Catalogue no. 11-622-MIE — No. 005
ISSN: 1705-6896
ISBN: 0-662-37239-5

Research Paper

The Canadian Economy in Transition Series

Are Knowledge Workers Found Only in High-technology Industries?

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Statistics Canada
Micro-economic Analysis Division

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Desmond Beckstead and Guy Gellatly

Published by authority of the Minister responsible for Statistics Canada

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May 2004

Catalogue no.11-622-MIE no. 005
Frequency: Occasional

ISSN 1705-6896
ISBN 0-662-37239-5

Ottawa

La version française de cette publication est aussi disponible (nº 11-622-MIF nº 005 au catalogue).

The authors' names are listed alphabetically.

This paper represents the views of the authors and does not necessarily reflect the opinions of Statistics Canada.

Note of appreciation
Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued cooperation and goodwill.

Acknowledgements

On behalf of all researchers who contribute to *The Canadian Economy in Transition Series*, we would like to thank our production team at Statistics Canada, whose efforts make the publication of these reports possible. Louise Laurin and Valerie Thibault oversee different aspects of the production process and work extensively with authors on the development of final products. Nicole Richer, Cindy Renaud, Hélène Villeneuve, Francine Simoneau and Shannon McPhail provide critical production support.

We are indebted to John Baldwin for many helpful comments and suggestions offered over several drafts of this paper.

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Preface

This study explores the industrial composition of Canada's *Knowledge Economy*. It uses a new occupational taxonomy to identify a small set of high-knowledge industries—industries that exhibit proportionately large concentrations of knowledge workers. It then compares these high-knowledge industries with two industrial aggregates that have recently been used to study growth trends in the *New Economy*: (1) information and communications technology (ICT) industries, and (2) science-based industries.

Two basic questions guide our analysis. First, are there industries—beyond those located in science and technology-based environments—that emerge as high-knowledge leaders when statistical estimates of knowledge intensity are based solely on occupational structure? Second, how do the growth and structural characteristics of these high-knowledge industries compare with those that characterize ICT-based environments, sectors that are home to the technology-based firms that develop, deliver and support many of the products and services associated with the New Economy?

Executive Summary

This study compares two sources of industrial dynamism—industries that via their technological or scientific characteristics have been associated with the development of the *New Economy*, and industries that because of their emphasis on high-wage, well-educated workers can lay claim as important stakeholders in what is often described as the emerging *Knowledge Economy*.

This report serves as a conceptual bridge between earlier studies in *The Canadian Economy in Transitions* series that focus on the growth of science and technology-based industries and a recent study that documented the gradual shift in Canada's occupational structure towards knowledge-intensive occupations. Two earlier studies in *Transitions—The Growth and Development of New Economy Industries* and *A Decade of Growth: The Emerging Geography of New Economy Industries in the 1990s*—investigate the long-run structural characteristics of information and communications technology (ICT) industries and science-based industries. The recent *Transitions* study on occupational structure—*Dimensions of Occupational Changes in Canada's Knowledge Economy 1971-1996*, explores the long-run growth of professional, management and technical occupations that, on the basis of their wage and educational characteristics, are classified as knowledge intensive. In what follows, we evaluate the extent to which this latter focus on knowledge-based occupations yields complementary, or competing, perspectives on the industrial composition of Canada's high-technology economy. Are there many industries outside of high-technology sectors that, on the strength of their occupational structure, can claim to be knowledge leaders?

1. Who is a knowledge worker?

In this analysis, we identify a small cluster of *high-knowledge* industries. This characterization derives from the fact that these industrial environments contain proportionately large numbers of knowledge workers—workers in certain occupations that have previously been designated as knowledge-based.

The knowledge-worker classification used in this study was developed by Beckstead and Vinodrai (2003) in *Dimensions of Occupational Changes in Canada's Knowledge Economy, 1971-1996* (the fourth paper in *The Canadian Economy in Transition* series). The authors identified 40 occupational categories as knowledge-based. These occupations fall under three general classes: professional workers, management workers and technical workers. Many individual occupations, such as computer programmers, engineers, and physical and life science professionals, conform with popular notions of the science- or technology-based, knowledge worker. Other occupations, such as creative and performing artists, teachers, and sales and advertising managers, typically garner less attention in studies that examine how skilled workers fuel systems of industrial innovation and growth. The knowledge-worker classification proposed by Beckstead and Vinodrai is ambitious in its scope—it includes many occupational categories from previous Canadian studies of knowledge workers, while also relying on multivariate methods to classify occupations as knowledge-based on the basis of their wage and educational characteristics.

2. Why focus only on knowledge workers when identifying high-knowledge industries?

In this paper, we focus on a single aspect of an industry's input structure—the representation of knowledge workers within its employment base—to identify a set of high-knowledge industries. Our decision to focus solely on occupational structure is motivated by the high degree of importance often attached to knowledge workers in debates over Canada's industrial competitiveness. Strategies for attracting, developing and retaining highly-skilled workers are perceived as requisites for success in an economy where competitive positions depend increasingly on information and technology management. In Canada, these issues are galvanized by the Brain Drain debate, the perceived loss of skilled Canadian workers to U.S. industries. While skill shortages in the technology sector garner widespread attention, the demand for knowledge workers extends well beyond the confines of highly visible, technology markets. Knowledge workers are seen as critical sources of innovation and growth in all sectors of the economy.

3. Which industries are knowledge leaders?

High-knowledge industries are those that exhibit proportionately large concentrations of knowledge-workers (i.e., workers employed in knowledge-based occupations) in relation to the size of their employment base. In this study, we utilize two basic thresholds for establishing the dividing line between high-knowledge industries and other industries. Both of these thresholds are meant to establish a conceptual linkage between the size of the knowledge economy, and what we referred to in an earlier study (Beckstead and Gellatly, 2003) as the science-based sector. Our first approach ensures that the employment coverage of high-knowledge industries and science industries is equivalent; our second approach ensures that the industrial coverage of the two classification schemes (the number of industries identified as either high-knowledge or science based) is equivalent.

When employment coverage is used to define our threshold, sixteen industries are classified as high-knowledge. Collectively, this high-knowledge group accounts for 10% of employment in the Canada's business sector—the same percentage of business sector employment accounted for by science-based industries (Beckstead and Gellatly, 2003). Not surprisingly, our high-knowledge grouping includes several technology- and science-based industries. ICT industries such as computers and related services and electronic equipment manufacturing industries are included in the high-knowledge group. One non-ICT science industry, architecture, engineering and scientific services, is also classified as a knowledge leader based on our occupational metric. But there are also many industries outside of science and technology environments that, on the strength of their occupational structure, can be seen as knowledge leaders. These include a range of financial service industries, such as financial intermediaries, accounting, and investment intermediaries. Business services such as management consultants also make the grade as high-knowledge. Also included in the high-knowledge group are industries that would not necessarily garner headlines in studies of the Knowledge Economy—such as theatrical and entertainment services, services incidental to fishing, and publishing industries. Yet knowledge workers contribute significantly to patterns of employment in these industries.

When industrial coverage is used as a basis for defining the knowledge sector, eight additional industries are added to the high-knowledge group. Examples include primary industries such as crude petroleum and natural gas and traditional business services such as lawyers and notaries.

4. How do high-knowledge industries compare with technology industries?

The high-knowledge industries examined in this paper are home to large concentrations of knowledge workers—workers in skilled, high-wage professions. These are the most knowledge-intensive industries, when the operational metric for evaluating cross-industry differences in knowledge is based entirely on occupational structure. What does an analysis of this high-knowledge classification reveal about the growth and structural characteristics of the New Economy?

First, it draws attention to the fact that there is much evidence of dynamic growth beyond the boundaries of the technology sector—notably in financial and business services environments. Financial services are illustrative. These are high-knowledge industries that were not previously classified as science- or technology-based. And estimates of long-run growth in output, employment, wages, and technological intensity for these financial service industries compare well with growth estimates for ICT services.

Second, our classification exercise demonstrates that high-levels of urbanization, often described as a core characteristic of emergent technology industries, are not unique to new technology-based environments. Most of the high-knowledge examples identified herein are highly urbanized—and growth-orientated financial services are about as urbanized as ICT service industries.

Third, our high-knowledge classification does yield new perspectives on the characteristics of the high-knowledge workforce. Many high-knowledge industries place more emphasis on university education than do technology industries. And many of these high-knowledge industries are home to larger concentrations of female workers.

Chapter 1. Introduction

Changes in industrial structure are driven by dual processes of growth and decline wherein economic resources, financial, physical and entrepreneurial, are diverted away from established industries and channeled into new emerging sectors. New industries are important sources of innovation and growth. They help shape perceptions of how competitive (and entrepreneurial) an economy is, be it local, provincial or national in scope. During the 1980s, policies designed to improve industrial competitiveness concentrated on developing high-growth industries. By the 1990s, high growth had become synonymous with high tech. Many analysts view the volume of economic activity accounted for by new technology-based industries, such as computer services, as a type of performance indicator—a barometer against which differences in industrial competitiveness can be evaluated.[1]

The 1990s also saw the emergence of what many analysts, economists, and entrepreneurs termed the New Economy—a more general process of economic restructuring driven by the rapid integration of new computer-based technologies (e.g., software and communications equipment), and fuelled by continual advances in the application and quality of these technologies. Computer-based innovations have revolutionized business models and production routines in both service industries and traditional manufacturing industries.[2]

In the first paper in *The Canadian Economy in Transition* series—*The Growth and Development of New Economy Industries*—we asked a series of basic questions about the industrial structure of the New Economy. First, we wanted to know whether information and communications technology (ICT) industries and science-based industries, industries often characterized as New Economy leaders, exhibit different input structures than other sectors of the economy. Understanding differences in input requirements are important because policies designed to bolster industrial competitiveness often focus on improving inputs, for example, by encouraging investments in training or in soft, intangible assets like R&D. Second, we wanted to know if emergent New Economy industries exhibit different productivity and profitability characteristics than other, less visible sectors. Productivity and profitability are core measures of industrial performance, and are sometimes used to *verify* the existence of the New Economy.

To answer these questions, we focused initially on the ICT sector—a collection of manufacturing and service industries that develop, deliver and support new technology-based products and services.[3] For many, ICT industries are the epicenter of the technology revolution. These technology industries grew rapidly in Canada during the 1990s. Employment in ICT industries increased by 31% between 1987 and 1997, while real (constant dollar) GDP grew by 96%. Despite these gains, however, the size of the ICT sector remains relatively modest, when viewed in relation to the size of Canada's business economy. By 2000, ICT industries accounted for roughly 5.5% of business sector employment and 5.7% of business revenue.[4] For this reason, we also choose to profile science-based industries—industries that make proportionately large investments in research and development and scientific labour.[5] Investments in R&D and skilled workers are two important determinants of an industry's science base, and are both widely regarded as requisites for success in the New Economy. And by focussing on science industries, we were able to extend our industrial profile of the New Economy well beyond the confines of the (highly-visible) technology sector. Science-based manufacturing includes ICT manufacturers (e.g., electronic products), but also more traditional R&D and skill-intensive manufacturing industries such as industrial chemicals, aircraft industries, and pharmaceuticals. Similarly, science-based services include core technology industries such as computer services and telecommunications, but also professional services such as engineering and architecture. This shift from ICT to science significantly increases the amount of economic activity emanating from New Economy industries. In 2001, science-based industries (both ICT and non-ICT) accounted for 9.6% of business sector employment and 10.9% of business revenue (Beckstead and Gellatly, 2003).

Extending our focus to science was also useful because it yields new insights into different sources of industrial dynamism that fuel the New Economy, insights which may have been overlooked if we had limited our focus solely to ICT industries. To explore these sources of dynamism, we focused (in *Growth and Development*) on a small collection of subsectors—specific industrial groupings within the ICT and science sectors. We found that core ICT services—industries comprised of firms that provide computer and telecommunications services—enjoyed higher rates of GDP and employment growth than other elements of the ICT or science economy. But we also found that it is ICT manufacturing, not core ICT services, that has enjoyed the largest long-run gains in labour and multifactor productivity. Non-ICT science-based industries also warrant emphasis. Profit margins and investment intensities are higher in science-based goods industries than in ICT manufacturing, and science-based services, not core ICT services, have enjoyed the largest long-run improvements in labour quality.

This dual ICT/science approach allowed us to develop a profile of the New Economy that is multidimensional—a view of the industrial landscape not dominated solely by industries producing advanced technologies, but one that extends more generally to other industries that place a premium on knowledge creation. In this analysis, we revisit this multidimensionality in a slightly different light. We ask whether ICT and science industries—industries that provide the scientific and technological foundations for the New Economy—are also those that employ the largest concentrations of knowledge workers. We investigate whether a singular focus on knowledge workers leads us to the same collection of industries that one obtains when focusing on ICT outputs or science-based inputs.

These exercises in classification are far from esoteric. Classification systems, especially when based on concepts like innovation, technology and knowledge, can create powerful impressions about the level of dynamism at work within an industry—and hence about the desirability of certain industries vis-à-vis others when assessing the competitiveness of an economy. If there are high-knowledge industries (presumably an asset on a competitive balance sheet), then there must also be low-knowledge industries (presumably a liability).[6] Here we ask which industries emerge as high-knowledge leaders—when estimates of knowledge intensity are based entirely on occupational structure. Is the high-knowledge group dominated by science and technology industries, or do other industries emerge as knowledge leaders? How do the growth and structural characteristics of high-knowledge industries located outside of science and technology environments compare with those that characterize the technology sector?

Endnotes

[1] The OECD (1997) has contributed to the competitiveness debate by publishing a high-tech scoreboard, which allows member countries to draw conclusions about the relative performance of their domestic technology industries.

[2] There is ample research from Canadian innovation and technology surveys documenting the extent and impact of innovative technologies on systems of production. For research on business service industries, see Baldwin *et al.* (1998) and Gellatly and Peters (2000). The impact of technology strategies on the performance of manufacturing firms has been examined by Baldwin and Sabourin (2001).

[3] For a list of four-digit ICT industries, see Appendix A. A lengthy analysis of long-run input and performance trends in the technology sector is found in Beckstead and Gellatly (2003).

[4] Of course, the indirect impact of ICT industries may be significantly larger, because of the dissemination of technology capital to other sectors of the economy. Understanding the impact that ICT investments have on output and productivity growth in different sectors is the focus of much of the empirical work on the New Economy.

[5] See also Appendix A.

[6] Baldwin and Gellatly (1998, 1999, 2001) have emphasized that there exist clusters of advanced firms in all sectors of the economy, and that one should not lose sight of the fact that so-called low-knowledge sectors still contain significant concentrations of advanced firms. In a similar vein, Beckstead and Vinodrai (2003) stress that knowledge workers, while better represented in certain industries than others, are also found in all sectors of the economy.

Chapter 2. Shifting the focus to knowledge workers

Prior to developing a list of high-knowledge industries, we want to stress that previous attempts to classify industries in accordance with their knowledge base are closely aligned with the concept of science industries discussed above. While the science-based designation originates with Baldwin and Johnson (1999), the classification technique used to identify certain industries as science-based was originally developed by Lee and Has (1996), who used different R&D and skilled labour indicators to sort industries into high-, medium-, and low-knowledge groupings. The OECD (2001) is currently developing an index of knowledge intensity using a similar technique, quantifying an industry's knowledge base from its R&D and human capital characteristics. Drolet and Morrisette (2002) have also recently used Baldwin and Johnson's list of science industries to investigate work patterns in the Knowledge Economy.

In this paper, we adopt a more straightforward measure of evaluating an industry's knowledge base—one based entirely on the share of workers in certain knowledge-based occupations. We opt for this more simplistic approach because of the enormous importance attached to knowledge workers when designing policies to enhance industrial competitiveness. Strategies for attracting, developing and retaining highly-skilled workers are perceived as requisites for success in the New Economy. In Canada, these issues are galvanized by the Brain Drain debate—the perceived loss of skilled Canadian workers to U.S. industries. While skill shortages in technology sectors garner widespread attention, the demand for knowledge workers extends well beyond the boundaries of highly visible, technology-producing industries. Knowledge workers are seen as critical to the process of competitive restructuring in all sectors of the economy.

In what follows, we ask some basic questions about the concentration of knowledge workers in different industrial environments. In *Growth and Development*, we reported that ICT and science-industries exhibit, in aggregate, relatively high concentrations of knowledge workers, and that the share of knowledge workers in science and technology environments increased rapidly during the 1990s (Beckstead and Gellatly, 2003). By 1996, nearly one half of workers in ICT and science industries were classified as knowledge-based, up from 25% and 29% of ICT- and science-based workers in 1981. Only 12% of business sector workers outside of science and technology environments were classified as knowledge-based in 1996, down from 17% in 1981. This creates the impression that skilled workers are far more at home in New Economy sectors such as ICT and science. And, on aggregate, this is indeed the case. However, these aggregate statistics do not tell us whether the most knowledge-intensive industries—industries with the highest concentrations of knowledge workers in relation to the size of their employment base—are also located in the ICT or science sectors. We explore this below.

Chapter 3. Who is a knowledge worker?

To measure an industry's complement of knowledge workers, we look to previous studies which have designated certain occupations as knowledge-based. The occupational categories that the OECD is using to develop its index of knowledge intensity is based on Canadian research by Lavoie and Roy (1998). In their view, knowledge-based occupations are those that "mainly involve the production of knowledge and/or the provision of expert opinion" (OECD, 2001: 16). Lavoie and Roy classified knowledge workers into five subcategories: applied science, pure-science, engineering, computer science, and social sciences and humanities. Lavoie and Roy's framework was analyzed by Boothby (1999), who evaluated the skill components (fine motor, gross motor, management, cognitive and communication skills) associated with different occupations. He found that knowledge occupations are more skill-intensive and require larger investments in education.

The knowledge-worker classification that we utilize herein is that proposed by Beckstead and Vinodrai in *Dimensions of Occupational Changes in Canada's Knowledge Economy 1971-1996*, the fourth paper in the *Transitions* series. Beckstead and Vinodrai (2003) draw extensively on the classification schemes developed by Lee and Has (1996) and Zhao, Drew and Murray (2000a, 2000b). Lee and Has' (1996) taxonomy of knowledge-based occupations includes "occupations in natural sciences, engineering and mathematics, in education and related occupations, other managers and administrators, social sciences, law and jurisprudence, medicine and health, and writing" (1996: 75). They use this list in conjunction with other skill indicators (i.e., the share of employees with post-secondary education, the ratio of engineers and scientists to total employment) to estimate the "human capital content" of an industry. The flow of knowledge workers to and from the Canadian economy has been studied recently by Zhao, Drew and Murray (2000a, 2000b). Their taxonomy of knowledge workers includes many of the occupations listed by Lee and Has (1996) and Lavoie and Roy (1998), but it also makes several additions, notably entrepreneurs, secondary school teachers, and certain arts and cultural occupations. Beckstead and Vinodrai (2003) utilized the results of these previous studies to define a more comprehensive list of knowledge-based occupations. In certain cases, the decision to designate an occupation as knowledge-intensive was based on relative wage rates, with higher-wage occupations having a higher likelihood of being classified as knowledge based. Beckstead and Vinodrai proposed three general categories of knowledge workers:

(a) Professional occupations—those with high relative wages and proportionately large numbers of university graduates.

(b) Technical occupations—those with lower relative wages but high post-secondary representation.

(c) Management occupations—those with high relative wages, but with lower levels of post-secondary education.

Beckstead and Vinodrai's resulting taxonomy is very comprehensive, covering a diverse cross-section of occupational groups. Managers from manufacturing and engineering, to finance, advertising and cultural industries are all designated as knowledge-based. Professional occupations include those in the fields of business, science and engineering, health and education, and arts and culture. Technical occupations include workers in physical and life sciences, engineering, architecture and electronics. A full list of knowledge-based occupational groups in these professional, technical and management classes is presented in Table 1.

Many of the occupational categories included in Table 1 are consistent with the popular notion of a knowledge workers as a science or technology-based professional (e.g., systems analysts and computer programmers). But Beckstead and Vinodrai's classification scheme also includes workers outside of science and technology (e.g., managers in finance, communications, administrative services) that more closely accord with Lavoie and Roy's second criteria, namely the "provision of expert opinion". Following Zhao, Drew and Murray (2000a, 2000b), Beckstead and Vinodrai also extend the concept of knowledge workers to occupational categories that are apt to be viewed by some as more controversial, such as teachers, nurses and arts and cultural professionals. The authors explored many of these "marginal cases" in their multivariate analysis of relative wage rates, and found sufficient evidence, based on a combination of wage and educational factors, to warrant their inclusion. And to this, one could add a substantial amount of anecdotal evidence that shows how technological innovations have been reshaping the nature of work in these occupations.

Table 1. Knowledge-based occupations

Occupations (based on the 1991 Standard Occupational Classification)

Management	A01	Legislators and senior management
	A11	Administrative services managers
	A12	Managers in engineering, architecture, science and information systems
	A13	Sales, marketing and advertising managers
	A30	Managers in financial and business services
	A31	Managers in communication (except broadcasting)
	A32	Managers in health, education, social and community services
	A33	Managers in public administration
	A34	Managers in art, culture, recreation and sport
	A38	Managers in primary production (except agriculture)
	A39	Managers in manufacturing and utilities
Business professionals	B01	Auditors, accountants and investment professionals
	B02	Human resources and business service professionals
Science and engineering professionals		
	C01	Physical science professionals
	C02	Life science professionals
	C03	Civil, mechanical, electrical and chemical engineers
	C04	Other engineers
	C05	Architects, urban planners and land surveyors
	C06	Mathematicians, systems analysts and computer programmers
Science–technical occupations		
	C11	Technical occupations in physical sciences
	C12	Technical occupations in life sciences
	C13	Technical occupations in civil, mechanical and industrial engineering
	C14	Technical occupations in electronics and electrical engineering
	C15	Technical occupations in architecture, drafting, surveying and mapping
	C16	Other technical inspectors and regulatory officers
	C17	Transportation officers and controllers
Health professionals	D01	Physicians, dentists and veterinarians
	D02	Optometrists, chiropractors and other health diagnosing and treating professionals
	D03	Pharmacists, dietitians and nutritionists
	D04	Therapy and assessment professionals
Other health occupations	D11	Nurse supervisors and registered nurses
	D21	Medical technologists and technicians (except dental health)
Education, law and social science-related		
	E01	Judges, lawyers and Quebec notaries
	E03	Policy and program officers, researchers and consultants
	E11	University professors and assistants
	E12	College and other vocational instructors
	E13	Secondary and elementary school teachers and counselors
Arts and culture professionals	F01	Librarians, archivists, conservators and curators
	F02	Writing, translating and public relations professionals
	F03	Creative and performing artists

Source: Beckstead and Vinodrai (2003).

Chapter 4. Identifying knowledge-intensive industries

Our classification exercise is based on data from the 2001 Census of Population—which includes detailed information on the occupational structure of 265 three-digit private sector industries.[7] To derive a set of high-knowledge industries, we calculate the percentage of paid employment in each industry accounted for by workers in knowledge-based occupations (i.e., the occupational groups listed in Table 1). This knowledge score is then used to rank industries along a continuum of knowledge intensity. Ours is a very straightforward approach in that it restricts the evaluation of an industry's knowledge base to a single dimension of interest: occupational structure. Next, we derive a working list of high-knowledge industries—simply the collection of industries that exhibit the highest knowledge scores. Two approaches are utilized to determine the boundaries of the knowledge sector, that is, the threshold that separates the high-knowledge group from the remaining (lower-knowledge) industries. To define these thresholds, we looked to the dimensions of the science sector, the larger of the New Economy aggregates profiled in *Growth and Development*. In 2001, the science sector (which includes almost all ICT industries) accounted for approximately 10% of business sector employment. To establish a basic symmetry between our science and knowledge classifications, we first generated a high-knowledge group by selecting industries with the highest knowledge scores until the combined employment of these industries reached 10% of business sector employment. Establishing this comparable employment coverage between our high-knowledge and science definitions results in a set of 16 high-knowledge industries.[8]

A second method of establishing some measure of symmetry between our high-knowledge and science classifications is to rely on the latter's industrial dimensions. Twenty-four three-digit industries are classified as science-based.[9] Accordingly, we augment our original list of 16 high-knowledge industries by also including the next 8 industries with the highest knowledge scores.

4.1 High-knowledge industries

Our first group of 16 high-knowledge industries (based on employment coverage, the more restrictive of our thresholds) is presented in Table 2a. We refer to these as first-tier knowledge industries, because they have the highest knowledge scores (i.e., the highest percentages of workers in knowledge-based occupations). Note that we have excluded public industries (government services) or quasi-public industries (education and health industries) from our classification, as these industries are not classified to the business sector.[10]

Table 2a. High-knowledge industries (First tier, based on employment coverage—business sector only)

Industry (SIC)	Knowledge score*	% of industry employment classified as ICT-based	% of industry employment classified as science-based
1. Computer and related services (772)	83.7	100.0	97.8
2. Architectural, engineering and other scientific and technical services (775)	78.3	0	100.0
3. Management consulting services (777)	69.2	0	0
4. Other financial intermediary industries (740)	68.5	0	0
5. Theatrical and other staged entertainment services (963)	65.0	0	0
6. Investment intermediary industries (720)	60.5	0	0
7. Services incidental to fishing (032)	55.4	0	0
8. Accounting and bookkeeping services (773)	54.9	0	0
9. Office, store and business machine industries (336)	53.0	100.0	100.0
10. Communication and other electronic equipment industries (335)	51.8	100.0	100.0
11. Other services n.e.c (999)	49.4	0	0
12. Publishing industries (283)	48.8	0	0
13. Business associations (982)	48.4	0	0
14. Labour organizations (984)	48.2	0	0
15. Political organizations (985)	47.8	0	0
16. Professional membership associations (983)	46.9	0	0

* Percentage of employment in knowledge-based occupations.

Only three industries in this group of sixteen—computers and related services (SIC 772), communications and electronic equipment (SIC 335), and office, store and business machines (SIC 336)—are classified, in whole or in part, as both ICT- and science-based. One other (non-ICT) science industry—architecture, engineering and scientific services (SIC 775)—is also included in our high-knowledge group. Two of these industries set the standard for knowledge workers. Computer services exhibits the highest knowledge score (84%) followed by architectural, engineering and scientific services (78%).

Our knowledge rankings also unearth a range of other industries located outside of science and technology environments that, on the strength of their occupational structure, could also be classified as knowledge leaders. Twelve out of the sixteen industries in Table 2a are neither ICT-based nor science-based. These include financial services, such as financial intermediaries (SIC 740) and investment intermediaries (SIC 720). Business services such as management consultants (SIC 777) and accounting (SIC 773) also make the grade as high-knowledge. Also included in the high-knowledge category are industries that would not necessarily garner headlines as knowledge leaders—such as theatrical and entertainment services (SIC 963), services incidental to fishing (SIC 032), and publishing industries (SIC 283). These industries employ significant concentrations of knowledge workers.

The second tier of knowledge industries (additions based on industrial coverage, the less restrictive of our thresholds) is reported in Table 2b. This group includes ICT manufacturers, such as scientific and professional manufacturing (SIC 391), along with science-based industries, such as pharmaceuticals and medicine (SIC 374) and pipeline transport (SIC

Table 2b. High-knowledge industries (Second tier, based on industrial coverage—business sector only)

Industry (SIC)	Knowledge score*	% of industry employment classified as ICT-based	% of industry employment classified as science-based
17. Offices of lawyers and notaries (776)	46.3	0	0
18. Crude petroleum and natural gas industries (071)	44.3	0	0
19. Telecommunication broadcasting industries (481)	44.2	29.3	29.3
20. Pharmaceutical and medicine industries (374)	43.3	0	100.0
21. Consumer and business financing intermediary industries (710)	43.1	0	0
22. Other services incidental to construction (449)	43.0	0	0
23. Pipeline transport industries (461)	42.5	0	100.0
24. Scientific and professional equipment industries (391)	42.0	91.5	100.0

* Percentage of employment in knowledge-based occupations.

461). Once again, industries outside of ICT and science environments make the grade as knowledge based. Examples include traditional business services, such as lawyers and notaries (SIC 776), and primary industries, such as crude petroleum and natural gas (SIC 071).

Tables 2a and 2b highlight many examples of industries with proportionately large concentrations of knowledge workers that lie outside the boundaries of ICT and science. That said, one should not conclude that ICT and science industries fare poorly in terms of their representation of knowledge workers. The group of 16 high-knowledge industries listed in Table 2a constitute only 10% of business sector employment. The remaining 90% of paid workers are spread across 249 other industries.[11] When viewed against this larger group, most ICT and science industries score highly in terms of their relative concentrations of knowledge workers. Tables 3 and 4 list all 3-digit industries that are comprised, in whole or in part, of ICT and science-based components.[12]

Table 3. Knowledge scores for ICT industries*

Industry (SIC)	Knowledge score**	Knowledge rank***
Computer and related services (772)	83.7	1
Office, store and business machine industries (336)	53.0	9
Communication and other electronic equipment industries (335)	51.8	10
Telecommunication broadcasting industries (481)	44.2	19
Scientific and professional equipment industries (391)	43.3	20
Telecommunication carriers industry (482)	39.2	29
Communications and energy wire and cable industry (338)	36.2	33
Other telecommunication industries (483)	35.7	34
Electrical and electronic machinery, equipment and supplies, wholesale (574)	35.3	35
Other machinery, equipment and supplies, wholesale (579)	29.3	50
Record player, radio and television receiver industry (334)	25.7	60
Machinery and equipment rental and leasing services (991)	8.9	199

* Industries in italics contain both ICT and non-ICT components.
** Percentage of employment in knowledge-based occupations.
*** Ranking out of 265 business sector industries.

Table 4. Knowledge scores for non-ICT science-based industries*		
Industry (SIC)	Knowledge score**	Knowledge rank***
Architectural, engineering and other scientific and technical services (775)	78.3	2
Pharmaceutical and medicine industry (374)	43.3	20
Pipeline transport industries (461)	42.5	23
Motion picture, audio and video production and distribution (961)	41.2	25
Service industries incidental to agriculture (021)	40.4	26
Refined petroleum industries (361)	38.2	30
Industrial chemicals industries (371)	38.2	31
Electric power systems industry (491)	37.2	32
Aircraft and aircraft parts industry (321)	33.6	38
Plastic and synthetic resin industry (373)	32.7	40
Electrical industrial equipment industries (337)	30.6	47
Other chemical products industries (379)	29.8	49
Agricultural chemical industries (372)	28.0	55
Other machinery and equipment industries (319)	26.2	58
Other petroleum and coal products industries (369)	22.3	71
Commercial refrigeration and air conditioning industries (312)	19.7	88
Agricultural implement industries (311)	16.8	114

* Industries in italics contain both science and non-science components.
** Percentage of employment in knowledge-based occupations.
*** Ranking out of 265 business sector industries.

Science and technology environments are well represented in the upper end of the knowledge distribution. Of the 12 industries with ICT representation, 10 place in the top quintile in terms of their knowledge score (the top 53 business sector industries). Similarly, 12 out of the 17 science industries that are not classified as ICT-based also place in the top quintile.

4.2 Are distinctions between science and knowledge statistically robust?

The above classification exercise draws distinctions between science and technology environments and other high-knowledge environments by focusing on small sets of individual industries which occupy the upper tail of the knowledge distribution—industries with the largest concentrations of knowledge workers. Certain highly visible, science and technology industries, such as computer services and electronic equipment manufacturers, are included in this high-knowledge group. But other industries, including a range of financial and business services, also make the grade as knowledge leaders.

These industry distinctions need to be set in context. Even if many ICT and science industries are not included in the first or second tier high-knowledge groups (Tables 2a and 2b), most, as we noted at the conclusion of the section 4.1, have relatively high knowledge scores. And we would expect this to be the case. The vast majority of ICT industries are included in the science sector. And, as discussed in Chapter 2, the science designation is itself based in part on human capital indicators that evaluate the knowledge and skill characteristics of an industry's workforce.

Table 5. Statistical relationships between science and knowledge classification schemes		
Method	Features of method	Results
1) Independence of classification – Null hypothesis: the classification schemes are independent of one another. – 2x2 contingency table, test statistic distributed as Chi-square. – Separate tests based on different coverage rules for defining threshold between high-knowledge and low-knowledge industries (employment-based coverage rule versus industry-based coverage rule).	– When employment coverage rule is used, dimensions of knowledge and science classification schemes differ (18 high-knowledge industries versus 24.2 science industries). – When industry-based coverage rule is used, dimensions of two classification schemes are (basically) equivalent (24 high-knowledge industries).	A) Employment-based coverage rule: – Reject at 5% the null that classification schemes are independent of one another. Cannot reject the null of independence at 1%. – Tests are very sensitive to changes in classification (i.e., reclassification of small numbers of industries). B) Industry-based coverage rule: – Reject at 1% the null that the classification schemes are independent of one another. General comment: Tests are influenced by the definition of the high-knowledge threshold.
2) Independence of classification – Null hypothesis: exact dependence (equivalent taxonomies). – 2x2 contingency table, test statistics distributed as Chi-square. – Separate tests based on employment-based coverage rule and industry-based coverage rule.	– Expected contingency tables based on the maximum number of science/knowledge pairings that are possible under equivalence.	– Reject at 1% the null that the classification schemes are exactly equivalent—regardless of whether the employment- or industry-based coverage rule is used.
3) Correlation analysis – Evaluates linear association between taxonomies.	– Compared continuous and binary definitions of the knowledge index to the binary science index. – Advantage: more complete use of knowledge worker data.	– Correlation coefficient between continuous knowledge index and binary science index is 0.44. – Correlation is 0.14 when the employment-based coverage rule is used to define the binary knowledge classification; 0.23 when the industry-based coverage rule is used to define the binary knowledge classification.

The nature of this functional relationship between science (the more comprehensive of the New Economy taxonomies) and knowledge is important. Even if some functional dependence exists between science and knowledge, there still may be important differences between the two classification systems (presumably the result of factoring R&D characteristics into the mix when estimating an industry's science base). At the extreme, however, if our science and knowledge classifications are essentially equivalent, then slight differences in the classification of individual industries (to the extent that these differences exist) may amount to little more than statistical aberrations.

We evaluate statistical relationships between the science and knowledge classifications in several ways. A brief overview of methods and results is presented in Table 5.

We begin with our initial expectation—that some functional relationship exists between the high-knowledge and science classifications. First, we used standard chi-square statistics to test for the independence of the two classification systems (high-knowledge versus science).[13] We performed separate tests based on the two coverage rules (employment coverage and industrial coverage) that were used separately to classify industries to the high-knowledge group. Regardless of whether the more restrictive (employment) threshold or the less restrictive (industrial) threshold was used to define the high-knowledge group, our test statistics rejected the null that the binary knowledge and science classifications are independent of one another. The high-knowledge classification contains a higher ratio of science-to non-science industries than does the low-knowledge classification. Because of the dimensionality of these classification schemes, however, these standard tests need to be interpreted with caution as, in certain cases, small changes in classification (e.g., the number of industries that are jointly classified as high-knowledge and science-based) have a significant impact on test results.[14]

A more intriguing concern, however, rests with the "extreme case" noted earlier—the case of exact functional dependence.[15] We can evaluate this null hypothesis (exact dependence) as a special case of the alternative hypothesis outlined above (some dependence). To test the null of exact dependence, we effectively treated our set of expected frequencies (e.g., the expected number of science and knowledge pairings) as exogenously determined. These expected frequencies correspond to the maximum number of identical science-knowledge pairings that we would observe if the science and knowledge taxonomies classified industries equivalently, in situations where the *possibility* of equivalence exists. Irrespective of whether the employment threshold or the industry threshold was used to construct the high-knowledge group, the null of exact dependence was strongly rejected.

The above tests are based on binary classifications. The science taxonomy developed by Baldwin and Johnson (1999) is binary—each industry is either designated as science-based or non-science based (the authors refer to these as "other" industries). No attempt is made to quantify the extent to which certain industries are more science-based than others. But the knowledge scores that we use to generate our binary high-knowledge and "other" groups are continuous, and rank industries along a continuous distribution. As a final exercise, we make more use of the continuous information that underlies our knowledge index. The correlation coefficient between the continuous knowledge index and the binary science taxonomy is 0.44. When these knowledge scores are used to construct binary high-knowledge/other industry groups, the correlation coefficient between the (binary) knowledge and science classification schemes reduces to 0.23 (when the less restrictive industry threshold is used to identify the high-knowledge group) and 0.14 (when the more restrictive employment threshold is used to define the high-knowledge group).

Our tests suggest that these knowledge and science taxonomies are related, but imperfectly. This, in turn, provides some statistical justification for drawing attention to the select group of high-knowledge industries located outside of science and technology environments. In the next section, we examine the growth and structural characteristics of these high-knowledge industries—against the backdrop of what many analysts view as the epicenter of the New Economy, the technology sector.

Endnotes

[7] Our classification is based on 1980 SIC industries (as opposed to the more current North American Industrial Classification System standard). This was done, first, to facilitate comparisons with the SIC-based definitions of ICT and science industries utilized in *Growth and Development*, and second, to ensure consistent industrial definitions for our analysis of long-run growth in Chapter 5. Note that in a small number of cases, industries in this Census database represent groupings of three-digit industries.

[8] One methodological difference between these science and knowledge classifications warrants mention. The 10% employment share for science industries reported in *Growth and Development* is based on that sector's share of paid worker jobs. In the current analysis, the 10% employment share that is used to classify industries to our high-knowledge group is based on a broader definition of employment, which includes both paid and self employment. Because both employment types are readily available from Census data, we saw no reason to exclude self employment from those tabulations.

[9] Science industries are defined at the four-digit level based on the 1980 SIC (see Appendix A). Twenty two three-digit industries are wholly classified as science-based (i.e., all the paid employment in these industries is located in four-digit industries that Baldwin and Johnson (1999) identify as science-based). Two other three-digit industries have the majority of their employment in four-digit science industries, while two others have minority science shares. Our group of 24 is based on industries with all or a majority of their employment classified as science-based. Data issues that limit our ability to compare high-knowledge industries to ICT and science industries are discussed in Appendix A.

[10] This conceptual limitation is examined in Appendix B. For comparative purposes, we generate an alternative definition of the high-knowledge group based on a mixture of public and private industries.

[11] A small employment residual is not classified to a specific industry.

[12] For background on why certain industries contain only "partial" ICT or science components, see Appendix A.

[13] These tests are based on contingency tables that examine the ratio of science to non-science industries across high- and low-knowledge strata. Under the null of independence (i.e., no functional relationship between science and knowledge), the proportion of science to non-science industries in the high-and low-knowledge groupings should be the same. For background on these tests, see Monks and Newton (1988).

[14] These analytical limitations reflect small counts in certain cells of the contingency table. For example, when the more restrictive employment threshold is used to define the high-knowledge group, only 4 industries are jointly classified as high-knowledge and science-based; the resulting test statistic allows us to reject the null of independence at the 5% level of confidence. If one additional observation was eliminated from this high-knowledge/science group, we could not reject the null.

[15] One way of conceptualizing this test of exact dependence is to ask whether the deviations that we observe between the two classifications are slight enough to be randomly generated by the construction of "equivalent" science and knowledge taxonomies.

Chapter 5. How do high-knowledge industries compare with technology industries?

In *The Growth and Development of New Economy Industries* (the second paper in the *Transitions* series), we asked whether ICT industries were "special" and concluded that they were. We also asked whether there exist other industries (or clusters of industries) with long-run production and performance profiles on par with those in the technology sector. And we found evidence to this effect—R&D-intensive science industries have also enjoyed high rates of GDP growth. Wages, investment intensities and productivity growth in these industries rival those in the technology sector. We thus concluded that a singular focus on ICT risks omitting potentially interesting groups of industries that are also making significant contributions to the growth of the New Economy.

We then extended this line of argument further (in *Growth and Development*) by showing that there are significant numbers of non-ICT / non-science industries—what we referred to as *other* or *traditional* industries—that outperform the average for technology industries in different aspects of their production and performance profile. (The number of these industries doing so depends, of course, on the metric used.) What is more, we also found small clusters of these more traditional industries that consistently outperformed the ICT average across a range of input and performance dimensions. Even in traditional sectors of the economy, evidence of dynamic growth is legion.

ICT industries produce, develop and support technology-based products. Science industries (many of which are also ICT-based) make relatively large investments in research and development and skilled workers. In *Dimensions of Occupational Changes in Canada's Knowledge Economy* (the fourth paper in the *Transitions* series), Beckstead and Vinodrai shifted the focus from ICT and science industries to knowledge workers. The concept of a knowledge industry advanced in *Dimensions* (and explored in this paper) is based solely on the representation of knowledge workers within an industry's occupational structure. In the present study, we note that some of the most knowledge-intensive industries (industries with the largest concentrations of knowledge workers given the size of their respective employment bases) lie outside the boundaries of these ICT and science classifications. In this section, we evaluate how the growth profiles and structural characteristics of high-knowledge industries located outside of science and technology environments compare with the growth and structural characteristics in the technology sector.

As in *Growth and Development*, we have selected ICT industries as our comparative benchmark because, for many analysts, these technology industries are most associated with the growth of the New Economy. Because long-run input and performance trends for ICT services differ from those in ICT manufacturing[16], we compare high-knowledge services to the ICT services average, and high-knowledge goods to the ICT manufacturing average.[17]

Table 6. Analysis variables	
Variable	Data source
Growth measures:	
1. Percentage point change in aggregate GDP share (1987-1997)	Productivity Accounts database
2. Average annual rate of growth of employment (1991-2001)	Census of Population
3. Average annual rate of growth of hourly earnings (1991-2001)	Census of Population
4. Percentage point change in average ICT investment intensity (1981-89 / 1994-2002)	Productivity Accounts database
Structural characteristics:	
5. Percentage of employment in urban areas (all CMAs, 2001)	Census of Population
6. Percentage of employment in largest urban areas (largest four CMAs, 2001)	Census of Population
7. Percentage of workforce with post-secondary degrees (2001)	Census of Population
8. Percentage of women in workforce (2001)	Census of Population

Our analysis variables are listed in Table 6. Four different aspects of the growth profile are examined, related to output, employment, earnings and technology use. On aggregate, ICT industries experienced significant GDP growth in the 1990s—increasing their share of total business sector output. We examine percentage point changes in nominal GDP shares over the 1987 to 1997 period to evaluate the extent to which individual high-knowledge industries outside of ICT and science environments are also becoming important parts of the private-sector economy.[18]

Long-run employment and earnings growth are two other areas in which technology industries have excelled (Beckstead and Gellatly, 2003). We evaluate labour market dynamics by comparing annual growth rates for employment and hourly earnings over the 1991 to 2001 period. Our final measure of growth focuses on technological intensity. ICT industries not only develop, deliver and support new technological products and services—they are also heavy consumers of these products (Beckstead and Gellatly, 2003). We examine the changing role of technological investment in high-knowledge industries by comparing the average contribution of high-technology capital (computer, software and telecommunications equipment) to total investment over two general periods (1981-1989, 1994-2002).

In addition to growth, we focus on a range of structural characteristics that describe different facets of the production environment. Four basic characteristics are examined—two related to urbanization, one related to educational attainment and one to female participation.

Knowledge-based industries are widely perceived as an urban phenomenon. Beckstead *et al.* (2003) used an analysis of location quotients to demonstrate that employment in Canadian technology industries is highly concentrated in large urban centres, and that the geographic concentration of ICT activity has accelerated in recent years. In what follows, we examine two basic measures of urbanization—the percentage of paid worker employment in Canadian CMAs (urban areas with populations of 100,000 or more[19]), and the percentage of paid worker employment in the largest CMAs (urban areas with populations of 1,000,000 or more[20]).

Education and female participation are two other areas that are often seen to differentiate technology industries from other sectors. According to Vaillancourt (2003), computer and telecommunications industries contain proportionately about twice as many university graduates as other industries. In addition, these are industries that are widely regarded as male dominated. Employment in computer and telecommunications is becoming "increasingly dominated by university-educated younger men" (Vaillancourt, 2003). From 1990 to 2002, the share of women in these technology industries actually declined. Vaillancourt notes that this reflects sharp differences in employment growth rates, as the long-run employment growth rate in these industries was significantly lower for women (51%) than for men (75%). Below we examine industry differences in degree intensity (the percentage of the workforce with a post-secondary degree) and in female participation (the percentage of the workforce that is female).

Results are reported in Tables 7a and 7b. Table 7a focuses on *first-tier* knowledge industries. This is the subset of 12 industries located outside of science and technology environments[21] that are classified as high-knowledge when the more restrictive of our two thresholds, employment coverage, is used to differentiate high-knowledge industries from other industries. Table 7b reports on the group of 4 *second tier* knowledge industries. These are (non ICT-based, non science-based) industries with lower knowledge scores than those in the first tier, but that are classified to the high-knowledge sector when the more inclusive of our thresholds, industrial coverage, is used to distinguish high-knowledge industries from other industries. Prior to our discussion of results, one data limitation warrants mention. Two of the growth variables featured in Table 6—GDP growth and long-run changes in technology-based investment—are derived from data sources that are used to support Statistics Canada's Productivity Accounts. On balance, these data sources contain less industry detail than the Census files that are used to generate the other analysis variables described in Table 6. This has direct implications for how precisely we can measure growth trends in certain industries. Accordingly, in certain cases, we can only evaluate whether a specific high-knowledge industry (e.g., investment intermediary industries) is part of a larger industrial environment (a collection of investments and other financial intermediary industries) in which GDP growth or long-run changes in technological intensity compare favourably with growth trends in the ICT sector. (We indicate situations in which these measurement issues arise via shading in Tables 7a and 7b.)[22]

In the technology sector, positive growth in nominal GDP was concentrated in ICT services (a percentage point change of 0.39). Only one of the high-knowledge service industries identified in Tables 7a and 7b, management consulting industries, is located in an industrial environment with larger growth in nominal GDP.[23] Financial service industries, three of which are classified herein as high-knowledge, also realized gains in their GDP share that were roughly comparable to those in ICT services.

The New Economy revolution of the 1990s fuelled substantial long-run employment gains in ICT services (an annualized rate of 5.3%). Yet four of the high-knowledge services listed in Table 7a—management consulting (6.7%), other financial intermediaries (11.7%), investment intermediaries (7.4%) and accounting and bookkeeping services (9.0%)—enjoyed larger long-run employment growth rates than ICT services. Average earnings growth also outpaced ICT services (3.1%) in other financial intermediaries (5.0%) and investment intermediaries (3.7%). Consumer and business financing intermediaries (3.8%) and lawyers and notaries (3.2%) are other high-knowledge services with significant long-run earnings growth.

Technology industries are both important producers and consumers of New Economy products and services. A large share of total investment in ICT service industries takes the form of expenditures on high-technology capital (hardware, software and telecommunications equipment). High-tech investment shares for ICT services in the recent reference period (1994-2002) were, on average, about 5 percentage points greater than for the historical period (1981-1989). Similar long-run gains in technological intensity (a shifting of the investment mix towards high-tech commodities) are also apparent in financial services—with an average increase of 7 percentage points between the two periods. While these growth comparisons mask basic differences in investment levels (ICT services, in both periods, exhibited much larger high-tech investment shares than all other service groups examined here), they do underscore the increasing role that advanced technology plays in the provision of traditional services such as financing.[24] A recent survey of firms in the banking and insurance industries highlights relationships between technological capital and innovation—over 90% of innovative financial services firms reported that computers and software were important to their innovation activities, while 50% of innovators identified high performance communications networks as important innovation inputs (Baldwin *et al.* 1998; Gellatly and Peters, 2000).

Our analysis of structural variables (measures of urbanization, degree attainment and female participation) is designed to highlight basic differences in the production environments that characterize high-knowledge industries. Technology industries are widely viewed as an urban phenomenon.[25] But high levels of urbanization are hardly unique to science- or technology-based environments. Employment in many of the knowledge-based services listed in Tables 7a and 7b is highly concentrated in large cities.[26] Only the two resource sector industries in our high-knowledge group—crude petroleum and natural gas industries and services incidental to fishing—have CMA shares less than 70% (54% and 20% respectively).[27] Even when the more stringent urbanization criteria is used (which focuses on employment in the four largest urban areas), many high-knowledge industries, particularly in financing and professional services, maintain urban employment shares that are comparable to the technology sector.

Sharper differences emerge when examining the educational characteristics of the high-knowledge workforce. While the technology sector has much higher levels of degree attainment than the business sector average, several service industries in our high-knowledge group exhibit attainment rates that are significantly higher than the technology services average (35%). Examples include management consultants (52%), lawyers and notaries (50%) and professional membership associations (44%).

Table 7a. Select growth and demographic characteristics: High-knowledge industries in non-ICT/non-science environments (first tier, based on employment coverage)

	KW score (%)	GDP growth (1987-1997)	Employment growth (1991-2001)	Wage growth (1991-2001)	Change in average ICT investment intensity (1981-1989, 1994-2002)	Urban share (all CMAs (2001)	Urban share (largest CMAs (2001)	Degree incidence (2001)	Female partici-pation (2001)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High-knowledge industry:									
Management consulting services (777)	62.9	0.59 (+)	6.65 (+)	2.93 (-)	1.77 (-)	85.6 (-)	60.6 (-)	51.8 (+)	46.0 (+)
Other financial intermediary industries (740)	68.5	0.31 (-)	11.73 (+)	4.96 (+)	7.05 (+)	87.3 (-)	60.3 (-)	42.2 (+)	45.9 (+)
Theatrical and other staged entertainment services (963)	65.0	0.04 (-)	2.63 (-)	1.61 (-)	3.54 (-)	85.5 (-)	59.8 (-)	30.3 (-)	43.9 (+)
Investment intermediary industries (720)	60.5	0.31 (-)	7.37 (+)	3.66 (+)	7.05 (+)	87.9 (+)	64.6 (+)	43.2 (+)	52.0 (+)
Services incidental to fishing (032)	55.4	-0.11 (-)	1.41 (-)	1.14 (-)	0.84 (-)	20.4 (-)	5.0 (-)	20.5 (-)	26.1 (-)
Accounting and bookkeeping services (773)	54.9	0.10 (-)	9.03 (+)	2.22 (-)	1.77 (-)	72.4 (-)	45.6 (-)	39.9 (+)	61.6 (+)
Other services n.e.c (999)	49.4	0.03 (-)	1.50 (-)	1.35 (-)	3.73 (-)	72.7 (-)	46.0 (-)	31.4 (-)	51.0 (+)
Publishing industries (283)	48.8	0.09 (+)	3.21 (-)	2.02 (-)	6.92 (+)	79.2 (-)	57. 9 (-)	36.0 (+)	60.9 (+)
Business associations (982)	48.4	0.11 (-)	2.16 (-)	2.40 (-)	16.8 (+)	72.0 (-)	47.4 (-)	35.6 (+)	62.7 (+)
Labour organizations (984)	48.2	0.11 (-)	-0.34 (-)	2.10 (-)	16.8 (+)	79.6 (-)	48.1 (-)	22.5 (-)	52.3 (+)
Political organizations (985)	47.8	0.11 (-)	-1.17 (-)	2.79 (-)	16.8 (+)	79.9 (-)	43.0 (-)	38.0 (+)	61.1 (+)
Professional membership associations (983)	46.9	0.11 (-)	-0.55 (-)	1.81 (-)	16.8 (+)	91.7 (+)	69.1 (+)	44.3 (+)	72.5 (+)
ICT manufacturing	48.7	-0.04	3.48	3.08	5.4	84.2	65.0	31.6	35.1
ICT services	62.5	0.39	5.33	3.10	4.9	87.5	61.9	35.2	34.7

Shaded cells: indicate cases where the estimate corresponds to a more aggregate industrial grouping that contains the three-digit high-knowledge industry. (+) denotes larger than the corresponding ICT estimate; (-) denotes smaller than the corresponding ICT estimate.

Table 7b. Select growth and demographic characteristics: high-knowledge industries in non-ICT/non-science environments (second tier, based on industrial coverage)

	KW score (%)	GDP growth (1987-1997)	Employment growth (1991-2001)	Wage growth (1991-2001)	Change in average ICT investment intensity (1981-1989, 1994-2002)	Urban share (all CMAs (2001)	Urban share (largest CMAs (2001)	Degree incidence (2001)	Female partici-pation (2001)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
High-knowledge industry:									
Offices of lawyers and notaries (776)	46.3	0.10 (-)	0.39 (-)	3.20 (+)	1.77 (-)	80.1 (-)	52.7 (-)	50.4 (+)	64.2 (+)
Crude petroleum and natural gas industries (071)	44.3	-0.47 (-)	-1.63 (-)	3.31 (+)	0.13 (-)	53.6 (-)	1.5 (-)	28.0 (-)	28.3 (-)
Consumer and business financing intermediary industries (710)	43.1	0.31 (-)	3.11 (-)	3.79 (+)	7.05 (+)	84.7 (+)	57.6 (-)	32.5 (-)	59.1 (+)
Other services incidental to construction (449)	43.0	-1.55 (-)	0.21 (-)	2.17 (-)	0.86 (-)	71.1 (-)	42.0 (-)	25.4 (-)	31.4 (-)
ICT manufacturing	48.7	-0.04	3.48	3.08	5.4	84.2	65.0	31.6	35.1
ICT services	62.5	0.39	5.33	3.10	4.9	87.5	61.9	35.2	34.7

Shaded cells: indicate cases where the estimate corresponds to a more aggregate industrial grouping that contains the three-digit high-knowledge industry. (+) denotes larger than the corresponding ICT estimate; (-) denotes smaller than the corresponding ICT estimate.

While technology industries are often viewed as male-dominated, the same cannot be said for many of the high-knowledge examples identified above. Female workers make up over 60% of the workforce in 6 of 16 cases—professional membership associations (73%), lawyers and notaries (64%), business associations (63%), accounting and bookkeeping services (62%), publishing industries (61%), and political organizations (61%). Women account for more than half the workforce in four other industries—consumer and business financing (59%), investment intermediaries (52%), labour organizations (52%) and other services (51%). And in many of the cases noted above (examples include investment intermediaries, publishing industries, other services, and business associations) these female workforces include large concentrations of knowledge workers.

The above exercise is designed to shed new light on the high-knowledge landscape. Earlier research on the New Economy's industrial structure (e.g., Beckstead and Gellatly, 2003) has focused on the growth of highly-visible technology industries, and on industries that make relatively large investments in scientific knowledge. A singular focus on knowledge workers brings other industries into the limelight, most notably those that supply financial services. Financial service industries have dynamic growth profiles—with rates of output, employment, wage, and technological change that compare well with rates of growth in ICT services. And financial services are just as highly urbanized as emergent technology industries. But financial services does yield a slightly different perspective on the demographics of the high-knowledge sector. The two financing industries in our first-tier group—other financial intermediaries and investment intermediaries—have slightly higher rates of degree attainment than ICT services. All of the financial services that are classified as high-knowledge employ a much higher percentage of female workers than ICT services. And the two first-tier financial services (other financial intermediaries and investment intermediaries) also contain large concentrations of female knowledge workers.

One other characteristic of our high-knowledge classification warrants mention—its emphasis on service industries. All of the industry examples noted above are service based. Only three of the high-knowledge industries listed in Tables 7a and 7b are classified as goods-producing: publishing industries, crude petroleum and natural gas industries and services incidental to fishing.[28] And, on balance, none of these industries have growth profiles on par with ICT manufacturing.[29]

This service-based focus accords with our expectations. Firms in service industries are often characterized as less intensive users of traditional innovation inputs, such as R&D. In fact, the science-based classification proposed by Baldwin and Johnson (1999), which depends in part on R&D-intensity, places a strong emphasis on manufacturing industries and less emphasis on services (see Appendix A). In service industries, firm-level differences in innovation and growth are strongly associated with underlying differences in human resource strategies (Baldwin and Johnson, 1996; Baldwin, 2000). More successful service firms are those that develop skilled workers. In this light, it is not surprising that many of the largest concentrations of knowledge workers are found in service environments.

Endnotes

[16] This is discussed in Beckstead and Gellatly (2003).

[17] As in *Growth and Development*, we take care to ensure that our ICT sector definition(s) conform with the standards developed by the OECD. In certain cases (most notably for ICT services industries), estimates for specific ICT industries are "split out" of larger industrial aggregates, and then combined to arrive at ICT manufacturing and service estimates that conform with the OECD standard.

[18] The selected time frame for these GDP comparisons reflects a limitation in our data source—as consistent industrial definitions of the ICT sector, for the purpose of tracking long-run growth, are not (currently) available beyond 1997.

[19] Twenty-five urban centres across Canada are classified as CMAs.

[20] Four urban areas are included in this group: Toronto, Montreal, Vancouver and Ottawa–Gatineau.

[21] Or, more accurately, these are industries that contain no ICT- or science-based employment representation at the four-digit level.

[22] In practice, these measurement limitations can range from minor to severe, depending on the industry in question. The extreme case is services incidental to fishing. This high-knowledge industry accounts for only 7% of employment in the fishing and trapping industry, the level at which GDP growth is measured.

[23] The growth estimate for management consulting is distributed across a range of services, including employment agencies and personnel suppliers as well as a residual grouping of other business services.

[24] The long-run growth estimate associated with membership organizations (e.g., business, professional, political, and labour) exemplifies this "growth versus level" distinction; the industrial grouping that includes these services experienced sharp growth in its investment mix towards high-tech commodities (a 17 percentage point increase between the two periods). In the first period, however, the high-tech investment share for this industrial grouping was very low, compared to those for financial services or ICT services. Consequently, the sharp growth stems from a much lower initial emphasis on technological capital.

[25] For discussion, see Beckstead *et al.* (2003).

[26] Many of these services are significantly more urbanized than the business sector average. Seventy-two percent of employment in business sector services is found in urban areas with populations greater than 100,000. And 43% of service employment is concentrated in the four largest urban centers.

[27] The CMA average for goods industries is 57%.

[28] The SIC classifies these support services to the goods sector.

[29] Specific examples to the contrary are wage growth in the crude petroleum and natural gas industry and changes in technological investment in publishing industries—both of which compare well with growth trends in ICT manufacturing.

Chapter 6. Conclusion

These classification exercises raise important questions about the underlying dimensionality of what is often termed the Knowledge Economy. Previous research on knowledge-based firms from a recent Canadian survey (Baldwin and Gellatly, 1998, 1999, 2001) has demonstrated that there exist a number of different dimensions to advanced knowledge (these studies explore a range of innovation, technology and labour practices within new technology-based firms), and not all of these can be expected to produce consistent portraits of the high-knowledge sector.

Using current research on Canada's knowledge-based occupations, this study demonstrates that the flow of knowledge workers to different areas of the economy follows a similar pattern. While many ICT and science industries place a high premium on knowledge workers, ICT and science industries do not possess a monopoly on highly skilled, highly educated labour. This is not to suggest that ICT or science industries do not warrant the attention that they receive, or that their role in fostering systems of innovation should be downplayed. But investments in knowledge are ubiquitous—they are found in many different industries, not just in high technology sectors. To exclude these other industries from a systematic evaluation of our competitive assets is to give only a partial account of human capital investments that are essential for innovation and growth.

In this study, we concentrated on a single aspect of an industry's input structure—the representation of certain knowledge-based occupations in its employment base—in order to quantify its emphasis on knowledge. We chose to do so because knowledge workers are often seen as a primary determinant of industrial competitiveness. This occupational approach is illuminating because it casts many different industries into the limelight—industries outside of science and technology environments that may otherwise be overlooked in discussions about the New Economy. Exercises in classification, of the sort examined herein, may help give rise to healthy debates about "what ought to be measured" and "whether our current set of operational tools is appropriate". These, in turn, help to shine light on the underlying dimensionality of the New Economy.

The high-knowledge industries identified in this paper are noteworthy in that they are home to large concentrations of knowledge workers—workers in professional, management and technical occupations that require relatively large investments in education and/or pay relatively high wages. These are the most knowledge-intensive industries, when the metric for evaluating differences in knowledge is based entirely on occupational structure. Are these industries making substantial contributions to the growth of the New Economy? For readers whose concept of the New Economy is closely related to the increasing demand for skilled workers, the answer is most likely yes (presuming, of course, that one accepts the classification of knowledge workers proposed herein). Alternatively, readers for whom the idea of a New Economy is grounded in empirical indictors such as output and productivity growth, or in the growth of new innovative sectors that develop scientific and technological capital, there may be less justification for focusing on industries simply because they are home to large numbers of knowledge workers.

At a basic level, our objective in this paper has been to draw attention to what are often amorphous distinctions between widely used constructs such as New Economy and Knowledge Economy. In *Growth and Development*, we argued that a singular focus on the technology sector may obscure important industries—industries that via their investments in R&D and human capital, are also making significant contributions to the growth of the New Economy. In this paper, we adopted a singular focus on knowledge workers, and asked whether this yields a different set of "leading-edge" industries. To a certain extent it does. As to whether this influences perceptions about the industrial structure of the New Economy depends on how significantly one views the concentration of knowledge workers as a characteristics of the New Economy in its own right—apart from other characteristics of high-technology environments such as high rates of technological innovation and R&D activity.

Appendix A: Comparing ICT and science industries to high-knowledge industries

We want to draw attention to one factor that limits our ability to compare our list of *high-knowledge* industries to ICT or science-based industries. Industries are classified as high-knowledge using occupational data from 2001 census records. These census data collect information for 3-digit Standard Industrial Classification (SIC) industries (the second most detailed industry categories in the SIC). In contrast, ICT- and science-based industries are defined using 4-digit SIC industries (the most detailed industrial category in the SIC). This, in turn, has implications for how accurately we can state that a high-knowledge industry (defined at the 3-digit level) is also ICT- or science-based. In some cases, a 3-digit high-knowledge industry is comprised entirely of one or more 4-digit industries, all of which are all classified as ICT- or science-based. For example, the 3-digit industry Computer and Related Services (772) makes the grade as knowledge-based, and is made up of two 4-digit industries, Computer Services (7721) and Computer Equipment Maintenance and Repair (7722), both of which are classified as ICT industries. Here, the above measurement issue is moot. In other cases, the status of a high-knowledge industry as ICT- or science-based is less apparent. Telecommunications broadcasting industries (3-digit industry 481) is also classified as high-knowledge, and it is made up of 4 separate 4-digit industries, only one of which is classified as an ICT industry (cable television, SIC 4814). This one ICT industry, cable television, accounts for 29% of total employment in this larger 3-digit combination of telecommunications broadcasting industries. In this case, we are not able to ascertain whether the ICT-based cable television industry has different occupational characteristics than the three other (non-ICT) 4-digit industries which collectively make up telecommunications broadcasting (SIC 481).

A complete list of ICT- and science-based industries—defined at the SIC 4-digit level—is reported below. Analysis at the subsectoral level is found in Beckstead and Gellatly (2003).

Table A1. ICT and science subsectors

Sector	Subsector	SIC code	Description
ICT	Core ICT services	4821	Telecommunication carriers industry
		4839	Other telecommunication industries
		7721	Computer services
		7722	Computer equipment maintenance and repair
	Other ICT services	4814	Cable television industry
		5743	Electronic machinery, equipment and supplies, wholesale
		5744	Computer and related machinery, equipment and packaged software, wholesale
		5791	Office and store machinery, equipment and supplies, wholesale
		9913	Office furniture and machinery rental and leasing
	ICT manufacturing	3341	Record player, radio and television receiver industry
		3351	Telecommunication equipment industry
		3352	Electronic parts and components industry
		3359	Other communication and electronic equipment industry
		3361	Electronic computing and peripheral equipment industry
		3362	Electronic office, store and business machine industry
		3369	Other office, store and business machine industry
		3381	Communications and energy wire and cable industry
		3911	Indicating, recording and controlling instruments industry
		3912	Other instruments and related products industry
Science	ICT science		Above SIC except for 5743, 5744, 5791, 7722 and 9913
	Non-ICT science-based goods	0231	Agricultural management and consulting services
		0239	Other services incidental to agriculture n.e.c.
		3111	Agricultural implement industry
		3121	Commercial refrigeration and air conditioning equipment industry
		3191	Compressor, pump and industrial fan industry
		3192	Construction and mining machinery and materials handling equipment industry
		3193	Sawmill and woodworking machinery industry
		3194	Turbine and mechanical power transmission equipment industry
		3199	Other machinery and equipment industries, n.e.c.
		3211	Aircraft and aircraft parts industry
		3371	Electrical transformer industry
		3372	Electrical switchgear and protective equipment industry
		3379	Other electrical and industrial equipment industries
		3611	Refined petroleum products industry (except lubricating oil and grease)
		3612	Lubricating oil and grease industry
		3699	Other petroleum and coal products industries
		3711	Industrial inorganic chemical industries n.e.c.
		3712	Industrial organic chemical industries n.e.c.
		3721	Chemical fertilizer and fertilizer materials industry
		3722	Mixed fertilizer industry
		3729	Other agricultural chemical industries
		3731	Plastic and synthetic resin industry
		3741	Pharmaceutical and medicine industry
		3791	Printing ink industry
		3792	Adhesives industry
		3799	Other chemical products industries n.e.c.
		3913	Clock and watch industry
		3914	Ophthalmic goods industry
		4911	Electric power systems industry
	Non-ICT science-based services	4611	Natural gas pipeline transport industry
		4612	Crude oil pipeline transport industry
		4619	Other pipeline transport industries
		7751	Offices of architects
		7752	Offices of engineers
		7759	Other scientific and technical services
		9611	Motion picture and video production
		9619	Other motion picture, audio and video services

Source: Beckstead and Gellatly (2003).

Appendix B: What about governments, education and health care?

The high-knowledge groupings reported in Tables 2a and 2b draw exclusively from the business sector. This was done to ensure comparability—as all ICT- and science-based industries are located in the business sector. However, as Beckstead and Vinodrai (2003) note, there exist large concentrations of knowledge workers in the public sector, or in industries with extensive public sector intervention (education, health and social services). In what follows, we regenerate our (employment-based) set of high-knowledge industries without making any industry exclusions *ex ante*. As in Table 2a, the set of industries that are classified as high-knowledge is determined by a 10% employment threshold (here based on total employment, as opposed to business sector employment).

The inclusion of health, education and government industries has a significant impact on the composition of the high-knowledge group (Table B1). Education industries—post-secondary (non-university), secondary & elementary, and university—exhibit among the highest knowledge scores, as do medical and health laboratories. Because these industries employ large numbers of workers, the overall number of industries required to obtain the 10% cutoff is reduced from 16 to 8. Computer services and architecture and engineering are the only ICT or science industries represented in this total economy grouping.

Table B1. High-knowledge industries*
(based on employment threshold, full industrial coverage)

Industry (SIC)	Knowledge score*	% of industry employment classified as ICT-based	% of industry employment classified as science-based
1. Computer and related services (772)	83.7	100.0	97.8
2. Architectural, engineering and other scientific and technical services (775)	78.3	0	100.0
3. *Post-secondary non-university education (852)*	74.6	0	0
4. *Medical and other health laboratories (868)*	72.7	0	0
5. *University education (853)*	71.0	0	0
6. Management consulting services (777)	69.2	0	0
7. Other financial intermediary industries (740)	68.5	0	0
8. *Elementary and secondary education (851)*	65.9	0	0

*Industries in italics are not classified to the business sector.

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