada.

4.3.3 Capital Input Data

To implement Equation (9) for capital input, data on property compensation and capital stocks are required. For both Canada and the United States, industry capital stocks are aggregated from four asset types — non-residential structures, machinery and equipment, land, and inventories.[12] For comparability, the two "structures" categories (building and engineering) in the Canadian data were added to form one asset type, while the 56 categories of producer durable equipment in the U.S. data were added to form "machinery and equipment."

The capital stock for the United States is estimated from investment data using geometric depreciation. These U.S. estimates use a 1.65 declining-balance rate for most machinery and equipment, and a 0.9 declining-balance rate for most non-residential structures. The capital stock data published by Statistics Canada are based on a modified double-declining-balance method for both machinery and equipment, and structures. To ensure comparability between

Canadian and U.S. capital stock estimates, we obtained an alternative set of capital stock estimates from the Investment and Capital Stock Division of Statistics Canada (see Appendix G, at the end of the manual). These alternative capital stocks estimates are based on the same declining-balance rates as those used for the United States. These estimates underlie our analysis of patterns of growth in Canadian and U.S. industries. However, for a comparison, we also present the results obtained with capital stocks used in Statistics Canada's productivity estimates shown in Annex B of this chapter.

The cost of capital for each asset is derived from sectoral value-added data using an equation that involves taxes and rates of return. Given the stocks described above, the P_{jt}^{Ki} in Equation (9) is scaled so that the total value of capital inputs for sector *i* is equal to the sectoral value added of capital in the National Income Accounts for the United States and the KLEMS database for Canada.[13]

4.4 Output Growth and Productivity Growth

BEFORE DISCUSSING THE RESULTS, we should emphasize that we are comparing growth rates here. The comparison of *absolute* productivity differences between the two countries is presented in Chapter 5. Given the finding there that Canada had a lower absolute productivity at the beginning of the sample period, amore rapid growth rate in Canada means a closing of the productivity gap with the United States.

4.4.1 Private Business Sector

To give an overview of the economy, we shall first examine the entire business sector and then consider sectoral estimates in the next section. For this, we use an approach similar to Jorgenson and Stiroh (1999), which expresses total value added as a function of capital, labour, and technology. Table 4.3 decomposes the growth of value added in the private business sector into the contributions of capital quantity and quality, labour quantity and quality, and productivity growth. The output of the private business sector grew faster in Canada than in the United States before 1988. For the most recent period — 1988-95 — output growth was slower in Canada: 1.5 percent versus 2.2 percent per year for the United States. The dominant factors of growth were increases in capital and labour inputs for both countries, with productivity growth contributing less than a third. For the entire period, capital input growth contributed 1.1 percent of the 3.7 percent rate of output growth in Canada, labour contributed 1.4 percent, and productivity growth 1.2 percent. The 1.1 percent capital input contribution can be decomposed further into 0.9 percent for capital accumulation and 0.2 percent for quality change. Similarly, the 1.4 percent labour input contribution is made up of 1.1 percent for increased hours worked and 0.3 percent for quality change. In the United States, of the 3.1 percent output growth rate, capital, labour, and productivity contributions were 1.0, 1.4, and 0.8 percent, respectively. One can see that quality changes in labour are roughly similar in the two countries, while capital quality growth is higher in the United States.

Productivity growth slowed down after 1973 in both countries, but the decline was more pronounced in Canada. Before 1973, productivity growth in the Canadian business sector was 2.5 percent per year, higher than the 1.6 percent rate recorded in the United States. After 1973, productivity growth was quite similar in the two countries. During 1988-95, productivity grew at about the same rate in both countries: 0.1 percent per year.

Table 4.3

Sources of Output Growth in the Private Business Sector, in Canada and the United States (Average % Growth per Year)

	Canada			
	1961-95	**1961-73**	**1973-88**	**1988-95**
Value Added	3.71	5.56	3.27	1.48
Contribution of Capital Stock	0.96	1.05	1.05	0.60
Contribution of Capital Quality	0.18	0.24	0.16	0.13
Contribution of Hours Worked	1.07	1.29	1.30	0.22
Contribution of Labour Quality	0.33	0.47	0.19	0.38
Productivity Growth	1.17	2.51	0.57	0.15
	United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**
Value Added	3.14	4.41	2.57	2.18
Contribution of Capital Stock	0.62	0.68	0.65	0.44
Contribution of Capital Quality	0.33	0.51	0.28	0.13
Contribution of Hours Worked	1.08	1.08	1.06	1.10
Contribution of Labour Quality	0.36	0.50	0.24	0.39
Productivity Growth	0.75	1.64	0.34	0.12

4.4.2 A Comparison across 33 Industries

We now turn to sectoral performance, measured with the methodology outlined in Section 4.2. Table 4.4 shows average annual growth rates of gross output in Canadian and U.S. industries over the period 1961-95 and in the three sub-periods (1961-73, 1973-88, and 1988-95).[14] The table also shows unweighted averages across the 33 industries. Before 1988, average growth rates of output in Canada were higher than in the United States for almost all industries, in particular mining and vehicles. After 1988, output growth in Canada was slower than in the United States in 21 of the 33 industries.

Tables 4.5 and 4.6 divide sectoral output growth into growth of all inputs and growth in total factor productivity (TFP). In line with the higher output growth, annual input growth rates in Canada were higher than in the United States in 28 of the 33 industries over the 1961-73 period, and in 29 industries over the 1973-88 period. For the period 1988-95, input growth rates were virtually identical in the two countries. A comparison of these two tables shows that the predominant source of output growth in most industries was the growth of capital, labour, and intermediate inputs, with TFP contributing only about a fifth in both countries. For the most recent period (1988-95), the contributions of capital, labour, and intermediate inputs were the predominant sources of output growth in 19 of 33 industries in Canada and in 21 of 33 industries in the United States.

In Table 4.6, we can see that most industries suffered a productivity growth slowdown after 1973, as noted above for the aggregate private business sector of both countries. Before 1973, productivity growth in most Canadian industries exceeded that of their U.S. counterparts, with the exception of food, tobacco, paper, printing, chemicals, petroleum refining, other transportation equipment, the finance, insurance, and real estate group (FIRE), and other services. After 1973, productivity in Canadian industries grew at a rate similar to that of U.S. industries. For the most recent period (1988-95), 13 of the 33 Canadian industries had faster TFP growth than their U.S. counterparts, including notably the FIRE, communications, transportation equipment, chemicals, lumber and wood, and crude petroleum and gas sectors.

Table 4.4

Output Growth in Canada and the United States (%)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric., For. and Fisheries	3.21	3.25	3.80	1.90	1.60	1.78	0.99	2.57
2. Metal Mining	2.09	4.26	1.33	0.01	0.34	1.68	-2.73	4.62
3. Coal Mining	5.46	5.96	7.79	-0.39	2.75	3.20	3.13	1.14
4. Crude Pet. and Gas	4.67	10.50	0.41	3.78	0.29	2.48	-0.39	-2.02
5. Non-met. Mining	3.19	6.84	2.21	-1.00	1.38	3.49	-0.05	0.80
6. Construction	2.31	4.09	2.76	-1.69	1.18	2.57	0.79	-0.38
7. Food	2.05	3.39	1.63	0.63	2.17	2.63	1.99	1.76
8. Tobacco	0.15	2.18	-1.10	-0.65	0.05	0.85	-0.64	0.16
9. Textile	2.59	6.04	1.60	-1.20	2.27	3.88	1.48	1.22
10. Apparel	1.96	4.82	1.43	-1.80	2.06	4.22	0.55	1.60
11. Lumber and Wood	3.36	4.87	3.13	1.26	2.40	4.64	1.73	-0.01
12. Furniture	3.18	6.88	2.24	-1.17	3.08	5.41	1.76	1.91
13. Paper	2.77	4.68	1.85	1.46	2.76	4.68	1.96	1.21
14. Printing	2.57	3.86	3.83	-2.35	2.46	3.26	3.01	-0.10
15. Chemicals	4.32	6.37	3.98	1.52	3.32	6.54	1.58	1.52
16. Petroleum Refining	2.40	6.18	-0.12	1.32	2.19	3.63	1.93	0.26
17. Rubber and Plastics	5.98	10.10	4.07	3.02	5.05	8.59	2.67	4.10
18. Leather	-1.23	0.88	-0.60	-6.18	-2.13	-0.51	-2.84	-3.36
19. Stone, Clay and Glass	2.02	6.10	1.05	-2.89	1.59	3.80	0.33	0.48
20. Primary Metals	2.67	5.18	1.31	1.28	0.74	4.15	-2.12	1.01
21. Fabricated Metals	2.86	6.80	1.55	-1.08	2.21	4.90	0.31	1.66
22. Non-elec. Machinery	5.81	7.87	3.32	7.64	4.79	6.14	3.19	5.91

Table 4.4 (cont'd)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
23. Electrical Machinery	4.55	7.26	2.97	3.26	5.10	6.88	3.27	5.97
24. Motor Vehicles	7.68	13.69	4.18	4.87	3.49	6.55	1.18	3.21
25. Other Trans. Equip.	3.18	4.23	2.45	2.94	1.42	2.75	2.48	-3.13
26. Misc. Manufacturing	3.06	5.95	2.05	0.28	3.61	5.34	3.50	0.86
27. Trans. and Warehouse	3.96	6.01	3.35	1.75	3.26	4.60	2.10	3.44
28. Communications	7.25	8.68	7.38	4.52	5.01	6.05	5.02	3.21
29. Electric Utilities	5.32	8.45	4.56	1.56	3.55	5.92	2.73	1.26
30. Gas Utilities	4.60	8.23	3.20	1.39	0.02	4.61	-2.44	-2.60
31. Trade	4.34	5.76	4.14	2.35	3.64	4.76	2.86	3.40
32. Finance, Ins. and Real Estate	4.37	5.21	4.22	3.26	3.44	4.15	3.83	1.39
33. Other Services	4.61	5.43	4.92	2.54	4.43	6.30	3.53	3.16
Average	3.55	6.06	2.75	0.97	2.41	4.24	1.42	1.40

Table 4.5

Input Growth in Canada and the United States (%)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric., For. and Fisheries	2.14	2.11	2.86	0.63	0.38	1.63	-0.54	0.20
2. Metal Mining	2.64	4.93	1.53	1.10	-0.51	2.96	-3.51	-0.03
3. Coal Mining	3.01	3.14	4.84	-1.12	1.52	3.73	1.96	-3.24
4. Crude Pet. and Gas	6.12	8.02	6.68	1.69	1.27	1.65	2.66	-2.37
5. Non-met. Mining	2.56	5.12	1.82	-0.23	1.02	2.42	-0.20	1.21
6. Construction	2.10	4.16	2.06	-1.37	1.84	3.18	1.29	0.72
7. Food	1.85	2.83	1.72	0.43	1.42	1.96	1.02	1.38
8. Tobacco	-0.37	1.50	-1.73	-0.66	0.01	-0.57	0.41	0.17
9. Textile	1.39	4.48	0.42	-1.83	0.76	3.35	-0.92	-0.08
10. Apparel	1.07	3.89	0.52	-2.59	0.97	3.42	-0.88	0.75
11. Lumber and Wood	2.74	4.09	2.02	1.94	2.48	4.95	0.69	2.09
12. Furniture	2.58	5.14	2.77	-2.22	2.37	4.79	0.84	1.51
13. Paper	2.74	4.49	1.88	1.55	2.47	3.84	1.73	1.72
14. Printing	2.56	3.38	3.33	-0.47	2.54	2.74	3.18	0.79
15. Chemicals	3.32	4.94	3.31	0.58	2.70	4.87	1.66	1.22
16. Petroleum Refining	2.09	5.57	-0.24	1.11	1.30	2.42	0.63	0.80
17. Rubber and Plastics	4.84	7.96	3.58	2.19	3.92	6.98	1.81	3.18
18. Leather	-1.81	0.26	-1.64	-5.73	-2.23	0.11	-3.65	-3.20
19. Stone, Clay and Glass	1.48	4.27	0.97	-2.21	1.08	3.26	-0.15	-0.01
20. Primary Metals	2.23	4.50	1.12	0.71	0.48	3.97	-2.28	0.41
21. Fabricated Metals	2.17	5.60	1.19	-1.59	1.62	4.07	-0.13	1.14
22. Non-elec. Machinery	4.80	6.37	2.94	6.11	3.09	5.36	1.23	3.17

Table 4.5 (cont'd)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
23. Electrical Machinery	3.30	5.22	2.08	2.64	3.11	5.15	1.49	3.08
24. Motor Vehicles	6.39	11.15	3.47	4.51	3.31	6.01	1.19	3.22
25. Other Trans. Equip.	2.79	3.77	2.63	1.43	0.93	1.96	2.00	-3.14
26. Misc. Manufacturing	2.41	4.59	1.92	-0.30	2.45	3.82	2.23	0.56
27. Trans. and Warehouse	2.76	3.28	2.57	2.29	2.23	2.66	1.56	2.94
28. Communications	3.90	4.27	3.99	3.06	4.37	5.34	4.48	2.50
29. Electric Utilities	4.96	5.87	4.68	4.01	2.61	3.66	3.02	-0.05
30. Gas Utilities	4.11	3.93	4.31	3.99	0.56	3.88	-0.72	-2.38
31. Trade	3.00	3.71	2.79	2.21	3.00	4.01	2.47	2.40
32. Finance, Ins. and Real Estate	5.14	6.23	5.74	2.01	3.72	4.26	3.85	2.51
33. Other Services	5.01	5.26	5.55	3.45	4.93	5.74	4.70	4.02
Average	2.91	4.67	2.48	0.83	1.87	3.56	1.00	0.82

Table 4.6

Productivity Growth in Canada and the United States (%)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric., For. and Fisheries	1.08	1.14	0.94	1.27	1.22	0.16	1.53	2.37
2. Metal Mining	-0.55	-0.68	-0.19	-1.09	0.85	-1.29	0.77	4.66
3. Coal Mining	2.45	2.83	2.94	0.73	1.23	-0.53	1.17	4.38
4. Crude Pet. and Gas	-1.46	2.48	-6.26	2.09	-0.98	0.83	-3.05	0.35
5. Non-met. Mining	0.63	1.73	0.40	-0.77	0.36	1.07	0.15	-0.41
6. Construction	0.22	-0.07	0.69	-0.32	-0.66	-0.61	-0.50	-1.10
7. Food	0.20	0.56	-0.08	0.20	0.74	0.67	0.97	0.39
8. Tobacco	0.52	0.68	0.63	0.01	0.04	1.42	-1.04	-0.01
9. Textile	1.20	1.56	1.18	0.63	1.51	0.53	2.40	1.29
10. Apparel	0.89	0.92	0.91	0.79	1.08	0.80	1.43	0.84
11. Lumber and Wood	0.62	0.77	1.10	-0.68	-0.08	-0.31	1.04	-2.10
12. Furniture	0.60	1.74	-0.53	1.05	0.71	0.62	0.92	0.40
13. Paper	0.03	0.19	-0.03	-0.09	0.29	0.84	0.23	-0.51
14. Printing	0.01	0.49	0.51	-1.87	-0.08	0.52	-0.17	-0.90
15. Chemicals	0.99	1.43	0.67	0.94	0.62	1.68	-0.08	0.31
16. Petroleum Refining	0.32	0.62	0.12	0.22	0.89	1.22	1.30	-0.54
17. Rubber and Plastics	1.14	2.13	0.49	0.83	1.14	1.60	0.86	0.92
18. Leather	0.59	0.62	1.05	-0.45	0.11	-0.63	0.81	-0.16
19. Stone, Clay and Glass	0.54	1.83	0.08	-0.69	0.50	0.54	0.48	0.49
20. Primary Metals	0.44	0.68	0.19	0.57	0.26	0.18	0.16	0.60
21. Fabricated Metals	0.69	1.20	0.36	0.51	0.59	0.83	0.44	0.52
22. Non-elec. Machinery	1.01	1.50	0.38	1.53	1.70	0.77	1.96	2.75

Table 4.6 (cont'd)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
23. Electrical Machinery	1.24	2.05	0.89	0.62	1.99	1.73	1.79	2.89
24. Motor Vehicles	1.28	2.54	0.71	0.37	0.18	0.55	-0.01	-0.02
25. Other Trans. Equip.	0.39	0.46	-0.18	1.52	0.49	0.80	0.48	0.01
26. Misc. Manufacturing	0.66	1.36	0.13	0.58	1.16	1.52	1.27	0.30
27. Trans. and Warehouse	1.19	2.73	0.78	-0.54	1.02	1.93	0.54	0.50
28. Communications	3.35	4.41	3.39	1.46	0.64	0.71	0.54	0.71
29. Electric Utilities	0.36	2.58	-0.11	-2.44	0.94	2.26	-0.29	1.31
30. Gas Utilities	0.49	4.30	-1.11	-2.60	-0.54	0.73	-1.72	-0.22
31. Trade	1.35	2.05	1.35	0.14	0.64	0.75	0.39	1.00
32. Finance, Ins. and Real Estate	-0.77	-1.02	-1.51	1.24	-0.28	-0.11	-0.03	-1.11
33. Other Services	-0.40	0.18	-0.63	-0.91	-0.50	0.57	-1.18	-0.86
Average	0.65	1.39	0.28	0.15	0.54	0.68	0.41	0.58

In tables 4.7 to 4.9, we present the growth of capital, labour, and intermediate inputs separately. An interesting feature of economic growth in Canada has been the high growth rates of intermediate inputs for almost all industries during the first two periods, 1961-73 and 1973-88. The growth rates of intermediate inputs were higher in 29 Canadian industries during first two periods and in 15 industries during the most recent period, 1988-95. In both countries, there has been a steady slowdown in the growth of capital, labour, and intermediate inputs in most industries since 1961. For example, the growth of capital input in Canada declined in 28 industries between 1961-73 and 1973-88, and in 24 industries between 1973-88 and 1988-95. In the United States, the growth of capital input declined in 24 industries between 1961-73 and 1973-88, and in 29 industries between 1973-88 and 1988-95. This steady slowdown in capital input growth occurred despite the rapid growth of investments in high-tech assets such as computers (Ho, Jorgenson and Stiroh, 1999).

Recall from Equations (11) and (14) that we divide the growth of factor inputs into quantity and quality growth (composition change). Table 4.10 shows the results for capital quality growth in the two countries. Capital quality increased in almost all industries in both countries during all three periods. The growth rates of capital quality in Canada were higher in 10 industries from 1961 to 1973, and in 13 industries for the subsequent period 1973-88. For the 1988-95 period, 20 of the 33 Canadian industries had higher growth of capital quality, mainly as a result of a faster shift toward machinery and equipment in the composition of capital stocks in Canada. A closer look at the data reveals that the Canadian sectors which experienced substantially higher growth rates of capital quality over the period 1988-95 include lumber and wood, furniture, rubber and plastics, motor vehicles, trade, and other services. In the United States, sectors that experienced higher growth rates include agriculture, forestry and fisheries, electrical machinery, and FIRE.

Table 4.11 shows annual average growth rates of labour quality in Canadian and U.S. industries. For the entire period, labour quality increased in all industries in both countries. The growth rates of labour quality in Canada were lower in 19 industries over the 1961-73 period, and in 22 industries over the 1973-88 period. For the most recent period (1988-95), the growth of labour quality was slower in Canada in almost all industries except crude petroleum and gas, petroleum refining, transportation and warehouse, and other services. The sectors with the largest gaps in the growth of labour quality were FIRE, communications, leather, lumber and wood, apparel, and coal mining, although the differences here are modest compared to the differences in capital quality growth.

Table 4.7

Growth of Capital Input in Canada and the United States (%)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric., For. and Fisheries	1.45	4.51	1.12	-3.07	1.73	1.92	1.14	2.66
2. Metal Mining	2.95	5.35	2.36	0.08	3.00	7.37	1.74	-1.82
3. Coal Mining	5.33	10.90	5.00	-3.53	4.13	4.15	6.65	-1.32
4. Crude Pet. and Gas	5.77	7.75	6.29	1.25	2.23	2.69	4.75	-3.94
5. Non-met. Mining	2.85	5.54	2.43	-0.86	3.07	4.95	2.14	1.85
6. Construction	1.55	1.48	1.44	1.93	1.31	3.34	1.56	-2.73
7. Food	2.30	4.07	1.57	0.81	3.12	4.20	3.46	0.54
8. Tobacco	0.17	2.28	-0.74	-1.50	2.49	0.03	5.17	0.94
9. Textile	1.05	4.20	-0.78	-0.42	2.94	3.29	3.38	1.41
10. Apparel	2.08	3.93	0.79	1.70	4.81	8.21	3.07	2.69
11. Lumber and Wood	2.35	4.82	1.33	0.29	2.30	2.86	2.96	-0.08
12. Furniture	1.70	4.03	1.65	-2.19	5.01	7.63	4.53	1.53
13. Paper	3.69	5.93	1.90	3.70	4.34	4.24	4.99	3.11
14. Printing	2.59	3.39	2.26	1.93	4.56	4.57	5.29	2.99
15. Chemicals	3.81	5.34	4.31	0.12	4.40	6.69	4.28	0.74
16. Petroleum Refining	2.98	3.92	3.41	0.47	2.50	3.29	1.42	3.46
17. Rubber and Plastics	3.87	6.15	2.45	3.02	5.27	6.36	5.48	2.96
18. Leather	0.45	2.45	-0.51	-0.90	0.36	1.09	0.89	-2.00
19. Stone, Clay and Glass	1.40	3.63	0.87	-1.26	2.19	2.87	3.65	-2.07
20. Primary Metals	2.89	4.58	2.10	1.70	1.89	2.75	2.44	-0.76
21. Fabricated Metals	0.92	4.38	0.72	-4.56	3.18	5.17	3.27	-0.39
22. Non-elec. Machinery	2.49	3.87	1.29	2.68	4.75	5.69	5.40	1.74

Table 4.7 (cont'd)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
23. Electrical Machinery	3.11	4.47	2.08	2.99	6.39	9.99	5.51	2.12
24. Motor Vehicles	4.75	5.00	5.48	2.75	3.04	5.21	2.35	0.78
25. Other Trans. Equip.	2.42	1.85	2.93	2.32	4.60	6.06	5.20	0.83
26. Misc. Manufacturing	3.44	6.21	1.99	1.80	4.91	5.43	5.33	3.13
27. Trans. and Warehouse	1.99	1.86	2.22	1.73	0.71	1.00	0.80	0.02
28. Communications	3.91	4.11	3.56	4.34	4.88	7.51	3.91	2.46
29. Electric Utilities	5.26	6.24	5.39	3.32	1.84	1.71	3.80	-2.16
30. Gas Utilities	4.79	5.16	4.96	3.79	3.55	3.77	3.16	4.01
31. Trade	2.34	2.23	2.18	2.87	4.62	5.95	4.22	3.19
32. Finance, Ins. and Real Estate	5.81	6.41	6.82	2.59	3.61	4.66	3.46	2.16
33. Other Services	6.62	6.06	7.43	5.86	5.10	7.22	3.78	4.27
Average	3.00	4.61	2.61	1.08	3.42	4.60	3.61	0.98

Table 4.8

Growth of Labour Input in Canada and the United States (%)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric., For. and Fisheries	-0.98	-2.95	0.38	-0.51	-1.09	-2.08	-1.03	0.48
2. Metal Mining	0.78	1.23	0.76	0.07	-0.72	0.94	-2.80	0.91
3. Coal Mining	0.16	-2.57	2.94	-1.09	-0.16	2.04	-0.54	-3.13
4. Crude Pet. and Gas	5.99	8.96	7.01	-1.29	0.67	-1.08	3.54	-2.50
5. Non-met. Mining	1.11	2.21	0.03	1.55	0.47	0.54	0.14	1.05
6. Construction	1.50	2.65	1.81	-1.12	2.36	2.90	2.08	2.04
7. Food	0.24	0.81	0.19	-0.62	0.06	0.08	-0.55	1.37
8. Tobacco	-2.09	-0.63	-3.37	-1.82	-1.21	0.22	-1.66	-2.69
9. Textile	-0.45	1.43	-0.86	-2.82	-0.74	1.21	-2.43	-0.48
10. Apparel	-0.89	1.00	-0.69	-4.56	0.01	1.92	-1.20	-0.67
11. Lumber and Wood	0.62	1.51	0.19	0.01	1.26	2.44	0.14	1.65
12. Furniture	1.51	3.33	1.90	-2.46	1.42	3.30	0.33	0.52
13. Paper	0.58	2.11	0.03	-0.88	0.95	1.77	0.18	1.19
14. Printing	1.64	2.04	2.33	-0.54	2.18	0.70	3.98	0.88
15. Chemicals	1.29	2.22	1.25	-0.22	1.22	1.63	1.03	0.91
16. Petroleum Refining	0.03	1.80	-0.58	-1.72	-0.69	-0.38	-0.86	-0.87
17. Rubber and Plastics	3.44	5.65	2.83	0.96	2.84	5.55	0.71	2.76
18. Leather	-3.04	-1.79	-2.55	-6.21	-3.03	-0.35	-5.32	-2.69
19. Stone, Clay and Glass	0.27	2.60	-0.02	-3.11	0.36	2.05	-0.95	0.30
20. Primary Metals	0.27	2.72	-0.30	-2.69	-0.70	1.97	-3.02	-0.32
21. Fabricated Metals	1.38	3.92	0.43	-0.94	0.81	2.50	-0.75	1.25
22. Non-elec. Machinery	2.58	4.13	2.51	0.09	1.44	3.32	0.26	0.77

Table 4.8 (cont'd)

	Canada				United States			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
23. Electrical Machinery	0.78	3.37	0.24	-2.53	1.35	2.76	0.92	-0.15
24. Motor Vehicles	4.03	8.56	1.53	1.60	1.72	3.57	-0.32	2.90
25. Other Trans. Equip.	1.09	1.80	1.78	-1.61	0.05	0.42	1.88	-4.49
26. Misc. Manufacturing	1.46	2.67	1.42	-0.53	1.42	2.61	1.60	-1.00
27. Trans. and Warehouse	1.95	1.50	1.98	2.65	1.48	1.20	0.82	3.37
28. Communications	2.30	3.54	2.43	-0.12	1.98	3.19	0.93	2.15
29. Electric Utilities	3.03	3.44	3.39	1.57	1.27	1.91	1.46	-0.22
30. Gas Utilities	2.40	1.07	2.91	3.60	0.07	0.67	-0.46	0.16
31. Trade	2.48	3.43	2.40	1.00	2.00	2.07	1.92	2.04
32. Finance, Ins. and Real Estate	3.42	4.76	3.74	0.44	3.11	3.63	3.18	2.07
33. Other Services	4.45	4.77	5.00	2.72	4.30	3.91	4.67	4.20
Average	1.31	2.46	1.31	-0.64	0.80	1.73	0.24	0.42

Table 4.9

Growth of Intermediate Inputs in Canada and the United States (%)

	Canada				United States			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	4.08	4.60	4.64	1.97	0.73	3.30	-0.68	-0.66
2. Metal Mining	3.93	7.64	2.01	1.70	-3.03	2.06	-9.35	1.80
3. Coal Mining	6.00	7.15	7.56	0.68	1.93	5.09	2.39	-4.48
4. Crude Pet. and Gas	7.89	8.85	9.03	3.83	0.05	1.63	-1.46	0.58
5. Non-met. Mining	3.10	6.83	2.00	-0.93	0.44	2.22	-1.19	0.86
6. Construction	2.47	5.17	2.35	-1.90	1.46	3.34	0.64	-0.04
7. Food	2.14	3.13	2.07	0.60	1.55	2.16	1.08	1.53
8. Tobacco	-0.04	1.76	-1.56	0.12	-0.60	-0.82	-1.00	0.64
9. Textile	2.25	5.86	1.19	-1.66	1.05	3.89	-0.71	-0.06
10. Apparel	1.94	5.42	1.15	-2.34	1.14	3.76	-1.04	1.34
11. Lumber and Wood	4.04	5.68	3.12	3.21	3.05	6.25	0.69	2.59
12. Furniture	3.43	6.43	3.50	-1.88	2.68	5.29	0.82	2.20
13. Paper	3.32	5.25	2.55	1.69	2.75	4.63	1.78	1.62
14. Printing	3.36	4.66	4.49	-1.29	2.28	3.81	2.11	0.01
15. Chemicals	3.94	5.86	3.79	0.96	2.82	5.57	1.16	1.66
16. Petroleum Refining	2.26	6.03	-0.25	1.19	1.47	2.74	0.85	0.64
17. Rubber and Plastics	5.75	9.50	4.13	2.78	4.35	7.85	1.96	3.46
18. Leather	-1.39	1.31	-1.30	-6.19	-2.10	0.26	-3.22	-3.74
19. Stone, Clay and Glass	2.19	5.46	1.59	-2.11	1.41	4.26	-0.29	0.15
20. Primary Metals	2.81	5.07	1.58	1.57	0.79	4.73	-2.38	0.84
21. Fabricated Metals	2.86	6.78	1.66	-1.27	1.89	4.82	-0.27	1.46
22. Non-elec. Machinery	6.52	8.47	3.60	9.42	3.87	6.57	1.15	5.08

Table 4.9 (cont'd)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
23. Electrical Machinery	4.63	6.51	3.08	4.73	3.66	5.70	1.26	5.32
24. Motor Vehicles	7.27	12.71	3.90	5.14	3.85	6.88	1.54	3.60
25. Other Trans. Equip.	3.96	5.42	3.15	3.20	1.26	2.68	1.86	-2.45
26. Misc. Manufacturing	2.79	5.52	2.19	-0.60	2.86	4.41	2.27	1.46
27. Trans. and Warehouse	4.07	6.16	3.29	2.18	3.54	4.99	2.49	3.32
28. Communications	6.51	6.17	7.63	4.68	6.18	5.25	8.53	2.73
29. Electric Utilities	6.32	7.86	3.95	8.80	4.40	7.02	3.30	2.28
30. Gas Utilities	3.65	3.10	3.14	5.67	-0.56	4.50	-1.87	-6.43
31. Trade	4.23	4.88	3.84	3.97	3.85	6.23	2.53	2.58
32. Finance, Ins. and Real Estate	5.86	7.13	6.31	2.71	4.27	4.31	4.77	3.15
33. Other Services	5.39	5.81	5.71	3.98	5.59	7.13	5.23	3.72
Average	3.86	6.01	3.18	1.65	2.09	4.32	0.76	1.11

Table 4.10

Growth of Capital Quality in Canada and the United States (%)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric., For. and Fisheries	1.04	3.87	0.50	-2.64	0.75	1.56	0.40	0.13
2. Metal Mining	-0.56	-0.98	-0.37	-0.25	0.07	0.24	0.09	-0.27
3. Coal Mining	-0.37	-0.66	-0.06	-0.53	-0.18	0.38	-0.52	-0.41
4. Crude Pet. and Gas	-0.09	-0.09	-0.02	-0.25	0.14	0.31	0.15	-0.17
5. Non-met. Mining	-0.32	-0.31	-0.26	-0.46	-0.02	0.22	-0.21	-0.02
6. Construction	0.90	1.48	0.51	0.75	-0.03	0.22	-0.13	-0.23
7. Food	0.34	0.57	0.17	0.31	0.50	0.88	0.40	0.04
8. Tobacco	0.30	0.48	0.24	0.14	0.04	0.15	-0.03	0.00
9. Textile	0.04	0.49	-0.32	0.06	0.61	1.58	0.19	-0.13
10. Apparel	0.11	0.77	-0.36	-0.02	0.33	0.95	0.02	-0.07
11. Lumber and Wood	0.57	0.98	0.02	1.05	0.22	0.44	0.18	-0.05
12. Furniture	0.44	0.31	-0.28	2.20	0.60	1.38	0.26	0.01
13. Paper	0.15	0.44	-0.12	0.22	0.51	0.81	0.48	0.08
14. Printing	0.10	0.11	0.23	-0.17	0.27	0.36	0.31	0.04
15. Chemicals	0.48	0.89	0.39	0.01	0.48	0.93	0.31	0.07
16. Petroleum Refining	3.92	6.16	3.64	0.69	0.97	1.25	0.79	0.88
17. Rubber and Plastics	0.77	0.64	0.65	1.26	0.21	0.35	0.12	0.17
18. Leather	0.00	1.07	-0.65	-0.42	0.40	0.95	0.14	0.03
19. Stone, Clay and Glass	0.40	0.50	0.34	0.36	0.61	1.16	0.57	-0.23
20. Primary Metals	0.67	0.85	0.51	0.71	0.67	1.38	0.50	-0.16

Table 4.10 (cont' d)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
21. Fabricated Metals	0.34	0.98	-0.20	0.42	0.41	0.80	0.29	-0.03
22. Non-elec. Machinery	0.37	0.51	0.23	0.40	0.49	0.59	0.73	-0.23
23. Electrical Machinery	0.06	0.55	0.17	-1.00	0.94	1.77	0.67	0.10
24. Motor Vehicles	1.57	1.01	1.84	1.94	0.66	1.18	0.85	-0.62
25. Other Trans. Equip.	-0.30	-0.52	-0.30	0.06	0.44	0.56	0.57	-0.02
26. Misc. Manufacturing	0.22	0.26	0.09	0.43	0.34	0.36	0.26	0.47
27. Trans. and Warehouse	0.23	-0.07	0.23	0.76	0.84	1.18	0.70	0.52
28. Communications	0.09	-0.02	0.16	0.10	0.51	1.15	0.23	0.01
29. Electric Utilities	0.43	0.58	0.50	0.05	0.42	0.59	0.41	0.17
30. Gas Utilities	0.42	0.34	0.52	0.32	0.28	-0.03	0.43	0.49
31. Trade	0.68	1.10	-0.05	1.51	1.07	1.83	0.83	0.26
32. Finance, Ins. and Real Estate	1.70	1.26	2.78	0.15	1.15	1.36	1.24	0.61
33. Other Services	2.91	2.84	3.68	1.35	0.85	1.79	0.49	0.00
Average	0.53	0.80	0.44	0.29	0.47	0.87	0.36	0.04

Table 4.11

Growth of Labour Quality in Canada and the United States (%)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
1. Agric., For. and Fisheries	0.50	0.41	0.61	0.41	0.93	1.22	0.67	1.02
2. Metal Mining	0.19	0.31	0.19	0.01	0.53	0.60	0.65	0.18
3. Coal Mining	0.39	0.79	0.34	-0.18	0.43	0.60	-0.05	1.16
4. Crude Pet. and Gas	0.25	0.06	0.28	0.52	0.36	-0.12	0.89	0.05
5. Non-met. Mining	0.37	0.55	0.26	0.30	0.46	0.77	0.03	0.85
6. Construction	0.37	0.44	0.41	0.19	0.33	0.18	0.25	0.74
7. Food	0.25	0.25	0.18	0.37	0.40	0.30	0.30	0.80
8. Tobacco	0.71	0.80	0.60	0.78	0.81	0.90	0.61	1.10
9. Textile	0.42	0.33	0.52	0.36	0.36	0.30	0.19	0.82
10. Apparel	0.06	0.01	0.00	0.26	0.52	0.47	0.23	1.22
11. Lumber and Wood	0.29	0.50	0.20	0.12	0.56	0.72	0.22	0.99
12. Furniture	0.20	0.20	0.16	0.30	0.38	0.73	-0.09	0.76
13. Paper	0.29	0.24	0.28	0.42	0.51	0.39	0.47	0.77
14. Printing	0.13	0.18	0.00	0.35	0.49	0.03	0.75	0.73
15. Chemicals	0.29	0.25	0.17	0.60	0.51	0.16	0.60	0.94
16. Petroleum Refining	0.32	0.31	0.16	0.67	0.23	0.39	0.02	0.42
17. Rubber and Plastics	0.17	0.02	0.23	0.30	0.27	0.33	-0.05	0.87
18. Leather	0.09	-0.08	0.07	0.42	0.41	0.99	-0.50	1.37
19. Stone, Clay and Glass	0.25	0.35	0.18	0.24	0.38	0.63	0.00	0.76
20. Primary Metals	0.24	0.28	0.21	0.23	0.36	0.34	0.26	0.59
21. Fabricated Metals	0.26	0.29	0.14	0.46	0.30	0.11	0.16	0.94
22. Non-elec. Machinery	0.25	0.34	0.14	0.32	0.44	0.23	0.41	0.87

Table 4.11 (cont'd)

	Canada				United States			
	1961-95	**1961-73**	**1973-88**	**1988-95**	**1961-95**	**1961-73**	**1973-88**	**1988-95**
23. Electrical Machinery	0.30	0.15	0.25	0.66	0.50	0.20	0.50	0.99
24. Motor Vehicles	0.17	0.19	0.06	0.38	0.42	0.31	0.32	0.83
25. Other Trans. Equip.	0.26	0.41	0.18	0.18	0.41	0.36	0.39	0.54
26. Misc. Manufacturing	0.23	0.20	0.14	0.45	0.58	0.50	0.50	0.87
27. Trans. and Warehouse	0.36	0.44	0.25	0.46	0.13	0.35	-0.13	0.32
28. Communications	0.35	0.52	0.31	0.14	0.57	0.21	0.53	1.25
29. Electric Utilities	0.45	0.59	0.38	0.33	0.26	0.07	0.14	0.85
30. Gas Utilities	0.27	0.34	0.27	0.14	0.31	0.25	0.28	0.47
31. Trade	0.24	0.40	0.08	0.32	0.42	0.42	0.27	0.71
32. Finance, Ins. and Real Estate	0.11	-0.05	0.09	0.41	0.45	0.24	0.23	1.30
33. Other Services	0.66	0.87	0.45	0.74	0.49	0.45	0.63	0.28
Average	0.29	0.33	0.24	0.35	0.44	0.41	0.29	0.80

4.5 Conclusion

IN THIS CHAPTER, WE APPLIED A SIMILAR METHODOLOGY to provide a consistent international comparison of the patterns of growth in Canadian and U.S. industries over the period 1961-95 and three sub-periods (1961-73, 1973-88, and 1988-95). The main findings are as follows: (1) Average annual growth rates of output in Canada were higher than in the United States in almost all industries before 1988. After 1988, output growth in Canada was slower than in the United States. (2) There was a substantial catch-up by Canadian industries to the productivity levels of U.S. industries during the period 1961-73. After 1973, productivity in Canadian industries grew at a rate similar to that of their U.S. counterparts. Over 1988-95, productivity in Canada grew at a slower rate than in the United States in 20 of 33 industries. (3) The dominant sources of output growth are the contributions of capital, labour, and intermediate inputs, with productivity growth responsible for about 20 percent of output growth in both countries during the entire period. (4) An interesting feature of Canadian economic growth has been the high growth of intermediate inputs. (5) The rise in capital and labour quality caused by composition changes contributes to the economic growth of both countries, in proportions varying from a seventh to a quarter of output growth.

Notes

1 In this study, we examine "total factor productivity" as opposed to labour productivity. That is, we consider all inputs — capital, labour, and intermediate goods.

2 The definition of the term "quality" is given in Section 4.2 below.

3 For an approach that does not assume Hicks neutrality and that estimates productivity growth econometrically, see Chapter 7 of Jorgenson, Gollop, and Fraumeni (1987).

4 The data on intermediate inputs comes from the input-output tables, and we work at the level corresponding to r = 33 for the United States.

5 In this study, we use official data produced by the two governments. There are serious discussions regarding the accuracy of these statistics, in particular for the hard-to-measure service sector. See, for example, Triplett and Bosworth (2000). Our estimates should be read with this caveat in mind.

6 The concordance between the 122 industries of the Canadian business sector and the 33 industries of its U.S. counterpart is presented in Annex A of this chapter.

7 The projections made by the Office of Employment of the BLS provided the time series of the I-O tables, as well as industry output and prices at the three-digit level of the Standard Industrial Classification (SIC, 1987 revision). Some of these data are available at ftp://ftp.bls.gov/pub/. The 185 sectors were aggregated to 35 sectors for the United States. The data in Jorgenson and Wilcoxen (1990) are based on the old SIC classifications and we mapped the two series in 1977. We extrapolated the I-O table to 1996 using industry output data for that year.

8 Details on the measurement of labour input are found in Appendix C for the United States and in Appendix F for Canada.

9 There is a slight difference in the educational attainment categories between Canada and the United States. Because of changes in the definition of educational attainment used for the Labour Force Survey of 1990, educational attainment is aggregated into four categories for Canada to ensure consistency over time. For the United States, there are six education categories. The difference in the number of categories is expected to have little effect on our estimates of labour input and labour quality.

10 Self-employed and unpaid family workers are combined into a single category in the United States. They are treated as two separate categories in Canada.

Labour compensation for self-employed workers in Canada was estimated using the wage rates of paid workers, while labour compensation for unpaid family workers was ignored. Compensation in the U.S. data is estimated as a residual of non-corporate value added less a capital income calculated to equate the rates of return of corporate and non-corporate capital.

11 The Census provides detailed information (age, education, hours worked, industry of employment, wages, etc.) for a 1 percent sample. The U.S. Department of Labor conducts annual surveys with similar detail for a smaller sample. These data are used to estimate the characteristics of the entire labour force on a time series basis.

12 Details on the measurement of capital inputs are provided in Appendix A for the United States and in Appendix E for Canada.

13 For the U.S. data, see "Gross Product by Industry" in *Survey of Current Business*, November 1997.

14 Gross output over time is affected by the degree of change in industrial organisation — that is, a vertical consolidation will reduce total gross output even if there are no physical changes. The comparison of output growth is misleading to the extent that these changes are different in the two countries. However, gross output growth rates are roughly in line with total value added (GDP) reported in Section 4.4.1; hence, this should not be a major concern.

Annex A:
Concordance Between Canadian and U.S. Industries

Table 4A.1

Concordance Between Canadian and U.S. Industries

Canada: 122 Industries	United States: 33 Industries	Abbreviation
1-2	1. Agriculture, Forestry, and Fisheries	1. Agric., For. and Fisheries
4-6, 13	2. Metal Mining	2. Metal Mining
10	3. Coal Mining	3. Coal Mining
11	4. Crude Petroleum and Natural Gas	4. Crude Pet. and Gas
7-9, 12	5. Non-metallic Mining	5. Non-met. Mining
98	6. Construction	6. Construction
14-24	7. Food and Kindred Products	7. Food
25	8. Tobacco Products	8. Tobacco
29-32	9. Textile Mill Products	9. Textile
33	10. Apparel and Other Textiles	10. Apparel
3, 34-38	11. Lumber and Wood	11. Lumber and Wood
39-41	12. Furniture and Fixtures	12. Furniture
42-45	13. Paper and Allied Products	13. Paper
46-47	14. Printing and Publishing	14. Printing
87-93	15. Chemicals	15. Chemicals
86	16. Petroleum and Coal Products	16. Petroleum Refining
26-27	17. Rubber and Plastics	17. Rubber and Plastics
28	18. Leather Products	18. Leather
80-85	19. Stone, Clay, and Glass	19. Stone, Clay and Glass
48-54	20. Primary Metals	20. Primary Metals

Table 4A.1 (cont' d)

Canada: 122 Industries	United States: 33 Industries	Abbreviation
55-59, 62	21. Fabricated Metals	21. Fabricated Metals
60-61, 63-65, 78	22. Non-Electrical Machinery	22. Non-Elec. Machinery
73-77, 79	23. Electrical Machinery	23. Electrical Machinery
67-69	24. Motor Vehicles	24. Motor Vehicles
66,70-72	25. Transportation Equipment and Ordnance	25. Other Trans. Equip.
94-97	26. Miscellaneous Manufacturing	26. Misc. Manufacturing
99-105	27. Other Transportation	27. Trans. and Warehouse
106-107	28. Communications	28. Communications
109	29. Electric Utilities	29. Electric Utilities
110	30. Gas Utilities	30. Gas Utilities
112-113	31. Trade	31. Trade
114-115	32. Finance, Insurance, Real Estate	32. Finance, Ins., Real Estate
111, 116-122	33. Other Services	33. Other Services
108	Not Allocated	

Annex B: Sources of Output Growth Based on the Capital Stock Data from Statistics Canada's KLEMS Database

STATISTICS CANADA'S ESTIMATES OF PRODUCTIVITY GROWTH are based on capital stock data, using a modified double-declining-balance method. For comparison purposes, Table 4B.1 presents the sources of output growth for the private business sector in Canada, using these capital stock data. Comparing Tables 4.B1 and 4.3, we find that the contributions of capital input were lower than those based on capital stock estimates that are comparable to the BLS estimates. As a result, productivity growth estimates were higher using the capital stock estimates based on a modified double-declining-balance method. There is a gradual increase in the differences between these two productivity growth estimates, from 0.06 percent over 1961-73 to 0.15 percent over 1973-88 and 0.24 percent over 1988-95.

Table 4.B1
Sources of Output Growth in the Private Business Sector (%), Based on Capital Stock Data from Statistics Canada's KLEMS Database

	Canada			
	1961-95	**1961-73**	**1973-88**	**1988-95**
Value Added	3.71	5.56	3.27	1.48
Contribution of Capital Stock	0.68	0.85	0.73	0.27
Contribution of Capital Quality	0.33	0.38	0.33	0.22
Contribution of Hours Worked	1.07	1.29	1.30	0.22
Contribution of Labour Quality	0.33	0.47	0.19	0.38
Productivity Growth	1.30	2.58	0.72	0.39

Productivity Levels and International Competitiveness Between Canada and the United States

5

Frank C. Lee and Jianmin Tang

5.1 Introduction

THE PURPOSE OF THIS PAPER is to compare total factor productivity (TFP) levels and international competitiveness between 33 Canadian and U.S. industries. To carry out such comparisons, we first need to construct purchasing power parities (PPPs) for output and inputs by industry. We use bilateral Canada-U.S. commodity price data to construct PPPs for output and intermediate inputs, and estimate PPPs for capital input based on the relative prices of investment goods, taking into account the flow of capital services per unit of capital stock. We then use hourly labour compensation rates, disaggregated by different worker types in the two countries, to estimate labour input PPPs. These PPPs take into account differences in the composition of the output and inputs of the industry under consideration between Canada and the United States, thereby allowing inter-country comparisons of both prices and quantities of output and inputs.

Following Jorgenson and Nishimizu (1978) for comparison between Japan and the United States, we use a translog production function originally introduced by Christensen, Jorgenson and Lau (1971, 1973) to estimate relative TFP levels in Canada and the United States. This framework was used extensively by Jorgenson and his associates, including Jorgenson, Kuroda and Nishimizu (1987), Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999). Following that tradition, relative TFP levels can be assumed to reflect differences in technology levels since the quality of inputs is already taken into account in this framework.

Based on a common framework using comparable data sets for Canada and the United States,[1] our results show that in 1995, 23 of 33 Canadian industries had lower TFP levels than their U.S. counterparts.[2] Our results also suggest that the relative TFP level is an important element of international competitiveness across industries. In fact, Canadian industries with higher TFP levels than their U.S. counterparts tend to be more competitive in terms of relative output prices. Over time, however, movements in the exchange rate appear to be the most significant factor behind international competitiveness.

From 1988 to 1995, the depreciation of the exchange rate helped 9 industries become more competitive than their U.S. counterparts. In addition, movements in the exchange rate coincided with movements in the relative output prices of the private business sector in the two countries over the 1961-95 period. Focusing on a more recent period, that between 1976 and 1995, Canada's private business sector saw its competitiveness improve relative to that of the U.S. business sector, even as its TFP performance was not improving — although a slight rebound has occurred in that respect since 1993.

The remaining sections of the chapter are organized as follows. In Section 5.2, we construct PPPs for output and inputs, while Sections 5.3 and 5.4 are devoted to a comparison of TFP levels and international competitiveness between Canadian and U.S. industries. In Section 5.5, we discuss the evolution of TFP and competitiveness in the Canadian and U.S. private business sectors. We conclude our study in Section 5.6.

5.2. Purchasing Power Parities for Output and Inputs

IN THIS SECTION, WE DISCUSS the data and methodology used in constructing Canada-U.S. bilateral PPPs for output and inputs in 33 industries. In this context, it is useful to keep in mind that the value of output is defined from the producer's point of view and the value of inputs, from the producer-purchaser's standpoint. This has implications for constructing PPPs, as will be seen later.

First, we group the 1992 Canadian and U.S. input-output tables[3] into 249 common commodity groups and 33 industries.[4] We then match 201 commodity PPPs[5] at purchasers' prices with commodities in the I-O tables. Among the remaining 48 commodities in the I-O tables, we first identify 26 that have close substitutes among the 201 commodities already matched, and then apply to them the PPPs of their close substitutes. In the case of the remaining 22 commodities, we use the 1993 market exchange rate. These commodities are mainly primary goods (such as grain, wheat, copper, steel, and precious metals) that are heavily traded in North American or world markets. The 249 PPPs and the I-O tables are used to develop PPPs for output and inputs other than labour.[6]

5.2.1 Purchasing Power Parities for Output

The output PPP is defined as the ratio of the amount of Canadian dollars received by Canadian producers for output sold in Canada, to the amount of U.S. dollars received by U.S. producers for selling the same amount of output in the United States. Thus output PPPs are at producers' prices, implying that we first need to convert commodity PPPs at purchaser's prices, $EPPP_j$, into commodity PPPs at producers' prices, PPP_j, by "peeling off" tax and distribution margins (the indirect commodity tax margin and the transportation and trade margins), using the I-O tables of both countries.[7]

We then proceed to construct output PPPs for each industry. The output PPP in industry i is obtained by aggregating 249 commodity PPPs in translog form, using nominal shares in the commodity mix as weights for industry i:

(1) $$\ln(PPP_i^Q) = \sum_{j=1}^{249} 1/2 \left[v_{i,j}^Q(Can) + v_{i,j}^Q(US)\right] \cdot \ln(PPP_j),$$

where $v_{i,j}^Q(S)$ is the value share of commodity j in industry i in country S, estimated from the *make* matrices of the I-O tables.

5.2.2 Purchasing Power Parities for Intermediate Inputs

Intermediate inputs include energy, materials, and purchased services. Their PPPs are computed in the same manner as output PPPs, but they are based on commodity PPPs at purchasers' prices, which include tax, transportation, and trade margins. With this in mind, the PPP for intermediate inputs in industry i is defined as the translog aggregate of the 249 commodity PPPs:

(2) $$\ln(PPP_i^M) = \sum_{j=1}^{249} 1/2 \left[v_{i,j}^M(Can) + v_{i,j}^M(US)\right] \cdot \ln(EPPP_j),$$

where $v_{i,j}^M(S)$ is the value share of goods (or services) of type j that are used as intermediate inputs in industry i in country S, estimated from the *use* matrices of the I-O tables. Here, $EPPP_j$, is the PPP at purchasers' prices for commodity j as defined earlier.

5.2.3 Purchasing Power Parities for Capital Input

As in Chapter 4, capital input is broken down here into four asset types — machinery and equipment (M&E), non-residential structures, inventories, and land. However, the price data available only allow us to construct investment PPPs for M&E and structures. Following Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999), we aggregate 249 commodity PPPs to construct investment PPPs for new investment type k (M&E or structures) in industry i from the purchasers' standpoint:

$$\ln(PPP_{i,k}^{I}) = \sum_{j=1}^{249} 1/2\left[v_{i,k,j}^{I}(Can) + v_{i,k,j}^{I}(US)\right] \cdot \ln(EPPP_{j}), \tag{3}$$

where $v_{i,k,j}^{I}(S)$ is the value share of investment good j of type k in industry i, estimated from the *investment flow* matrices of the I-O tables.

We then derive a capital input PPP for each type (M&E and structures) in industry i by multiplying the ratio of each type's rental price for Canada relative to the United States by its corresponding investment PPP,

$$PPP_{i,k}^{K} = \left(\frac{P_{i,k}^{K}(Can) / P_{i,k}^{I}(Can)}{P_{i,k}^{K}(US) / P_{i,k}^{I}(US)}\right) PPP_{i,k}^{I}, \tag{4}$$

where $P_{i,k}^{K}(S)$ is the capital input price of asset type k in country S, while $P_{i,k}^{I}(S)$ is the investment price index for that asset type. For each asset type, the ratio of the capital input price to the investment price index is the rental price of capital input of this asset type. As described in previous chapters, the rental price of capital input is estimated by taking account of the rate of return on capital, economic depreciation rates, and various tax parameters in each country. Thus, in deriving capital input PPPs, we implicitly assume that the relative efficiency of new capital goods in a given industry is the same in both countries. However, the decline in the efficiency of capital input for each component is estimated separately for each country.

We assume that the capital input PPP for land is the same as that for structures. Furthermore, we assume that the capital input PPP for inventories is the same as the weighted average of capital input PPPs for M&E, structures and land. The total capital input PPPs in this paper are then derived by aggregating individual capital input PPPs across p types of capital input (M&E,

structures, land, and inventories), using the average compensation in the two countries for each type of capital input as weights:

$$(5) \qquad \ln(PPP_i^K) = \sum_{k=1}^{p} 1/2\left[v_{i,k}^K(Can) + v_{i,k}^K(US)\right] \cdot \ln(PPP_{i,k}^K),$$

where $v_{i,k}^K(S)$ is the capital compensation share of type k capital in industry i in country S.

5.2.4 Purchasing Power Parities for Labour Input

For each of the 33 industries, labour inputs in Canada and the United States are matched by sex, employment status, age, and education, as shown in Table 5.1. We estimate the labour input PPP for industry i by aggregating the ratio of hourly labour compensation rates between the two countries over q types (112) of labour:

$$(6) \qquad \ln(PPP_i^L) = \sum_{l=1}^{q} \left\{1/2\left[v_{i,l}^L(Can) + v_{i,l}^L(US)\right] \cdot \ln\left[\frac{P_{i,l}^L(Can)}{P_{i,l}^L(US)}\right]\right\},$$

where $P_{i,l}^L(S)$ is the average labour compensation per hour of type l worker in industry i in country S, and $v_{i,l}^L(S)$ is the total labour compensation share for that worker type.

Table 5.1
Classification of the Canadian and U.S. Workforce

Worker Characteristics	Number of Categories	Type
Sex	2	Female; Male
Employment Category	2	Paid Employees; Self-employed[1]
Age	7	16-17;[2] 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	0-8 Years Grade School; Some or Completed High School; Some or Completed Post-Secondary School; University or Higher

Notes: [1] U.S. self-employed includes unpaid workers.
[2] The age group is 15-17 for Canada.

5.2.5 Summary of Purchasing Power Parities Between Canada and the United States, 1993

PPPs for output and three types of inputs in 1993 are reported in Table 5.2.[8] The output PPPs are generally in line with the exchange rate (1.29 in 1993) for most industries. However, for coal mining, tobacco, and electric utilities, they are on the lower side.

Capital input PPPs are highly variable across industries. These variations stem from the variations in the rental prices of capital input between the two countries since capital investment prices are generally comparable. For instance, the rental price of capital input in the motor vehicles, rubber and plastics, and industrial machinery industries is higher in Canada than in the United States, while the opposite is true in the paper and allied products, petroleum refining, and other services industries. The higher rental price of capital input in other services in the United States is mainly due to a higher rental price in private education and legal services in that country than in Canada. A close examination reveals that the substantial differences in the rental prices of capital input noted between Canada and the United States are attributable to large differences in the capital compensation figures from the two countries' I-O tables relative to their respective capital stocks.

With respect to the PPPs for labour input, we first observe that variations across industries are very small. In addition, labour input PPPs are below unity for 17 industries, which is significantly below the exchange rate.

Finally, intermediate input PPPs are fairly constant across industries and more or less equal to the exchange rate for all industries except tobacco. The Canadian tobacco industry pays a higher price for intermediate inputs than does its U.S. counterpart, mainly because of the difference in the taxation on semi-finished tobacco products between the two countries.

Table 5.2
Purchasing Power Parities by Industry, 1993 (U.S. = 1.00)

Industry	Output	Capital Input	Labour Input	Intermediate Inputs
1. Agric., For. and Fisheries	1.35	1.93	0.62	1.35
2. Metal Mining	1.29	1.70	1.06	1.27
3. Coal Mining	0.88	0.99	0.88	1.29
4. Crude Pet. and Gas	1.45	1.09	1.02	1.26
5. Non-met. Mining	1.35	1.82	1.04	1.29
6. Construction	1.13	2.08	1.13	1.34
7. Food	1.42	2.13	1.11	1.36
8. Tobacco	0.74	2.23	1.05	1.57
9. Textile	1.46	2.36	1.06	1.35
10. Apparel	1.34	2.29	0.96	1.38
11. Lumber and Wood	1.25	1.88	1.21	1.24
12. Furniture	1.36	2.41	0.93	1.35
13. Paper	1.55	0.75	1.16	1.30
14. Printing	1.52	2.45	1.12	1.35
15. Chemicals	1.28	1.19	0.81	1.32
16. Petroleum Refining	1.13	0.47	0.99	1.29
17. Rubber and Plastics	1.58	2.73	1.02	1.31
18. Leather	1.32	0.83	1.06	1.27
19. Stone, Clay and Glass	1.41	2.08	1.01	1.32
20. Primary Metals	1.28	1.10	1.07	1.26
21. Fabricated Metals	1.40	1.85	0.89	1.29
22. Industrial Machinery	1.30	2.55	0.85	1.28
23. Electrical Machinery	1.17	1.70	0.92	1.23
24. Motor Vehicles	1.23	3.59	0.76	1.35
25. Other Trans. Equip.	1.35	2.19	0.97	1.31
26. Misc. Manufacturing	1.29	2.40	0.80	1.30
27. Trans. and Warehousing	1.33	1.60	0.85	1.29
28. Communications	1.18	1.23	0.93	1.23
29. Electric Utilities	0.90	1.15	1.12	1.19
30. Gas Utilities	1.30	1.95	0.86	1.26
31. Trade	1.19	1.60	1.05	1.29
32. Finance, Ins. and Real Estate	1.32	2.05	0.81	1.24
33. Other Services	1.08	0.37	0.98	1.25
Private Business	1.22[1]	1.23	0.96	

Note: [1] For value added from Statistics Canada's Canada-U.S. GDP purchasing power parity.

5.3 Relative Productivity Levels

BASED ON THE PPPS CONSTRUCTED ABOVE, we estimate relative TFP levels between Canada and the United States for 33 industries.[9] As Jorgenson and Nishimizu (1978) for the comparison between Japan and the United States, our theoretical framework for this comparison is based on a translog production function originally introduced by Christensen, Jorgenson, and Lau (1971, 1973). Here, output is a translog function of capital input, labour input, and intermediate inputs, as well as a dummy variable equal to one for Canada and zero for the United States, and time as an index of technology for each industry. However, as did Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999), we find that it is more convenient to work with the dual price function of output to analyse international competitiveness and relative TFP levels. The dual price function is derived from the production function under competitive conditions. The price function for the *i*th industry can be represented as:

$$\begin{aligned} \ln P_i = {} & \ln P_i^{X'} \alpha_i^X + \alpha_i^t t + \alpha_i^D D + 1/2 \ln P_i^{X'} \beta_i^{XX} \ln P_i^X + \ln P_i^{X'} \beta_i^{Xt} t \\ & + \ln P_i^{X'} \beta_i^{XD} D + 1/2\, \beta_i^{tt} t^2 + \beta_i^{tD} tD + 1/2\, \beta_i^{DD} D^2, \end{aligned} \tag{7}$$

where P_i is the output price of the *i*th industry; $\ln P_i^X$ denotes $\{\ln P_i^K \ln P_i^L \ln P_i^M\}$, a vector of logarithms of capital input price (P_i^K), the labour input price (P_i^L), and the intermediate input price (P_i^M) of the *i*th industry; t denotes time as an index of technology; and D is a dummy variable, equal to one for Canada and zero for the United States.

In this presentation, scalars $\{\alpha_i^t, \alpha_i^D, \beta_i^{tt}, \beta_i^{tD}, \beta_i^{DD}\}$, the vectors $\{\alpha_i^X, \beta_i^{Xt}, \beta_i^{XD}\}$, and the matrix $\{\beta_i^{XX}\}$ are constant parameters. However, these parameters differ among industries, reflecting differences among technologies. Within each industry, differences in technology among time periods are represented by time as an index of technology. Differences in technology between Canada and the United States are associated with the dummy variable.

Based on the above price function, Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999) show that differences in the logarithms of the TFP levels between Canada and the United States, $\overline{v}_i^D$ can be expressed as the negative value of the differences between the logarithms of the output prices, less a weighted average of the differences between the logarithms of input prices,

$$(8) \qquad \bar{v}_i^D = -\left\{ \ln\left[\frac{P_i(Can)}{P_i(US)}\right] - \bar{v}_i^K \ln\left[\frac{P_i^K(Can)}{P_i^K(US)}\right] - \bar{v}_i^L \ln\left[\frac{P_i^L(Can)}{P_i^L(US)}\right] - \bar{v}_i^M \ln\left[\frac{P_i^M(Can)}{P_i^M(US)}\right] \right\},$$

where $\bar{v}_i^j = 1/2\left[v_i^j(Can) + v_i^j(US)\right]$, the average compensation share of input j in Canada and the United States for the ith industry. The price ratios in the above equation are the PPPs for output and inputs.

We first calculate 1993 relative TFP levels in Canada and the United States for 33 industries based on the estimated 1993 PPPs using Equation (8). We then use the TFP indices constructed in the previous chapter to estimate relative TFP levels in other years. The estimated relative TFP levels by industry are reported in Table 5.3. In 1995, Canada was less productive than the United States in 23 of the 33 industries. In particular, Canada was much less productive in agriculture, forestry and fisheries; crude petroleum and gas; paper; printing; rubber and plastics; leather; stone, clay, and glass; fabricated metals; industrial machinery; and transportation and warehousing. On the other hand, in 1995 Canada was significantly more productive than the United States in coal mining, construction, tobacco, petroleum refining, electric utilities, and gas utilities.

To examine the trend in relative TFP levels in Canadian and U.S. industries, we estimated the variance of relative TFP levels by industry for the period 1961-95. As shown in Figure 5.1, the variance for all industries declined dramatically in the 1960s. After 1970, however, it remained fairly stable. This implies that TFP performance in Canada and the United States converged across industries during the 1960s. Indeed, in 19 of the 25 industries where Canada lagged behind the United States with respect to TFP levels in 1961, Canada improved its relative TFP performance from 1961 to 1973; the largest improvements were in those industries where TFP gaps were the widest (coal mining and communications). At the same time, Canada lost some of its relative TFP advantage in 2 industries (tobacco and petroleum refining) where that advantage was the largest in 1961. Between 1973 and 1988, the variance remained more or less steady. Over this period, some low-productivity Canadian industries were catching up to their U.S. counterparts, but their relative gains were modest. At the same time, these gains were offset by U.S. industries catching up to highly productive Canadian industries (metal mining, petroleum refining, and both machinery industries). Over the 1988-95 period, the variance of the relative TFP gap between the two countries decreased. Most of the decline can be attributed to U.S. industries (such as metal mining, coal mining, and electrical machinery) catching up to, and in some instances surpassing, the TFP levels of Canadian industries. Meanwhile, most Canadian industries that were less productive than their U.S. counterparts either were unable to catch up to U.S. TFP levels or only made modest gains.

To give another perspective on this issue, we also examined the number of Canadian industries that were less productive than their U.S. counterparts. That number decreased from 20 in 1961 to 17 in 1973, as shown in Table 5.3. However, it rose to 21 in 1988 and 23 in 1995. Thus the number of Canadian industries that were less productive than their U.S. counterparts has increased since 1973. These numbers provide a snapshot of performance in a given year, but they do not help to assess the improvement or deterioration of Canada's relative TFP performance over time.

Figure 5.1
Variance of the Productivity Gap (in Logs) Among Industries

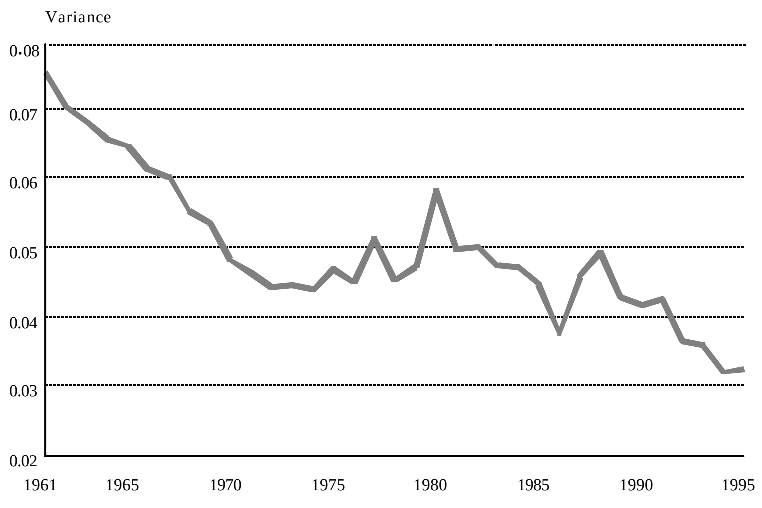


Table 5.3
TFP Levels in Canada Relative to the United States, (U.S. = 1.00)

Industry	1961	1973	1988	1995
1. Agric., For. and Fisheries	0.87	0.98	0.89	0.83
2. Metal Mining	1.44	1.55	1.34	0.90
3. Coal Mining	0.77	1.15	1.50	1.16
4. Crude Pet. and Gas	0.83	1.01	0.62	0.71
5. Non-met. Mining	0.87	0.95	0.98	0.96
6. Construction	0.87	0.93	1.11	1.18
7. Food	1.15	1.13	0.97	0.96
8. Tobacco	1.75	1.60	2.06	2.06
9. Textile	1.09	1.23	1.03	0.98
10. Apparel	1.06	1.08	1.00	0.99
11. Lumber and Wood	0.79	0.90	0.91	1.01
12. Furniture	1.00	1.14	0.92	0.96
13. Paper	0.91	0.84	0.81	0.83
14. Printing	0.86	0.86	0.95	0.88
15. Chemicals	0.82	0.80	0.89	0.93
16. Petroleum Refining	1.39	1.30	1.09	1.15
17. Rubber and Plastics	0.85	0.91	0.86	0.85
18. Leather	0.71	0.82	0.85	0.83
19. Stone, Clay and Glass	0.86	1.01	0.95	0.87
20. Primary Metals	0.90	0.96	0.96	0.96
21. Fabricated Metals	0.81	0.85	0.84	0.84
22. Industrial Machinery	1.11	1.21	0.95	0.88
23. Electrical Machinery	1.26	1.31	1.15	0.98
24. Motor Vehicles	0.73	0.93	1.04	1.07
25. Other Trans. Equip.	1.02	0.98	0.89	0.98
26. Misc. Manufacturing	1.09	1.07	0.90	0.92
27. Trans. and Warehousing	0.82	0.90	0.94	0.87
28. Communications	0.39	0.61	0.94	0.99
29. Electric Utilities	1.51	1.57	1.61	1.24
30. Gas Utilities	0.81	1.24	1.36	1.15
31. Trade	0.80	0.94	1.08	1.02
32. Finance, Ins. and Real Estate	1.29	1.15	0.92	1.09
33. Other Services	0.90	0.86	0.93	0.93

We now turn to that issue. When we examine the performance of relative TFP levels over time, the pervasiveness of the decline in Canada becomes evident. From 1961 to 1973, only 9 Canadian industries experienced a decline in TFP relative to their U.S. counterparts. However, that number rose to 16 between 1973 to 1988 and to 17 between 1988 to 1995. In summary, the deterioration of Canada's TFP levels relative to those of the United States has become more widespread across industries since 1973.

5.4 Competitiveness in Canadian and U.S. Industries

THIS SECTION ASSESSES DIFFERENCES IN COMPETITIVENESS between Canadian and U.S. industries and links these differences to their relative TFP levels. Following Jorgenson and Kuroda (1995), we measure competitiveness by relative output prices, defined as output PPPs divided by the exchange rate ($CDN per $US).

To facilitate our analysis, we decompose relative output prices into relative TFP levels and relative capital, labour, and intermediate input prices. We rearrange Equation (8) and divide each price ratio by the exchange rate:

$$(9) \qquad \ln RP_i = -\bar{v}_i^D + \bar{v}_i^K \ln RP_i^K + \bar{v}_i^L \ln RP_i^L + \bar{v}_i^M \ln RP_i^M ,$$

where RP_i is the relative price of output; $\bar{v}_i^D$ is the TFP gap between Canada and the United States for industry i; and RP_i^K, RP_i^L, and RP_i^M are the relative prices of capital, labour, and intermediate inputs, respectively.

The relative prices for output, for capital, labour, and intermediate inputs, and for relative TFP levels in 1995 are reported in Table 5.4. In 1995, more than half of Canadian industries had a lower relative output price than their U.S. counterparts.

With respect to capital input, Canada had higher capital input prices than the United States in 27 industries. In particular, Canadian capital input prices were substantially higher than U.S. prices in metal mining, textiles, apparel, furniture, paper, rubber and plastics, primary metals, motor vehicles, other transportation equipment, and miscellaneous manufacturing in 1995. However, in some Canadian industries — such as coal mining, crude petroleum and natural gas, leather, and other services — capital input prices were lower than in the corresponding U.S. industries. As discussed earlier, it is helpful to keep in mind that differences in relative capital input prices reflect differences not only in capital investment prices but also in the rental price of capital input.

In contrast with the situation regarding capital input prices, all Canadian industries had an advantage over their U.S. counterparts in terms of labour costs, and the variations in relative labour input prices across industries were very small in 1995. As a result of this difference in labour costs, the industrial structures of the two countries are also different. Canadian industries are generally more labour-intensive, while U.S. industries tend to be more capital-intensive. This is evident when we compare capital intensity (the ratio of capital stock to hours) of the two countries. For instance, in 1993, capital intensity in Canada (capital stock PPP-based) was only 79 percent that of the United States.[10]

Finally, most Canadian industries paid almost the same price for their intermediate inputs as did their U.S. counterparts.

When examining the links between competitiveness, relative TFP levels, and relative input prices, a simple correlation among these variables is a good starting point for discussion. The correlation coefficient between relative output prices and relative TFP levels is –0.69 based on 1995 data, while in the case of capital, labour, and intermediate inputs, the coefficients stand at 0.47, 0.16, and 0.12, respectively. These coefficients indicate that variations in relative output prices across industries are strongly related to inter-industry differences in relative TFP levels.

We summarize the relationship between output prices and TFP levels by plotting relative output prices against relative TFP levels for 1995 across industries in Canada and the United States, as shown in Figure 5.2. To better illustrate the relationship between competitiveness and relative TFP levels, we divide the figure into four quadrants. In quadrants I and II are found those Canadian industries which are less competitive than their U.S. counterparts, while quadrants III and IV show Canadian industries that are more competitive than their U.S. equivalents. At the same time, Canadian industries in quadrants II and III are more productive than their U.S. competitors, while relatively less productive industries in Canada are located in quadrants I and IV.

Table 5.4

Relative Prices* and TFP Levels by Industry, 1995 (U.S. = 1.00)

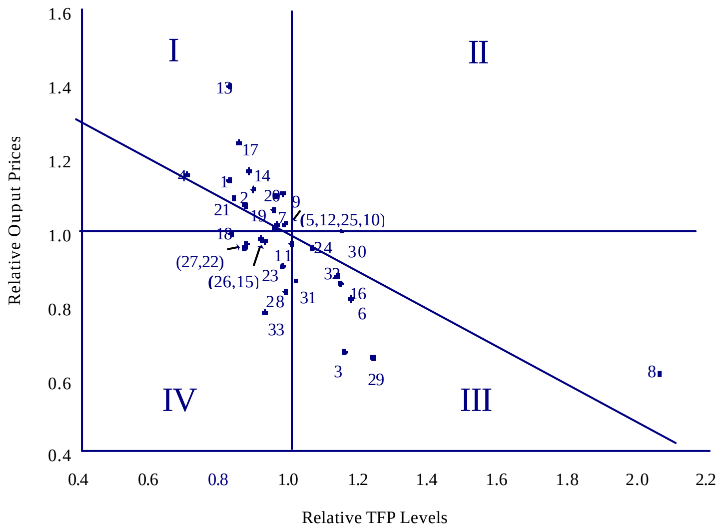
Industry	Output	TFP	Capital Input	Labour Input	Intermediate Inputs
1. Agric., For. and Fisheries	1.13	0.83	1.76	0.56	1.03
2. Metal Mining	1.11	0.90	2.07	0.68	0.91
3. Coal Mining	0.67	1.16	0.70	0.66	0.99
4. Crude Pet. and Gas	1.15	0.71	0.76	0.80	0.91
5. Non-met. Mining	1.00	0.96	1.31	0.69	0.96
6. Construction	0.81	1.18	1.31	0.83	1.00
7. Food	1.05	0.96	1.21	0.78	1.03
8. Tobacco	0.61	2.06	1.74	0.69	1.29
9. Textile	1.10	0.98	3.26	0.77	1.05
10. Apparel	1.01	0.99	2.34	0.72	1.05
11. Lumber and Wood	0.96	1.01	1.20	0.98	0.92
12. Furniture	1.01	0.96	3.17	0.67	1.01
13. Paper	1.39	0.83	2.99	0.84	1.07
14. Printing	1.16	0.88	1.96	0.80	1.05
15. Chemicals	0.97	0.93	1.01	0.59	1.01
16. Petroleum Refining	0.85	1.15	1.21	0.75	0.99
17. Rubber and Plastics	1.23	0.85	2.20	0.79	1.04
18. Leather	0.99	0.83	0.48	0.72	1.01
19. Stone, Clay and Glass	1.06	0.87	1.49	0.71	0.95
20. Primary Metals	1.09	0.96	2.24	0.79	1.05
21. Fabricated Metals	1.08	0.84	1.54	0.66	0.98
22. Industrial Machinery	0.96	0.88	1.12	0.64	0.96

Table 5.4 (cont' d)

Industry	Output	TFP	Capital Input	Labour Input	Intermediate Inputs
23. Electrical Machinery	0.90	0.98	1.35	0.64	0.92
24. Motor Vehicles	0.95	1.07	3.50	0.56	1.02
25. Other Trans. Equip.	1.01	0.98	2.70	0.70	1.02
26. Misc. Manufacturing	0.97	0.92	2.48	0.55	1.00
27. Trans. and Warehouse	0.95	0.87	1.10	0.64	0.93
28. Communications	0.83	0.99	0.91	0.66	0.89
29. Electric Utilities	0.65	1.24	0.75	0.79	0.87
30. Gas Utilities	0.99	1.15	1.56	0.59	0.95
31. Trade	0.86	1.02	1.47	0.76	0.89
32. Finance, Ins. and Real Estate	0.88	1.09	1.51	0.64	0.87
33. Other Services	0.77	0.93	0.32	0.73	0.88

Note: * PPP rates divided by the exchange rate.

Figure 5.2
Relative Output Prices Against Relative TFP Levels,1995 (U.S. = 1.00)



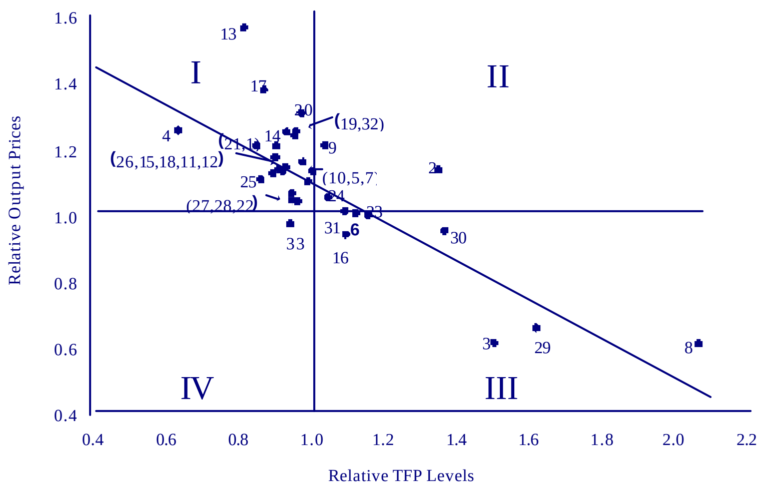
Note: The numbers in this figure refer to those industries listed in Table 5.2.

In 1995, 15 Canadian industries were less competitive and less productive than the corresponding U.S. industries (quadrant I). In 7 industries (food, textiles, apparel, paper, printing, rubber and plastics, and primary metals), lower productivity combined with higher input prices (affecting all three types of inputs) to reduce competitiveness. Low input prices in 6 of the remaining industries were not strong enough to offset the effects of lower productivity and make these industries more competitive. No industry was less competitive but more productive than its U.S. counterpart (quadrant II).

An examination of quadrant III reveals that 10 Canadian industries were more competitive and more productive than the corresponding U.S. industries. Seven of these — coal mining; construction; lumber and wood; petroleum refining; electric utilities; finance, insurance, and real estate (FIRE); and trade — were identified as having relatively lower input prices than their U.S. counterparts. The remaining 3 industries — tobacco, gas utilities, and motor vehicles — had higher input prices than their U.S. competitors, but the difference was not large enough to make them less competitive than the U.S. industries.

Finally, quadrant IV shows the industries where Canada was more competitive but less productive than the United States — chemicals; leather; industrial machinery; electrical machinery; miscellaneous manufacturing; communications; transportation and warehousing; and other services. Canada's competitive position in those cases stemmed from lower input prices rather than higher TFP levels. Thus, it appears that the main factor behind variations in international competitiveness across industries is the gap in relative TFP levels.

Figure 5.3
Relative Output Prices Against Relative TFP Levels, 1988 (U.S. = 1.00)



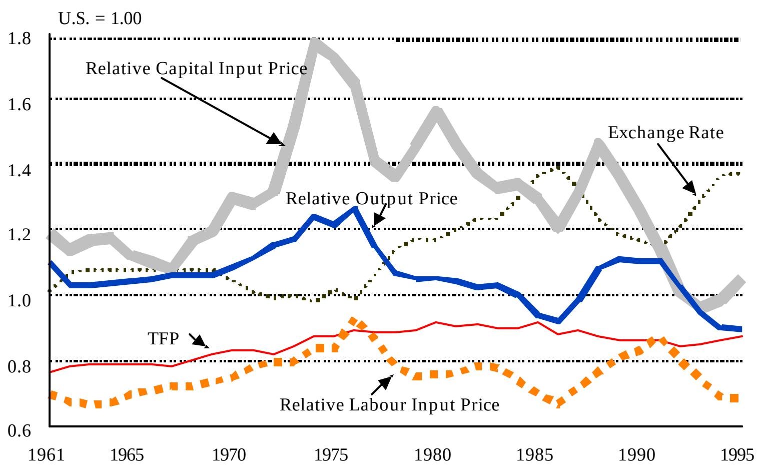
Note: The numbers in this figure refer to those industries listed in Table 5.2.

However, movements in international competitiveness over time are strongly influenced by variations in the exchange rate through relative input prices. For the purpose of illustration, we compare international competitiveness between 1988 and 1995. We plot relative output prices against relative TFP levels for 1988, as shown in Figure 5.3, to facilitate the discussion. In 1988, only 8 Canadian industries were more competitive than their U.S. counterparts, compared to 18 industries in 1995. This change is explained by the fact that the Canadian dollar depreciated by more than 10 percent during the intervening period. If the exchange rate in 1995 had remained at its 1988 level, only 9 Canadian industries would have been more competitive than their U.S. counterparts that year. In addition, several Canadian industries — lumber and wood, chemicals, leather, industrial machinery, motor vehicles, miscellaneous manufacturing, transportation and warehousing, and communications — would have lost ground and become less competitive than their U.S. counterparts by 1995.

5.5 Canada-U.S. Differences in Productivity and International Competitiveness in the Private Business Sector

IN THIS SECTION, we examine the relative performance of the Canadian and U.S. private business sectors with respect to TFP levels and competitiveness over the 1961-95 period.[11] We plot relative TFP levels, relative output and input prices, as well as the exchange rate in Figure 5.4.

Figure 5.4
Relative Productivity and Competitiveness Between Canada and the United States in the Private Business Sector



The results show that Canada's TFP levels were catching up to U.S. levels, rising from 76 percent of the U.S. level in 1961 to almost 92 percent in 1980. However, the gap between the two countries began to widen after 1985 and stood at 12 percent in 1995.

Meanwhile, Canada's relative competitive position worsened between 1963 and 1976. This deterioration would have been much worse without the improvements in relative TFP levels that occurred in the Canadian business sector over this period. Canada's competitive position then improved from 1976 to 1995, not as a result of TFP improvements but of the Canadian dollar depreciation through its impact on relative input prices.

Relative labour prices tend to be in line with relative output prices. Despite the volatility associated with the exchange rate, labour costs were consistently lower in Canada than in the United States over the 35-year period 1961-1995. In addition, the trend was fairly stable over that period. In contrast, relative capital input prices have been much more volatile. Since 1975, relative capital input prices have declined, in line with the depreciation of the Canadian dollar. In general, however, they have remained higher in Canada than in the United States, except in 1993 and 1994.

5.6 Summary and Conclusion

THIS STUDY ILLUSTRATES that it is critical to use PPPs rather than the market exchange rate to assess the relative productivity levels and international competitiveness of two countries. PPPs vary across industries and types of output and inputs. Based on a common framework and using comparable data sets, 23 of 33 Canadian industries had lower TFP levels compared to their U.S. counterparts in 1995. Relative TFP levels are an important element in determining international competitiveness. Our analysis indicates that Canadian industries with high relative productivity compared to their U.S. counterparts tend to be more competitive. Over time, however, movements in the exchange rate appear to be the most significant factor behind international competitiveness. From 1988 to 1995, the falling exchange rate helped 9 Canadian industries become more competitive than their U.S. counterparts.

Our analysis of the private business sector reinforces our findings at the industry level showing that movements in the exchange rate coincide with variations in relative output prices. Over the 1976-95 period, during which the competitiveness of Canada's private business sector improved relative to that of the U.S. private business sector, Canada's relative TFP performance did not improve, despite a slight rebound after 1993.

This study is a first step towards understanding the differences in productivity and international competitiveness between Canada and the United States. A number of refinements could prove fruitful. First, it would be useful to collect more data comparing prices between Canada and the United States in order to increase the reliability of PPP estimates. A second avenue would be to expand capital asset categories for Canada to match Jorgenson's categories for the United States or those of the U.S. Bureau of Labor Statistics. Future research may also benefit from an assessment of the comparability of the two countries' I-O tables, with a special focus on capital compensation data.

Notes

1 A description of the data is provided in the last chapter.

2 See Chapter 4 for data sources.

3 The I-O tables for both countries include make, use, final demand, and investment flow matrices.

4 The Canadian I-O tables are aggregated from 479 commodities and 170 industries; the U.S. tables are aggregated from 541 commodities and 541 industries.

5 These are 1993 PPPs, aggregated on the basis of data pertaining to more than 2,000 commodities obtained from Statistics Canada. Statistics Canada uses the data to estimate a bilateral GDP PPP between Canada and the United States.

6 Although these 249 commodities cover all commodities in the I-O tables, some of them may not be used as inputs. In that case, they are not entered into the calculation of input PPPs.

7 Hooper and Vrankovich (1995) adjust commodity PPPs for international trade in constructing output PPPs. Our analysis shows that incorporating this methodology does not significantly change the results since it is based on two restrictive assumptions: both export and import prices equal world prices; and world prices equal the average of the prices in the two countries, weighted by their expenditures. Since we are unable to justify these two assumptions, we use output PPPs without international trade adjustments.

8 The output PPP for the private business sector is approximated by the bilateral value-added PPP for the total economy, as calculated by Statistics Canada.

9 An assessment of the implications of quality adjustments to capital and labour inputs for estimating relative TFP levels is found in the Annex of this chapter.

10 Canada's capital intensity is based on an alternative set of capital stock estimates produced by the Investment and Capital Stock Division of Statistics Canada. These alternative capital stock estimates are based on the same declining-balance rates as those used in the United States. Capital intensity for Canada would be much lower if we used capital stock data from Statistics Canada's KLEMS database (see details in Appendix G).

11 The aggregate price function gives the value-added price as a function of capital and labour input prices, so that the intermediate input price is excluded. Similar to Equation (8), the difference in the logarithms of the TFP levels between the Canadian and U.S. private business sectors can be expressed as the negative value of the difference between the logarithm of the value-added price and the weighted average of the difference between the logarithms of capital and labour input prices.

Annex:
Quality of Capital and Labour Inputs and Relative TFP Levels

IN THIS ANNEX, WE FIRST COMPARE relative levels of capital and labour input quality in Canada and the United States and assess their implications for relative TFP levels. Following Dougherty (1992), we estimate relative capital input levels (PPP-adjusted) for Canada and the United States, with each country's asset type (M&E, structures, land, and inventories) weighted by the average compensation share in the two countries:

$$\text{(A-1)}\quad \ln\left[K_i(Can)/K_i(US)\right]=\sum_{k=1}^{4}1/2\left[v_{i,k}^{K}(Can)+v_{i,k}^{K}(US)\right]\ln\left[A_{i,k}(Can)/A_{i,k}(US)\right].$$

Here, $K_i(S)$ denotes capital input in industry i in country S, $v_{i,k}^{K}(S)$ is the capital compensation share of type k capital asset in total capital compensation in industry i in country S, and $A_{i,k}(S)$ is the net stock of type k capital asset in industry i in country S. We then use the following expression to estimate relative capital quality levels for Canada and the United States:

$$\text{(A-2)}\quad \ln\left[q_i^k(Can)/q_i^k(US)\right]=\ln\left[K_i(Can)/K_i(US)\right]-\ln\left[A_i(Can)/A_i(US)\right],$$

where $A_i(S)=\sum_{k=1}^{4}A_{i,k}(S)$ denotes the total capital stock in industry i in country S.

Likewise for capital input, relative labour input levels in Canada and the United States for industry i can be expressed as:

$$\text{(A-3)}\quad \ln\left[L_i(Can)/L_i(US)\right]=\sum_{j=1}^{112}1/2\left[v_{i,j}^{L}(Can)+v_{i,j}^{L}(US)\right]\ln\left[H_{i,j}(Can)/H_{i,j}(US)\right],$$

where $v_{i,j}^{L}(S)$ denotes the labour compensation shares of type j workers in industry i in country S, and $H_{i,j}(S)$ denotes the hours worked by workers of type j in industry i in country S. As with capital quality, relative labour quality levels are estimated by the following expression:

$$\text{(A-4)}\quad \ln\left[q_i^L(Can)/q_i^L(US)\right]=\ln\left[L_i(Can)/L_i(US)\right]-\ln\left[H_i(Can)/H_i(US)\right],$$

where $H_i(S)=\sum_{j=1}^{112}H_{i,j}(S)$ is the total number of hours worked by all types of workers in industry i in country S.

We then use the relative quality levels of capital and labour inputs to estimate relative raw TFP levels (commonly referred to as relative Solow residuals). The relationship between the relative raw TFP levels and our estimates of relative TFP levels is given below:

$$\text{(A-5)} \quad \overline{\varphi}_i^D = \overline{v}_i^D + \overline{v}_i^K \ln\left[\frac{q_i^K(Can)}{q_i^K(US)}\right] + \overline{v}_i^L \ln\left[\frac{q_i^L(Can)}{q_i^L(US)}\right],$$

where $\overline{\varphi}_i^D$ is the raw TFP, $\overline{v}_i^D$ is the TFP, and $\overline{v}_i^K$ and $\overline{v}_i^L$ are the average capital and labour compensation shares of the two countries in industry *i*, as discussed in Section 5.3.

In Table 5.A1, we report relative quality levels of capital and labour inputs and assess their implications for relative TFP levels. Generally speaking, there are some variations in the relative levels of capital quality across industries between Canada and the United States. On the other hand, labour quality in Canada is slightly lower than in the United States in virtually all industries. In most cases, the effect of capital quality is offset by labour quality, resulting in a slight difference between relative raw TFP levels and the estimated TFP levels that incorporate capital and labour input quality differences.

Table 5.A1
Relative Capital and Labour Quality Levels and TFP Levels, 1995 (U.S. = 1.00)

Industry	Capital Quality	Labour Quality	TFP	Raw TFP
1. Agric., For. and Fisheries	1.57	0.99	0.83	0.89
2. Metal Mining	0.92	0.96	0.90	0.86
3. Coal Mining	0.83	0.98	1.16	1.09
4. Crude Pet. and Gas	0.91	0.92	0.71	0.66
5. Non-met. Mining	0.93	1.00	0.96	0.94
6. Construction	1.02	0.97	1.18	1.16
7. Food	1.00	0.95	0.96	0.95
8. Tobacco	0.95	1.01	2.06	2.02
9. Textile	0.98	1.01	0.98	0.98
10. Apparel	1.00	0.97	0.99	0.98
11. Lumber and Wood	1.06	0.97	1.01	1.01
12. Furniture	0.99	0.98	0.96	0.96
13. Paper	1.11	1.00	0.83	0.84
14. Printing	0.93	0.96	0.88	0.86
15. Chemicals	1.01	0.96	0.93	0.92
16. Petroleum Refining	0.74	0.99	1.15	1.12
17. Rubber and Plastics	1.12	0.97	0.85	0.86
18. Leather	1.11	0.95	0.83	0.83
19. Stone, Clay and Glass	1.07	0.98	0.87	0.88
20. Primary Metals	1.20	0.97	0.96	0.97
21. Fabricated Metals	1.05	0.98	0.84	0.84
22. Industrial Machinery	1.04	0.96	0.88	0.87
23. Electrical Machinery	0.87	0.98	0.98	0.96
24. Motor Vehicles	1.67	0.94	1.07	1.09
25. Other Trans. Equip.	0.88	0.95	0.98	0.95
26. Misc. Manufacturing	0.93	0.91	0.92	0.88
27. Trans. and Warehousing	0.81	0.97	0.87	0.84
28. Communications	1.00	0.97	0.99	0.98
29. Electric Utilities	0.98	0.98	1.24	1.22
30. Gas Utilities	0.97	0.96	1.15	1.13
31. Trade	0.83	0.95	1.02	0.97
32. Finance, Ins. and Real Estate	0.96	0.84	1.09	1.02
33. Other Services	1.00	0.94	0.93	0.90
Private Business Sector	1.02	0.97	0.88	0.86

Appendix A:
Estimating Output for the United States

Dale W. Jorgenson and Kevin J. Stiroh

WE BEGIN WITH the National Income and Product Accounts (NIPA) as our primary source data. The data correspond to the most recent benchmark revision published by the Bureau of Economic Analysis (BEA) on October 29, 1999. The data provide measures of investment and consumption, in both current and chained 1996 dollars. The framework developed by Christensen and Jorgenson (1973), however, calls for a somewhat broader treatment of output than that of the national accounts. Most important, consumers' durable goods are treated symmetrically with investment goods, since both are long-lived assets that are accumulated and provide a flow of services over their lifetime. We use a rental price to impute a flow of consumers' durables services included in both consumption output and capital input. We also employ a rental price to make relatively small imputations for the service flows from owner-occupied housing and institutional equipment.

Table A.1 presents the time series of total output in current dollars and the corresponding price index for 1959-98. The table also includes the current dollar value and price index for information technology output components — computer investment, software investment, communications investments, computer and software consumption, and the imputed service flow of computer and software consumer durables — as described in Equation (4) of Chapter 2.

Table A.1

Private Domestic Output and High-Tech Assets

Year	Private Domestic Output		Computer Investment		Software Investment		Communications Investment		Computer and Software Consumption		Computer and Software Consumption Services	
	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1959	484.1	0.25	0.00	0.00	0.00	0.00	1.80	0.47	0.00	0.00	0.00	0.00
1960	472.8	0.24	0.20	697.30	0.10	0.61	2.30	0.47	0.00	0.00	0.00	0.00
1961	490.1	0.24	0.30	522.97	0.20	0.62	2.70	0.47	0.00	0.00	0.00	0.00
1962	527.1	0.25	0.30	369.16	0.20	0.63	3.00	0.46	0.00	0.00	0.00	0.00
1963	562.1	0.25	0.70	276.29	0.40	0.63	2.90	0.46	0.00	0.00	0.00	0.00
1964	606.4	0.26	0.90	229.60	0.50	0.64	3.00	0.47	0.00	0.00	0.00	0.00
1965	664.2	0.26	1.20	188.74	0.70	0.65	3.50	0.47	0.00	0.00	0.00	0.00
1966	728.9	0.27	1.70	132.70	1.00	0.66	4.00	0.47	0.00	0.00	0.00	0.00
1967	763.1	0.28	1.90	107.71	1.20	0.67	4.20	0.49	0.00	0.00	0.00	0.00
1968	811.0	0.28	1.90	92.00	1.30	0.68	4.70	0.51	0.00	0.00	0.00	0.00
1969	877.7	0.29	2.40	83.26	1.80	0.70	5.80	0.54	0.00	0.00	0.00	0.00
1970	937.9	0.31	2.70	74.81	2.30	0.73	6.70	0.57	0.00	0.00	0.00	0.00
1971	991.5	0.32	2.80	56.98	2.40	0.73	6.80	0.60	0.00	0.00	0.00	0.00
1972	1,102.9	0.33	3.50	45.93	2.80	0.73	6.80	0.62	0.00	0.00	0.00	0.00
1973	1,255.0	0.36	3.50	43.53	3.20	0.75	8.40	0.64	0.00	0.00	0.00	0.00
1974	1,345.9	0.38	3.90	35.55	3.90	0.80	9.40	0.69	0.00	0.00	0.00	0.00
1975	1,472.7	0.42	3.60	32.89	4.80	0.85	9.70	0.76	0.00	0.00	0.00	0.00
1976	1,643.0	0.44	4.40	27.47	5.20	0.87	11.10	0.80	0.00	0.00	0.00	0.00
1977	1,828.1	0.47	5.70	23.90	5.50	0.89	14.40	0.78	0.00	0.00	0.00	0.00
1978	2,080.4	0.50	7.60	16.17	6.60	0.90	17.70	0.81	0.10	33.68	0.02	17.84
1979	2,377.8	0.56	10.20	13.40	8.70	0.95	21.40	0.83	0.10	32.81	0.07	19.01

Table A.1 (cont'd)

	Private Domestic Output		Computer Investment		Software Investment		Communications Investment		Computer and Software Consumption		Computer and Software Consumption Services	
Year	**Value**	**Price**	**Value**	**Price**	**Value**	**Price**	**Value**	**Price**	**Value**	**Price**	**Value**	**Price**
1980	2,525.9	0.59	12.50	10.46	10.70	1.01	25.70	0.88	0.20	22.11	0.20	25.93
1981	2,825.6	0.65	17.10	9.19	12.90	1.07	29.00	0.96	0.40	18.79	0.25	13.90
1982	2,953.5	0.69	18.90	8.22	15.40	1.12	31.10	1.01	1.40	15.12	0.74	11.96
1983	3,207.7	0.72	23.90	6.86	18.00	1.13	31.90	1.03	2.90	10.71	2.07	10.39
1984	3,610.3	0.75	31.60	5.55	22.10	1.14	36.60	1.07	3.00	9.41	2.37	6.07
1985	3,844.1	0.76	33.70	4.72	25.60	1.13	39.90	1.09	2.90	8.68	2.70	4.93
1986	3,967.4	0.76	33.40	4.06	27.80	1.12	42.10	1.10	5.20	6.54	4.84	5.61
1987	4,310.8	0.79	35.80	3.46	31.40	1.12	42.10	1.10	6.20	5.91	4.91	3.54
1988	4,766.1	0.84	38.00	3.21	36.70	1.14	46.70	1.10	8.20	5.41	6.65	3.24
1989	5,070.5	0.86	43.10	3.00	44.40	1.11	46.90	1.10	8.30	5.02	7.89	2.85
1990	5,346.8	0.89	38.60	2.72	50.20	1.09	47.50	1.11	8.90	4.22	10.46	2.97
1991	5,427.2	0.91	37.70	2.45	56.60	1.10	45.70	1.11	11.90	3.53	11.66	2.44
1992	5,672.4	0.92	43.60	2.09	60.80	1.04	47.80	1.10	12.10	2.68	14.96	2.25
1993	5,901.8	0.93	47.20	1.78	69.40	1.04	48.20	1.09	14.50	2.07	16.26	1.71
1994	6,374.4	0.96	51.30	1.57	75.50	1.02	54.70	1.07	18.00	1.81	16.14	1.17
1995	6,674.4	0.97	64.60	1.31	83.50	1.02	60.00	1.03	21.00	1.44	22.64	1.13
1996	7,161.2	1.00	70.90	1.00	95.10	1.00	65.60	1.00	23.60	1.00	30.19	1.00
1997	7,701.8	1.02	76.70	0.78	106.60	0.97	73.00	0.99	26.20	0.69	33.68	0.71
1998	8,013.3	1.01	88.51	0.57	123.41	0.96	83.60	0.97	30.40	0.48	36.53	0.48

Notes: Values are in billions of current dollars. All price indexes are normalized to 1.0 in 1996.

Appendix B: Estimating Capital Services for the United States

Dale W. Jorgenson and Kevin J. Stiroh

B.1 Capital Services Methodology

WE BEGIN WITH SOME NOTATION for measures of investment, capital stock, and capital services, for both individual assets and aggregates. For individual assets:

$I_{i,t}$ = quantity of investment in asset i at time t
$P_{i,t}$ = price of investment in asset i at time t
δ_i = geometric depreciation rate for asset i
$S_{i,t}$ = quantity of capital stock of asset i at time t
$P_{i,t}$ = price of capital stock of asset i at time t
$K_{i,t}$ = quantity of capital services from asset i at time t
$c_{i,t}$ = price of capital services from asset i at time t

where the i subscript refers to different types of tangible assets: equipment and structures, as well as consumers' durable assets, inventories, and land, all for time period t.

For economy-wide aggregates:

I_t = quantity index of aggregate investment at time t
$P_{I,t}$ = price index of aggregate investment at time t
S_t = quantity index of aggregate capital stock at time t
$P_{S,t}$ = price index of aggregate capital stock at time t
K_t = quantity index of aggregate capital services at time t
c_t = price of capital services at time t
$q_{K,t}$ = quality index of aggregate capital services at time t

Our starting point is investment in individual assets. We assume that the price index for each asset measures investment goods in identically productive "efficiency units" over time. For example, the constant-quality price deflators in the NIPA measure the large increase in computing power as a decline in the price of computers.[1] Thus, a faster computer is represented by more $I_{i,t}$

in a given period and a larger accumulation of $S_{i,t}$, as measured by the perpetual inventory equation:

(1) $$S_{i,t} = S_{i,t-1}(1-\delta_i) + I_{i,t} = \sum_{\tau=0}^{\infty}(1-\delta_i)^{\tau} I_{i,t-\tau} ,$$

where capital is assumed to depreciate geometrically at the rate δ_i.

Equation (1) has the familiar interpretation — the capital stock is the weighted sum of past investments, where weights are derived from the relative efficiency profile of capital of different ages. Moreover, since $S_{i,t}$ is measured in base-year efficiency units, the appropriate price for valuing the capital stock is simply the investment price deflator, $P_{i,t}$. Furthermore, $S_{i,t}$ represents the installed stock of capital, but we are interested in $K_{i,t}$, the flow of capital services from that stock over a given period. This distinction is not critical at the level of individual assets, but becomes important when we aggregate heterogeneous assets.

For individual assets, we assume that the flow of capital services is proportional to the average of the stock available at the end of the current and prior periods:

(2) $$K_{i,t} = q_i \frac{\left(S_{i,t} + S_{i,t-1}\right)}{2} ,$$

where q_i denotes this constant of proportionality, set equal to unity. Note that this differs from our earlier work, e.g., Jorgenson (1990), Jorgenson and Stiroh (1999), and Ho, Jorgenson, and Stiroh (1999), where capital service flows were assumed proportional to the lagged stock of individual assets.

Our approach assumes that any improvement in input characteristics, such as a faster processor in a computer, is incorporated into investment $I_{i,t}$ via deflation of the nominal investment series. That is, investment deflators transform recent vintages of assets into an equivalent number of efficiency units of earlier vintages. This is consistent with the perfect substitutability assumption across vintages and our use of the perpetual inventory method, where vintages differ in productive characteristics due to the age-related depreciation term. We estimate a price of capital services that corresponds to the quantity flow of capital services via a rental price formula. In equilibrium, an investor is indifferent between two alternatives: earning a nominal rate of return, i_t, on a different investment or buying a unit of capital, collecting a rental fee, and then selling the depreciated asset in the next period. The equilibrium condition, therefore, is:

(3) $$(1+i_t)P_{i,t-1} = c_{i,t} + (1-\delta_i)P_{i,t}\,,$$

and rearranging yields a variation of the familiar cost of capital equation:

(4) $$c_{i,t} = (i_t - \pi_{i,t})P_{i,t-1} + \delta_i P_{i,t}\,,$$

where the asset-specific capital gains term is $\pi_{i,t} = (P_{i,t} - P_{i,t-1}) / P_{i,t-1}$.

This formulation of the cost of capital effectively includes asset-specific revaluation terms. If an investor expects capital gains on his investment, he will be willing to accept a lower service price. Conversely, investors require high service prices for assets like computers with large capital losses. Empirically, asset-specific revaluation terms can be problematic due to wide fluctuations in prices from period to period that can result in negative rental prices. However, asset-specific revaluation terms are becoming increasingly important as prices continue to decline for high-tech assets. Jorgenson and Stiroh (1999), for example, incorporated economy-wide asset revaluation terms for all assets and estimated a relatively modest growth contribution from computers.

As discussed by Jorgenson and Yun (1991), tax considerations also play an important role in rental prices. Following Jorgenson and Yun, we account for investment tax credits, capital consumption allowances, the statutory tax rate, property taxes, debt/equity financing, and personal taxes, by estimating an asset-specific, after-tax real rate of return, $r_{i,t}$, that enters the cost of capital formula:

(5) $$c_{i,t} = \frac{1 - ITC_{i,t} - \tau_t Z_{i,t}}{1-\tau_t}\left[r_{i,t}P_{i,t-1} + \delta_i P_{i,t}\right] + \tau_p P_{i,t-1}\,,$$

where $ITC_{i,t}$ is the investment tax credit, τ_t is the statutory tax rate, $Z_{i,t}$ is the capital consumption allowance, τ_p is a property tax rate, all for asset i at time t, and $r_{i,t}$ is calculated as:

(6) $$r_{i,t} = \beta[(1-\tau_t)i_t - \pi_{i,t}] + (1-\beta)\left[\frac{\rho_t - \pi_{i,t}(1-t_q^g)}{(1-t_q^e)\alpha + (1-t_q^g)(1-\alpha)}\right],$$

where β is the debt/capital ratio, i_t is the interest cost of debt, ρ_t is the rate of return to equity, α is the dividend payout ratio, and t_q^g and t_q^e are the tax rates on capital gains and dividends, respectively. $\pi_{i,t}$ is the inflation rate of asset i, which allows $r_{i,t}$ to vary across assets.[2]

Equations (1) through (6) describe the estimation of the price and quantity of capital services for individual assets: $P_{i,t}$ and $I_{i,t}$ for investment; $P_{i,t}$ and $S_{i,t}$ for capital stock; and $c_{i,t}$ and $K_{i,t}$ for capital services. For an aggregate production function analysis, we require an aggregate measure of capital services, $K_t = f(K_{1,t}, K_{2,t}, \ldots K_{n,t})$, where n includes all types of reproducible fixed assets, consumers' durable assets, inventories, and land. We employ quantity indices to generate aggregate capital services, capital stock, and investment series.[3]

The growth rate of aggregate capital services is defined as a share-weighted average of the growth rate of the components:

(7) $$\Delta \ln K_t = \sum_i \bar{v}_{i,t} \Delta \ln K_{i,t},$$

where weights are value shares of capital income:

(8) $$\bar{v}_{i,t} = \frac{1}{2}\left(\frac{c_{i,t}K_{i,t}}{\sum_i c_{i,t}K_{i,t}} + \frac{c_{i,t-1}K_{i,t-1}}{\sum_i c_{i,t-1}K_{i,t-1}}\right),$$

and the price index of aggregate capital services is defined as:

(9) $$c_t = \frac{\sum_i c_{i,t}K_{i,t}}{K_t}.$$

Similarly, the quantity index of capital stock is given by:

(10) $$\Delta \ln S_t = \sum_i \overline{w}_{i,t} \Delta \ln S_{i,t},$$

where the weights are now value shares of the aggregate capital stock:

(11) $$\overline{w}_{i,t} = \frac{1}{2}\left(\frac{P_{i,t} S_{i,t}}{\sum_i P_{i,t} S_{i,t}} + \frac{P_{i,t-1} S_{i,t-1}}{\sum_i P_{i,t-1} S_{i,t-1}} \right),$$

and the price index for the aggregate capital stock index is:

(12) $$P_{S,t} = \frac{\sum_i P_{i,t} S_{i,t}}{S_t}.$$

Finally, the aggregate quantity index of investment is given by:

(13) $$\Delta \ln I_t = \sum_i \overline{u}_{i,t} \Delta \ln I_{i,t},$$

where the weights are now value shares of aggregate investment:

(14) $$\overline{u}_{i,t} = \frac{1}{2}\left(\frac{P_{i,t} I_{i,t}}{\sum_i P_{i,t} I_{i,t}} + \frac{P_{i,t-1} I_{i,t-1}}{\sum_i P_{i,t-1} I_{i,t-1}} \right),$$

and the price index for the aggregate investment index is:

(15) $$P_{I,t} = \frac{\sum_i P_{i,t} I_{i,t}}{I_t}$$

The most important point from this derivation is the difference between the growth rate of aggregate capital services, Equation (7), and the growth rate of capital stock, Equation (10); this difference reflects two factors. First, the weights are different. The index of aggregate capital services uses rental prices as weights, while the index of aggregate capital stock uses investment prices. Assets with a rapidly falling asset price will have a relatively large rental price. Second, as can be seen from Equation (2), capital services are proportional to a two-period average stock, so the timing of capital services growth and capital stock growth differ for individual assets. In steady-state with a fixed capital to output ratio, this distinction is not significant, but if asset accumulation is either accelerating or decelerating, this timing matters.

A second point to emphasize is that we can define an "aggregate index of capital quality," $q_{K,t}$, analogously to Equation (2). We define the aggregate index of capital quality as $q_{K,t} = K_t/((S_t+S_{t-1})/2)$, and it follows that the growth of capital quality is defined as:

$$(16) \qquad \Delta \ln q_{K,t} = \Delta \ln K_t - \Delta \ln\left(\frac{(S_t + S_{t-1})}{2}\right) = \sum_i (\overline{v}_{i,t} - \overline{w}_{i,t}) \Delta \ln\left(\frac{(S_{t,i} + S_{t-1,i})}{2}\right).$$

Equation (16) defines growth in capital quality as the difference between the growth in capital services and the growth in average capital stock. This difference reflects substitution towards assets with relatively high rental price weights and high marginal products. For example, the rental price for computers is declining rapidly as prices fall, which induces substitution towards computers and rapid capital accumulation. However, the large depreciation rate and large negative revaluation term imply that computers have a high marginal product, so their rental price weight greatly exceeds their asset price weight. Substitution towards assets with higher marginal products is captured by our index of capital quality.

B.2 Investment and Capital Data

OUR PRIMARY DATA SOURCE for estimating the flow of capital services is the *Investment Estimates of Fixed Reproducible Tangible Wealth, 1925-1997* (BEA, 1998c). These data contain historical cost investment and chain-type quantity indices for 47 types of non-residential assets, 5 types of residential assets, and 13 different types of consumers' durable assets from 1925 to 1997. Table B.1 shows our reclassification of the BEA data into 52 non-residential assets, 5 residential assets, and 13 consumers' durable assets.[4]

Table B.2 presents the value and price index of the broadly defined capital stock, as well as individual information technology assets. Table B.3 presents similar data, but for capital service flows rather than capital stocks.[5] The price of capital stocks for individual assets in Table B.2 is the same as the investment price in Table A.1, but the prices differ for aggregates due to differences between weights based on investment flows and those based on asset stocks. The price index for investment grows more slowly than the price index for assets, since short-lived assets with substantial relative price declines represent a greater proportion of investment.

An important caveat about the underlying investment data is that it runs only through 1997 and is not consistent with the BEA benchmark revision of October 1999. We have made several adjustments to reflect the BEA revision, to make the data consistent with our earlier work, and to extend the investment series to 1998. First, we have replaced the Tangible Wealth series on "computers and peripheral equipment" with the NIPA investment series for "computers and peripheral equipment," in both current and chained 1996 dollars. These series were identical in the early years and differed by about 5 percent in current dollars in 1997. Similarly, we used the new NIPA series for investment in "software," "communications equipment," and for personal consumption of "computers, peripherals, and software" in both current and chained 1996 dollars. These NIPA series enable us to maintain a complete and consistent time series that incorporates the latest benchmark revisions and the expanded output concept that includes software.

Second, we have combined investment in residential equipment with "other equipment," a form of non-residential equipment. This does not change the investment or capital stock totals, but reallocates some investment and capital from the residential to the non-residential category.

Third, we control the total value of investment in major categories — structures, equipment and software, residential structures, and total consumers' durables — to correspond with NIPA aggregates. This adjustment maintains a consistent accounting for investment and purchases of consumers' durables as inputs and outputs. Computer investment, software investment, communications investment, and consumption of computers, peripherals, and software series are not adjusted.

Table B.1
Investment and Capital Stock by Asset Type and Class

Asset	Geometric Dep. Rate	1998	
		Investment	Capital Stock
Total Capital	n.a.		27,954.7
Fixed Reproducible Assets	n.a.	4,161.7	20,804.2
Equipment and Software		829.1	4,082.0
Household Furniture	0.1375	2.3	13.1
Other Furniture	0.1179	37.6	224.4
Other Fabricated Metal Products	0.0917	15.9	134.5
Steam Engines	0.0516	2.7	60.1
Internal Combustion Engines	0.2063	1.6	6.9
Farm Tractors	0.1452	10.8	60.7
Construction Tractors	0.1633	2.9	15.3
Agricultural Machinery, Except Tractors	0.1179	13.1	89.2
Construction Machinery, Except Tractors	0.1550	20.6	99.5
Mining and Oilfield Machinery	0.1500	2.4	15.6
Metalworking Machinery	0.1225	37.1	228.6
Special Industry Machinery, N.E.C.	0.1031	38.6	288.7
General Industrial, Including Materials Handling, Equipment	0.1072	34.5	247.5
Computers and Peripheral Equipment	0.3150	88.5	164.9
Service Industry Machinery	0.1650	17.9	92.0
Communication Equipment	0.1100	83.6	440.5
Electrical Transmission, Distribution, and Industrial Apparatus	0.0500	26.7	313.0
Household Appliances	0.1650	1.5	6.9
Other Electrical Equipment, N.E.C.	0.1834	15.2	64.5
Trucks, Buses, and Truck Trailers	0.1917	104.5	367.0
Autos	0.2719	19.4	70.2
Aircraft	0.0825	23.0	174.5
Ships and Boats	0.0611	3.0	48.4
Railroad Equipment	0.0589	5.3	69.1
Instruments (Scientific and Engineering)	0.1350	30.9	172.6

Table B.1 (cont'd)			
Asset	**Geometric Dep. Rate**	**1998**	
		Investment	**Capital Stock**
Photocopy and Related Equipment	0.1800	22.6	103.0
Other Non-residential Equipment	0.1473	35.4	184.3
Other Office Equipment	0.3119	8.4	24.5
Software	0.3150	123.4	302.4
Non-Residential Structures		2,271.3	5,430.6
Industrial Buildings	0.0314	36.4	766.6
Mobile Structures (Offices)	0.0556	0.9	9.8
Office Buildings	0.0247	44.3	829.8
Commercial Warehouses	0.0222	0.0	0.0
Other Commercial Buildings, N.E.C.	0.0262	55.7	955.8
Religious Buildings	0.0188	6.6	155.3
Educational Buildings	0.0188	11.0	157.4
Hospital and Institutional Buildings	0.0188	17.76	355.12
Hotels and Motels	0.0281	17.08	210.57
Amusement and Recreational Buildings	0.0300	9.14	103.55
Other Confirm Buildings, N.E.C.	0.0249	2.07	67.68
Railroad Structures	0.0166	5.78	210.36
Telecommunications	0.0237	13.19	282.09
Electric Light and Power (Structures)	0.0211	12.12	490.04
Gas (Structures)	0.0237	4.96	170.98
Local Transit Buildings	0.0237	0.00	0.00
Petroleum Pipelines	0.0237	1.11	39.20
Farm Related Buildings and Structures	0.0239	4.59	202.73
Petroleum and Natural Gas	0.0751	22.12	276.99
Other Mining Exploration	0.0450	2.03	38.96
Other Confirm Structures	0.0450	6.39	107.70
Railroad Track Replacement	0.0275	0.00	0.00
Nuclear Fuel Rods	0.0225	0.00	0.00

Table B.1 (cont' d)

Asset	Geometric Dep. Rate	1998	
		Investment	Capital Stock
Residential Structures		363.18	8,309.62
1-to-4-Unit Homes	0.0114	240.27	5,628.27
5-or-More-Unit Homes	0.0140	21.11	871.81
Mobile Homes	0.0455	14.64	147.17
Improvements	0.0255	86.29	1,634.15
Other Residential	0.0227	0.87	28.23
Consumers Durables		698.20	2,981.97
Autos	0.2550	166.75	616.53
Trucks	0.2316	92.53	327.85
Other (Rvs)	0.2316	18.63	64.98
Furniture	0.1179	56.02	372.26
Kitchen Appliances	0.1500	29.83	161.75
China, Glassware	0.1650	29.65	141.44
Other Durable	0.1650	64.03	309.67
Computers and Software	0.3150	30.40	52.30
Video, Audio	0.1833	75.15	289.22
Jewelry	0.1500	44.58	228.38
Ophthalmic	0.2750	16.53	53.44
Books and Maps	0.1650	25.34	132.51
Wheel Goods	0.1650	48.76	231.66
Land	0.0000		5,824.18
Inventories	0.0000		1,326.31

Note: Values of investment and capital stock are in millions of current dollars. Equipment and Software and Other non-residential equipment include NIPA residential equipment.

Source: BEA (1998a, 1998b, 1998c) and author calculations.

Table B.2
Total Capital Stock and High-Tech Assets

Year	Total Stock of Capital and CD Assets		Computer Capital Stock		Software Capital Stock		Communications Capital Stock		Computer and Software CD Stock	
	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1959	1,300.3	0.17	0.00	0.00	0.00	0.00	9.97	0.47	0.00	0.00
1960	1,391.0	0.18	0.20	697.30	0.10	0.61	11.11	0.47	0.00	0.00
1961	1,478.5	0.18	0.40	522.97	0.27	0.62	12.53	0.47	0.00	0.00
1962	1,583.6	0.19	0.50	369.16	0.39	0.63	14.06	0.46	0.00	0.00
1963	1,667.7	0.19	0.95	276.29	0.67	0.63	15.50	0.46	0.00	0.00
1964	1,736.0	0.19	1.44	229.60	0.97	0.64	16.99	0.47	0.00	0.00
1965	1,848.3	0.19	2.01	188.74	1.37	0.65	18.56	0.47	0.00	0.00
1966	2,007.7	0.20	2.67	132.70	1.95	0.66	20.69	0.47	0.00	0.00
1967	2,150.6	0.21	3.38	107.71	2.55	0.67	23.21	0.49	0.00	0.00
1968	2,394.9	0.22	3.88	92.00	3.09	0.68	26.38	0.51	0.00	0.00
1969	2,670.4	0.24	4.81	83.26	3.98	0.70	30.57	0.54	0.00	0.00
1970	2,874.8	0.24	5.66	74.81	5.12	0.73	35.16	0.57	0.00	0.00
1971	3,127.9	0.26	5.75	56.98	5.91	0.73	39.66	0.60	0.00	0.00
1972	3,543.0	0.28	6.68	45.93	6.86	0.73	43.77	0.62	0.00	0.00
1973	4,005.0	0.30	7.83	43.53	8.04	0.75	48.30	0.64	0.00	0.00
1974	4,250.3	0.31	8.28	35.55	9.77	0.80	55.98	0.69	0.00	0.00
1975	4,915.0	0.35	8.85	32.89	11.89	0.85	64.49	0.76	0.00	0.00
1976	5,404.1	0.37	9.46	27.47	13.52	0.87	71.56	0.80	0.00	0.00
1977	6,151.9	0.41	11.34	23.90	15.01	0.89	76.27	0.78	0.00	0.00
1978	7,097.4	0.45	12.86	16.17	17.00	0.90	88.54	0.81	0.10	33.68
1979	8,258.3	0.50	17.50	13.40	21.01	0.95	101.62	0.83	0.17	32.81
1980	9,407.4	0.56	21.85	10.46	25.93	1.01	122.33	0.88	0.28	22.11
1981	10,771.2	0.62	30.26	9.19	31.72	1.07	146.61	0.96	0.56	18.79
1982	11,538.6	0.66	37.45	8.22	38.14	1.12	168.74	1.01	1.71	15.12

Table B.2 (cont' d)

Year	Total Stock of Capital and CD Assets		Computer Capital Stock		Software Capital Stock		Communications Capital Stock		Computer and Software CD Stock	
	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1983	12,033.2	0.67	45.29	6.86	44.40	1.13	185.59	1.03	3.73	10.71
1984	13,247.3	0.71	56.70	5.55	52.68	1.14	207.81	1.07	5.25	9.41
1985	14,837.5	0.77	66.72	4.72	61.66	1.13	228.43	1.09	6.21	8.68
1986	15,985.5	0.81	72.77	4.06	69.38	1.12	246.93	1.10	8.41	6.54
1987	17,137.5	0.85	78.26	3.46	79.17	1.12	262.59	1.10	11.40	5.91
1988	18,632.2	0.90	87.79	3.21	91.54	1.14	280.64	1.10	15.35	5.41
1989	20,223.2	0.96	99.26	3.00	105.64	1.11	297.05	1.10	18.06	5.02
1990	20,734.0	0.96	100.29	2.72	121.57	1.09	311.95	1.11	19.30	4.22
1991	21,085.3	0.97	99.42	2.45	140.37	1.10	324.37	1.11	22.97	3.53
1992	21,296.9	0.96	101.84	2.09	151.41	1.04	334.48	1.10	24.05	2.68
1993	21,631.7	0.96	106.68	1.78	173.39	1.04	342.48	1.09	27.20	2.07
1994	22,050.0	0.96	115.74	1.57	191.63	1.02	353.46	1.07	34.28	1.81
1995	23,346.7	0.99	130.78	1.31	215.13	1.02	362.23	1.03	39.71	1.44
1996	24,300.2	1.00	139.13	1.00	239.73	1.00	380.00	1.00	42.49	1.00
1997	26,070.4	1.04	150.57	0.78	266.63	0.97	407.58	0.99	46.20	0.69
1998	27,954.7	1.08	164.87	0.57	302.41	0.96	440.52	0.97	52.30	0.48

Note: Values are in billions of current dollars. Total capital stock includes reproducible assets, consumers' durable assets (CD), land, and inventories. All price indices are normalized to 1.0 in 1996.

Table B.3

Total Capital Services and High-Tech Assets

Year	Total Service Flow from Capital and CD Assets		Computer Capital Service Flow		Software Capital Service Flow		Communications Capital Service Flow		Computer and Software CD Service Flow	
	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1959	214.7	0.32	0.00	0.00	0.00	0.00	2.55	0.50	0.00	0.00
1960	183.7	0.26	0.05	407.59	0.02	0.64	2.65	0.47	0.00	0.00
1961	192.3	0.26	0.25	602.38	0.08	0.61	2.85	0.45	0.00	0.00
1962	211.9	0.28	0.41	480.68	0.15	0.65	3.44	0.48	0.00	0.00
1963	241.7	0.30	0.56	291.73	0.22	0.60	3.32	0.42	0.00	0.00
1964	260.2	0.31	0.77	196.86	0.34	0.59	3.68	0.42	0.00	0.00
1965	289.2	0.32	1.15	169.47	0.52	0.64	4.73	0.50	0.00	0.00
1966	315.4	0.33	1.99	161.83	0.74	0.65	5.00	0.48	0.00	0.00
1967	333.8	0.33	2.13	103.65	1.03	0.68	5.14	0.45	0.00	0.00
1968	330.2	0.31	2.40	81.43	1.29	0.69	5.43	0.44	0.00	0.00
1969	349.2	0.31	2.54	63.64	1.57	0.69	6.02	0.44	0.00	0.00
1970	382.5	0.33	3.27	61.40	2.09	0.74	7.23	0.48	0.00	0.00
1971	391.4	0.32	4.83	68.40	2.83	0.83	8.34	0.51	0.00	0.00
1972	439.6	0.35	4.44	45.09	3.01	0.77	8.86	0.51	0.00	0.00
1973	517.9	0.38	4.02	30.87	3.47	0.77	12.48	0.68	0.00	0.00
1974	546.6	0.38	6.04	36.38	3.99	0.78	11.48	0.58	0.00	0.00
1975	619.2	0.42	5.36	26.49	5.17	0.88	13.41	0.64	0.00	0.00
1976	678.1	0.44	6.01	24.25	5.60	0.84	13.61	0.62	0.00	0.00
1977	742.8	0.47	6.35	19.16	6.26	0.86	22.37	0.94	0.00	0.00
1978	847.5	0.51	10.71	20.84	7.31	0.91	19.02	0.72	0.02	17.84
1979	999.1	0.57	10.45	12.30	8.19	0.89	26.30	0.89	0.07	19.01
1980	1,026.9	0.56	15.03	10.96	9.99	0.93	23.94	0.72	0.20	25.93
1981	1,221.4	0.66	15.92	7.33	11.76	0.94	23.89	0.64	0.25	13.90

Table B.3 (cont'd)

Year	Total Service Flow from Capital and CD Assets		Computer Capital Service Flow		Software Capital Service Flow		Communications Capital Service Flow		Computer and Software CD Service Flow	
	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1982	1,251.7	0.65	17.29	5.47	12.54	0.87	25.32	0.62	0.74	11.96
1983	1,359.1	0.71	22.77	5.06	15.11	0.92	29.54	0.67	2.07	10.39
1984	1,570.1	0.79	30.79	4.54	19.02	0.99	33.20	0.70	2.37	6.07
1985	1,660.5	0.79	33.72	3.43	22.41	0.99	39.30	0.77	2.70	4.93
1986	1,559.9	0.71	36.44	2.82	25.88	0.99	43.39	0.79	4.84	5.61
1987	1,846.6	0.80	45.07	2.76	31.84	1.07	55.49	0.94	4.91	3.54
1988	2,185.3	0.89	43.85	2.18	37.72	1.11	67.22	1.07	6.65	3.24
1989	2,243.0	0.89	47.89	1.97	45.96	1.16	67.90	1.02	7.89	2.85
1990	2,345.0	0.90	53.28	1.89	51.07	1.10	69.86	1.00	10.46	2.97
1991	2,345.8	0.88	52.65	1.69	54.07	1.01	66.05	0.91	11.66	2.44
1992	2,335.4	0.86	57.69	1.60	69.11	1.12	70.72	0.94	14.96	2.25
1993	2,377.4	0.85	62.00	1.42	69.32	0.98	80.23	1.02	16.26	1.71
1994	2,719.5	0.94	63.16	1.17	84.14	1.05	89.16	1.09	16.14	1.17
1995	2,833.4	0.94	77.77	1.11	89.18	0.99	101.18	1.17	22.64	1.13
1996	3,144.4	1.00	96.36	1.00	101.46	1.00	92.91	1.00	30.19	1.00
1997	3,466.3	1.05	103.95	0.77	119.80	1.04	100.13	1.00	33.68	0.71
1998	3,464.8	0.99	118.42	0.61	128.32	0.97	103.35	0.94	36.53	0.48

Note: Values are in billions of current dollars. Service prices are normalized to 1.0 in 1996. Total service flows include reproducible assets, consumers' durable assets (CD), land, and inventories. All price indices are normalized to 1.0 in 1996.

Fourth, we extended the investment series through 1998 based on NIPA estimates. For example, the 1998 growth rates for other fabricated metal products, steam engines, internal combustion engines, metalworking machinery, special industry machinery, general industrial equipment, and electrical transmission and distribution equipment were taken from the “other” equipment category of NIPA. The growth rate of each type of consumers’ durables was taken directly from NIPA.

These procedures generated a complete time series of investment in 57 private assets (29 types of equipment and software, 23 types of non-residential structures, and 5 types of residential structures) and consumption of 13 consumers’ durable assets in both current dollars and chained-1996 dollars from 1925 to 1998. For each asset, we created a real investment series by linking the historical cost investment and the quantity index in the base year 1996. Capital stocks were then estimated using the perpetual inventory method in Equation (1) and a geometric depreciation rate, based on Fraumeni (1997) and reported in Table B.1.

Important exceptions are the depreciation rates for computers, software, and autos. BEA (1998a) reports that computer depreciation is based on the work of Oliner (1993, 1994), is non-geometric, and varies over time. We estimated a best-geometric approximation to the latest depreciation profile for different types of computer assets and used an average geometric depreciation rate of 0.315 for computer investment, software investment, and consumption of computers, peripherals, and software. Similarly, we estimated a best geometric approximation to the depreciation profile for autos of 0.272.

We also assembled data on investment and land to complete our capital estimates. The inventory data come primarily from NIPA in the form of farm and non-farm inventories. Inventories are assumed to have a depreciation rate of zero and do not face an investment tax credit or capital consumption allowance, so the rental price formula is a simplified version of Equation (5).

Data on land are somewhat more problematic. Through 1995, the Federal Reserve Board published detailed data on land values and quantities in its *Balance Sheets for the U.S. Economy* study (Federal Reserve Board, 1995), but the underlying data became unreliable and are no longer published. We use the limited land data available in the *Flow of Funds Accounts of the United States* and historical data described in Jorgenson (1990) to estimate the price and quantity of private land. As a practical matter, this quantity series varies very little, so its major impact is to slow the growth of capital by assigning a positive weight to the zero growth rate of land. Like inventories, depreciation, the investment tax credit, and capital consumption allowances for land are zero.

A final methodological detail involves negative service prices that sometimes result from the use of asset-specific revaluation terms. As can be seen from the simplified cost of capital formula in Equation (5), an estimated service price can be negative if asset inflation is high relative to the interest rate and depreciation rate. Economically, this is possible, implying that capital gains were higher than expected. Negative service prices make aggregation difficult so we made adjustments for several assets. In a small number of cases for reproducible assets and inventories, primarily structures in the 1970s, we used smoothed inflation for surrounding years rather than the current inflation in the cost of capital calculation. For land, which showed large capital gains throughout and has no depreciation, we used the economy-wide rate of asset inflation for all years.

Notes

1 See BLS (1997), particularly Chapter 14, for details on the quality adjustments incorporated into the producer price indices used as the primary deflators for the capital stock study. Cole *et al.* (1986) and Triplett (1986, 1989) provide details on the estimation of hedonic regressions for computers.

2 A complication, of course, is that ρ_t is endogenous. We assume that the after-tax rate of return to all assets is the same and estimate ρ_t as the return that exhausts the payment of capital across all assets in the corporate sector. In addition, tax considerations vary across ownership classes (e.g., corporate, non-corporate, and household). We account for these differences in our empirical work, but do not go into details here. See Jorgenson and Yun (1991, Chapter 2).

3 See Diewert (1980) and Fisher (1992) for details.

4 Katz and Herman (1997) and Fraumeni (1997) provide details on the BEA methodology and underlying data sources.

5 Note that these price indices have been normalized to 1.0 in 1996, so they do not correspond to the components of the capital service formula in Equation (5).

Appendix C:
Estimating Labour Input

Dale W. Jorgenson and Kevin J. Stiroh

C.1 Labour Input Methodology

WE AGAIN BEGIN WITH SOME NOTATION for measures of hours worked, labour inputs, and labour quality for worker categories:

$H_{j,t}$ = quantity of hours worked by worker category *j* at time *t*
$w_{j,t}$ = price of an hour worked by worker category *j* at time *t*
$L_{j,t}$ = quantity of labour services from worker category *j* at time *t*

and for economy-wide aggregates:

H_t = quantity of aggregate hours worked at time *t*
W_t = average wage of hours worked at time *t*
L_t = quantity index of labour input at time *t*
$P_{L,t}$ = price index of labour input at time *t*
$q_{L,t}$ = quality index of labour input at time *t*

In general, the methodology for estimating labour input parallels capital services, but the lack of an investment-type variable makes the labour input somewhat more straightforward. For each individual category of workers, we begin by assuming that the flow of labour services is proportional to hours worked:

$$(1) \qquad L_{j,t} = q_{L,j} H_{j,t} \, ,$$

where $q_{L,j}$ is the constant of proportionality for worker category *j*, set equal to unity.

The growth rate of aggregate labour input is defined as the share-weighted aggregate of the components as:

$$(2) \qquad \Delta \ln L_t = \sum_j \bar{v}_{j,t} \Delta \ln L_{j,t} \, ,$$

where weights are value shares of labour income:

(3) $$\bar{v}_{j,t} = \frac{1}{2}\left(\frac{w_{j,t}L_{j,t}}{\sum_j w_{j,t}L_{j,t}} + \frac{w_{j,t-1}L_{j,t-1}}{\sum_j w_{j,t-1}L_{j,t-1}}\right),$$

and the price of aggregate labour input is defined as:

(4) $$P_{L,t} = \frac{\sum_j w_{j,t}L_{j,t}}{L_t}\cdot$$

We define the "aggregate index of labour quality", $q_{L,t}$, by $q_{L,t} = L_t/H_t$, where H_t is the unweighted sum of labour hours:

(5) $$H_t = \sum_j H_{j,t}\cdot$$

The growth in labour quality is then defined as:

(6) $$\Delta \ln q_{L,t} = \sum_j \bar{v}_{j,t}\Delta \ln H_{j,t} - \Delta \ln H_t\cdot$$

Equation (6) defines growth in labour quality as the difference between weighted and unweighted growth in labour hours. As with capital, this reflects substitutions among heterogeneous types of labour with different characteristics and different marginal products. As described by Ho and Jorgenson (1999), one can further decompose labour quality into components associated with different characteristics of labour, such as age, sex, and education.

C.2 Labour Data

OUR PRIMARY DATA SOURCES are individual observations from the decennial Census of Population for 1970, 1980, and 1990, the NIPA, and the annual Current Population Survey (CPS). The NIPA provides totals for hours worked, and the Census and CPS allow us to estimate labour quality growth. Details on the construction of the labour data are presented in Ho and Jorgenson (1999). Table C.1 reports the primary labour input data used in this study, including the price, quantity, value, and quality of labour input, as well as employment, weekly hours, hourly compensation, and hours worked.

Briefly, the Census of Population provide detailed data on employment, hours, and labour compensation across demographic groups in census years. The CPS data are used to interpolate similar data for intervening years, and the NIPA data provide control totals. The demographic groups include 168 different types of workers, cross-classified by sex (male, female), class (employee, self-employed or unpaid), age (16-17, 18-24, 25-34, 35-44, 45-54, 55-64, 65+), and education (0-8 years of grade school, 1-3 years of high school, 4 years of high school, 1-3 years of college, 4 years of college, 5+ years of college).[1] Adjustments to the data include allocations of multiple job-holders, an estimation procedure to recover "top-coded" income data, and bridging to maintain consistent definitions of demographic groups over time.

These detailed data cover the period 1959 to 1995 and are taken from Ho and Jorgenson (1999). They allow us to estimate the quality of the labour input for the private business sector, general government, and government enterprises, where only the private business sector index is used in the aggregate growth accounting results. For the years 1996-98, we estimate labour quality growth by holding relative wages across labour types constant, and by incorporating demographic projections for the labour force. Hours worked by employees are taken from the latest data in the NIPA; hours worked by the self-employed are estimated by Ho and Jorgenson (1999).

Note

1 There is also an industry dimension, which we do not exploit in this aggregate framework, but it is used in the industry productivity analysis discussed below.

Table C.1

Labour Input

Year	Labour Input				Employment	Weekly Hours	Hourly Compensation	Hours Worked
	Price	Quantity	Value	Quality				
1959	0.15	1,866.7	269.8	0.82	58,209	38.0	2.3	115,167
1960	0.15	1,877.5	289.1	0.82	58,853	37.7	2.5	115,403
1961	0.16	1,882.0	297.7	0.83	58,551	37.4	2.6	113,996
1962	0.16	1,970.7	315.3	0.86	59,681	37.5	2.7	116,348
1963	0.16	2,000.2	320.4	0.86	60,166	37.5	2.7	117,413
1964	0.17	2,051.4	346.2	0.87	61,307	37.4	2.9	119,111
1965	0.18	2,134.8	375.1	0.88	63,124	37.4	3.0	122,794
1966	0.19	2,226.9	413.7	0.89	65,480	37.1	3.3	126,465
1967	0.19	2,261.8	429.3	0.90	66,476	36.8	3.4	127,021
1968	0.21	2,318.8	480.8	0.91	68,063	36.5	3.7	129,194
1969	0.22	2,385.1	528.6	0.91	70,076	36.4	4.0	132,553
1970	0.24	2,326.6	555.6	0.90	69,799	35.8	4.3	130,021
1971	0.26	2,318.3	600.2	0.90	69,671	35.8	4.6	129,574
1972	0.28	2,395.5	662.9	0.91	71,802	35.8	5.0	133,554
1973	0.29	2,519.1	736.4	0.91	75,255	35.7	5.3	139,655
1974	0.32	2,522.2	798.8	0.91	76,474	35.0	5.7	139,345
1975	0.35	2,441.8	852.9	0.92	74,575	34.6	6.3	134,324
1976	0.38	2,525.6	964.2	0.92	76,925	34.6	7.0	138,488
1977	0.41	2,627.2	1,084.9	0.92	80,033	34.6	7.5	143,918
1978	0.44	2,783.7	1,232.4	0.93	84,439	34.5	8.1	151,359
1979	0.48	2,899.6	1,377.7	0.93	87,561	34.5	8.8	157,077
1980	0.52	2,880.8	1,498.2	0.94	87,788	34.1	9.6	155,500
1981	0.55	2,913.8	1,603.9	0.94	88,902	33.9	10.2	156,558
1982	0.60	2,853.3	1,701.6	0.94	87,600	33.6	11.1	153,163

Table C.1 (cont'd)

Year	Labour Input				Employment	Weekly Hours	Hourly Compensation	Hours Worked
	Price	Quantity	Value	Quality				
1983	0.66	3,095.5	2,040.2	0.95	93,176	34.0	12.4	164,870
1984	0.64	2,904.9	1,849.0	0.94	88,638	33.9	11.9	156,049
1985	0.69	3,174.6	2,183.5	0.95	95,410	33.9	13.0	168,175
1986	0.75	3,192.8	2,407.1	0.95	97,001	33.5	14.2	169,246
1987	0.74	3,317.1	2,464.0	0.96	99,924	33.7	14.1	174,894
1988	0.76	3,417.2	2,579.5	0.96	103,021	33.6	14.3	179,891
1989	0.80	3,524.2	2,827.0	0.96	105,471	33.7	15.3	184,974
1990	0.84	3,560.3	3,001.9	0.97	106,562	33.6	16.1	186,106
1991	0.88	3,500.3	3,081.4	0.97	105,278	33.2	16.9	181,951
1992	0.94	3,553.4	3,337.0	0.98	105,399	33.2	18.3	182,200
1993	0.95	3,697.5	3,524.4	0.99	107,917	33.5	18.8	187,898
1994	0.96	3,806.4	3,654.6	0.99	110,888	33.6	18.9	193,891
1995	0.98	3,937.5	3,841.2	1.00	113,707	33.7	19.3	199,341
1996	1.00	4,016.8	4,016.8	1.00	116,083	33.6	19.8	202,655
1997	1.02	4,167.6	4,235.7	1.01	119,127	33.8	20.3	209,108
1998	1.06	4,283.8	4,545.7	1.01	121,934	33.7	21.3	213,951

Note: The quantity of labour input is measured in billions of 1996 dollars; the value of the labour input is measured in billions of current dollars. Employment is in thousands of workers, hourly compensation is expressed in dollars, and hours worked are in millions. The price of the labour input and the index of labour quality are normalized to 1.0 in 1996.

Appendix D: Estimating Industry-level Productivity for the United States

Dale W. Jorgenson and Kevin J. Stiroh

OUR PRIMARY DATA ARE ANNUAL TIME SERIES of inter-industry transactions in current and constant prices, including final demands by commodity, investment and labour inputs by industry, and output by industry. The first building block is a set of inter-industry transactions produced by the Employment Projections Office of the Bureau of Labor Statistics (BLS). These data report intermediate inputs and total value-added (the sum of capital and labour inputs and taxes) for 185 industries from 1977 to 1995. A major advantage of this BLS inter-industry data is that it provides the necessary interpolations between benchmark years.

We aggregate the data from the *make* and *use* tables to generate inter-industry transactions for 35 private business industries at approximately the two-digit Standard Industrial Classification (SIC) level. These tables enable us to generate growth rates of industry outputs, growth rates of intermediate inputs, and shares of intermediate inputs as needed in Equation (2) of Chapter 2. They also provide control totals for value added in each industry, the sum of the values of capital and labour services and taxes.

Estimation of capital services and labour input follows the procedures described above for each industry. We collected information from three sources to estimate prices and quantities of capital and labour inputs by industry. An industry-level breakdown of the value of capital and labour input is available in the "gross product originating" series described in Lum and Yuskavage (1997) of the BEA. Investments by asset classes and industries are from the BEA Tangible Wealth Survey (BEA, 1998a, described by Katz and Herman, 1997). Labour data across industries are from the decennial Census of Population and the annual Current Population Survey. We use the prices and quantities of labour services for each industry constructed by Ho and Jorgenson (1999).

We also generate capital and labour services for a Private Household sector and the Government sector.[1] For private households, the value of labour services equals labour income in the BLS private household industry, while capital income reflects the imputed flow of capital services from residential housing, consumers' durables, and household land as described above. For the Government sector, labour income equals labour compensation of general government employees and capital income is an estimate of the flow of capital services from government capital.[2] Note that the Government Enterprises sector is treated as a private business industry and is separate from the General Government sector.

Notes

1 The Private Household and Government sectors include only capital and labour as inputs. Output in these sectors is defined via a Tornqvist index of capital and labour inputs, so productivity growth is zero by definition.

2 The BEA includes a similar imputation for the flow of government capital services in the national accounts, but our methodology includes a return to capital, as well as depreciation as estimated by the BEA.

Appendix E: Measuring the Quantity and Cost of Capital Inputs in Canada

Wulong Gu and Frank C. Lee

E.1 Introduction

IN THIS APPENDIX, WE PRESENT THE METHODOLOGY for estimating the indices of capital inputs in Canada over the 1961-98 period. Unlike simple measures of capital stocks, our measure of capital inputs takes into account the changing composition of capital stocks (relatively more equipment than structures). The change in our measure reflects both capital accumulation and a changing composition of capital stocks.

Capital stocks would be a valid measure of capital inputs if capital assets were homogeneous. They are, however, heterogeneous, and their composition changes over time (Griliches and Jorgenson, 1966; and Jorgenson and Griliches, 1967). Tangible assets have different acquisition prices, service lives, depreciation rates, tax treatments, and ultimately different marginal products. The capital stock measure does not account for these differences in capital stocks. However, the capital stock measure is easily available and much work on productivity has used that measure. For example, Statistics Canada employs net capital stock in its productivity estimates at the detailed industry level (Statistics Canada, 1994b). The Organization for Economic Co-operation and Development (OECD) uses gross capital stock in its international comparison of productivity in OECD countries (OECD, 1998).

Jorgenson, Gollop and Fraumeni (1987) constructed indices of capital inputs for forty-six private industrial sectors and the civilian U.S. economy over the 1947-79 period. Their measures of capital inputs incorporate the characteristics of physical assets, cross-classified by six classes of assets (producers' durable equipment, consumers' durable equipment, tenant-occupied residential or non-residential structures, owner-occupied residential structures, inventory, and land) and four legal forms of ownership (corporate business, non-corporate business, household, and institution). More recently, Ho, Jorgenson and Stiroh (1999) extended the analysis and estimated the annual indices of capital inputs for the private U.S. economy over 1948-96.

The desirability of using capital inputs for productivity analysis has been recognized by the U.S. Bureau of Labor Statistics. In 1983, the BLS developed the indices of capital inputs from data on forty-seven types of assets and three major industrial sectors (farm, manufacturing, and other industrial).[1] In recent empirical work, the BLS (1999) made substantial revisions to the procedures used for calculating capital inputs. The most notable are a decrease in the depreciation rates for non-residential structures and a finer classification of capital inputs by industrial sector.

Indices of aggregate capital input have been constructed for Canada by Dougherty (1992), Diewert and Lawrence (1999), and Jorgenson and Yip (1999). Dougherty's indices of capital inputs were built from data on eight types of capital assets and two types of ownership (corporate and personal sectors). Jorgenson and Yip (1999) extended the analysis to a more recent period. Diewert and Lawrence (1999) also constructed indices of aggregate capital input for Canada and examined the sensitivity of their measures to various asset depreciation patterns.

We have constructed indices of capital inputs for the aggregate business sector and each industrial sector in Canada for the 1961-98 period. This appendix explains the methodology and data sources used in the construction of capital inputs. In Section E.2 below, we outline the methodology. In Section E.3, we describe the data sources used for constructing the indices of capital inputs. In Section E.4, we present the annual estimates of capital inputs for each industrial sector and the aggregate business sector for the 1961-98 period. Section E.5 concludes.

E.2 Methodology for Measuring the Quantity and Cost of Capital Inputs

OUR OBJECTIVE IS TO CONSTRUCT indices of capital inputs or capital services for the business sector and each of the 123 industries of the business sector (called the P-level industry aggregation) over the 1961-98 period. The indices of capital inputs take into account the changing composition of capital stocks and are built from five types of tangible assets: machinery labour equipment, building structures, engineering structures, inventories, and land.

E.2.1 Estimating Capital Inputs

To construct an index of capital inputs, we assume that the aggregate capital input $\{K\}$ can be expressed as a translog function of its individual components$\{K_k\}$. The growth rate of the aggregate capital input is therefore the weighted average of the growth rates of its components:

$$(1) \qquad \Delta \ln K = \sum_k \bar{v}_k \Delta \ln K_k \,,$$

where Δ denotes a first difference, or change between two consecutive periods, for example:

$$(2) \qquad \Delta \ln K = \ln K(t) - \ln K(t-1) \,.$$

The weights are given by the average share of the individual components in the value of capital compensation:

$$(3) \qquad \bar{v}_k = \frac{1}{2}\left[v_k(t) + v_k(t-1)\right], \; v_k = \frac{c_k K_k}{\sum_k c_k K_k} \,,$$

where $\{c_k\}$ is the set of user costs of the components of the capital input.[2] At market equilibrium, the user cost of a capital input equals the value of its marginal product. Aggregating capital inputs by means of user costs therefore effectively accounts for the differences in productive contribution from various assets.

The quantity of services for each component of capital input $\{K_k\}$ is proportional to the stock of capital $\{A_k\}$ at the beginning of the period:

$$(4) \qquad K_k(t) = Q_k A_k(t) \,,$$

where the constants of proportionality $\{Q_k\}$ transform capital stock into the quantity of services produced by that stock per period.

We assume that the quantity of services delivered per unit of capital stock $\{Q_k\}$, per computer for example, is constant at all points in time. The improvement in the quality of computers (e.g., increased processing speed) is incorporated in the measurement of real capital stock via the proper construction of the price index for computers. Indeed, major efforts have been undertaken in recent years to construct these quality-adjusted price deflators for goods, such as computers that experienced dramatic quality improvement (BLS, 1997; and Gordon, 1997).

Using Equation (4), we can express the growth rate of capital inputs in terms of the growth rates of the capital stock components $\{A_k\}$:

(5) $$\Delta \ln K = \sum_k \bar{v}_k \Delta \ln K_k = \sum_k \bar{v}_k \Delta \ln A_k \cdot$$

At the heart of the above methodology for estimating capital inputs is the distinction between capital stock $\{A_k\}$ and the flow of services received from the capital stock in one period $\{K_k\}$. A distinction is also made between the price of acquiring an asset $\{P_k\}$ and the cost of using the asset for one period. $\{c_k\}$. As evident in rental markets, these distinctions exist for computers, automobiles, office equipment and furniture, and so on. In fact, a possible approach to measuring capital inputs would be to compile data on transactions in theses rental markets. However, this approach is rarely pursued since there is no rental market for most assets.

The compositional or quality change of capital inputs is the difference between the growth rates of capital inputs and the simple sum of the capital stock components:

(6) $$\Delta \ln Q = \Delta \ln K - \Delta \ln A,$$

where $A = \sum_k A_k$ is the simple sum of capital stock components. In Equation (6), the growth of capital inputs ($\Delta \ln K$) is decomposed into capital accumulation ($\Delta \ln A$) and compositional change. ($\Delta \ln Q$) In terms of individual components, the growth rate of capital quality can be written as:

(7) $$\Delta \ln Q = \sum_k \bar{v}_k \Delta \ln A_k - \Delta \ln \sum_k A_k \cdot$$

An examination of Equation (7) shows that capital quality remains unchanged if all components of capital stock increase at the same rate. Capital quality increases if the share of the components with relatively higher user costs (e.g., equipment) increases, and it declines if that share decreases.

E.2.2 Estimating Capital Stock and the Cost of Capital Services

The indices of capital inputs are constructed using Equation (5) with data on capital stock and the user cost of capital inputs. We assume that assets follow geometric depreciation patterns and calculate capital stock using the perpetual inventory method (see Appendix C for details on the construction of the capital stock). Capital stock of asset *k* at the beginning of period *t* is:

(8) $$A_k(t) = A_k(t-1)(1-\delta_k) + I_k(t-1) = \sum_{\tau=1}^{\infty}(1-\delta_k)^{\tau-1} I_k(t-\tau),$$

where I_k is real investment of asset type *k* and δ_k is the depreciation rate.

For an asset with a geometric depreciation pattern, the cost of using the asset over one period or the cost of capital services is (see Jorgenson and Yun, 1991, for details):

(9) $$c_k = \frac{1-e_k-tz_k}{1-t} P_k \left[(r_k-\pi_k)+(1+\pi_k)\delta_k)\right] + t^p P_k,$$

where t is the combined federal and provincial corporate income tax rate, e_k is the investment tax credit, z_k is the present value of capital cost allowances on one dollar's worth of investment, P_k is the price of new investment good *k*, r_k is the nominal rate of return on asset type *k*, $\pi_k = (P_k(t) - P_k(t\text{-}1) / P_k(t)$ is the capital gain for asset *k*, δ_k is the depreciation rate for asset *k*, and t^p is the property tax rate.

The user-cost equation (9) reflects the nominal rate of return on assets, the rate of economic depreciation, and capital gains on assets. It also takes into account the effects of taxation, such as corporate income taxes, investment tax credits, and capital consumption allowances on the user cost of capital.

Since there is no investment tax credit, capital consumption allowances, property tax rate, or economic depreciation, the user-cost equation for land and inventories simplifies to:

(10) $$c_k = (\frac{r_k - \pi_k}{1-t} + t_p)P_k \cdot$$

All parameters in the user-cost equation are available from various sources. The nominal rate of return on an asset can be estimated in two ways. First, it can be estimated from data on returns to debt and equity. This is problematic due to the multiplicity of returns. In this study, we have chosen to estimate the nominal rate of return *ex post* from data on the total value of capital compensation. We assume that the nominal rate of return is the same for all types of assets in an industry. The nominal rate of return on an asset is chosen such that the sum of the values of the capital input components is equal to the total capital compensation:

(11) $$\sum_k c_k A_k = V, \text{ and } r_k = r,$$

where V is total capital compensation.

E.3 Data Sources

THE TWO DATA COMPONENTS used in the construction of capital inputs are capital stock and the cost of capital. Our first task is to construct capital stocks for the five asset types and each industrial sector over the period 1961-98.

The capital stock of depreciable assets (M&E and structures) in the United States was estimated from investment data using geometric depreciation. These U.S. estimates use a 1.65 declining-balance rate for most machinery and equipment, and a 0.9 declining-balance rate for most non-residential structures. Capital stock data published by Statistics Canada are based on a modified double-declining-balance method for both machinery and equipment, and structures. To ensure comparability between Canadian and U.S. capital stock estimates, we obtained an alternative set of capital stock estimates from the Investment and Capital Stock Division of Statistics Canada (see Appendix C). These alternative capital stock estimates have been calculated with the same declining-balance rates as those used in the United States.

These measures will be used in our estimates of capital inputs in Canadian industries. However, for comparison purposes, we also present the results based on capital stocks used in Statistics Canada's productivity estimates.

Inventory stocks are estimated from data in industry balance sheets, national balance sheets, and input-output tables. The industry balance sheets provide data on the book value of inventory stocks at the 1970 three-digit industry classification level for the 1972-87 period. For that period, we set inventory stocks in current prices to their book values. For other years, we have estimated inventory stocks using data on inventory investment from the input-output tables. Since there is no depreciation for inventories, the inventory stock in a year is equal to the stock of the preceding year plus the investment made in the current year. The price deflators of inventory stocks are set to the average of the price deflators of raw materials and final output. Finally, the estimates of inventory stocks are adjusted to the inventory stock of the business sector in national balance sheets.

To estimate land input by industry, we first obtain the nominal value of land in Canada for the 1961-98 period from the National balance sheet accounts. We assume that the quantity of land remains constant and derive its price index. We then remove the real values of farm, residential, and government land from the real value of land in Canada. The remaining non-agricultural, non-government land is allocated across industries. For the 1972-87 period, the allocation is based on the book value of land in the industry balance sheets. For other years, the land value of an industry is extrapolated using the growth of non-residential structures and then adjusted to the national total in National balance sheet accounts.

Our second task is to construct estimates of the user cost by industrial sector for the five asset types over the 1961-98 period.[3] The cost of capital is estimated from data on corporate tax rates, investment tax credit, the present value of capital cost allowances, and economic rates of depreciation.[4] To calculate the combined federal and provincial corporate tax rate of an industry we have taken into account the variation of corporate income tax rates by province, firm size, and the nature of productive activities. First, the corporate income tax rates vary across provinces. While there is only one federal corporate tax rate in all provinces, each province can apply a different corporate income tax rate. Second, Canadian-controlled private corporations (CCPC) are eligible for small business tax reductions. For example, the small business tax rate reduction in 1996 was 16 percent on the first $200,000 of active business income. Third, since 1973, a tax reduction is offered to corporations engaged in manufacturing and processing. As an example, the manufacturing and processing tax credit after 1994 is 7 percent of federal tax on manufacturing and processing profits that do not qualify for the small business deduction. Table E.1 presents the combined federal and provincial tax rates in 1996 by province, firm size, and type of productive activities.

The average corporate tax rate of an industry is calculated as a weighted-sum of statutory tax rates using appropriate taxable income shares as weights. Data on taxable income by province, firm size and industry are obtained from the industry balance sheets and income statements. From these sources, we have the distribution of taxable income across the ten provinces by industry for the 1961-87 and 1993-96 periods, and the share of small business deduction by industry for the 1974-94 period. The income shares for other years are set to the shares of the nearest year.

To encourage investment, a credit was granted for new production facilities as of 1976. Starting at 5 percent for all industries, the rate was raised to 7 percent in 1979 and regional variations with higher rates were introduced. In 1989, investment tax credits were discontinued except for the Atlantic provinces (Williamson and Lahmer, 1996).

Table E.1

Combined Federal and Provincial Corporate Tax Rate, 1996

Province	General Rate	Small Business Rate	Small Business M&P Rate	M&P Rate
Newfoundland	43.12	18.12	18.12	27.12
Prince Edward Island	44.12	20.62	20.62	37.12
Nova Scotia	45.12	18.12	18.12	38.12
New Brunswick	46.12	20.12	20.12	39.12
Quebec	45.37	18.87	18.87	31.02
Ontario	44.62	22.62	22.62	35.62
Manitoba	46.12	23.12	23.12	39.12
Saskatchewan	46.12	21.12	21.12	39.12
Alberta	44.62	19.12	19.12	36.62
British Columbia	45.62	22.12	22.12	38.62

Source: Williamson and Lahmer, 1996.

For a declining-balance depreciation method, the present value of depreciation allowances in the user-cost equation is (for details, see Dougherty, 1992):

(12) $$z = t\alpha / \left[i\left(1-t\right)+\alpha\right],$$

and the present value of depreciation allowances for a straight-line depreciation is:

(13) $$z = \frac{\mu\alpha\left[1+i(1-t)\right]}{i(1-t)}\left(1-\frac{1}{\left[1+i(1-t)\right]^{T}}\right),$$

where α is the tax-allowable depreciation rate, *i* is the nominal interest rate on the Government of Canada three-month treasury bills (Cansim matrix 2560, B140007), and *T* is the lifetime of the asset.

To calculate the present value of capital cost allowances, we take geometric depreciation rates of 5 percent for structures and 20 percent for equipment over the entire period with the following exceptions. First, the straight-line method was used for structures and equipment for the 1961-66 period. During that period, equipment was written off within 2 years (T = 2, α = 0.5) and structures within 5 years (T = 5, α = 0.2). Second, before 1981, firms were able to claim a full year's capital cost allowance on an asset in the year it was acquired. After 1981, only one-half of the normal capital cost allowance was written off in the year an asset was acquired, the remainder being depreciated over subsequent years. Third, after 1972, accelerated capital cost allowances were granted for machinery and equipment used in manufacturing and processing (M&P) activities. Equipment for M&P firms was written off within two years during the 1972-81 period and within three years after 1981.

The economic rate of depreciation is set to be the rate implicit in capital stock and investment data. It is equal to gross investment in a year minus net investment in the year, divided by capital stock at the beginning of the year:

(14) $$K(t+1) = K(t)\left[1-\delta(t)\right]+I(t)\text{, or } \delta(t) = \frac{I(t)-\left[K(t+1)-K(t)\right]}{K(t)}.$$

Business property taxes in the user-cost equation are mainly levied on land and structures, with machinery being free of such taxes. To estimate the property tax rates, we first obtain the property tax base as the nominal values of land and structures at the P-level of industry aggregation. We then divide the tax base into taxes on production from the input-output tables to get average property tax rates.

E.4 Empirical Results

THIS SECTION PRESENTS THE INDICES OF CAPITAL INPUTS in each industrial sector and the aggregate business sector for the 1961-98 period. The indices of capital inputs are aggregated from five asset types: machinery labour equipment (M&E), building structures, engineering structures, land, and inventories.

Figure E.1 shows the share of fixed reproducible investment by asset type.[5] The share of M&E in real fixed reproducible investment has grown steadily over the period 1961-98. The investment share of equipment almost doubled over that period, from 34 percent in 1961 to 60 percent in 1998. The increase in the share of equipment occurred at the expense of structures. The share of building structures fell from about a quarter of total investment in 1961 to 13 percent in 1998. Similarly, the share of engineering structures fell from about 40 percent to little over a quarter of total investment over that period.

These investment patterns directly determine the composition of the capital stock. The rising share of M&E in total investment leads to an increase in its capital stock share, as shown in Figure E.2. The share of equipment in total capital has experienced the fastest growth. It increased from 13 percent in 1961 to 22 percent in 1998. The structures' share of total capital also increased from 1961 to 1998, while the share of inventories remained virtually unchanged. The land share declined sharply over the period – from 37 percent of total capital stock in 1961 to a little over 10 percent of capital stock in 1998. Land was the largest component of total capital stock in 1961. However, its share had fallen below the capital shares of M&E, non-residential building structures, and engineering structures in 1998. This shift in the composition of capital stock towards short-lived equipment is a major source of the increase in capital quality.

All else being equal, short-lived equipment has a higher depreciation rate and thus a relatively high user-cost. This is evident from Figure E.3, which shows the highest user cost of equipment for almost all years during the 1961-95 period. Land input has the lowest user cost for most of the period. Compared with engineering structures, the user cost of equipment and building structures declined over the 1961-95 period. The decline in the relative user cost of equipment is mainly attributed to the decline in the price of equipment relative to engineering structures. Figure E.3 also shows that the user cost of capital exhibited large fluctuations over the business cycle.

Figure E.4 shows the indices of capital inputs, capital stock and capital quality in the business sector.[6] The indices of capital services, capital stock, and capital quality all increased over the 1961-98 period. Capital services growth was faster than capital stock growth, partly reflecting the substitution of relatively short-lived and high user-cost equipment for long-lived and low user-cost structures. This shift in the capital stock composition directly lead to an increase in capital quality over the period.

Table E.2 provides a decomposition of capital input growth in the business sector for the period 1961-98 and three sub-periods: 1961-73, 1973-88, and 1988-98. Capital inputs increased at an annual rate of 3.11 percent in the business sector during the 1961-98 period. Of the 3.11 percent growth in capital inputs, capital accumulation contributed 2.63 percentage points while the compositional or quality change contributed 0.48 percentage points.

The slow growth during the 1990s was the most noticeable trend of capital inputs in the business sector. The index of capital inputs increased at 2.21 percent per year over the 1988-98 period, compared to 3.65 percent over the 1961-73 period and 3.28 percent over the 1973-88 period.

We have also constructed indices of capital inputs, capital stock, and capital quality for each industrial sector over the 1961-98 period (see Chapter 3). Our estimates show that capital input growth exceeded capital stock growth and capital quality increased in a majority of industries over that period.

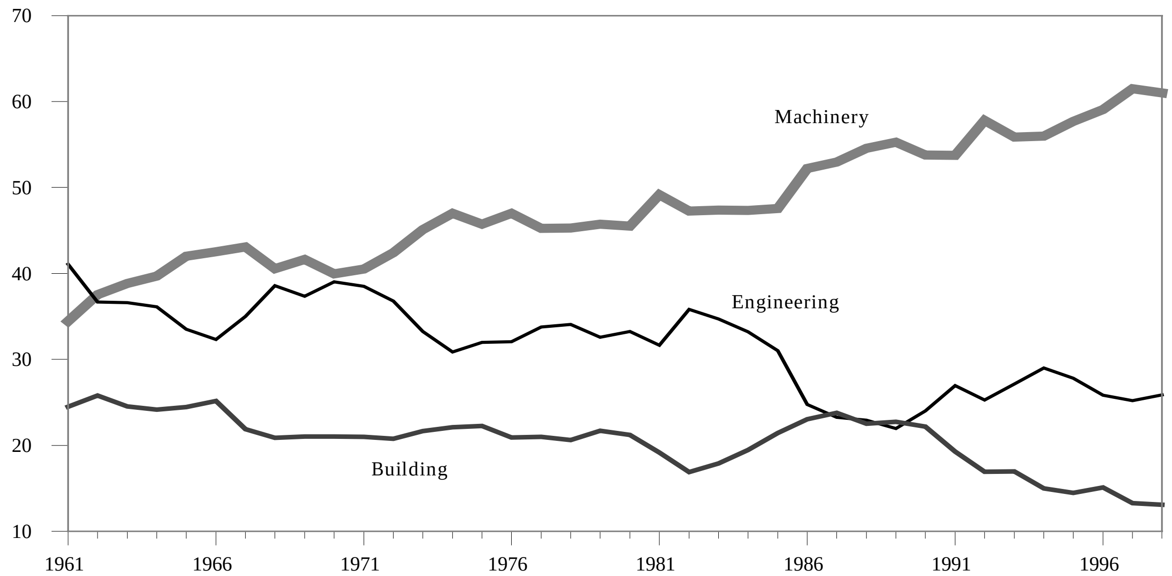
Table E.2

Decomposition of Capital Input Growth in the Business Sector (%)

	1961-98	1961-73	1973-88	1988-98
Growth of Capital Inputs	3.11	3.65	3.28	2.21
Growth of Capital Stock	2.63	2.98	2.85	1.88
Growth of Capital Quality	0.48	0.67	0.43	0.32

Figure E.1

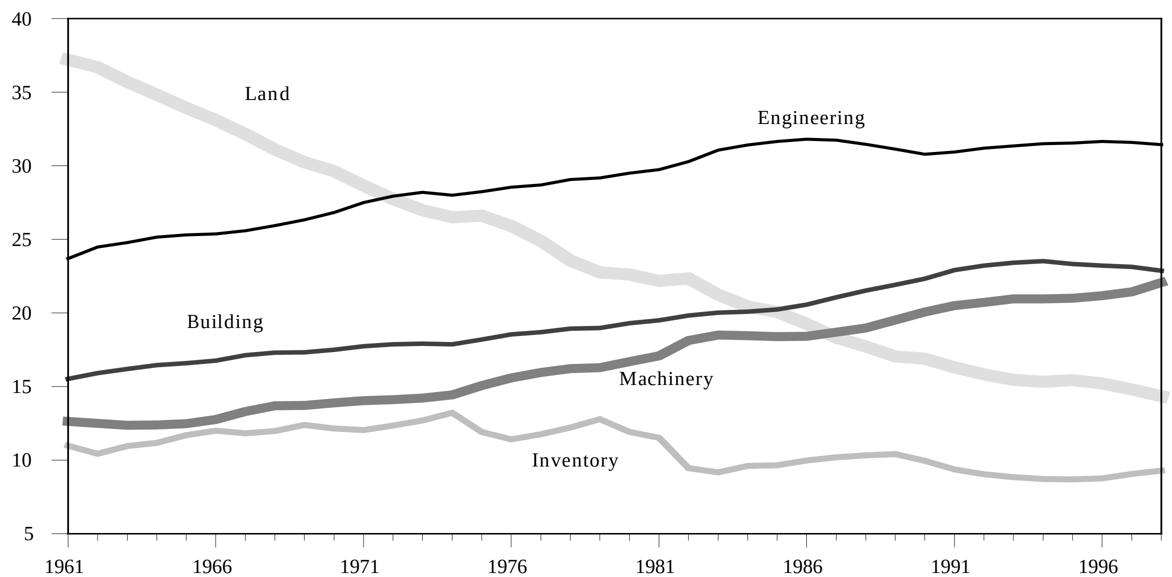
Share of Investment by Asset Type (%)*



* Investment in constant 1992 dollars.

Figure E.2

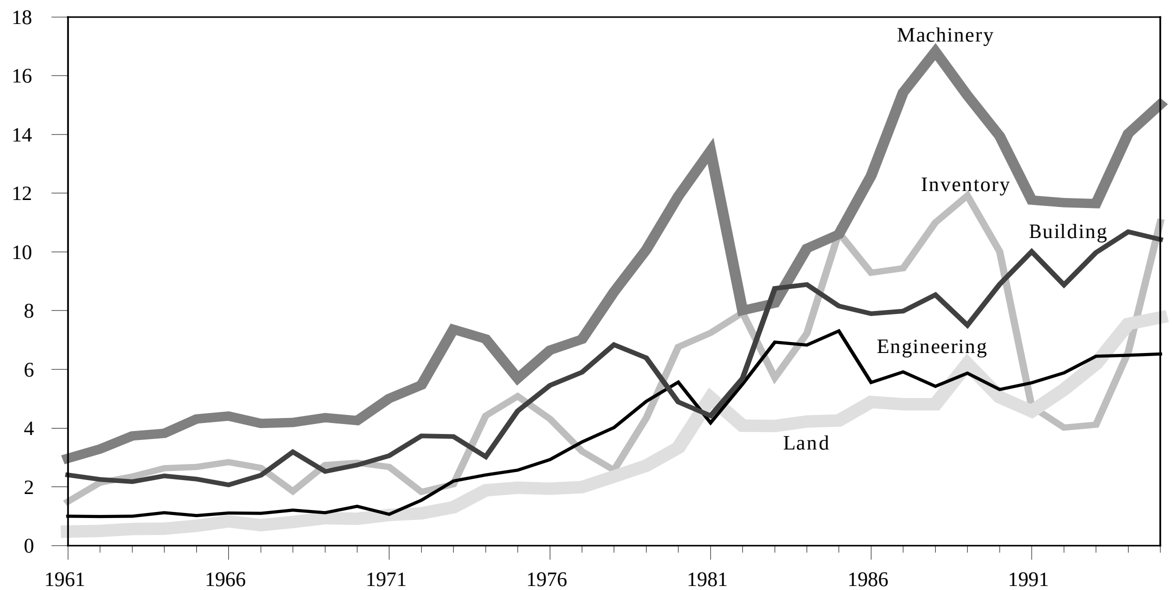
Share of Capital Stock by Asset Type (%)*



* Capital stock in constant 1992 dollars.

Figure E.3

User Cost by Asset Type (%)*



* The user cost is set to 1.0 in 1961 for engineering structures.

Figure E.4

Indices of Capital Inputs, Capital Stock and Capital Quality

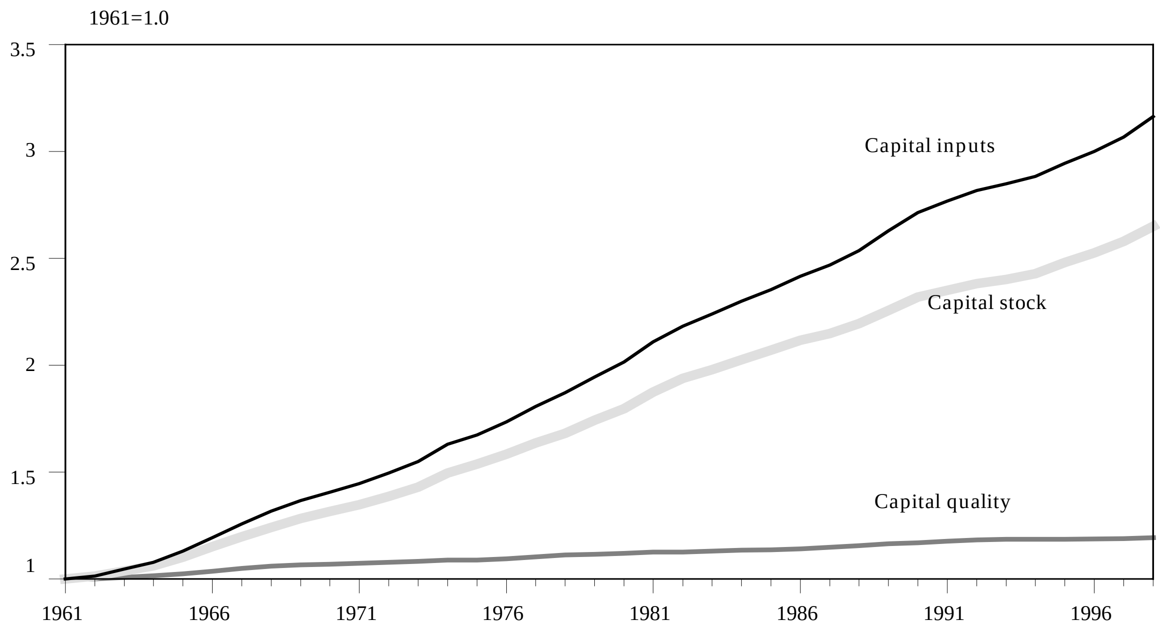


Table E.3
Decomposition of Capital Input Growth in the Business Sector,
Based on Capital Stock Data from Statistics Canada's KLEMS Database (%)

	1961-98	1961-73	1973-88	1988-98
Growth of Capital Inputs	2.71	3.47	2.90	1.52
Growth of Capital Stock	1.85	2.40	1.98	1.01
Growth of Capital Quality	0.86	1.07	0.92	0.52

The capital input measures presented above are constructed from capital stocks estimated using the BEA methodology. M&E capital stock is estimated using a 1.65 declining-balance depreciation rate and structure capital stock is estimated using a 0.91 declining-balance rate. For a comparison, we have also constructed the indices of capital inputs using capital stock data from Statistics Canada's KLEMS database. These capital stocks are estimated using a modified double-declining-balance method (see Appendix C for details). The results are presented in Table E.3. A comparison of Tables E.2 and E.3 shows that capital stock in the KLEMS database grew much more slowly than the capital stock estimated with the U.S. methodology. The growth of capital inputs aggregated from the KLEMS capital stock data was also slower.

E.5 Conclusion

THIS APPENDIX PRESENTS THE METHODOLOGY for estimating the indices of capital inputs and capital quality for each industrial sector and the aggregate business sector over the 1961-98 period. We find that capital inputs, capital stock, and capital quality all increased in the business sector during that period. A decomposition of capital input growth shows that both capital accumulation and the change in composition contributed to the growth of capital inputs in the business sector. The increase in capital inputs and capital quality was pervasive across industries during the 1961-98 period.

A noticeable trend in capital inputs was the slow growth during the 1990s. The annual growth rate of capital inputs in the 1990s was slower than during the preceding three decades by over a full percentage point. This occurred despite the dramatic increase in investments in information and communications technology in the 1990s.

Notes

1 But it was not until 1993 that the BLS developed analogous measures of labour input that incorporate characteristics of workers such as age, sex, and education.

2 A distinction is sometime made between the user cost of capital and the rental price of capital (Jorgenson and Yun, 1991). c_k in Equation (3) is usually called the rental price of capital services and it measures the unit cost of using a capital good for a specified period of time. The cost of capital is defined as the rental price of capital services divided by the price of acquisition of a capital good. The cost of capital therefore transforms the acquisition price of capital good into rental price. In this paper, we will use the rental price and the user cost of capital interchangeably. They both measure the unit cost of using a capital good for a specified period of time.

3 There were no estimates of sectoral capital compensation after 1995 at the time of this study. The cost of capital over the 1996-98 period is assumed to be the same as in 1995 for the purpose of constructing the capital inputs.

4 The cost of capital in this study does not include every provision in the corporate tax system that could have an impact on the cost of using capital services in one specified period. For example, the estimates of the user cost do not take into account the special treatment of banks and insurance companies, the provisions for intangible exploration and drilling costs, and depletion allowances in resource extraction industries. To the extent these special tax treatments have the same proportional effect on the cost of using all types of assets within a given industry, they will not affect the indices of capital services and capital quality for that industry.

5 Real land stock is assumed to be constant in the aggregate business sector and there is no investment in land. Inventory investment is very sensitive to cyclical fluctuations. Therefore, we only present the composition of fixed reproducible investment.

6 For the purpose of constructing the capital inputs, the user cost of an asset over the 1996-98 period is assumed to be the same as in 1995.

Appendix F: The Changing Composition of the Canadian Workforce, 1961-95

Wulong Gu and Jean-Pierre Maynard

F.1 Introduction

THIS APPENDIX PRESENTS THE METHODOLOGY for estimating labour inputs in the aggregate business sector and each industrial sector over the 1961-95 period. Unlike the simple measure of hours worked, the labour input measure in this study takes into account the compositional or quality change of the workforce (relatively more educated and older workers). The estimates incorporate individual data from the Census of Population. They also use data from the annual Survey of Consumer Finance (SCF) and the monthly Labour Force Survey (LFS).

Hours of work (or employment) would be a valid measure of labour inputs for productivity analysis if workers were homogeneous. However, they differ by sex, age, education, and class of employment (paid vs. self-employed) and their composition changes over time. But the number of hours worked is relatively easy to estimate and is used extensively in productivity analysis. Statistics Canada uses hours worked in productivity estimates at the detailed industry level (Statistics Canada, 1994b). As another example, until the publication of the Bureau of Labor Statistics (BLS, 1993) study on labour composition in the United States, all official productivity estimates made by that agency used hours of work as a measure of labour inputs.

Jorgenson, Gollop and Fraumeni (1987) constructed labour input data for 51 industries and the aggregate civilian U.S. economy over the 1947-79 period. Their measure takes into account the compositional changes of workers by age, sex, education, class of employment, and occupation. Ho and Jorgenson (1999) extended the analysis and estimated labour inputs in the U.S. civilian economy over 1948-95 period. The BLS (1993) estimated labour inputs in the U.S. private business sector, incorporating demographic changes in the workforce such as the rising educational attainment, the baby boom and baby bust, and the rising female labour force participation.

The aggregate labour input was also constructed for Canada by Dougherty (1992), and Jorgenson and Yip (1999). The indices of labour inputs in Dougherty

(1992) were aggregated from data on workers by educational attainment and employment class. Jorgenson and Yip (1999) extended the analysis and constructed labour inputs for the Canadian economy over the 1960-95 period.

Section F.2 below presents the methodology for constructing labour input indices. The data sources used in constructing labour inputs are described in Section F.3, along with the methodology for generating annual time series of hours worked and labour compensation, cross-classified by sex, age, education, class, and industry of employment. Section F.4 presents the estimates of labour inputs and examines the contribution to the composition of labour of demographic changes such as rising educational attainment, the baby boom and baby bust, and rising female labour force participation. Section F.5 concludes.

F.2 Methodology for Constructing Indices of Labour Inputs [1]

THE INDICES OF LABOUR INPUTS are constructed from data on hours of work and labour compensation per hour by worker type. To construct an index of labour inputs, we assume that the aggregate labour input (L) can be expressed as a translog function of its individual components. The growth rate of the aggregate labour input is therefore a weighted average of the growth rates of its components $\{L_l\}$:

(1) $$\Delta \ln L = \sum_l \bar{v}_l \Delta \ln L_l ,$$

where Δ denotes a first difference, or change between two consecutive periods, for example:

(2) $$\Delta \ln L = \ln L(t) - \ln L(t-1) .$$

The weights are given by the average share of the components in the value of labour compensation:

(3) $$\bar{v}_l = \frac{1}{2}\left[v_l(t) + v_l(t-1)\right], \quad v_l = \frac{p_l^L L_l}{\sum_l p_l^L L_l} ,$$

where $\{p_l^L\}$ is the hourly compensation of all types of workers. At market equilibrium, the hourly compensation of a worker is equal to its marginal product. Therefore, aggregating labour inputs by means of compensation rates effectively accounts for the differences in the productive contribution of various types of workers.

For each type of workers, we assume that labour input $\{L_l\}$ is proportional to hours worked $\{H_l\}$:

(4) $$L_l(t) = Q_l H_l(t),$$

where the constants of proportionality $\{Q_l\}$ transform hours worked into flows of labour services.

Using Equation (4), we can rewrite Equation (1) and express the growth rate of labour inputs in terms of the components of hours worked $\{H_l\}$:

(5) $$\Delta \ln L = \sum_l \bar{v}_l \Delta \ln L_l = \sum_l \bar{v}_l \Delta \ln H_l \cdot$$

The compositional or quality change of labour inputs is defined as the difference between the growth of labour inputs and the unweighted sum of hours worked:

(6) $$\Delta \ln Q^L = \Delta \ln L - \Delta \ln H,$$

where $H = \sum_l H_l$ is the unweighted sum of hours worked. This quality index measures the contribution to labour inputs from substitution among its components. In terms of its components, the growth rate of labour quality can be written as:

(7) $$\Delta \ln Q^L = \sum_l \bar{v}_l \Delta H_l - \Delta \ln H \cdot$$

An examination of Equation (7) shows that labour quality remains unchanged if all components of hours worked grow at the same rate. Labour quality increases if the share of workers with relatively higher earnings (more educated and older workers) increases. Labour quality falls if the share of those workers declines.

To identify the contribution to labour inputs from worker characteristics such as gender, age, education, and employment class separately, we construct the partial indices of labour inputs corresponding to these worker characteristics. For this purpose, we denote H_{saec} the components of hours worked, classified by sex *s*, age *a*, education *e*, and employment class *c*. We also consider shares of these components in the value of labour compensation v_{saec}. A partial index of labour inputs corresponding to, for example, sex, is defined as follows:

(8)
$$\Delta \ln L^{sex} = \sum_{s} \bar{v}_s \Delta \ln H_s ,$$
$$= \sum_{s} \bar{v}_s \Delta \ln\left(\sum_{a} \sum_{e} \sum_{c} H_{saec} \right),$$

where:

$$\bar{v}_s = \frac{1}{2}\left[v_s(t) + v_s(t-1) \right],$$
$$v_s = \sum_{a} \sum_{e} \sum_{c} v_{saec} .$$

The partial index of labour inputs corresponding to sex captures substitution between the two sexes alone. Similarly, the partial labour input indices for age, education or employment class measure substitution between age groups, educational attainment levels, or employment classes.

The growth rate of the partial labour quality index is the difference between the growth rates of the partial labour input index and hours worked. These partial quality indices measure the contribution to labour quality from gender, age, education, and employment class separately.

F.3 Data Sources and Data Construction

THE TWO DATA COMPONENTS for the construction of labour inputs are the matrices of annual hours worked and annual worker earnings. To ensure the comparability of labour input measures between Canada and the United States, we employed a classification scheme similar to the one used for the United States by Ho and Jorgenson (1999). We have 2 sexes, 7 age groups, 4 educational levels, and 3 classes of employment, as shown in Table F.1. Thus, the classification involves a total of 2 x 7 x 4 x 3 = 168 types of workers and 123 industries in the business sector.

Table F.1

Classification of the Canadian Workforce

Worker Characteristics	Number of Categories	Description
Sex	2	Male; Female
Employment Class	3	Paid Employees; Self-employed; Unpaid Family Workers
Age	7	15-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	0-8 Years of Grade School; Some or Completed High School; Some or Completed Post-secondary; University or Above

The task is to generate annual estimates of hours worked and worker earnings for the 20,664 cells of the cross-classification between 168 worker types and 123 industrial sectors over the 1961-95 period. The main features of our methodology are as follows. The methodology begins with the Census of Population for 1961, 1971, 1981, 1986, 1991, and 1996. We use the Census micro-data files to construct the benchmark matrices of annual hours worked and earnings for the Census reference years (the year prior to the Census).[2] We then employ data from the Labour Force Survey (LFS) and the Survey of Consumer Finance to estimate the hours and earnings matrices for years between the Census benchmarks. For this purpose, we employ the method of iterative proportional fitting (for details, see Jorgenson, Gollop and Fraumeni, 1987). A weighted average of the two neighbouring benchmark matrices is used to initialize the method of proportional fitting. The data on annual hours worked and earnings from the LFS and SCF are used to control the marginal distribution of hours worked and worker earnings by sex, age, education, and employment class. All matrices of hours worked and worker earnings are then adjusted to annual hours worked and earnings by industry and class of employment in Statistics Canada's productivity account.

F.3.1 Matrices of Annual Hours Worked

F.3.1.1 Benchmark Matrices from the Census

The Census provides benchmark matrices of annual hours worked for the Census reference years 1960, 1970, 1980, 1985, 1990, and 1995. For each member of the household surveyed, the Census micro-data files provide data on sex, age, education, industry and class of employment, and hours worked during the week prior to the Census (reference week). The files also provide data on weeks worked and income from paid employment and self-employment during the year prior to the Census (reference year). Using these Census micro-data files, we have constructed matrices of annual hours worked for the 20,664 cells of the cross-classification between 168 worker types and 123 industrial sectors. Annual hours worked for an employed person during a reference year is calculated as the number of weeks worked in the reference year multiplied by the number of hours worked in the reference week.[3]

As of the 1981 Census, self-employed workers were subdivided into those with and those without an incorporated business. We include in the paid-employment category both paid workers and self-employed workers with an incorporated business. The self-employment category only includes those who have not incorporated their business.

In the 1971 Census, a person was simply asked whether he or she was self-employed or a paid employee. No distinction was made between the self-employed who incorporated their business and those who did not. However, a distinction was made between self-employment income from an unincorporated business and the income from an incorporated business. The income received from an unincorporated business was reported as self-employment income, while the income received from an incorporated business was reported as wages and salaries. We have used that distinction to reclassify a worker between paid employment and self-employment. A worker was classified as a paid worker if his wage and salary income exceeded his self-employment income. On the other hand, a worker was classified as self-employed if his self-employment income was greater than his wage and salary income.

The class of employment in the Census refers to whether the worker is a paid, self-employed, or unpaid family worker in the reference week. However, a worker's employment status in the reference week does not necessarily reflect his status in the reference year. We have thus reclassified a worker between paid employment and self-employment by comparing his paid employment and self-employment income in the reference year.

Micro-data files are not available for the 1961 Census. But existing publications on the 1961 Census provide us with considerable detailed information on one-way, two-way, and sometimes three-way tabulations of employment including: (1) number of paid workers by gender and industry; (2) number of workers by sex, age, education, and employment status; (3) number of workers by sex, age, and employment status; (4) number of workers by sex, age and industry; and (5) number of workers with university education and number of workers with post-secondary education. We have used these cross-tabulations to generate the full employment matrix — six-way tabulations of employment by sex, age, education, and class and industry of employment. The value of each cell in the 1961 employment matrix is first initialized at its value in 1970. All available cross-classifications for 1961 are then used in the method of iterative proportional fitting to control the distribution of employment among cells. To obtain the hours worked matrix for 1961, we multiply the estimated employment in 1961 by the average annual hours of work in 1970 for each type of worker.

F.3.1.2 Estimating Hours Worked Matrices in the Inter-censual Years from the LFS

For the 1976-95 period, we used micro-data files from the LFS to obtain one-way tabulations of annual hours worked by sex, age, education and employment class. These tabulations are then used as control marginals in the method of iterative fitting to estimate the hours worked matrices between the censuses for that period. For the 1961-75 period, we estimate the hours worked matrix as a weighted average of the two neighbouring hours worked matrices and then adjust the resulting matrix to hours worked by industry and class of employment in Statistics Canada's productivity account.

The monthly LFS provides data for each worker type on usual hours worked, sex, age, education, and employment class during the reference week (usually the week containing the 15th day of the month). For each worker type, annual hours worked is calculated as the average weekly hours worked in a year times the number of working weeks in a year (which is set at 52 weeks). For multiple jobholders, hours worked on the second job are aggregated to the employment class of the second job.

In January 1990, the LFS revised the questions used to measure the educational attainment of respondents. From 1976 to 1989, education reflected the number of years of primary and secondary education completed. Post-secondary education was limited to education that normally requires high-school graduation. Since January 1990, education reflects the highest grade completed. Post-secondary education now includes any education that could be counted towards a degree, certificate or diploma from an educational institution.

The high-school graduation requirement is dropped in this new definition of post-secondary education. These changes in the questions on educational attainment caused a reallocation of respondents from secondary to post-secondary education in 1990, which is evident in Figure F.3.

F.3.2 Matrices of Annual Worker Earnings

F.3.2.1 Benchmark Matrices from the Census

To construct time series on annual worker earnings by worker type, we again proceed in two steps. First, we construct benchmark matrices of worker earnings for the Census reference years. We then employ earnings data from the SCF to estimate matrices of annual worker earnings between censuses.

The Census provides data on wage and salary income of paid workers.[4] Supplementary income such as employers' contribution to pension plans and unemployment insurance is not included in the wage and salary income. But it should be included in labour compensation since it reflects the cost of labour inputs from the viewpoint of an employer. To address the issue, we have adjusted the earnings matrices from the Census to total sectoral compensation of paid workers in Statistics Canada's productivity account. Essentially, we distribute the sectoral compensation among types of paid workers in proportion to their wage and salary income.

A second issue relates to the estimation of earnings of self-employed workers. Self-employment income as reported in the Census includes both labour and property income. But self-employment earnings should only include labour income. To estimate earnings from self-employment, we made two adjustments to self-employment income as reported in the Census. First, self-employment income is set to zero for those workers who reported negative self-employment income. A negative self-employment income is almost surely attributed to the use of capital. Second, Statistics Canada imputed earnings of self-employed workers in an industry on the basis that the hourly earnings is the same between paid and self-employed workers. We have used these sectoral earnings from self-employment to adjust the earnings matrices.

A third issue is the treatment of unpaid family workers. Unpaid family workers are persons who work without pay on a farm or in a business or professional practice owned and operated by another family member. In this study, we set earnings of unpaid family workers to zero.[5] To the extent that unpaid family workers contribute to industry output, our measure of labour inputs is underestimated. But any bias is likely to be negligible since the share of unpaid family workers in total employment is very small.

Due to the absence of micro-data files in the 1961 Census, we used the method of iterative fitting to estimate the earnings matrix for 1961. We first multiply the hourly earnings of a worker in 1970 by his annual hours of work in 1961. The resulting matrix is used to initialize our method of iterative fitting. The control marginals for the method of iterative fitting include annual income by industry for male and female paid workers and annual income by sex, age and education.

F.3.2.2 Estimating Earnings Matrices in Inter-censual Years from the SCF

For the 1976-95 period, we used earnings data from the SCF to estimate the earnings matrices between censuses. First, we estimated from the SCF micro-data files hourly earnings by gender, age, education, and employment status. The earnings per hour was then multiplied by hours worked from the LFS to obtain one-way tabulation of annual earnings by gender, age, education, and employment status. These one-way tabulations are used as control marginals in our method of iterative fitting to estimate the earnings matrices between the Census benchmarks.[6] For the 1961-75 period, we calculated the earnings matrix as a weighted average of the two neighbouring earnings matrices and then adjusted the resulting matrix to total sectoral compensation.

F.4 Empirical Results

IN THIS SECTION, WE PRESENT THE INDICES OF LABOUR INPUTS over the 1961-95 period. These indices are aggregated from data on 168 types of workers by gender, age, education, and employment class.

F.4.1 Trends in Hours Worked

The change in the composition of hours worked contributes either positively or negatively to labour inputs. The compositional change contributes positively to labour inputs if there is an increase in the share of workers with relatively higher earnings, such as relatively more educated workers, workers of prime working age, paid relative to self-employed workers, or male relative to female workers.

Figure F.1 shows that the share of hours worked represented by men declined steadily over the 1961-95 period in the business sector. The share of women almost doubled during that period — from about 20 percent in 1961 to about 40 percent in 1995 .

Figure F.2 presents the share of total hours worked by age group from 1961 to 1995. For the 1961-80 period, the share of hours worked represented by young workers aged 15-24 showed a steady increase as the baby boomers entered the workforce. The share of the prime working age group (35-54) declined from 45 to 35 percent during that period. However, the trend reversed in the early 1980s as the baby boomers reached their prime working age. During the 1980-95 period, the share of the 15-24 age group declined sharply, from 24 to 13 percent. The share of the prime working age group increased from 37 to 50 percent during the same period. These shifts in the age composition of hours worked are the major determinant of labour quality change in the business sector.

Figure F.3 shows the share of hours worked by education level in the aggregate business sector. The share of workers with post-secondary education or above shows a more than fivefold increase, from 9 percent in 1961 to 57 percent in 1995. The rising educational attainment is the ongoing source of the increase in the quality of the Canadian workforce. The change in the definition of education introduced in the LFS in 1990 resulted in a noticeable re-allocation of hours worked from secondary to post-secondary education.

The share of hours worked by paid workers is presented in Figure F.4. The share of paid workers increased steadily from 1961 to the late 80s. The increase was particularly strong before the mid-70s. After the late 80s, the share of paid workers declined and the share of self-employed workers increased.

Figure F.1
Share of Hours Worked by Male Workers in the Business Sector (%)

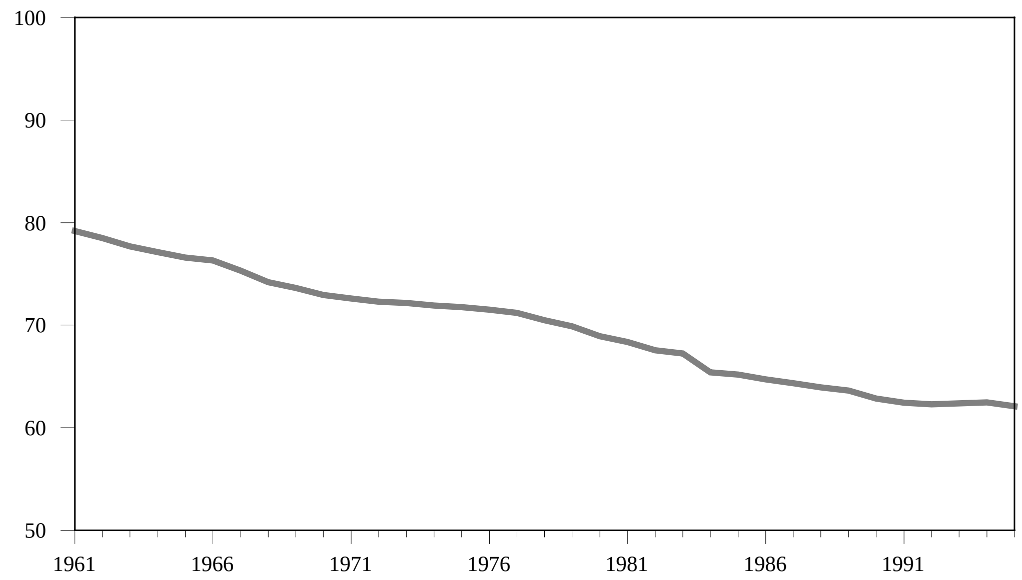


Figure F.2
Share of Hours Worked by Age Group in the Business Sector (%)

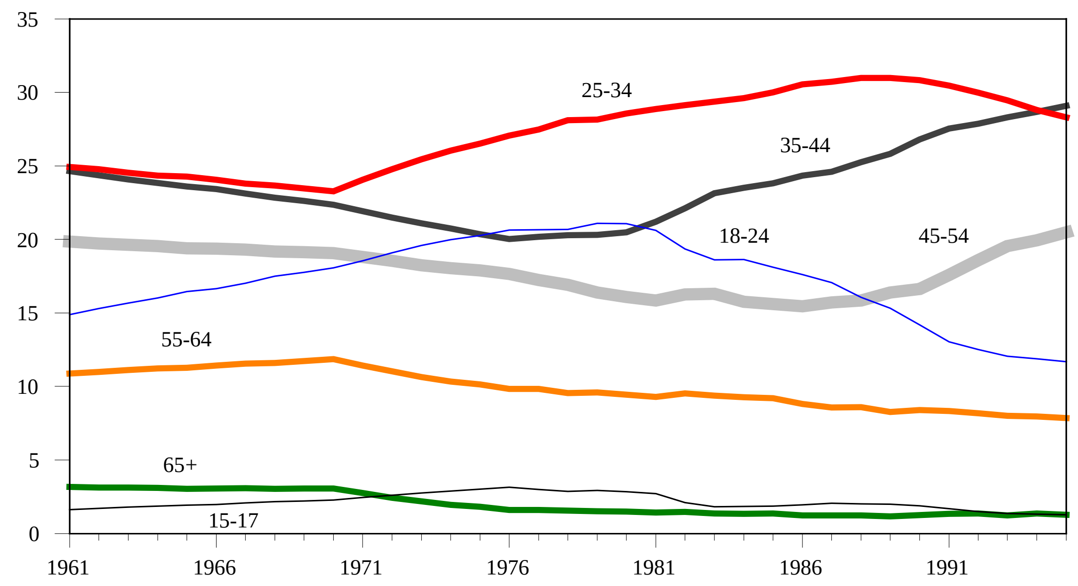


Figure F.3
Share of Hours Worked by Educational Attainment in the Business Sector (%)

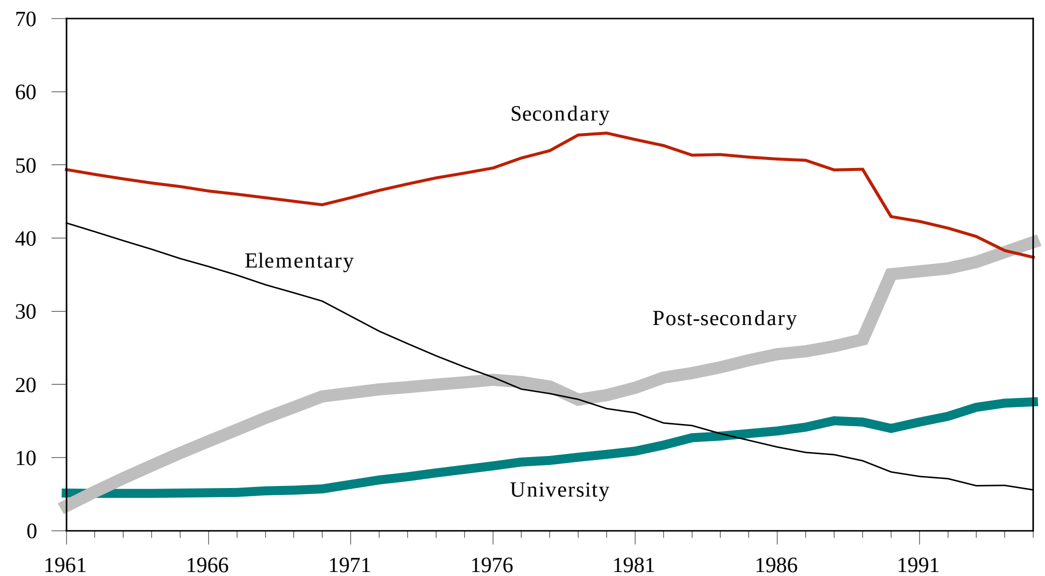
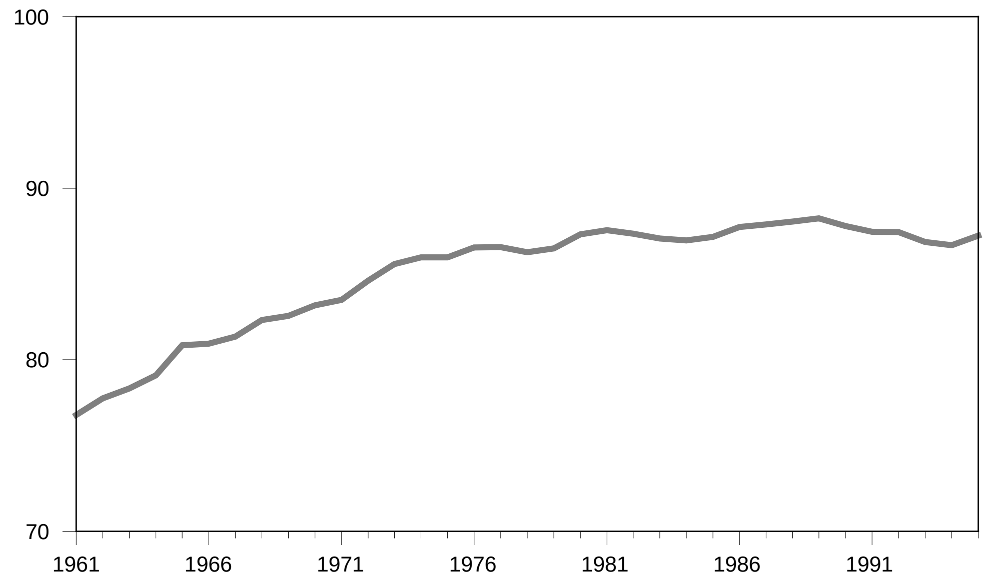


Figure F.4
Share of Hours Worked by Paid Workers in the Business Sector (%)



F.4.2 Indices of Labour Inputs and Labour Quality

Table F.2 presents the growth rates of labour inputs, labour quality and hours worked in the business sector for the 1961-95 period and three sub-periods: 1961-73, 1973-85 and 1985-95 (also shown in Figure F.5). For the 1961-95 period, the annual growth rate of labour quality was 0.61 percent. It accounted for a quarter of the growth in labour inputs over that period. The annual growth in labour quality was highest over the 1961-73 period (0.86 percent), accounting for about 30 percent of the growth in labour inputs. The growth of labour quality slowed down during the 1973-85 period (0.37 percent), and then recovered in the 1985-95 period (0.59 percent).

Table F.2

Average Annual Growth Rate of Labour Inputs and Labour Quality in the Business Sector (%)

	1961-95	1961-73	1973-85	1985-95
Growth of Labour Inputs	2.47	3.08	2.15	2.11
Growth of Hours Worked	1.86	2.22	1.78	1.51
Growth of Labour Quality	0.61	0.86	0.37	0.59
First-order Quality Indices				
Sex	-0.15	-0.22	-0.15	-0.07
Age	0.04	-0.15	0.04	0.25
Education	0.53	0.86	0.33	0.36
Class of Employment	0.15	0.27	0.13	0.04

Table F.2 also presents the growth in the first-order contributions to labour quality by gender, age, education and employment class (also shown in Figure F.6). As a result of the rising educational attainment of the workforce, the education contribution had an average annual growth of 0.53 percent from 1961 to 1995. The contribution of employment class was positive for most of the period as the share of paid workers increased. But that contribution declined sharply after the mid-1980s as the growth of self-employed increased. The increasing share of female workers contributed to a decline of 0.15 percent per year in labour input over the period.[7] The contribution of age was positive and amounted to 0.04 percent for the 1961-95 period. However, it was negative for the 1961-73 period as young workers from the postwar baby boom entered the workforce. After the mid-1980s, as the baby boomers entered their prime working age, the age contribution increased.

Figure F.5
Indices of Labour Inputs, Labour Quality and Hours Worked in the Business Sector

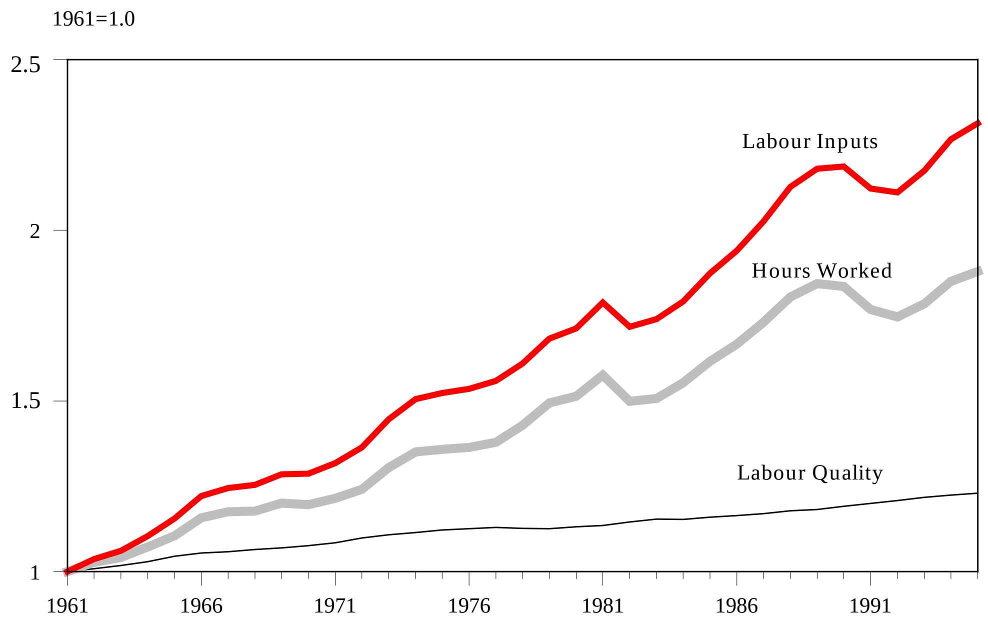
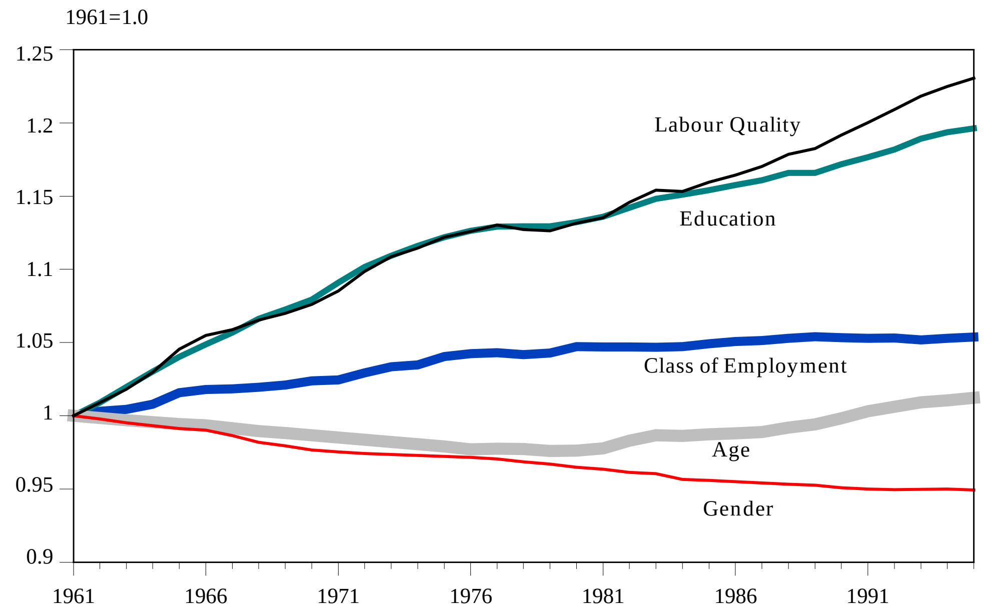


Figure F.6
First-order Indices of Labour Quality in the Business Sector



Nearly all of the trend in labour quality improvement over the 1961-95 period can be attributed to the increase in the level of educational attainment. However, this is a consequence of offsetting trends in gender, age, and employment class. The slowdown in the growth of labour quality over the 1973-85 period was primarily due to the entry of young and less-educated workers in the workforce.

We have also constructed labour input, hours worked, and labour quality measures for each of the 123 industrial sectors over the 1961-95 period. The results show that labour quality increased in almost all industries over this period.

F.5 Conclusion

THIS APPENDIX PRESENTS THE METHODOLOGY for constructing the composition-adjusted labour input measures for Canada. Over the 1961-95 period, the compositional or quality change contributed 0.61 percentage points or a quarter of the labour input growth in the business sector. The growth of labour quality was highest in the 1961-73 period (0.86 percent per year), accounting for about 30 percent of the growth in labour inputs. The 1973-85 period witnessed a slow growth in labour quality, primarily a result of the entry of baby boomers in the workforce. After the mid-1980s, the growth of labour quality increased as baby boomers reached their prime working age.

The share of more educated workers showed a steady increase from 1961 to 1995. This shift towards relatively more-educated workers contributed to the increase in the labour inputs in the business sector at a rate of 0.53 percent per year from 1961 to 1995. The rise in educational attainment explains almost all the trend in labour quality over that period. However, as indicated earlier, this is a consequence of offsetting trends in contributions from gender, age, and employment class.

Notes

1 This section follows Ho and Jorgenson (1999).

2 The micro-data files for the 1961 Census are not available. However, very detailed information on employment and earnings cross-classified by one, two, and three characteristics of labour inputs are published by Statistics Canada. We thus employed the method of iterative proportional fitting to estimate the matrices of hours worked and compensation for 1961.

3 The number of hours worked is set at 75 for a worker who reported more than 75 hours of work during the reference week.

4 Consistent with our definition of paid employees that includes self-employed workers with an incorporated business, income received from businesses which have corporate status is reported as wages and salaries income.

5 Ho and Jorgenson (1999) assumed that unpaid family workers and self-employed workers are in the same employment class.

6 The annual Survey of Consumer Finance is not used for estimating hourly earnings for the 1971-75 period since the corresponding micro-data files from the Labour Force Survey, used to estimate hours by worker characteristics, are not available.

7 This is partly due to the fact that women are traditionally concentrated in low paying industries and low paying occupations.

Appendix G:
Net Capital Stock Estimates and Depreciation Profiles for Canada: A Comparison Between Existing Series and a Test Series Using the BEA Methodology for the United States[1]

Peter Koumanakos, Richard Landry, Kuen Huang and Susanna Wood

G.1 Introduction[2]

CAPITAL STOCKS ARE REPRODUCIBLE TANGIBLE ASSETS used as factors of production in combination with other factor inputs such as labour, energy and other natural resources or materials. The stock of capital consists of building construction (such as plants and offices), engineering construction (such as roads and dams), and machinery and equipment used in the production process. These are distinguished from non-reproducible assets such as land, mineral deposits and natural resources, which are not produced but are directly incorporated in the production of other commodities.

Although capital stocks by industry can be measured in a variety of ways such as surveys of physical stock or book values, the method traditionally used by Statistics Canada is the perpetual inventory method. This method, which is a flexible way to develop time series of capital stocks, accumulates investment expenditures by industry to obtain estimates of capital stock in any particular year. It requires information on the value of investment, price indices for capital goods, service lives, and methods of depreciation.

The essence of the perpetual inventory method is to add each year's gross investment (gross fixed capital formation) to the capital stock of the previous year. If the value of assets which cease to exist each year is subtracted from this accumulated investment, then a gross measure of the capital stock is obtained. If yearly deductions for depreciation are made, then a net measure of the capital stock is the result.

Section G.2, Current Methodology, describes the methodology underlying the current measures of capital stock. Section G.3, BEA-type Geometric Depreciation Methodology, describes another set of measures more in line with the latest measures of capital stock being produced in the United States' Bureau of

Economic Analysis (BEA).[3] Section G.4 compares the results of the two different geometric methodologies and Section C.5 concludes.

G.2 Current Methodology

STATISTICS CANADA PROVIDES ESTIMATES of gross and net capital stocks for broad categories of assets and industries.

G.2.1 Gross Stocks and Retirements

The gross stock is an accumulation of past gross investment with yearly deductions (called retirements or discards) of the value of assets which cease to exist in that year. Thus, this measure of the capital stock assumes that the efficiency of the capital asset remains the same over its entire service life. The retirement pattern is a bell-shaped distribution which has been truncated so that all retirements occur between 50 percent and 150 percent of the mean useful life. The asset lives used are derived from the Capital and Repair Expenditures Survey.[4]

Table G.1

Truncated Normal Retirement Distribution Applied to a Cohort of Assets Worth $100,000 with a Mean Service Life of 10 Years

Sub-cohort	Length of Life of Sub-cohort	Fraction of Cohort	Value in Dollars of Sub-cohort
1	5	0.0032	320
2	6	0.0314	3,140
3	7	0.0762	7,620
4	8	0.1273	12,730
5	9	0.1692	16,920
6	10	0.1854	18,540
7	11	0.1692	16,920
8	12	0.1273	12,730
9	13	0.0762	7,620
10	14	0.0314	3,140
11	15	0.0032	320
Total		1.0000	100,000

The assets which the investment of a given year represents are described as a cohort of assets. If the mean service life of a cohort of assets is 10 years, then when the truncated normal retirement distribution is applied, there are 11 sub-cohorts each with its own service life. Table G.1 above shows the division into sub-cohorts of a cohort of assets with a value of $100,000 when purchased and with a mean useful life of 10 years.

G.2.2 Net Stocks and Depreciation

The net stock concept attempts to measure the productive capacity of the capital stock. This means that in addition to assembling data on investment flows, price indices and asset lives, the analyst must make assumptions about the pattern of aging and loss of efficiency of the assets and incorporate them into the perpetual inventory method in the form of depreciation. The estimates of net stocks are derived from the gross by making yearly deductions for depreciation. Various methods can be used to measure the deterioration of assets making up the capital stock. Three sets of depreciation and net stock estimates are produced by using the straight-line form, the double-declining balance form and the hyperbolic or "delayed" form of depreciation. Following is a brief comparison of the methods used to produce the current measures and the relationships between them.

Probably the most familiar model of depreciation is the straight-line method in which equal dollar amounts are deducted from the stock every year. The amount of straight-line depreciation (SL) is given by $x = 1,2,3,\ldots, L$:

$$d_{x,SL} = \frac{1}{L},$$

$$x = 1,2,3\ldots,L ,$$

where L is the number of years over which the asset is depreciated and x is the age of the asset.

In the linear form, all of the asset's value has disappeared from the capital stock by the end of the asset's service life. When the truncated normal retirement pattern is applied to straight-line depreciation, the effect is to produce an accelerated rate of depreciation (see Table G.2a).

The geometric rate of depreciation is one type of accelerated depreciation. The term "accelerated" is used because the dollar amounts of depreciation deducted are highest in the earlier years of the asset's life and become progressively smaller with each year of the asset's life.

With the geometric form (G), the declining-balance rate is the same every year:

$$d_G = \frac{R}{L},$$

where R is the rate relative to the straight-line rate of 1. Thus the double-declining-balance rate is $2/L$. The higher the value of R, the more accelerated the rate, i.e. the higher the dollar values deducted in the earlier years.

The depreciation for 1 dollar of investment using the geometric pattern is:

$$d_{x,G} = \delta_G(1-\delta_G)^{x-1}$$

$$x = 1,2,3...,L\ .$$

The current measures also include a pattern called hyperbolic or delayed depreciation:

$$d_{x,D} = \frac{L-(x-1)}{L-ß(x-1)} - \frac{L-x}{L-ßx},$$

which has the following form:

$$x = 1,2,3...,L\ .$$

where ß is a curvature parameter.

This form can help in understanding the relationships between the other forms. When the parameter ß is equal to zero, the beta-decay form is reduced to straight-line depreciation. When ß is equal to 1, the result is the gross stock concept where depreciation is zero for every year of the asset's life except the last, when it is 100 percent. For values of ß between 0 and 1, the graphical representation of the depreciation is concave to the origin, i.e. it is bowed outwards. This means that depreciation is lower in the early years of the asset's life and increases as the asset ages. This "delay" in the depreciation increases the closer ß is to 1. When ß is negative, the result is an accelerated form of depreciation. As β becomes a very large negative value, the curve approaches a pattern in which all the depreciation occurs in the first year of the asset's life and is zero for all other years i.e. it is the mirror image of the extreme when β is equal to 1. Figure G.1 illustrates the effect of β on this pattern of depreciation of an asset with a service life of 10 years.

In the current delayed depreciation measures, the value of β is equal to 0.75 for structures and 0.5 for machinery and equipment.

For all three of these depreciation patterns, to calculate the depreciation for an entire investment cohort, each sub-cohort must be depreciated according to its own rate. For example, if the straight-line form of depreciation is used, the first sub-cohort will be depreciated at a rate of 1/5 or 20 percent per year ($64 in the above example) for 5 years. Similarly, the second sub-cohort will be depreciated at a rate of 1/6 or 16.67 percent ($523) for 6 years and so on until the 11^{th} sub-cohort, for which the depreciation will be 1/15 or 6.67 percent ($21) for 15 years. The following tables illustrate the combined effects of the truncated normal retirement pattern with each of the three depreciation patterns: straight line (Table G.2a), geometric (Table G.2b) and delayed (Table G.2c). As before, the value of the cohort is assumed to be $100,000 and the average useful life to be 10 years.

G.2.3 Geometric Depreciation in the Current Measures

Since the geometric pattern of depreciation is infinite, some further explanation is necessary in order to understand the geometric rates of depreciation presented in Table G.2b.

Column 2 in the table below shows the first 20 years of the geometric distribution for a sub-cohort of assets with a service life of 10 years (i.e. the rate, δ, is 2/10). When the cut-off point is at age 10, the depreciation function is adjusted so that the area under the truncated distribution is 1 and the depreciation is zero from age 11 onwards (i.e. the assets in the sub-cohort are fully depreciated by the end of their service life). This is accomplished in two steps. First the original distribution is moved downwards by the amount of depreciation at age 11 (giving column 3 in the table). The total value of this new distribution is then adjusted proportionally to give the values in column 4. For example, 0.178525 divided by 0.677877 gives 0.263359. The accompanying graph shows the two distributions. The area redistributed is the area on the graph bounded by the heavy line.

Table G.2a

Truncated Normal Retirement Pattern and Straight-line Depreciation Pattern

Sub-cohort	Life		Percentage Reduction by Age															Weight from Retirement Fraction
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	5	Depreciation	20	20	20	20	20											0.0032
		Weighted	0.06	0.06	0.06	0.06	0.06											
2	6	Depreciation	16.67	16.67	16.67	16.67	16.67	16.67										0.0314
		Weighted	0.52	0.52	0.52	0.52	0.52	0.52										
3	7	Depreciation	14.28	14.28	14.28	14.28	14.28	14.28	14.28									0.0762
		Weighted	1.09	1.09	1.09	1.09	1.09	1.09	1.09									
4	8	Depreciation	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5								0.1273
		Weighted	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59								
5	9	Depreciation	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11	11.11							0.1692
		Weighted	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88							
6	10	Depreciation	10	10	10	10	10	10	10	10	10	10						0.1854
		Weighted	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85						
7	11	Depreciation	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09					0.1692
		Weighted	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54					
8	12	Depreciation	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33				0.1273
		Weighted	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05				
9	13	Depreciation	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69			0.0762
		Weighted	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59			
10	14	Depreciation	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14		0.0314
		Weighted	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23		
11	15	Depreciation	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	0.0032
		Weighted	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00	
		Total weights																1.0000
Total Weighted Percentages			10.43	10.43	10.43	10.43	10.43	10.37	9.84	8.76	7.16	5.28	3.43	1.89	0.84	0.26	0.00	99.98
Total Dollar Value of Depreciation for Cohort of $100,000			10,430	10,430	10,430	10,430	10,430	10,370	9,840	8,760	7,160	5,280	3,430	1,890	840	260	20	100,000

Bibliography

Baily, Martin Neil and Robert J. Gordon. "The Productivity Slowdown, Measurement Issues, and the Explosion of Computer Power." *Brookings Papers on Economic Activity*, 2 (1988): 347–420.

Blinder, Alan S. "The Speed Limit: Fact and Fancy in the Growth Debate." *The American Prospect,* 34 (September-October 1997): 57–62.

Brynjolfsson, Erik and Chris F. Kemerer. "Network Externalities in Microcomputer Software: An Econometric Analysis of the Spreadsheet Market." *Management Science*, 42, 12 (December 1996): 1627–47.

Brynjolfsson, Erik and Shinkyu Yang. "Information Technology and Productivity: A Review of the Literature." *Advances in Computers*, 43 (February 1996): 179–214.

Bureau of Economic Analysis. *Fixed Reproducible Tangible Wealth of the United States, 1925–96*, NCN-0136, May 1998a.

_____. "Fixed Reproducible Tangible Wealth in the United States: Revised Estimates for 1995–97 and Summary Estimates for 1925–1997." *Survey of Current Business*, September 1998b, pp. 36–45.

_____. *Investment Estimates of Fixed Reproducible Tangible Wealth, 1925–1997*. 1998c.

_____. "National Accounts Data – Data from the Latest GDP Release." http://www.bea.doc.gov/bea/dn/niptbl-d.htm, 1999.

Bureau of Labor Statistics. *Capital Stock Estimates for Input-Output Industries: Methods and Data*, Washington (DC): Government Printing Office Bulletin 2034, Washington (DC): Government Printing Office, 1979.

_____. *Trends in Multifactor Productivity, 1948–1981*, Washington (DC): Government Printing Office, 1983.

_____. *Labor Composition and U.S. Productivity Growth, 1948–1990*, Bulletin 2426, Washington (DC): Government Printing Office, 1993.

_____. *BLS Handbook of Methods*, Washington (DC): Government Printing Office, 1997.

_____. *Multifactor Productivity: Revisions to Capital Inputs for the BLS Multifactor Productivity Measures*, Washington (DC): Government Printing Office,1998.

_____. *Multifactor Productivity Trends*. USDL 99-36, February 11, 1999.

_____. *Productivity and Costs: Preliminary Fourth Quarter and Annual Averages, 1999*. USDL 00-37, February 8, 2000.

Christensen, Laurits R. and Dale W. Jorgenson "Measuring Economic Performance in the Private Sector," in *The Measurement of Economic and Social Performance*. Edited by Milton Moss. New York: Columbia University Press, 1973, pp. 233–38.

Christensen, Laurits R., Dale W. Jorgenson, and Lawrence J. Lau. "Conjugate Duality and the Transcendental Logarithmic Production Function." *Econometrica*, 39, 4 (July 1971): 255–56.

_____. "Transcendental Logarithmic Production Function." *Review of Economics and Statistics*, 55 (1973): 28–45.

Cole, Roseanne, Y. C. Chen, Joan A. Barquin-Stolleman, Ellen Dulberger, Hurhan Helvacian, and James H. Hodge. "Quality-adjusted Price Indexes for Computer Processors and Selected Peripheral Equipment." *Survey of Current Business*, 66, 1 (January 1986): 41–50.

Congressional Budget Office. "CBO's Method for Estimating Potential Output." *CBO Memorandum*, October 1995.

_____. "An Economic Model for Long-run Budget Simulations." *CBO Memorandum*, 1997.

_____. *The Budget and Economic Outlook: Fiscal Years 2000–2009*. Washington (DC): Government Printing Office, January 1999a.

_____. "The Budget and Economic Outlook: An Update." *CBO Papers*, July 1999b.

_____. *The Budget and Economic Outlook: Fiscal Years 2001–2010*. Washington (DC): Government Printing Office, January 2000.

Corrado, Carol and Lawrence Slifman. "Decomposition of Productivity and Unit Costs." *American Economic Review, Papers and Proceedings*, 89, 2 (May 1999): 328–32.

Council of Economic Advisors. *The Annual Report of the Council of Economic Advisors*, Washington (DC): Government Printing Office, 2000.

Dean, Edward R. "The Accuracy of the BLS Productivity Measures." *Monthly Labor Review*, February 1999, pp. 24–34.

Department of Commerce. *The Emerging Digital Economy II*, Washington (DC), June 1999.

Diewert, W. Erwin. "Functional Forms for Profit and Transformation Functions." *Journal of Economic Theory*, 6 (1973): 284–316.

_____. "Aggregation Problems in the Measurement of Capital," in *The Measurement of Capital*. Edited by Dan Usher. Chicago: University of Chicago Press, 1980.

Diewert, W. Erwin and Denis A. Lawrence. "Progress in Measuring the Price and Quantity of Capital." Mimeo, University of British Columbia, 1999.

Domar, Evsey. "On the Measurement of Technological Change." *Economic Journal*, 71 (1961): 709–29.

Dougherty, J. Chrysostom. "A Comparison of Productivity and Economic Growth in the G-7 Countries." Ph.D. Dissertation, Harvard University, 1992.

Dougherty, J. Chrysostom and Dale W. Jorgenson. "There Is No Silver Bullet: Investment and Growth in the G7." *National Institute Economic Review*, 162 (October 1997): 57–74.

Durand, René. "Aggregation, Integration and Productivity Analysis: An Overall Framework." *Aggregate Productivity Measures*, Statistics Canada, Cat. No. 15-204, July 1989.

_____. "Transforming Input-output Tables for Productivity Analysis." Mimeo, Statistics Canada, 1998.

Federal Reserve Board. *Balance Sheets for the U.S. Economy*. Release C.9, June 1995.

_____. *Flow of Funds Accounts of the United States*. Release Z.1, 1997.

Fisher, Franklin M. *Aggregation – Aggregate Production Functions and Related Topics*. Cambridge (MA): The MIT Press, 1992.

Fisher, Lawrence M. "New Era Approaches: Gigabyte Chips." *New York Times*, February 7, 2000, p. C8.

Flamm, Kenneth. "Measurement of DRAM Prices: Technology and Market Structure," in *Price Measurements and their Uses*. Edited by Murray F. Foss, Marilyn E. Manser, and Allan H. Young. Chicago: University of Chicago Press, 1993.

Fraumeni, Barbara. "The Measurement of Depreciation in the U.S. National Income and Public Accounts." *Survey of Current Business*, July 1997.

Gandal, Neil, "Hedonic Price Indexes for Spreadsheets and an Empirical Test for Network Externalities." *RAND Journal of Economics*, 25, 1 (Spring 1994): 160–70.

General Accounting Office. "The Deficit and the Economy: An Update of Long-term Simulations." GAO / AIMD / OCE-95-119, 1995.

_____. "Deficit Reduction and the Long Term." GAO / T-AIMD-96-66, 1996.

Gordon, Robert J. *The Measurement of Durable Goods Prices*, Chicago: University of Chicago Press, 1990.

_____. *The Economics of New Goods*, Chicago: University of Chicago Press, 1997.

_____. "U.S. Economic Growth Since 1870: What We Know and Still Need to Know." *American Economic Review, Papers and Proceedings*, 89, 2 (May 1999a): 123–28.

_____. "Has the 'New Economy' Rendered the Productivity Slowdown Obsolete?" Manuscript, Northwestern University, June 12, 1999b.

Greenwood, Jeremy, Zvi Hercowitz, and Per Krusell. "Long-run Implications of Investment Specific Technological Change." *American Economic Review*, 87, 3 (1997): 342–63.

Griliches, Zvi. "The Search for R&D Spillovers." *Scandinavian Journal of Economics*, 94 (1992): 29–47.

_____. "Productivity, RD, and the Data Constraint." *American Economic Review*, 84, 1 (March 1994): 1–23.

Griliches, Zvi and Dale W. Jorgenson. "Sources of Measured Productivity Changes: Capital Input." *American Economic Review*, 56 (May 1966): 50–61.

Grimm, Bruce T. "Quality Adjusted Price Indexes for Digital Telephone Switches." Bureau of Economic Analysis, unpublished memo, 1997.

Gullickson, William and Michael J. Harper. "Possible Measurement Bias in Aggregate Productivity Growth." *Monthly Labor Review*, February 1999, pp. 47–67.

Haimowitz, Joseph H. "Has the Surge in Computer Spending Fundamentally Changed the Economy?" *Economic Review*, Federal Reserve Bank of Kansas City, 2nd Quarter, 1998, pp. 27–42.

Hall, Robert E. "The Relation Between Price and Marginal Cost in U.S. Industry." *Journal of Political Economy*, 96,5 (1988): 921–47.

Hercowitz, Zvi. "The 'Embodiment' Controversy: A Review Essay." *Journal of Monetary Economics*, 41 (1998): 217–24.

Ho, Mun S. and Dale W. Jorgenson. "The Quality of the U.S. Workforce, 1948–95." Mimeo, Harvard University, 1999.

Ho, Mun S., Dale W. Jorgenson, and Kevin J. Stiroh. "U.S. High-tech Investment and the Pervasive Slowdown in the Growth of Capital Services." Mimeo, Harvard University, 1999.

Hooper, Peter and Elizabeth Vrankovich. "International Comparisons of the Level of Unit Labor Costs in Manufacturing." *International Finance Discussion Papers*, 527, Board of Governors of the Federal Reserve System, 1995.

Hulten, Charles R. *Total Factor Productivity: A Short Biography*. NBER Working Paper 7471, January 2000.

Johnson, Joanne. "A KLEMS Database: Describing the Input Structure of Canadian Industry." *Aggregate Productivity Measures*, Statistics Canada, Cat. No. 15-204E, 1994, pp. 19–32.

Jorgenson, Dale W. "The Embodiment Hypothesis." *Journal of Political Economy*, 74, 1 (1966): 1–17.

_____. "Productivity and Economic Growth," in *Fifty Years of Economic Measurement*. Edited by E. Berndt and J. Triplett. Chicago: University of Chicago Press, 1990.

_____. "Empirical Studies of Depreciation." *Economic Inquiry*, 34, 1 (January 1996): 24–42.

_____ ed. "Productivity and Postwar U.S. Economic Growth," in *Productivity, Volume 1: Postwar U.S. Economic Growth*, MIT Press, 1995a, pp. 1–23.

_____. ed., "Productivity and Economic Growth," in *Productivity, Volume 2: International Comparisons of Economic Growth*, MIT Press, 1995b, pp. 1–98.

Jorgenson, Dale W., Frank Gollop, and Barbara Fraumeni. *Productivity and U.S. Economic Growth*. Harvard University Press, 1987.

Jorgenson, Dale W. and Zvi Griliches. "The Explanation of Productivity Change." *Review of Economic Studies*, July 1967.

Jorgenson, Dale W. and Masahiro Kuroda. "Productivity and International Competitiveness in Japan and the United States, 1960–1985," in *Productivity, Volume 2, International Comparisons of Economic Growth*. Edited by Dale W. Jorgenson, MIT Press, 1995.

Jorgenson, Dale W., Masahiro Kuroda, and Mieko Nishimizu. "Japan-U.S. Industry-level Productivity Comparisons, 1960–1979." *Journal of the Japanese and International Economies*, 1 ,1 (1987): 1–30.

Jorgenson, Dale W. and Mieko Nishimizu. "U.S. and Japanese Economic Growth, 1952–1974." *Economic Journal*, 88 (December 1978): 707–26.

Jorgenson, Dale W. and Kevin J. Stiroh. "Computers and Growth." *Economics of Innovation and New Technology*, 3, 3–4 (1995): 295–316.

_____. "Information Technology and Growth." *American Economic Review, Papers and Proceedings*, 89, 2 (May 1999): 109–15.

_____. "U.S. Economic Growth at the Industry Level." *American Economic Review, Papers and Proceedings*, May 2000.

Jorgenson, Dale W. and P. J. Wilcoxen. "Environmental Regulation and U.S. Economic Growth." *The Rand Journal of Economics*, 21, 2 (Summer 1990): 314–40.

Jorgenson, Dale W. and Eric Yip. "Whatever Happened to Productivity Growth? Investment and Growth in the G-7." in *New Developments in Productivity Analysis*. Edited by E. R. Dean, M. J. Harper, and C. Hulten, University of Chicago Press, 1999.

Jorgenson, Dale W. and Kun-Young Yun. *Tax Reform and the Cost of Capital*. Oxford: Clarendon Press, 1991.

Katz, Arnold J. and Shelby W. Herman. "Improved Estimates of Fixed Reproducible Tangible Wealth, 1925–95." *Survey of Current Business*, May 1997, pp. 69–92.

Katz, Lawrence F. and Alan B. Krueger. "The High-pressure U.S. Labor Market of the 1990s." *Brookings Papers on Economic Activity*, 1 (1999): 1–87.

Kemp, Katharine. *International Price and Quantity Comparisons: Purchasing Power Parities and Real Expenditures, Canada and the United States* National Accounts and Environment Division, Technical Series Number 25, Statistics Canada, 1993.

Kiley, Michael T. "Computers and Growth with Costs of Adjustment: Will the Future Look Like the Past." Mimeo, Federal Reserve Board, July 1999.

Koumanakos, Peter, Richard Landry, Kuen Huang, and Susanna Wood. Canadian Net Capital Stock Estimates and Depreciation Profiles: A Comparison Between the Existing Series and a Test Series Using the U.S. (BEA) Methodology. Working Paper, Investment and Capital Stock Division, Statistics Canada, 1999.

Krugman, Paul. *The Age of Diminished Expectations: U.S. Economic Policy in the 1990s*. Cambridge (MA): MIT Press, 1990.

_____. "How Fast Can the U.S. Economy Grow?" *Harvard Business Review*, 75, 4 (July-August 1997): 123–29.

Kuroda, Masahiro and Koji Nomura." Productivity and International Competitiveness." Mimeo, Keio University, 1999.

Lum, Sherlene K. S. and Robert E. Yuskavage. "Gross Product by Industry, 1947–96." *Survey of Current Business*, November 1997, pp. 20–34.

McGuckin, Robert H. and Kevin J. Stiroh. "Do Computers Make Output Harder to Measure?" *Journal of Technology Transfer*, forthcoming, 2000.

Moulton, Brent R., Robert P. Parker, and Eugene P. Seskin. "A Preview of the 1999 Comprehensive Revision of the National Income and Product Accounts, Definitional and Classification Changes." *Survey of Current Business*, August 1999, pp. 7–19.

OECD. *International Sectoral Database*. Paris, 1998.

Office of Management and Budget. *Analytical Perspectives, Budget of the United States Government, Fiscal Year 1998*. Washington (DC): Government Printing Office, 1997.

_____. *Analytical Perspectives, Budget of the United States, Fiscal Year 2001*. Washington (DC): Government Printing Office, 2000.

Oliner, Stephen D. "Constant-quality Price Change, Depreciation, and the Retirement of Mainframe Computers," in *Price Measurement and Their Uses*. Edited by Murray F. Foss, Marilyn E. Manser, and Allan H. Young. Chicago: University of Chicago Press, 1993, pp. 19–61.

_____. *Measuring Stocks of Computer Peripheral Equipment: Theory and Application*. Board of Governors of the Federal Reserve System, May 1994.

Oliner, Stephen D. and Daniel E. Sichel. "Computers and Output Growth Revisited: How Big Is the Puzzle?" *Brookings Papers on Economic Activity*, 2 (1994): 273–334.

_____. "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" Mimeo, Federal Reserve Board, February 2000.

Parker, Robert and Bruce Grimm. "Software Prices and Real Output: Recent Developments at the Bureau of Economic Analysis." Paper presented at the NBER Program on Technological Change and Productivity Measurement, March 17, 2000.

Sichel, Daniel E. *The Computer Revolution: An Economic Perspective*. Washington (DC): The Brookings Institution, 1997.

_____. "Computers and Aggregate Economic Growth." *Business Economics*, 34, 2 (April 1999): 18–24.

Social Security Administration. *Economic Projections for OASDI Cost and Income Estimates: 1992*." Actuarial Study No. 108, SSA Pub. No. 11-11551, December 1992.

_____. *1996 Annual Report of the Board of Trustees of the Federal Old-age and Survivors Insurance and Disability Trust Funds*. Washington (DC): Government Printing Office, 1996.

Solow, Robert M. "Technology Change and the Aggregate Production Function." *The Review of Economics and Statistics*, 39 (August 1957): 312–20.

_____. "Investment and Technical Progress," in *Mathematical Methods in the Social Sciences, 1959*. Edited by Kenneth J. Arrow, Samuel Karlin, and Patrick Suppes. Stanford (CA): Stanford University Press, 1960.

_____. "We'd Better Watch Out." *New York Times Book Review*, July 12, 1987.

Statistics Canada. *Fixed Capital Flows and Stocks, 1961–1994 Historical*. Catalogue No. 13-568, 1994a.

_____. *Aggregate Productivity Measures*. Catalogue No. 15-204, 1994b.

_____. *Documentation for Micro DataFile, Survey of Consumer Finance*. Household Surveys Division, Ottawa, 1996.

_____. *Guide to the Labor Force Survey*, Ottawa, 1997.

Stiroh, Kevin J. "Computers, Productivity, and Input Substitution." *Economic Inquiry*, 36, 2 (April 1998a): 175–91.

_____. "Long-run Growth Projections and the Aggregate Production Function: A Survey of Models Used by the U.S. Government." *Contemporary Economic Policy*, 16 (October 1998b): 467–79.

_____. "Is There a New Economy?" *Challenge*, July-August 1999, pp. 82–101.

Tevlin, Stacey and Karl Whelan. "Explaining the Equipment Investment Boom of the 1990s." Mimeo, Division of Research and Statistics, Federal Reserve Board, December 1999.

Triplett, Jack E. "The Economic Interpretation of Hedonic Methods." *Survey of Current Business*, 66, January 1986, pp. 36–40.

_____. "Price and Technological Change in a Capital Good: A Survey of Research on Computers," in *Technology and Capital Formation*. Edited by Dale W. Jorgenson and Ralph Landau, Cambridge (MA): The MIT Press, 1989.

_____. "High-tech Industry Productivity and Hedonic Price Indices." *OECD Proceedings: Industry Productivity, International Comparison and Measurement Issues*, 1996, pp. 119–42.

_____. "Economic Statistics, the New Economy, and the Productivity Slowdown." *Business Economics*, 34, 2 (April 1999): 13–7.

Triplett, Jack E. and Barry Bosworth. "Productivity in the Service Sector." Mimeo, The Brookings Institution, Washington (DC), January 2000.

Whelan, Karl. "Computers, Obsolescence, and Productivity." Mimeo, Division of Research and Statistics, Federal Reserve Board, December, 1999.

Williamson, W. Gordon and A. Craig Lahmer. *Preparing Your Corporate Tax Returns*, CCH Canadian Limited, 1996.

Industry Canada Research Publications

INDUSTRY CANADA WORKING PAPER SERIES

No. 1 **Economic Integration in North America: Trends in Foreign Direct Investment and the Top 1,000 Firms**, Micro-Economic Policy Analysis staff including John Knubley, Marc Legault, and P. Someshwar Rao, Industry Canada, 1994.

No. 2 **Canadian-Based Multinationals: An Analysis of Activities and Performance,** Micro-Economic Policy Analysis staff including P. Someshwar Rao, Marc Legault, and Ashfaq Ahmad, Industry Canada, 1994.

No. 3 **International R&D Spillovers Between Industries in Canada and the United States**, Jeffrey I. Bernstein, Carleton University and National Bureau of Economic Research, under contract with Industry Canada, 1994.

No. 4 **The Economic Impact of Mergers and Acquisitions on Corporations**, Gilles Mcdougall, Micro-Economic Policy Analysis, Industry Canada, 1995.

No. 5 **Steppin' Out: An Analysis of Recent Graduates Into the Labour Market**, Ross Finnie, School of Public Administration, Carleton University, and Statistics Canada, under contract with Industry Canada, 1995.

No. 6 **Measuring the Compliance Cost of Tax Expenditures: The Case of Research and Development Incentives**, Sally Gunz and Alan Macnaughton, University of Waterloo, and Karen Wensley, Ernst & Young, Toronto, under contract with Industry Canada, 1996.

No. 7 **Governance Structure, Corporate Decision-Making and Firm Performance in North America**, P. Someshwar Rao and Clifton R. Lee-Sing, Micro-Economic Policy Analysis, Industry Canada, 1996.

No. 8 **Foreign Direct Investment and APEC Economic Integration**, Ashfaq Ahmad, P. Someshwar Rao, and Colleen Barnes, Micro-Economic Policy Analysis, Industry Canada, 1996.

No. 9 **World Mandate Strategies for Canadian Subsidiaries**, Julian Birkinshaw, Institute of International Business, Stockholm School of Economics, under contract with Industry Canada, 1996.

No. 10 **R&D Productivity Growth in Canadian Communications Equipment and Manufacturing**, Jeffrey I. Bernstein, Carleton University and National Bureau of Economic Research, under contract with Industry Canada, 1996.

No. 11 **Long-Run Perspective on Canadian Regional Convergence**, Serge Coulombe, Department of Economics, University of Ottawa, and Frank C. Lee, Industry Canada, 1996.

No. 12 **Implications of Technology and Imports on Employment and Wages in Canada**, Frank C. Lee, Micro-Economic Policy Analysis, Industry Canada, 1996.

No. 13 **The Development of Strategic Alliances in Canadian Industries: A Micro Analysis,** Sunder Magun, Applied International Economics, under contract with Industry Canada, 1996.

No. 14 **Employment Performance in the Knowledge-Based Economy**, Surendra Gera, Industry Canada, and Philippe Massé, Human Resources Development Canada, 1996.

No. 15 **The Knowledge-Based Economy: Shifts in Industrial Output**, Surendra Gera, Industry Canada, and Kurt Mang, Department of Finance, 1997.

No. 16 **Business Strategies of SMEs and Large Firms in Canada**, Gilles Mcdougall and David Swimmer, Micro-Economic Policy Analysis, Industry Canada, 1997.

No. 17 **Impact of China's Trade and Foreign Investment Reforms on the World Economy**, Winnie Lam, Micro-Economic Policy Analysis, Industry Canada, 1997.

No. 18 **Regional Disparities in Canada: Characterization, Trends and Lessons for Economic Policy**, Serge Coulombe, Department of Economics, University of Ottawa, under contract with Industry Canada, 1997.

No. 19 **Inter-Industry and U.S. R&D Spillovers, Canadian Industrial Production and Productivity Growth**, Jeffrey I. Bernstein, Carleton University and National Bureau of Economic Research, under contract with Industry Canada, 1998.

No. 20 **Information Technology and Labour Productivity Growth: An Empirical Analysis for Canada and the United States**, Surendra Gera, Wulong Gu, and Frank C. Lee, Micro-Economic Policy Analysis, Industry Canada, 1998.

No. 21 **Capital-Embodied Technical Change and the Productivity Growth Slowdown in Canada**, Surendra Gera, Wulong Gu, and Frank C. Lee, Micro-Economic Policy Analysis, Industry Canada, 1998.

No. 23 **Restructuring in Canadian Industries: A Micro Analysis**, Sunder Magun, Applied International Economics, under contract with Industry Canada, 1998.

No. 24 **Canadian Government Policies Toward Inward Foreign Direct Investment**, Steven Globerman, Simon Fraser University and Western Washington University, and Daniel Shapiro, Simon Fraser University, under contract with Industry Canada, 1998.

No. 25 **A Structuralist Assessment of Technology Policies – Taking Schumpeter Seriously on Policy,** Richard G. Lipsey and Kenneth Carlaw, Simon Fraser University, with a contribution by Davit D. Akman, research associate, under contract with Industry Canada, 1998.

No. 26 **Intrafirm Trade of Canadian-Based Foreign Transnational Companies,** Richard A. Cameron, Micro-Economic Policy Analysis, Industry Canada, 1998.

No. 27 **Recent Jumps in Patenting Activities: Comparative Innovative Performance of Major Industrial Countries, Patterns and Explanations**, Mohammed Rafiquzzaman and Lori Whewell, Micro-Economic Policy Analysis, Industry Canada, 1998.

No. 28 **Technology and the Demand for Skills: An Industry-Level Analysis**, Surendra Gera and Wulong Gu, Industry Canada, and Zhengxi Lin, Statistics Canada, 1999.

No. 29 **The Productivity Gap Between Canadian and U.S. Firms**, Frank C. Lee and Jianmin Tang, Micro-Economic Policy Analysis, Industry Canada, 1999.

No. 30 **Foreign Direct Investment and Productivity Growth: The Canadian Host-Country Experience**, Surendra Gera, Wulong Gu and Frank C. Lee, Micro-Economic Policy Analysis, Industry Canada, 1999.

No. 31 **Are Canadian-Controlled Manufacturing Firms Less Productive than their Foreign-Controlled Counterparts?** Someshwar Rao and Jianmin Tang, Micro-Economic Policy Analysis, Industry Canada, 2000.

No. 32 **The Canada-U.S. Productivity Growth Paradox**, Serge Coulombe, Department of Economics, University of Ottawa, under contract with Industry Canada, 2000.

INDUSTRY CANADA DISCUSSION PAPER SERIES

No. 1 **Multinationals as Agents of Change: Setting a New Canadian Policy on Foreign Direct Investment**, Lorraine Eden, Carleton University, under contract with Industry Canada, 1994.

No. 2 **Technological Change and International Economic Institutions**, Sylvia Ostry, Centre for International Studies, University of Toronto, under contract with Industry Canada, 1995.

No. 3 **Canadian Corporate Governance: Policy Options**, Ronald. J. Daniels, Faculty of Law, University of Toronto, and Randall Morck, Faculty of Business, University of Alberta, under contract with Industry Canada, 1996.

No. 4 **Foreign Direct Investment and Market Framework Policies: Reducing Frictions in APEC Policies on Competition and Intellectual Property**, Ronald Hirshhorn, under contract with Industry Canada, 1996.

No. 5 **Industry Canada's Foreign Investment Research: Messages and Policy Implications**, Ronald Hirshhorn, under contract with Industry Canada, 1997.

No. 6 **International Market Contestability and the New Issues at the World Trade Organization,** Edward M. Graham, Institute for International Economics, Washington (D.C.), under contract with Industry Canada, 1998.

No. 7 **Implications of Foreign Ownership Restrictions for the Canadian Economy – A Sectoral Analysis,** Steven Globerman, Western Washington University, under contract with Industry Canada, 1999.

No. 8 **Determinants of Canadian Productivity Growth: Issues and Prospects**, Richard G. Harris, Simon Fraser University and Canadian Institute for Advanced Research, under contract with Industry Canada, 1999.

No. 9 **Is Canada Missing the "Technology Boat"? Evidence from Patent Data**, Manuel Trajtenberg, Tel Aviv University, National Bureau of Economic Research and Canadian Institute for Advanced Research, under contract with Industry Canada, 2000.

INDUSTRY CANADA OCCASIONAL PAPER SERIES

No. 1 **Formal and Informal Investment Barriers in the G-7 Countries: The Country Chapters**, Micro-Economic Policy Analysis staff including Ashfaq Ahmad, Colleen Barnes, John Knubley, Rosemary D. MacDonald, and Christopher Wilkie, Industry Canada, 1994.

Formal and Informal Investment Barriers in the G-7 Countries: Summary and Conclusions, Micro-Economic Policy Analysis staff including Ashfaq Ahmad, Colleen Barnes, and John Knubley, Industry Canada, 1994.

No. 2 **Business Development Initiatives of Multinational Subsidiaries in Canada**, Julian Birkinshaw, University of Western Ontario, under contract with Industry Canada, 1995.

No. 3 **The Role of R&D Consortia in Technology Development**, Vinod Kumar, Research Centre for Technology Management, Carleton University, and Sunder Magun, Centre for Trade Policy and Law, University of Ottawa and Carleton University, under contract with Industry Canada, 1995.

No. 4 **Gender Tracking in University Programs**, Sid Gilbert, University of Guelph, and Alan Pomfret, King's College, University of Western Ontario, under contract with Industry Canada, 1995.

No. 5 **Competitiveness: Concepts and Measures**, Donald G. McFetridge, Department of Economics, Carleton University, under contract with Industry Canada, 1995.

No. 6 **Institutional Aspects of R&D Tax Incentives: The SR&ED Tax Credit**, G. Bruce Doern, School of Public Administration, Carleton University, under contract with Industry Canada, 1995.

No. 7 **Competition Policy as a Dimension of Economic Policy: A Comparative Perspective**, Robert D. Anderson and S. Dev Khosla, Economics and International Affairs Branch, Bureau of Competition Policy, Industry Canada, 1995.

No. 8 **Mechanisms and Practices for the Assessment of the Social and Cultural Implications of Science and Technology**, Liora Salter, Osgoode Hall Law School, University of Toronto, under contract with Industry Canada, 1995.

No. 9 **Science and Technology: Perspectives for Public Policy**, Donald G. McFetridge, Department of Economics, Carleton University, under contract with Industry Canada, 1995.

No. 10 **Endogenous Innovation and Growth: Implications for Canada**, Pierre Fortin, Université du Québec à Montréal and Canadian Institute for Advanced Research, and Elhanan Helpman, Tel Aviv University and Canadian Institute for Advanced Research, under contract with Industry Canada, 1995.

No. 11 **The University-Industry Relationship in Science and Technology**, Jérôme Doutriaux, University of Ottawa, and Margaret Barker, Meg Barker Consulting, under contract with Industry Canada, 1995.

No. 12 **Technology and the Economy: A Review of Some Critical Relationships**, Michael Gibbons, University of Sussex, under contract with Industry Canada, 1995.

No. 13 **Management Skills Development in Canada**, Keith Newton, Micro-Economic Policy Analysis, Industry Canada, 1995.

No. 14 **The Human Factor in Firm's Performance: Management Strategies for Productivity and Competitiveness in the Knowledge-Based Economy**, Keith Newton, Micro-Economic Policy Analysis, Industry Canada, 1996.

No. 15 **Payroll Taxation and Employment: A Literature Survey**, Joni Baran, Micro-Economic Policy Analysis, Industry Canada, 1996.

No. 16 **Sustainable Development: Concepts, Measures, Market and Policy Failures at the Open Economy, Industry and Firm Levels**, Philippe Crabbé, Institute for Research on the Environment and Economy, University of Ottawa, under contract with Industry Canada, 1997.

No. 17 **Measuring Sustainable Development: A Review of Current Practice,** Peter Hardi and Stephan Barg, with Tony Hodge and Laszlo Pinter, International Institute for Sustainable Development, under contract with Industry Canada, 1997.

No. 18 **Reducing Regulatory Barriers to Trade: Lessons for Canada from the European Experience**, Ramesh Chaitoo and Michael Hart, Centre for Trade Policy and Law, Carleton University, under contract with Industry Canada, 1997.

No. 19 **Analysis of International Trade Dispute Settlement Mechanisms and Implications for Canada's Agreement on Internal Trade**, E. Wayne Clendenning and Robert J. Clendenning, E. Wayne Clendenning & Associates Inc., under contract with Industry Canada, 1997.

No. 20 **Aboriginal Businesses: Characteristics and Strategies for Growth**, David Caldwell and Pamela Hunt, Management Consulting Centre, under contract with Aboriginal Business Canada, Industry Canada, 1998.

No. 21 **University Research and the Commercialization of Intellectual Property in Canada,** Wulong Gu and Lori Whewell, Micro-Economic Policy Analysis, Industry Canada, 1999.

No. 22 **A Regional Perspective on the Canada-U.S. Standard of Living Comparison,** Raynald Létourneau and Martine Lajoie, Micro-Economic Policy Analysis, Industry Canada, 2000.

No. 23 **Linkages Between Technological Change and Productivity Growth**, Steven Globerman, Western Washington University, under contract with Industry Canada, 2000.

No. 24 **Investment and Productivity Growth – A Survey From the Neoclassical and New Growth Perspectives**, Kevin J. Stiroh, Federal Reserve Bank of New York, under contract with Industry Canada, 2000.

No. 25 **The Economic Determinants of Innovation**, Randall Morck, University of Alberta, and Bernard Yeung, New York University, under contract with Industry Canada, 2000.

No. 26 **SMEs, Exports and Job Creation: A Firm-level Analysis**, Élisabeth Lefebvre and Louis A. Lefebvre, CIRANO and École Polytechnique de Montréal, under contract with Industry Canada, 2000.

CANADA IN THE 21ST CENTURY SERIES

No. 1 **Global Trends: 1980-2015 and Beyond**, J. Bradford DeLong, University of California, Berkeley, under contract with Industry Canada, 1998.

No. 2 **Broad Liberalization Based on Fundamentals: A Framework for Canadian Commercial Policy**, Randy Wigle, Wilfrid Laurier University, under contract with Industry Canada, 1998.

No. 3 **North American Economic Integration: 25 Years Backward and Forward**, Gary C. Hufbauer and Jeffrey J. Schott, Institute for International Economics, Washington (D.C.), under contract with Industry Canada, 1998.

No. 4 **Demographic Trends in Canada, 1996-2006: Implications for the Public and Private Sectors**, David K. Foot, Richard A. Loreto, and Thomas W. McCormack, Madison Avenue Demographics Group, under contract with Industry Canada, 1998.

No. 5 **Capital Investment Challenges in Canada**, Ronald P.M. Giammarino, University of British Columbia, under contract with Industry Canada, 1998.

No. 6 **Looking to the 21st Century – Infrastructure Investments for Economic Growth and for the Welfare and Well-Being of Canadians**, Christian DeBresson, Université du Québec à Montréal, and Stéphanie Barker, Université de Montréal, under contract with Industry Canada, 1998.

No. 7 **The Implications of Technological Change for Human Resource Policy**, Julian R. Betts, University of California, San Diego, under contract with Industry Canada, 1998.

No. 8 **Economics and the Environment: The Recent Canadian Experience and Prospects for the Future**, Brian R. Copeland, University of British Columbia, under contract with Industry Canada, 1998.

No. 9 **Individual Responses to Changes in the Canadian Labour Market**, Paul Beaudry and David A. Green, University of British Columbia, under contract with Industry Canada, 1998.

No. 10 **The Corporate Response – Innovation in the Information Age**, Randall Morck, University of Alberta, and Bernard Yeung, University of Michigan, under contract with Industry Canada, 1998.

No. 11 **Institutions and Growth: Framework Policy as a Tool of Competitive Advantage for Canada**, Ronald J. Daniels, University of Toronto, under contract with Industry Canada, 1998.

PERSPECTIVES ON NORTH AMERICAN FREE TRADE SERIES

No. 1 **Can Small-Country Manufacturing Survive Trade Liberalization? Evidence from the Canada-U.S. Free Trade Agreement**, Keith Head and John Ries, University of British Columbia, under contract with Industry Canada, 1999.

No. 2 **Modelling Links Between Canadian Trade and Foreign Direct Investment,** Walid Hejazi and A. Edward Safarian, University of Toronto, under contract with Industry Canada, 1999.

No. 3 **Trade Liberalisation and the Migration of Skilled Workers,** Steven Globerman, Western Washington University and Simon Fraser University, under contract with Industry Canada, 1999.

No. 4 **The Changing Industry and Skill Mix of Canada's International Trade**, Peter Dungan and Steve Murphy, Institute for Policy Analysis, University of Toronto, under contract with Industry Canada, 1999.

No. 5 **Effects of the Canada-United States Free Trade Agreement on Interprovincial Trade**, John F. Helliwell, University of British Columbia, Frank C. Lee, Industry Canada, and Hans Messinger, Statistics Canada, 1999.

No. 6 **The Long and Short of the Canada-U.S. Free Trade Agreement,** Daniel Trefler, University of Toronto, under contract with Industry Canada, 1999.

MONOGRAPH

Industry-level Productivity and International Competitiveness Between Canada and the United States, edited by Dale W. Jorgenson, Harvard University, and Frank C. Lee, Industry Canada, 2001.

RESEARCH VOLUME SERIES

No. 1 **Foreign Investment, Technology and Economic Growth**, Donald G. McFetridge ed., University of Calgary Press, 1991.

No. 2 **Corporate Globalization Through Mergers and Acquisitions**, L. Waverman ed., University of Calgary Press, 1991.

No. 3 **Multinationals in North America**, Lorraine Eden ed., University of Calgary Press, 1994, reprinted in 1996.

No. 4 **Canadian-Based Multinationals**, Steven Globerman ed., University of Calgary Press, 1994.

No. 5 **Corporate Decision-Making in Canada**, Ronald J. Daniels and Randall Morck eds., University of Calgary Press, 1995.

No. 6 **Implications of Knowledge-Based Growth for Micro-Economic Policies,** Peter Howitt ed., University of Calgary Press, 1996.

No. 7 **The Asia Pacific Region in the Global Economy: A Canadian Perspective,** Richard G. Harris ed., University of Calgary Press, 1996.

No. 8 **Financing Growth in Canada**, Paul J.N. Halpern ed., University of Calgary Press, 1997.

No. 9 **Competition Policy and Intellectual Property Rights in the Knowledge-Based Economy**, Robert D. Anderson and Nancy T. Gallini eds., University of Calgary Press, 1998.

JOINT PUBLICATIONS

Capital Budgeting in the Public Sector, in collaboration with the John Deutsch Institute, Jack Mintz and Ross S. Preston eds., 1994.

Infrastructure and Competitiveness, in collaboration with the John Deutsch Institute, Jack Mintz and Ross S. Preston eds., 1994.

Getting the Green Light: Environmental Regulation and Investment in Canada, in collaboration with the C.D. Howe Institute, Jamie Benidickson, G. Bruce Doern, and Nancy Olewiler, 1994.

To obtain copies of documents published under Industry Canada's Research Publications Program, please contact:

Publications Officer
Micro-Economic Policy Analysis
Industry Canada
5th Floor, West Tower
235 Queen Street
Ottawa, Ontario, K1A 0H5

Tel.: (613) 952-5704
Fax: (613) 991-1261
E-mail: mepa.apme@ic.gc.ca