Intangible Assets and Their Contribution to Productivity Growth in Ontario*

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Preliminary

Abstract

Recent empirical studies confirm that investment in intangible assets is a non-negligible component of business sector output. The contribution of intangible capital to total labour productivity growth is comparable to that of tangible capital for a wide range of the countries, including the US, UK, Canada, Germany, France etc. Following Corrado *et al.* (2005) and Baldwin *et al.* (2012), this paper focuses on an assessment of business sector investment in intangible assets and an analysis of the contribution of intangible capital to labour productivity growth at the provincial level in Canada, namely in Ontario. The findings indicate that the Ontario business investment in intangible assets accounts on average for 10 percent of revised business sector output in the 1998-2008 period. The growth rate of real investment in intangibles exceeds that of investment in tangible assets. Investment in economic competencies is as large as investment in innovative property and computerized information combined. The results of this growth accounting exercise demonstrate that intangible capital contributes significantly to the total labour productivity growth in Ontario. In 1998-2008 intangible capital contributed on average 26.2 percentage points to total labour productivity growth while tangible capital contributed 17.9 percentage points and labour composition contributed 8.7 percentage points. Innovative property contributed the most among all categories of intangible capital, followed by economic competencies and computerized information.

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1 Introduction

"Research has highlighted the important role played by intangible capital, such as the knowledge embodied in the workforce, business plans and practices, and brand names. This research suggests that technological progress and the accumulation of intangible capital together accounted for well over half of the increase in output per hour in the United States during the past several decades"

Ben Bernanke, Chairman of the Federal Reserve, keynote address to the opening of the New Building Blocks for Jobs and Economic Growth Conference (May 2011)

Canada in general and Ontario in particular has a significant prosperity gap with international peers, most notably in the United States[1]. According to the Task Force on Competitiveness, Productivity and Economic Progress, this prosperity gap is a productivity gap[2]. In Ontario, average annual labour productivity growth has slowed down from 1.3 percent between 1985 and 2000 to 0.5 percent between 2001 and 2010[3].

Productivity growth comes from various sources. The contribution of labour composition and physical, or tangible, capital deepening to total labour productivity has been well researched. Currently, the major challenge is to measure investment in intangible assets and assess the size of the stock of intangible capital as well as the contribution of intangible assets to total labour productivity growth.

Intangible assets are generally defined as assets that provide future benefits but do not have a physical embodiment. A study of intangibles, conducted by Corrado *et al.* (2009), pioneered research of intangible assets and their contribution to labour productivity growth in the US. Similar studies have been conducted in Canada, Australia and Europe. Currently, it is commonly accepted that the main categories of intangibles include[4]:

- Computerized information:
  - software, which consists of purchased software and own-account spending on software;
  - computerized databases, i.e. expenditures on data processing and database activities.
- Innovative property:

[1] "Today's Innovation, Tomorrow's Prosperity", Task Force on Competitiveness, Productivity and Economic Progress, 9th annual report, 2010

[2] ibid

[3] 2012 Ontario Budget, p.149

[4] Corrado *et al.*, (2009)

- scientific and engineering research and development (R&D) that leads to a patent or a licence that includes industrial R&D, R&D expenditures in mining, oil and gas extraction and other geophysical and geological explorations;
- non-scientific R&D that includes information sector R&D that leads to a copyright or license and service industries R&D that might not lead to a patent or copyright;
- development costs in financial industry;
- new architecture and engineering design; and
- other science and engineering services.

- Economic competencies:
  - brand equity, i.e. purchased advertising and market and consumer research;
  - investment in human capital that includes direct and indirect expenses on training;
  - organizational structure that comprises cost of purchased and own account organizational change.

Until recently, spending on intangible assets was counted as an intermediate expense in the systems of national accounts rather than as investment in intangible capital. Corrado *et al.* (2009) indicate that specific features of intangible assets, such as non-rivalness and lack of verifiability, visibility and appropriability of the returns explain the fact that the majority of intangible assets are disqualified as capital[5]. The authors, however, argue that these distinct features do not make intangible assets an intermediate good. They simply differentiate intangible capital from other types of capital. Despite their uniqueness, intangible assets share core characteristics of physical capital. As any other type of capital, intangibles are used in production of goods and services and provide future benefits. As investment in physical capital, investment in intangible assets represents foregone current consumption for the benefit of greater future consumption.

Thus, intangible assets should be classified as capital; and, spending on intangibles should be counted as investment rather than operational or intermediate expenses. Otherwise, the aggregate level of economic activity remains underestimated. This potentially creates distortions in business investment and resource allocation. In addition, effectiveness of public policy may also be adversely affected if investment and capital in the economy are measured imprecisely. These negative effects could ultimately lead to a decline in productivity and economic growth.

[5]For details see Corrado *et al.* (2009)

The recent empirical evidence shows that intangible capital contributes significantly to productivity growth, which is ultimately reflected in economic growth. Belhocine (IMF Working Paper 240, 2009) finds that in Canada, if spending on intangible assets is not included in aggregate investment, the real gross domestic product (GDP) growth is on average underestimated by 0.1 percentage point per year from 1999 to 2001. It is underestimated by about 0.25 percentage points for 2004. Corrado *et al.* (2009) indicate that in the U.S., if investment in intangibles is not included, GDP growth is underestimated by about 0.25 percentage points per year from 1995 to 2002.

Van Ark *et al.* (2009) examined the contribution of intangible capital deepening to the total labour productivity growth in the U.S. and selected European countries for the period from 1995 to 2006. In the U.S., it is estimated that intangible capital deepening contributed on average 0.83 percentage points, or about a quarter, to the annual change in total labour productivity. A similar picture emerges in the larger European countries. The estimates show that growth in intangible capital per unit of labour contributed on average around 0.72, 0.69, 0.5 and 0.4 percentage points to the annual growth rate of total labour productivity in Denmark, U.K., France and Germany respectively.

According to a study of intangible assets and productivity growth, conducted by the Australian Government Productivity Commission in 2010, the estimated average annual productivity growth rate in Australia market sector between 1993-1994 and 2005-2006 is 0.24 percentage points higher when all intangibles are capitalized. Moreover, in both the manufacturing and the service sectors, labour productivity growth rate increased after capitalizing all intangibles as compared to no intangibles. Labour productivity growth rate is 0.43 and 0.19 percentage points (or around 19 and 8 percent) higher in the manufacturing and the services sectors respectively when intangibles are treated as capital.

Growing global interest in intangible capital has drawn a lot of attention to knowledge-creating investments and has led to world-wide recognition of intangibles as an important source of productivity and economic growth. As a result, some categories of intangibles have already been capitalized in the systems of national accounts. In Canada, prior to December 2012, only software and mineral exploration expenditures were treated as investment in the System of National Accounts. As a result of a historic revision of the national accounts, completed by Statistics Canada in December 2012, spending on research and development, along with software and oil and gas and mineral exploration, is treated as investment and capitalized in the national accounts in the intellectual property products category[6].

The paper is organized as follows. The next section describes the data sources for our estimates of business sector investment in intangibles in Ontario. Section

[6]Canadian System of National Accounts 2012 Historic Revision

3 examines the state of investment in intangibles in the province. The results of the growth accounting that includes intangible assets as inputs of production are summarized in section 4. Section 5 concludes the paper.

2 Data Sources

Computerized Information

Following Corrado's *et al.* (2005) definition, computerised information comprises two categories: software and computerized database. Since spending on software has been capitalized in the Canadian System of National Accounts, Statistics Canada publishes provincial total industry software investment data as part of non-residential investment (CANSIM table 031-0004) and provincial business sector investment in total intellectual property products, which includes oil and gas and mineral exploration, research and development, and software (CANSIM table 031-0002). Ontario's business sector investment in software is estimated using the share of investment in software in the total industry's intellectual property product category.

Statistics Canada also provides detailed estimates of own-account and purchased software expenditures at the national level. The data are currently unavailable for both business sector own-account and purchased software expenditures at the provincial level.

Computerized databases are not capitalized in the national accounts. Expenditure on computerized databases is used as a proxy for investment in this category of intangibles. Such an expenditure, however, is not directly observed, so as in Belhocine (2009), expenditure on computerised databases is approximated by operating revenues of the data processing, hosting and related service industries (NAICS[7] code 51821), which are published by Statistics Canada in the CANSIM table 354-0005.

Innovative Property

Two categories of innovative property – research and development and oil and gas and mineral exploration – have also been capitalized in the Canadian System of National Accounts. Statistics Canada publishes provincial total industry investment in R&D and oil and gas and mineral exploration as part of non-residential investment (CANSIM table 031-0004) and provincial business sector investment in total intellectual property products (CANSIM table 031-0002). As with investment in software, Ontario's business sector investments in R&D and in oil and gas and mineral exploration are estimated using the shares of investments in oil and gas

[7]North American Industry Classification System

and mineral exploration and in R&D in the total industry's intellectual property product category.

As in Corrado *et al.* (2009) and Baldwin *et al.* (2012), other categories of innovative property are approximated by expenditure on:

- development costs in financial industry;
- new architecture and engineering design; and
- other science and engineering services (purchased and own-account).

Similar to other industries, the financial services industry is engaged in research and development of new processes and products. According to Baldwin *et al.* (2012), this industry's research and development expenditure should be accounted for in the total investment in intangible assets. Since it is not explicitly observed, development cost in the financial industry is approximated by total intermediate purchases by the financial services industry (NAICS 521 and 522)[8]. According to Corrado *et al.* (2005), only 20 percent of the purchases are counted as investment.

Corrado *et al.* (2005) estimated the value of new architecture and engineering design from the revenues of architectural and engineering design industries. For the presented study, the data on the revenues of these industries are obtained from the Ontario input-output tables of Statistics Canada. Ontario's business sector investment in new architecture and engineering design is estimated as 50 percent of total expenditure on architectural and engineering services (NAICS 5413). The data are combined with "purchased other science and engineering services"so as to meet confidentiality requirements. The purchased other science and engineering services are approximated by business sector spending on royalties and licensing fees, which are also obtained from the Ontario input-output tables.

Baldwin *et al.* (2009) suggest that knowledge creation happens not only in the natural and social sciences, humanities, finance and other sectors outlined by Corrado *et al.* (2005), but also in other industries, scientific activities of which are not captured in R&D statistics. Thus, the innovative property category of intangibles should include own-account other science and engineering expenditures and purchased other science and engineering expenditures.

Following Baldwin *et al.* (2009), own-account other science and engineering investment is approximated by the labour compensation of scientists and engineers. Only 20 percent of total expenditure is counted as investment. In addition, industries such as financial services (NAICS 521), architectural, engineering and related services (NAICS 5413), management, scientific, and technical consulting services (NAICS 5416), scientific research and development services (NAICS 5417), advertising and related services (NAICS 5418), and other professional, scientific and tech-

[8]Baldwin *et al.* (2012) indicate that partial double-counting is possible.

nical services (NAICS 5419) are excluded. Investments in intangible assets in these industries are already captured in other categories of intangibles. To avoid double-counting, the wage component of software and R&D expenditure is also excluded from this category.

Economic Competencies

Economic competencies is the third broad category of intangible assets. It is commonly accepted[9] that knowledge that is imbedded in brand names, firm specific human capital and organizational structure should be treated as intangible assets; and, business expenditure on these assets should be counted as investment. Following existing studies of intangible investment, this study includes advertising expenditure as brand equity, direct and indirect firm expenses on training as firm specific human capital and purchased and own-account organizational structure in the economic competence category of intangible assets.

Investment in advertising is estimated as 60 percent of total business sector expenditure on various advertising services and products[10]. It can be argued that advertising spending spending only redistributes sales among firms, and does not create value[11]. However, "such spending is necessary for developing new brands and maintaining the value of existing brands"[12]. Direct firm expenses on firm specific human capital comprise the costs of developing workforce skills, such as on-the-job training, tuition reimbursement, etc. Indirect expenses are related to the opportunity cost of employee time spent on formal and informal training. Direct and indirect expenses are estimated as annual spending by business sector on learning and development. Currently, provincial data are not available, thus the Ontario business investment on firm specific human capital is estimated using the data on direct Canadian business sector direct annual spending per employee.

Investment in organizational structure plays an important role in building the stock of intangible capital. According to the economic literature, successful implementation of information and communication technology (ICT), namely achievement of a significant productivity improvement, is possible if the implementation is accompanied by organizational change[13]. As in Corrado *et al.* (2005), purchased investment in organizational structure is approximated by the total revenue of the management consulting services industry (NAICS 54161). Own-account investment in organizational structure is estimated as 20 percent of labour compensation of total management occupations.

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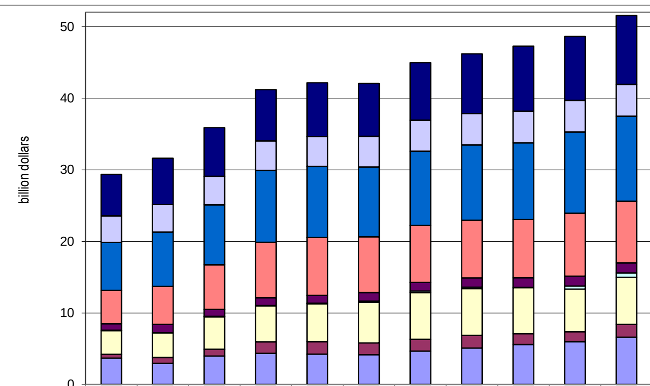
[9] See Corrado *et al.* (2005, 2009), Baldwin *et al.* (2012), Van Ark *et al.* (2009)
[10] See Appendix for a compete list.
[11] Thanks to Andrew Sharpe for bringing it to my attention
[12] Corrado *et al.* (2005)
[13] Guiri *et al.* (2005)

3 Investment in Intangibles in Ontario

In this paper it is estimated that in 2008, Ontario's businesses spent 51.6 billion dollars[14] on intangibles, which is 22.2 billion dollars more than the businesses spent on intangibles in 1998. According to these estimates, every year starting from 2001, business investment in intangibles assets in Ontario exceeds business investment in tangible assets(see Figure 1).

Figure 1: Nominal Intangible Investment in Ontario



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
3.3. Organizational Structure	5.8	6.5	6.8	7.2	7.5	7.4	8.0	8.4	9.1	8.9	9.6
3.2. Firm Specific Human Capital (training cost)	3.7	3.8	4.0	4.1	4.2	4.3	4.3	4.4	4.4	4.4	4.4
3.1. Brand Equity	6.7	7.6	8.4	10.0	9.9	9.7	10.4	10.5	10.7	11.3	11.9
2.4. New Architecture and Engineering Design and 2.5. Other Science and Engineering Services	4.7	5.3	6.2	7.8	8.1	7.8	8.0	8.1	8.1	8.8	8.6
2.3. Development Costs in Financial Industry	0.9	1.2	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4
2.2. Oil, Gas and Mineral Exploration	0.1	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.4	0.6
2.1. R&D	3.3	3.4	4.5	5.0	5.3	5.7	6.5	6.5	6.4	6.0	6.6
1.2. Computerized Databases	0.5	0.8	1.0	1.6	1.7	1.6	1.6	1.8	1.5	1.4	1.8
1.1. Software	3.7	3.0	4.0	4.4	4.3	4.2	4.7	5.1	5.6	6.0	6.6

Source: Statistics Canada, author's calculations

Similar to existing studies of intangible assets in the US, UK, Canada, Europe and Australia, presented paper found that economic competencies is the largest category of investment in intangibles in Ontario (see Figure 2. In 2008, the Ontario business sector spent almost 26 billion dollars on brand equity, firm-specific human capital and organizational change. The share of the economic competencies category in the total amount of nominal investment in intangibles was around 50 percent for the better part of the last decade. Brand equity (advertising expenditure) and organizational structure are the largest components of the economic competencies

[14] Canadian dollars

category, In 2008, businesses in Ontario spent around 12 billion dollars on brand equity and 10 billion dollars on organizational structure. Estimated expenditure by Ontario businesses on advertising contributed almost 70 percent to the total business spending on advertising in Canada in 2008 (as estimated by Baldwin *et al.* (2009)). Given that some data are not available at the provincial level and the estimation approach that we used for the purpose of this study differs from the one adopted by Baldwin *et al.* (2009), the estimates of the Ontario business sector expenditure on firm-specific human capital cannot be compared with the national estimates.

Innovative property is the second largest component of investment in intangibles in Ontario. According to my estimates, Ontario businesses spent around 17 billion dollars on this category of intangible assets. This expenditure amounted to 33.4 percent of total business spending on intangibles.

Figure 2: Composition of the Total Intangible Investment in Ontario

Source: Statistics Canada, author's calculations

Expenditure on research and development and combined expenditure on new architecture and engineering design and purchased other science and engineering are the major business sector investments in innovative property in Ontario. In 2008, these two categories amounted to 38.3 percent and 50.1 percent of total businesses expenditure on innovative property respectively. Development cost in the financial industry is a non-negligible component of investment in innovative property. In Ontario, estimated business spending on this type of intangibles was around 1.4 billion dollars in 2008.

In Canada, mineral exploration is a relatively significant part of business spending on innovative property, accounting for about 8 percent of total business investment in intangibles in 2008. Perhaps because other provinces in Canada are either better endowed with natural resources or at a more advanced stage of the resource exploration, Ontario's share of business expenditure on oil, gas and mineral exploration is quite modest - 1.14 percent of total business spending on intangibles in the province. Ontario.

Computerized information is the smallest category of total investment in intangibles. In 2008, the share of computerized information in total business spending on intangibles was circa 8.4 billion dollars or 16.3 percent of the total spending on intangibles by businesses in Ontario. Software is the largest component of this category of intangible assets. In 2008, the Ontario business sector spending on software amounted to 79 percent of total business spending on computerized information.

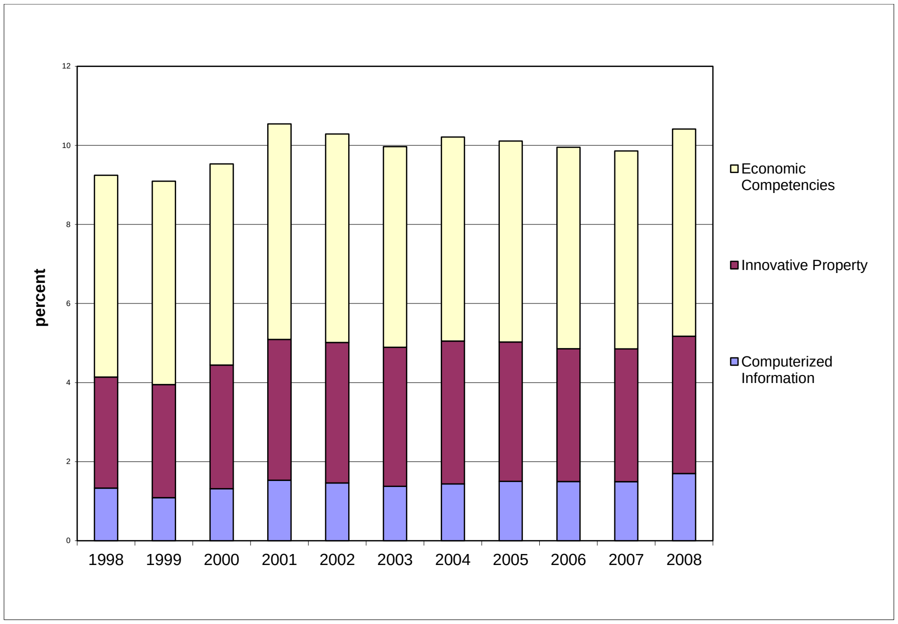
Empirical evidence shows that investment in intangible capital contributes significantly to the total value of business sector output. In Ontario, as a percentage of the total business sector output[15], business investment in intangible assets increased from 9.2 percent of the output in 1998 to 10.4 percent of the output 2008 (see Figure 3). At the same time, the share of investment in tangible assets, i.e. machinery and equipment, buildings and structures, fell from 12 percent of business sector output in 1998 to 10 percent of business sector output in 2008.

In real terms, business investment in intangible assets in Ontario has been growing steadily for the better part of the 1998-2008 period (see Table 1). Similar to business investment in tangible capital, investment in intangibles is highly volatile and very sensitive to business cycles. According to my estimates, the peak of the annual growth in real investment in intangibles in Ontario was in 2001, when investment in intangibles grew at the annual rate of 5.6 percent. After the "dot com" bust in 2000, the growth rate of investment in intangibles dropped to negative 0.3 percent in 2003, but recovered quickly to 2.7 percent in 2004. After a dip to 0.9 percent during the recent recession, the annual growth rate of investment in intangibles increased to 2.1 percent in 2008. In contrast, the growth rate of investment in tangible capital was only 1.1 percent in 2008.

During the 1998-2000 period, expenditure on computerized databases and oil, gas and mineral exploration and evaluation were the fastest growing categories of

[15] Revised output - estimates of business sector investment in intangibles are included in business sector output.

Figure 3: Intangible Investment as a percentage of Ontario's Business Sector Output.



Source: Statistics Canada, author's calculations

Ontario's business investment in intangibles. However, given its modest contribution to the total intangible investment, Ontario's business expenditure on mineral exploration and evaluation did not have a significant impact on the overall growth rate of expenditure on intangibles.

4 Growth Accounting

The Solow-Jorgenson-Griliches source-of-growth framework is traditionally used to evaluate the contribution of various inputs of production to total labour productivity growth. The method is based on evaluation of the income shares and the growth rates of inputs of production:

$$g_{Q,t} = s_{L,t} \times g_{L,t} + s_{K,t} \times g_{K,t} + g_A \tag{1}$$

Corrado *et al.* (2009) argue that this framework underestimates output and

Table 1: Growth Rate of Real Investment in Intangible Capital, percent

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	99-08
Total Intangible Assets	3.4	5.2	5.6	0.3	-0.3	2.7	1.1	1.1	0.9	2.1	2.2
1. Computerized information	-3.5	12.2	9.0	1.0	2.3	6.2	4.8	5.7	3.5	4.6	11.3
1.1. Software	-8.5	13.8	4.7	0.6	4.4	8.4	5.4	8.5	4.9	3.7	12.4
1.2. Computerized databases	17.8	6.4	22.4	2.1	-3.4	-1.0	2.6	-7.3	-5.1	10.7	6.2
2. Innovative property	4.6	6.9	6.6	0.9	-0.1	2.3	0.0	-1.3	0.5	1.1	2.9
2.1. Business R&D	1.3	11.6	4.0	1.2	2.2	5.3	-0.4	-1.8	-4.3	3.8	2.9
2.2. Oil, gas and mining exploration	-17.0	28.7	17.6	27.3	20.6	9.7	-6.6	49.7	81.6	14.5	25.8
2.3. Development costs in financial industry	11.8	-8.4	4.4	-1.4	2.5	0.5	2.2	0.3	0.8	-0.1	2.7
2.4. New architecture and engineering design and 2.5.2. Purchased other science and engineering services	6.0	6.3	9.7	1.3	-2.5	0.2	-0.5	-0.7	2.5	-1.7	2.4
2.5.1. Own account other science and engineering services	2.2	6.2	1.8	-6.2	-0.7	-1.2	6.5	0.8	-1.2	1.6	0.4
3. Economic competencies	4.2	2.7	4.2	-0.3	-1.1	2.0	0.5	0.9	0.0	1.7	2.3
3.1. Brand equity	5.2	3.9	7.2	-1.5	-1.7	1.9	0.1	-0.3	1.4	1.5	2.5
3.2. Firm-specific human capital	1.6	1.7	1.3	0.6	1.0	0.5	0.3	0.5	0.0	0.2	1.3
3.3. Organizational structure	4.5	1.6	1.7	1.0	-1.5	2.9	1.1	2.6	-1.8	2.6	2.5

Source: Statistics Canada, author's calculations

productivity growth. In addition, since intangible capital is not included in the conventional growth accounting framework, the estimates of the contribution of physical capital, labour and technology are biased. Thus, intangible capital should be included in an analysis of output and productivity growth.

I first start with the estimates of intangible capital stock. Currently, only the software, R&D and oil, gas and mineral exploration categories of intangible assets are measured and reported by Statistics Canada. Thus, the perpetual inventory method is used to construct the series of estimates of the real intangible capital stock, R_t. This method also requires estimates of the real investment in intangible assets, N_t, investment growth rate, g, depreciation rates of intangible assets, δ, and an estimate of the initial capital stock, R_0:

$$R_0 = \frac{N_0}{\delta + g} \tag{2}$$

$$R_t = N_t + (1 - \delta) \times R_{t-1} \tag{3}$$

Investment growth rate, g, is estimated as the annual average growth rate for the first three years of the available data series. Real investment in intangibles is estimated using software price indexes and output deflators. Depreciation rates for each category of intangible assets are taken from Corrado *et al* (2009) and Baldwin *et al.* (2012) (see Table 2).

Table 2: Depreciation Rates for Intangible Capital

1.	Computerized Information		0.33
2.	Innovative Property		
	2.1.	Business R&D	0.2
	2.2.	Oil, gas and mineral exploration and evaluation	0.134
	2.3.	Development costs in financial industry	0.2
	2.4.	New architecture and engineering design	0.2
	2.5.	Other science and engineering services	0.2
3.	Economic Competencies		
	3.1.	Brand equity	0.6
	3.2.	Firm-specific human capital	0.4
	3.3.	Organizational structure	0.4

Source: Corrado *et al.* (2009), Baldwin *et al.* (2012).

The estimates indicate that real intangible capital stock grew steadily for the better part of the last decade and reached 163 billion dollars in 2008. Innovative property is the largest category of intangible capital. It accounts for more than half of the total stock of intangibles. Innovative property is followed by the economic competencies and computerized information categories of intangible capital, which reached 49 and 21 billion dollars in 2008 respectively. Real intangible capital stock grew at an average annual growth rate of 2.53 percent in the 1998-2008 period. Computerized databases, being one of the smallest categories of intangibles, was the fastest growing category of intangible capital. It grew at an average annual rate of 5.8 percent for the same period. "Business R&D" and "New architecture and engineering design", combined with "Purchased other science and engineering services", also grew at the above average rate of 4.1 and 3.1 percent respectively. The annual average growth rate of intangible capital in the software and firm-specific human capital categories was the lowest among all intangible assets. In the period 1998-2008, each of these two categories grew at the average annual growth rate of 0.91 percent.

Having estimated the stock of intangible capital, I can proceed with the growth accounting exercise. It is assumed that the production function is a constant return to scale Cobb-Douglas function:

$$Y_t = A \times {K_t}^{\alpha} \times {R_t}^{\beta} \times {L_t}^{1-\alpha-\beta} \tag{4}$$

where Y_t is business sector output, A - technology, K_t - tangible capital, R_t - intangible capital, L_t - labour, and α and β are input shares.

In contrast to the conventional growth accounting equation, equation (4) includes intangible capital as an input of production. The accumulation equation for intangible capital is similar to that of tangible capital and is given by equation (3). Intangible capital is also included in the output identity equation:

$$P_{Q,t} \times Q_t = P_{L,t} \times L_t + \sum_{i=1}^{n}(P_{K_{i,t}} \times K_{i,t}) + \sum_{j=1}^{m}(P_{R_{j,t}} \times R_{j,t}) \tag{5}$$

where Q_t is business sector output[16], i and j - categories of tangible and intangible capital respectively.

Following Corrado *et al.* (2009), intangible capital is added to the conventional growth accounting method[17] to examine the contribution of intangible capital to productivity growth in Ontario.

The source-of-growth system of equations is derived taking logarithmic differentiation of equation (4):

$$g_{Q,t} = s_{L,t} \times g_{L,t} + s_{K,t} \times g_{K,t} + s_{R,t} \times g_{R,t} + g_A \tag{6}$$

The income shares of the inputs of production are also derived from the output identity equation:

$$s_{L,t} = \frac{P_{L,t} \times L_t}{P_{Q,t} \times Q_t} \tag{7}$$

$$s_{K,t} = \frac{P_{K,t} \times K_t}{P_{Q,t} \times Q_t} \tag{8}$$

$$s_{R,t} = \frac{P_{R,t} \times R_t}{P_{Q,t} \times Q_t} \tag{9}$$

$$\tag{10}$$

where g stands for the rate of growth of the respective variable and s stands for the input share of a respective variable, P stands for the user cost associated with the user services of respective input, K_t is a sum of all categories of tangible capital and R_t is a sum of all categories of intangible capital.

The growth rates of labour and capital inputs are calculated using annual data on labour input, tangible capital stock and annual estimates of intangible capital

[16]Business sector output includes investment in intangibles

[17]Solow-Jorgenson-Griliches sources-of-growth framework

stock. Both tangible and intangible capital are not consumed entirely in production process. Thus, the user cost of capital services is required to estimate an income share of each category of capital. The measure of the user cost of capital is based on the rate of return to capital and a price of investment in each category of capital. The growth accounting framework allows for either endogenous or exogenous rate of return to capital. Following Corrado *et al.* (2009) I use an endogenous rate of return to capital. I also assume that if an arbitrage opportunity exists then business investments will flow to a specific category of capital until an arbitrage opportunity is eliminated. Thus it is assumed that the net real rate of return to capital is equalized across all categories of tangible and intangible capital. There is an ongoing debate in economic literature whether real or nominal rate of return should be used in the growth accounting[18]. For the purposes of this study the net real rate of return is used. The user cost of capital is calculated using equation:

$$P_t{}^{R_i} = (r_t + \delta_i - \pi_{i,t}) \times P_t{}^{N_i} \tag{11}$$

where r is the real rate of return and π is expected capital gains. The expected capital gains term is calculated using a three-year moving average of changes in the output deflator.

The modified growth accounting equation (6) was used to estimate the contribution of both tangible and intangible capital, labour and technology to the total labour productivity growth. The results indicate that multifactor productivity and total capital deepening were the major contributors to the total labour productivity growth in Ontario in the 1998-2008 period.

Intangible assets contribute significantly to business sector output and total labour productivity growth in Ontario. In the 1998-2008 period, intangibles contributed on average 0.34 percentage points while tangible capital contributed on average 0.23 percentage points to productivity growth in Ontario. For almost every year from 1998 to 2008 the contribution of intangible assets to the total labour productivity growth in the province exceeded that of tangible capital. Moreover, in contrast to tangible capital, in each year from 1998 to 2008 the contribution of intangibles to labour productivity growth was positive. In 2003, when tangibles dragged labour productivity growth down by 0.28 percentage points, intangibles added 0.18 percentage points to labour productivity growth.

Not surprisingly, when intangibles are included in growth accounting, the share of total capital deepening in the total labour productivity growth is greater than the percent contribution of tangible capital deepening. At the same time, the shares

[18] Baldwin and Gu (2007) provide an excellent discussion on the alternative ways to estimate capital services.

of labour and multifactor productivity are smaller when compared with the results of no-intangibles growth accounting.

In a study of labour productivity in Ontario, which does not include intangible assets, the Centre for the Study of Living Standards[19] estimated that capital deepening, labour quality and multifactor productivity contributed 32.3, 18.8 and 48.1 percent to the total labour productivity growth by source from 1997 to 2007. The results obtained in the presented study and CSLS's results differ because in the latter the contribution of intangible assets to the total labour productivity growth was partially and implicitly counted in the contribution of labour and multifactor productivity. Thus, by including intangibles into productivity analysis we not only expand our knowledge of productivity and the sources of productivity growth but we also partially eliminate the biases inherent in the conventional growth accounting framework.

The contribution of each major category of intangibles – computerized information, innovative property and economic competencies – to the total labour productivity growth varies for different jurisdictions (see Table 4). According to Van Ark *et al* (2009), in Austria, Spain and Germany innovative property contributes more than a half of the total contribution of intangibles to labour productivity growth. The authors estimate that the greatest contribution of innovative property to labour productivity growth was in Germany. It reached 60.5 percent of total contribution of intangibles in the 1995-2006 period. Economic competencies are reported to contribute the most to labour productivity growth in the US[20] and UK[21] – 41.7 and 45.9 percent of total contribution of intangible assets respectively. Van Ark *et al* also reports that computerized information contributed the most to the total labour productivity growth only in Denmark – 40.3 percent of total contribution of intangibles. In other jurisdictions, such as the US, UK, and France computerized information contributed almost one-third of the total contribution of intangibles. Moreover, in the US the share of computerized information has increased from 27.9 percent in 1973-1998 to 32.1 percent in 1995-2003.

Presented study of the contribution of intangibles to productivity growth reveals that in Ontario innovative property contributed the most to the total labour productivity growth in the 1998-2008 period – 0.15 percentage points, followed by economic competencies with 0.11 percentage points and computerized information with 0.06 percentage points.

I also find that in the innovative property category, scientific and engineering research and development and new architecture and engineering design, combined with purchased other science and engineering, contributed 0.07 percentage points

[19] CSLS research report, April 2011
[20] Corrado *et al.*, 2009
[21] Haskel *et al.*, 2011

Table 3: Total Labour Productivity Growth by Source, selected jurisdictions

Sources	US 1973-1998		US 1995-2003		UK 1995-2006		Canada 2000-2008		Ontario 1998-2008	
Labour productivity growth	1.63	100	3.09	100	2.24	100	0.8		1.30	100
Contribution of:										
1. Capital deepening	0.97	59.5	1.68	54.4	1.18	52.7	1.4		0.57	44.2
1.1. Tangibles	0.55	33.7	0.85	27.5	0.67	29.9	0.8		0.23	17.9
1.2. Intangibles	0.43	26.4	0.84	27.2	0.51	22.8	0.6		0.34	26.2
2. Labour composition	0.25	15.3	0.33	10.7	0.16	7.1	0.3		0.11	8.7
3. Multifactor productivity	0.41	25.2	1.08	35.0	0.9	40.2	-0.8		0.61	47.2
Contribution of Intangibles										
1.2. Intangible capital deepening	0.43	100	0.84	100	0.37	100	0.6	*	0.34	*
1.2.1. Computerized information	0.12	27.9	0.27	32.1	0.1	27.0	0.1	16.7	0.06	17.6
1.2.2. Innovative property	0.13	30.2	0.22	26.2	0.09	24.3	0.2	33.3	0.15	44.1
1.2.3. Economic competencies	0.17	39.5	0.35	41.7	0.17	45.9	0.2	33.3	0.11	32.4

Source: US estimates are from Corrado *et al.* (2009), Canadian estimates are from Baldwin *et al.* (2012), UK estimates are from Haskel *et al.* (2011), Ontario estimates are author's calculations * detail may not sum to totals due to rounding

each. Development costs in financial industry contributed 0.01 percentage point. The contributions of mineral exploration and own account other science and engineering services were relatively small - only 0.003 and 0.004 percentage points respectively.

It is estimated that brand equity from the economic competencies category contributed 0.07 percentage points to total labour productivity growth. Purchased organizational structure and own account organizational structure contributed equally - 0.02 percentage points each. Firm specific human capital was not a significant source of productivity growth in 1998-2008 in Ontario. This category added only 0.0014 percentage points to the total labour productivity growth.

In contrast to the US, UK, France, Italy, Austria and Denmark, in Ontario computerized information contributed the least to labour productivity growth - only 0.06 percentage points or 17.6 percent of the total intangible capital contribution in the 1998-2008 period. At the same time the contribution of computerized information in the province was greater than that in Canada. According to Baldwin *et al.* (2012) computerized information contributed 16.7 percent of total intangible capital contribution to the labour productivity growth in Canada (see Table 3).

Labour composition, or labour quality, which encompasses education, training and skills, contributed on average only 0.11 percentage points in the same period or 8.7 percent of the total labour productivity growth in Ontario. These results are in line with the estimates of the contribution of labour composition to the total labour productivity growth in the US, UK, Austria and Denmark. In the US and

Table 4: Total Labour Productivity growth by Source, continued

Sources	Germany 1995-2006		France 1995-2006		Italy 1995-2006		Spain 1995-2006		Austria 1995-2006		Denmark 1995-2006	
Labour productivity growth	1.79	100	2.00	100	0.29		0.47		2.36	100	2.11	100
Contribution of:												
1. Capital deepening	1.06	59.2	0.91	45.5	0.52		0.8		0.79	33.5	1.4	66.4
1.1. Tangibles	0.68	38.0	0.43	21.5	0.4		0.68		0.24	10.2	0.68	32.2
1.2. Intangibles	0.38	21.2	0.48	24.0	0.12		0.12		0.55	23.3	0.72	34.1
2. Labour composition	-0.15	-8.4	0.4	20.0	0.22		0.64		0.22	9.3	0.17	8.1
3. Multifactor productivity	0.88	49.2	0.69	34.5	-0.45		-0.96		1.35	57.2	0.53	25.1
Contribution of Intangibles												
1.2. Intangible capital deepening	0.38	100	0.48	100	0.12	100	0.12		0.55	100	0.72	100
1.2.1. Computerized information	0.07	18.4	0.15	31.3	0.03	25.0	0.05		0.13	23.6	0.29	40.3
1.2.2. Innovative property	0.23	60.5	0.18	37.5	0.05	41.7	0.15		0.29	52.7	0.27	37.5
1.2.3. Economic competencies	0.07	18.4	0.15	31.3	0.04	33.3	-0.08		0.13	23.6	0.17	23.6

Source: Van Ark *et al.*, (2009)

France, the share of labour composition in the total labour productivity growth was higher than it was in Ontario. However, Corrado *et al.* (2009) show that in the US the share of labour composition in the total labour productivity growth fell from an annual average of 15.3 percent in 1973-1998 to 10.7 percent in 1995-2003. When compared with a study of productivity in Ontario, which does not include intangibles[22], our estimate of the contribution of labour composition to the total labour productivity growth (8.7 percent) appears significantly smaller than it is in CSLS's study. In the absence of intangibles, labour quality contributed 18.8 percent to the total labour productivity growth by source in 1997-2007[23].

Inclusion of intangible assets into growth accounting did not alter dramatically the estimate of the contribution of multifactor productivity to the total labour productivity growth. The results show that in the 1998-2008 period multifactor productivity accounted for 47.2 percent of the total labour productivity growth. It is 0.9 percentage points lower than the results obtained in a no-intangibles study of productivity in Ontario, conducted by the CSLS. This indicates that more research is needed to fully understand multifactor productivity and through which channels the technological advances are transmitted into labour productivity growth.

5 Conclusion

The presented study aimed to provide the answers to the following questions:

[22]CSLS
[23]ibid

- How much do Ontario's businesses spend on various categories of intangible assets?
- How big is Ontario's stock of intangible capital and how fast is it growing?
- How important are intangibles as a contributor to total labour productivity growth in Ontario?

In line with existing research of intangible assets in various jurisdictions, the results of this study confirm that intangible assets are a valuable component of business sector output in Ontario. The nominal investment in intangibles has grown from 29 billion dollars in 1998 to almost 52 billion dollars in 2008. As a percentage of business sector output investment in intangibles increased from 9.2 percent in 1998 to 10.4 percent in 2008.

By nature, capital investment is highly volatile and very sensitive to the changes in economic conditions. The waves and tides of investment follow business cycle expansions and downturns. In Ontario, the growth rate of the business sector's real investment in intangibles oscillated from negative 0.25 percent to positive 5.65 percent in the 1998-2008 period. However, on average in the same period the growth rate of investment in intangibles exceeded the growth rate of investment in tangibles. In addition, investment in intangibles was not as volatile as investment in tangible capital.

According to this study, real intangible capital stock grew at an average rate of 2.5 percent from 1998 to 2008 and reached 163 billion dollars in 2008. Computerized databases, although one of the smallest categories of intangibles, was the fastest growing category in 1998-2008. It grew at an average annual rate of 5.8 percent, followed by scientific R&D with the average annual growth rate of 4.1 percent.

My estimates indicate that innovative property contributed the most to the total labour productivity growth in Ontario in the 1998-2008 period. On the average innovative property contributed 0.15 percentage points to total productivity growth, which is 44.1 percent of total contribution of intangible capital. The contribution of economic competencies was somewhat comparable to that of innovative property. In the 1998-2008 period, economic competencies contributed on average 0.11 percentage points to total labour productivity growth or 32.4 percent of total contribution of intangibles. Computerized information contributed only 0.06 percentage points or 17.6 percent of the total contribution of intangibles to total labour productivity growth. It appears that, compared with other jurisdictions, Ontario businesses do not invest significantly in organizational structure, which in turn might explain the low contribution of the computerized information category of intangibles to total labour productivity growth. According to Bresnahan *et al.* (2002), organizational change should accompany information and communication technology (ICT) adoption in order to boost labour productivity growth.

This study is an initial attempt to measure investment in intangible assets, estimate the stock of intangible capital and evaluate the contribution of intangibles to total labour productivity growth in Ontario. Further research is needed to deepen our understanding of intangibles and their role in economic activity of business sector. The next steps would be to continue improving the measures of intangible assets in Ontario and refining the estimates of the contribution of intangibles to output and productivity growth in the province.

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A Appendix 1

Asset	Description
1. Computerized Information	
1.1. Software	Spending on software has been capitalized in the Canadian System of National Account. Statistics Canada publishes provincial software investment data as part of non-residential investment (*CANSIM table 031-0004*).
1.2. Computerized databases	Expenditure on computerised databases is approximated by operating revenues of the data processing, hosting and related service industries (NAICS code 51821), which are published by Statistics Canada in the *CANSIM table 354-0005*.
2. Innovative Property	
2.1. Business R&D	Business spending on R&D has been capitalized in the Canadian System of National Account. Statistics Canada publishes provincial R&D investment data as part of non-residential investment (*CANSIM table 031-0004*).
2.2. Oil, gas and mineral exploration	Spending on oil, gas and mineral exploration has been capitalized in the Canadian System of National Account. Statistics Canada publishes provincial oil, gas and mineral exploraton investment data as part of non-residential investment (*CANSIM table 031-0004*).
2.3. Development costs in financial industry	Estimated as 20% of all intermediate purchases of Financial Services industry (NAICS 521 and 522). Source: Ontario *Input-Output tables*
2.4. New architecture and engineering design	Estimated as 50% of total expenditure on architectural and engineering services (NAICS 5413). Source: Ontario *Input-Output tables* Note: combined with 2.5.2. to meet confidentiality requirements.
2.5. Other science and engineering services	2.5.1. plus 2.5.2.
2.5.1. Own account other science and engineering services	Estimated as 20% of labor compensation of scientists and engineers. To avoid double-counting, the following industries are excluded: • financial services (NAICS 521). Ontario data is not available for NAICS 521, so it was estimated as 1/6 of NAICS 52 (NAICS 52 consists of 6 categories). It is captured in 2.3. • architectural, engineering and related services (NAICS 5413). It is captured in 2.4. • management, scientific and technical consulting services (NAICS 5416). Captured in 3.3. • scientific research and development services (NAICS 5417). Captured in 2.1. • advertising and related services (NAICS 5418) Captured in 3.1.1. • other professional, scientific and technical services (NAICS 5419). Captured in 2.1. Source: Statistics Canada *customized tables* (LFS)
2.5.2. Purchased other science and engineering services	Estimated as 50% of total expenditure on royalties and licensing fees. Source: Ontario *Input-Output tables* Note: combined with 2.4. to meet confidentiality requirements.
3. Economic Competencies	
3.1. Brand Equity	3.1.1. plus 3.1.2.
3.1.1. Advertising expenditure	Estimated as 60% of business sector expenditure on: • advertising flyers, catalogs and directories • advertising in print media, • advertising services, • advertising and promotion Source: Ontario *Input-Output tables*
3.1.2. Market and consumer research	n/a for Ontario
3.2. Firm-specific human capital (training cost)	3.2.1. plus 3.2.2.
3.2.1. Direct firm expenses	Estimated by using *Conference Board of Canada* data on Canadian business sector direct annual spending per employee and total number of employees (Statistic Canada) Caveat: data are in constant 2010 dollars only
3.2.2. Indirect expenses	Estimated by using *Conference Board of Canada* data on Canadian business sector indirect direct annual spending per employee and total number of employees (Statistic Canada) Caveat: data are in constant 2010 dollars only.
3.3. Organizational structure	3.3.1 plus 3.3.2.
3.3.1.Purchased	Approximated as the total operating revenue of the "management consulting services" industry (MAICS 54161), *CANSIM table 360-0001*
3.3.2. Own account	Estimated as 20% of labor compensation of total management occupations (LFS)