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Productivity Growth in the Canadian Telecommunication Industry: Evidence from Micro Data

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1. Introduction

The Canadian telecommunication[1] industry has experienced rapid growth and accelerating technological change over the last two decades. The real gross output increased at annual rate of 3.9% per year over that period. The industry had one of the most rapid multifactor productivity growth rates among Canadian industries over the period 2000 to 2008.[2]

However, the Canadian telecommunication industry has had relatively lower productivity growth performance compared with the U.S. (Baldwin and Gu, 2008). The industry was a main contributor to the overall lower productivity growth in the Canadian business sector relative to the U.S. business sector over the period after 2000. The final report from the Telecommunications Policy Review Panel concluded that Canada's telecommunication industry is losing its competitive edge. This is especially true in the two most important and fastest growing sectors of the telecommunication industry: wireless and broadband services (Sinclair et al., 2006). Canada has the most expensive wireless voice and data rates among the OECD countries (Li and Nina-Moses, 2010). Canada is also lagging behind Japan, South Korean and the United States in rolling out fibre optic cable and the development of next generation networks (Sinclair et al., 2006).

The lack of competition and scale in Canada compared to the United States have been cited as two major causes of the relatively lower productivity growth performance in the Canadian telecommunication industry. Canada restricts foreign control of telecommunication providers (Sinclair et al., 2006).[3] Canada has relatively small market size compared with the U.S. that may have negative effect on the productivity performance of the Canadian telecommunication industry, an industry where scale

[1] Although we will use the term 'telecommunication' throughout the paper, we are also referring to broadcasting.
[2] Statistics Canada Productivity Program, CANSIM table 383-0022.
[3] The Canadian government firm to loosen the foreign control restriction in the Canadian telecommunication sector to foster competition in that sector.

economies are important. Moreover, the industry is composed of a small number of large companies that account for most of the market share (Baldwin and Lafrance 2011).

The objective of this paper is to quantify the sources of measured aggregate productivity growth in the Canadian telecommunication industry. Two questions are posed: first, the extent to which the aggregate productivity growth in the sector came from scale economies as opposed to technical progress; second, the extent to which aggregate productivity growth came from firm entry and exit and reallocation among incumbents—the dynamic forces associated with competitive change. The answers to these questions shed light on the extent to which competition, scale economies and technical progress contributed to the productivity growth experienced by the Canadian telecommunications sector post 2000.

As the telecommunication industry is characterized by increasing returns to scale and imperfect competition, the growth accounting framework that was developed under perfect competition and constant returns to scale needs to be extended to take into account those non-neoclassical features (Solow, 1957, Jorgenson and Griliches, 1967 and Diewert 1976). That framework has been developed by Denny et al. (1981), Diewert (1991), Hall (1988, 1990), Basu and Fernald (2001, 2002), Petrin et al. (2010), and Diewert et al. (2011).

Baldwin et al. (2012) have adapted that framework for use with firm-level data and derived a method for aggregation that can be used to show the extent to which the total growth in productivity comes from different underlying sources. The aggregate productivity growth is decomposed into a within-firm component, between-firm component and effect of net entry. The within-firm component captures the effect of capital and intermediate input deepening, technological progress, scale economies, and input utilization at the firm level. The between-firm component reflects the effect of the reallocation of inputs and outputs across firms on both aggregate capital deepening and aggregate multifactor productivity growth.

The rest of paper is organized as follow. Section 2 provides background information about the regulatory framework in Canadian telecommunication. It also summarizes previous empirical studies on the productivity growth of that sector. Section 3 presents the method that is used to examine the productivity growth of the telecommunication industry. This section borrows heavily from Baldwin et al. (2012). Section 4 presents the data and Section 5 presents the empirical evidence. Section 6 concludes the paper.

2. An Overview of the Canadian Telecommunication Sector

The telecommunications industry consists of wired or wireline (the largest segment) and wireless telecommunications carriers as well as satellite telecommunications, while the broadcasting industry comprises radio and television broadcasting, as well as pay and specialty television. The penetration of telephone services in Canada is among the highest in the world; however, there continues to be a migration from traditional fixed-line to wireless services among Canadians. Canada also has a high rate of broadband Internet access. These potential opportunities have attracted entrants; however, neither of these industries is devoid of entry barriers. In broadcasting, the availability of licenses is limited, while entry in telecommunications requires significant capital outlay.

A number of previous studies have examined the productivity growth of the Canadian telecommunication sector. Denny et al. (1981) showed that the MFP growth from the traditional accounting framework is no longer equal to technical progress when one departs from perfect competition and constant returns to scale. Rather it is the sum of the three components: technical progress, the effect of scale economies and the effect of non-marginal cost pricing arising from the rate of return regulation. They applied that methodology to Bell Canada – Canada's largest telephone company and reported that

MFP for Bell Canada increased 3.4% per year over the period 1956 to 1976, 64% of which represented scale economies, 20% the effect of technical progress, and 16% the result of non-marginal cost pricing.

Other studies have confirmed the importance of scale economies. Fuss and Waverman's (2002) survey of empirical studies on scale economies in the telecommunication industry reports widespread evidence of increasing returns to scale.

A second issue examined in previous studies relates to the multi-product nature of the telecommunication industry and non-marginal cost pricing of the outputs. When an industry produces multiple products and the price is not proportional to marginal costs as a result of regulation—either rate-of-return or price-cap regulation, the correct weight used to aggregate individual outputs is the share of cost elasticities instead of revenue share that is appropriate in the case of perfect competition. Fuss (1994) found that the price is lower than marginal costs for local phone services but higher for the toll services for the telephone company, Bell Canada. The bias from using incorrect weights is quite significant in the case of Bell Canada.

The telecommunication industry is capital intensive and requires extensive investment. The traditional growth accounting framework often requires the assumption of long-run equilibrium with capital being fully adjusted to demand conditions. In the short run, capital is not fully adjusted which may result in excess capacity. As a direct observation on the rate of utilization of capital input is often not available, the previous empirical studies have often used a proxy for capacity utilization to adjust the quantity of capital input that is used to calculate total input and MFP growth.[4] Berndt and Fuss (1982) developed a framework to take into account changes in capacity utilization that is based on production theory. They argue that an adjustment to account for this problem

[4] Some studies provided direct evidence on the rate of capital utilization using survey (INSEE has such survey).

should be made to the price of capital input that is used to weight capital input in order to derive aggregate input. More recently, Gu and Wang (2012) argue that an adjustment can be made to the quantity of capital input rather than the value of capital input for this same purpose.

3. Methodology

This section presents the methodology for tracing aggregate labour and multifactor productivity growth in the telecommunication industry into what takes place at the firm level. The section follows Baldwin et al. (2012).

Previous empirical studies have decomposed aggregate productivity growth into the effect of reallocation arsing from those among incumbents and those from firm entry and exit, and the effect of within-firm growth (Bartelsman et. al, 2005; Foster, Haltiwanger, and Krizan 2001; Griliches and Regev, 1995). The decomposition method proposed by Baldwin et al. (2012) delves deeper into these two micro-components of aggregate labour and multifactor productivity (MFP) growth. For aggregate MFP growth, the within-firm component is decomposed into the effect of technological progress, scale economies and variable input utilization at the firm level; for aggregate labour productivity growth, it is decomposed into those effects plus the effect of capital deepening. For aggregate MFP growth, the between-firm component captures the effect of reallocation across firms; for aggregate labour productivity growth, it is decomposed into the effects of reallocation on aggregate MFP growth and aggregate capital deepening.

The decomposition builds on earlier work (Jorgenson 1966, Jorgenson, et al. 2005) that decomposes aggregate productivity growth into its industry components but applies it in this instance at the level of the firm. It also introduces non-neoclassical features of the firm-level economic environment such as imperfect competition and economies of scale, whereas the original Jorgenson decomposition was developed under the assumption of perfect competition and constant returns to scale.

Jorgenson (1966) and Jorgenson et al. (2005) developed two alternative approaches for constructing the aggregate estimates of labour and multifactor productivity growth –a production possibility frontier approach and the direct aggregation across micro producers (firms or plants). The former is the traditional approach used to estimate productivity when only industry data are available. The latter allows for a decomposition of the within- and between-firm components.

3.1 Production Possibility Frontier Approach

The production possibility frontier approach assumes that capital, labour and intermediate inputs receive the same price in all firms, but firms have different production functions that relate gross output (V) to capital, labour and intermediate inputs at the firm level and the price of gross output differs across firms. Under these assumptions, aggregate gross output can be expressed as a function of aggregate capital, aggregate labour, aggregate intermediate input, and a time variable that proxies technology (T), whereas the aggregate gross output can be written as a Tornqvist aggregation of gross output across firms:

(1) $$V = F(K, L, M, T), \text{ and } \Delta \ln V = \sum_i \bar{w}_i \Delta \ln V_i ,$$

where $\Delta \ln$ denotes the change between periods t-1 and t in logarithm, and $\bar{w}_i$ is the share of firm i in aggregate nominal gross output, averaged over the two periods. Aggregate labour productivity growth, defined as the difference between growth in aggregate gross output and growth in aggregate labour input, can be written as*:*

$$(2)\quad \begin{aligned}\Delta \ln P &= \Delta \ln V - \Delta \ln L \\ &= \sum_i \bar{w}_i \Delta \ln P_i + \left(\sum_i \bar{w}_i \Delta \ln L_i - \Delta \ln L \right),\end{aligned}$$

Where $\Delta \ln P_i = \Delta \ln V_i - \Delta \ln L_i$ is labour productivity growth at firm i, defined as the difference between output growth $\Delta \ln V_i$ and labour input growth $\Delta \ln L_i$.

The growth on aggregate labour productivity in equation 2 is decomposed into two components: the within-firm effect and between-firm reallocation effect. The within-firm effect measures the contribution to overall productivity growth of growth within individual firms, holding their shares of output constant. The second term is the between-firm effect that represents the effect of reallocation of labour input on aggregate labour productivity growth.

When the product and factor markets are competitive and the aggregate production function is characterized by constant returns to scale, aggregate multifactor productivity growth can be expressed as the difference between aggregate labour productivity growth and the effect of capital and intermediate-input deepening:

$$(3)\quad v_T = \Delta \ln P - \bar{\alpha}_K \Delta \ln(K/L) - \bar{\alpha}_M \Delta \ln(M/L),$$

where v_T is multifactor productivity growth, and $\bar{\alpha}_K$ and $\bar{\alpha}_M$ are the shares of capital and intermediate inputs in nominal gross output, averaged over the two periods.

3.2 Direct Aggregation across Firms

The alternative approach for estimating aggregate labour and multifactor productivity is direct aggregation across firms (Jorgenson et al 1987, 2005). This method relaxes the assumption adopted in the approach that uses the production-possibility frontier and that assumes that all inputs receive the same price across all firms. Instead, it assumes that the prices of capital, labour and intermediate inputs differ across firms.

For the purpose of this paper, the direct aggregation approach is extended to take into account non-neoclassical features of the economic environment facing firms. More specifically, it is assumed that the production function of individual firms is characterized by increasing returns to scale and there is imperfect competition in the product market.

Firm *i* is assumed to have a production function that expresses gross output (V_i) as a function of capital (K_i), labour (L_i), intermediate input (M_i) and technology (T_i) :

(4) $$V_i = F^i(e_{Ki}K_i, e_{Li}L_i, e_{Mi}M_i, T_i)\,,$$

where e_{Ki}, e_{Li}, e_{Mi} denote the unobserved utilization of capital, labour and intermediate inputs, and T_i indexes technology. The production function exhibits increasing returns to scale γ_i.

Following Hall (1990), and Basu and Fernald (2001, 2002), output growth can be written as[5]:

(5) $$\Delta \ln V_i = \mu_i \Delta \ln X_i + a_i \Delta \ln e_i + v_{T,i}\,,$$

where $\Delta \ln X_i$ is a weighted sum of input growth using the share of input costs in nominal gross output as weights

(6) $$\Delta \ln X_i = (\bar{\alpha}_{Ki}\Delta \ln K_i + \bar{\alpha}_{Li}\Delta \ln L_i + \bar{\alpha}_{Mi}\Delta \ln M_i)\,,$$

and $\Delta \ln e_i$ is a weighted sum of the changes in input utilization:

(7) $$\Delta \ln e_i = \bar{\alpha}_{Ki}\Delta \ln e_{Ki} + \bar{\alpha}_{Li}\Delta \ln e_{Li} + \bar{\alpha}_{Mi}\Delta \ln e_{Mi}\,.$$

$\bar{\alpha}_{Ki}$, $\bar{\alpha}_{Li}$, and $\bar{\alpha}_{Mi}$ are the average shares of capital, labour and intermediate inputs in nominal gross output. The sum of those input cost shares in gross output is less than one if there is economic profit. $v_{T,i}$ is multifactor productivity growth. μ_i is the mark-up

[5] It is assumed that mark-ups do not change over a period. When they do change, the average mark-up over the period should used in the equation.

over marginal cost. The mark-up is related to the returns to scale γ_i and the ratio of economic profits to total revenue $s_{\pi i}$ by the following equation:

(8) $$\mu_i = \frac{P_i}{MC_i} = \frac{AC_i}{MC_i}\frac{P_i}{AC_i} = \gamma_i / (1 - s_{\pi i}) .$$

The first equality in equation (8) follows from the definition of mark-up as the ratio of output price (P_i) to marginal cost (MC_i). The last equality follows from an implication of cost minimization that the ratio of average cost (AC_i) to marginal cost equals the extent of returns to scale, which is captured by the parameter γ_i .

In the empirical analysis that follows, economic profits will be assumed to be zero. This will be the case if the industry is characterized by monopolistic competition. When economic profits are zero, markup is equal to returns to scale and the sum of input costs share in nominal gross output is equal to one. Subtracting labour input growth from both sides of equation (5) yields the following equation that shows the source of growth in labour productivity at firm *i*:

(9) $$\Delta \ln P_i = (\mu_i - 1)\Delta \ln X_i + \bar{\alpha}_{Ki}\Delta \ln(K_i / L_i) + \bar{\alpha}_{Mi}\Delta \ln(M_i / L_i) + a_i \Delta \ln e_i + v_{T,i} .$$

The equation decomposes the growth in firm labour productivity into its various components including scale economies, capital deepening, intermediate input deepening, variable input utilization, and technological progress.

The growth in firm labour productivity can be aggregated to derive aggregate labour productivity growth using equation (2), which is then substituted in equation (3) to obtain a decomposition of aggregate multifactor productivity growth:

(10) $$\begin{aligned} v_T &= \sum_i \bar{w}_i (\mu_i - 1)\Delta \ln X_i + \sum_i \bar{w}_i a_i \Delta \ln e_i + \sum_i \bar{w}_i v_{T,i} + \sum_J REALL_J \\ REALL_J &= \bar{\alpha}_J \left(\sum_i \bar{w}_{Ji} \Delta \ln J_i - \Delta \ln J \right),\ w_{Ji} = \frac{P_{Ji} J_i}{P_J J},\ J = K, L, M \end{aligned} ,$$

where $\bar{w}_{Ji}$ is the share of firm i in the cost of input *J* averaged over two periods, P_{Ji} is the price that input *J* receives at a firm , and P_J is the price of input *J* in the production possibility frontier approach.[6]

Aggregate multifactor productivity growth is decomposed into a within-firm component and a between-firm component. The within-firm component captures the effect of changes taking place at individual firms holding their output share constant, and it is further decomposed into the effect of scale economies, the effect of variable input utilization, and the effect of technical progress. The last term of the decomposition is the between-firm component that measures the effect of reallocation of capital, labour and intermediate inputs on aggregate multifactor productivity growth. The reallocation of an input contributes positively to aggregate MFP growth if the input is shifted towards those firms with higher input price and higher marginal product. The MFP decomposition (10) simplifies to the decomposition (8.34) in Jorgenson, et al. (2005) under the assumption of constant returns to scale, perfect composition, and no excess capacity.

Aggregation of firm labour productivity growth given in equation (9) using equation (2) yields a decomposition of aggregate labour productivity growth:

(11)

$$\Delta \ln P = \sum_i \bar{w}_i \Delta \ln P_i + \left(\sum_i \bar{w}_i \Delta \ln L_i - \Delta \ln L \right),$$

$$\sum_i \bar{w}_i \Delta \ln P_i = \sum_i \bar{w}_i (\mu_i - 1) \Delta \ln X_i + \sum_{J=K,M} \sum_i \bar{w}_i \bar{\alpha}_{Ji} \Delta \ln(J_i / L_i) + \sum_i \bar{w}_i a_i \Delta \ln e_i + \sum_i \bar{w}_i v_{T,i},$$

$$\left(\sum_i \bar{w}_i \Delta \ln L_i - \Delta \ln L \right) = \sum_{J=K,L,M} REALL_J + \sum_{J=K,M} \bar{\alpha}_J \left(\Delta \ln(J / L) - \sum_i \bar{w}_{Ji} \Delta \ln(J_i / L_i) \right).$$

[6] When firm output is based on gross output and aggregate output is a value-added concept, the correct weights for aggregating MFP growth across firms are Domar weights which are equal to the ratio of firms' gross output to aggregate nominal value-added (Domar 1961).

Aggregate labour productivity growth is decomposed into a between-firm and a within-firm component. The within-firm effect in equation (11) is the sum of following components: a scale effect, a capital deepening and intermediate input deepening effect, a variable input utilization effect and technical progress. The between-firm reallocation effect is traced to the effect of the reallocation of labour and capital inputs on aggregate MFP growth and the effect of reallocation on capital deepening and intermediate input deepening.

The decomposition of aggregate MFP growth and aggregate labour productivity growth can be extended to estimate the impact of entry and exit. For entrants, inputs and outputs are only observed at the end of the period, while for exiters, inputs and outputs are only observed at the start of the period. As such, the growth rates of inputs, outputs and productivity over a period cannot be calculated for entrants and exiters. For this reason, recent empirical studies often focused on continuing firms and ignored the effect of entry and exit (Basu and Fernald, 2002 and Petrin and Levinsohn, 2010).

In order to estimate the effect of entry and exit, it is assumed that a hypothetical firm exists whose inputs and outputs at the start of the period are set equal to those of exiters, and whose inputs and outputs at the end of the period are set equal to those of entrants at the end of the period. The contribution of entry and exit to aggregate MFP growth, labour productivity growth and capital deepening effect can be measured as the contribution of the hypothetical firm to the within-firm component in the decomposition. For example, the contribution of entry and exit to aggregate labour productivity is estimated as the difference between the average labour productivity of the entry cohort at the end of a period and that of the exit cohort at the start of the period, multiplied by their average shares in aggregate output.

4. Data

This paper examines productivity growth in the Canadian broadcasting and telecommunications industry over the 1984 to 2008 period. The firm-level data used are from Statistics Canada's T2-LEAP longitudinal database. The dataset covers all incorporated firms in Canada that hire employees. It contains detailed information from firm financial statements, including balance sheets and income statements. It contains a longitudinal firm identifier that can be used to examine the amount of entry and exit over time. The industry affiliation that is used to define the broadcasting and telecommunications industry is at the 2007 four-digit North American Industry Classification System (NAICS).

For the empirical analysis, we use sales as a measure of output. The real output of a firm is derived by deflating the nominal output (or sales) by a gross output deflator at industry level taken from the Productivity Accounts of Statistics Canada (Baldwin and Gu 2009). Total assets will be used to proxy a firm's capital input. An alternative measure of capital input is total tangible assets. But that variable is only available after 1998.[7] Gross profits will be used to proxy capital income.

The T2-LEAP file contains a measure of average employment, called "average labour unit" (ALU), which is calculated as the ratio of total payroll of a firm to average annual wages of the workers in that firm's industry, size class and province. This measure of employment is used in the empirical analysis to proxy employment.

The cost of intermediate inputs is calculated as the difference between sales and the sum of payroll and gross profits. The cost of intermediate inputs in constant dollars is derived from by deflating the cost of intermediate inputs by an intermediate input deflator at the industry level from the Productivity Accounts of Statistics Canada.

[7] The estimation and decomposition results from those two measures of capital input are similar for the period 1998 to 2008 when both measures are available.

The growth rates of output, inputs and productivity derived from the T2-LEAP micro file are compared with the aggregate statistics from the Productivity Accounts of Statistics Canada in Table 1. Data from both sources show similar variations in the growth rates in output, inputs and productivity, although the rates are generally one to two percentage points higher in the T2-LEAP file (Gu and Lafrance 2008)[8]. For the decomposition, the T2-LEAP data are benchmarked to the aggregate data from the Productivity Accounts.

Figure 1 presents the number of firms, output and inputs estimated from the T2-LEAP file for the broadcasting and telecommunication sector over the period 1984 to 2008. The number of firms increased from about 500 in 1984 to about 2000 in 2008. Gross output, capital and intermediate input all showed dramatic increases over the period. While labour input increased over the period, its growth was much slower than output and capital and intermediate inputs. Output and inputs showed large increases before 2000 and then large decline after 2000, as a result of the telecom bubble in the early 2000s. The number of firms also declined during that period.

Annual entry and exit rates of firms in the broadcasting and telecommunications industry are presented in Table 2. These are calculated as the percentage of the total number of firms accounted for by entering and exiting firms averaged over the 1986-to-2008 period, with the averages split between two periods, 1986 to 1998 and 1999 to 2008. To avoid the problem of partial-year reporting during the birth year of new firms, entrants in year *t* are defined as firms that were absent in *t-2*, but appeared in *t-1* and *t*. Exiting firms are defined in year *t* as firms that were present in years *t-2* and *t-1* but absent in year *t*.

[8] The T2-LEAP file only consists of incorporated firms, which have been shown to be more productive than their unincorporated counterparts, which are included in the Productivity Accounts. However, it was not possible to determine how much of the gap in growth rates is explained by this.

Over the 1986-to-2008 period, entry rates were higher than exit rates. Both entry rates and exit rates increased over the period, with entry rates increasing from 12.6% in the 1986-to-1998 period to 15.4% post-1999. Exit rates have almost doubled over time, from 5.9% to 11.1%. The total turnover rate, which is the sum of the entry and exit rate, increased from 18.5% to 26.5%. Although the turnover rate in the broadcasting and telecommunications industry has increased, most of the market share in the industry is held by incumbent firms (Baldwin and Lafrance 2011).

5. Empirical Results

This section reports parameter estimates of the production function and scale economies that will be used to decompose aggregate productivity growth. The estimation equation is obtained from rewriting the first-difference equation (5) in a level form:

(12) $\ln V_{it} = \alpha_K \ln K_{it} + \alpha_L \ln L_{it} + \alpha_M \ln M_{it} + a \ln e_{it} + \delta_t + c_i + \nu_{it}$,

where δ_t is a year effect. c_i is an unobserved firm effect, ν_{it} is a i.i.d. errors, The estimate of returns to scale is derived as the sum of the coefficients on capital, labour and intermediate inputs, α_K α_L and α_M.

The equation is estimated using a fixed effect model. We also allow for endogeneity or measurement errors of the capital input variable. In model 1, we used total assets lagged one period as instruments for tangible assets. In model 2, we used share of gross profits in total sales lagged one period as instruments.

The sample used for estimation consists of all firms in the T2-LEAP longitudinal file that existed for the period 1998 to 2008. We focused on this period for estimation purposes since the measure of tangible assets that is used to capture capital is not available before 1998 and there is a break in the measure of gross profits contained in the file. The estimates of the production function and the degree of returns to scale and the effect of capacity utilization are presented in Table 3.

The estimated return to scale is about 1.05 in column 1 and it is 1.17 in column 2 for the broadcasting and telecommunication industry, indicating that, on average, increasing returns to scale are present. The evidence on increasing returns to scale is similar to the consensus estimate for that industry from previous studies (Fuss and Waverman, 2002). The coefficient on the capital utilization variable is statistically significant. But the ratio of gross-profit to total sales in the file is too volatile to be used in our decomposition. We will exclude the effect of capacity utilization in our decomposition. We will instead use the parameter estimates from model 2 where gross profits are used as instruments for tangible assets.

Table 4 presents the decomposition results for aggregate labour productivity growth from the production possibility frontier approach. It provides a decomposition of the aggregate labour productivity growth into its main sources: one coming from aggregate capital and intermediate input deepening and the other arising from the growth in aggregate multifactor productivity growth.

Aggregate labour productivity experienced a rapid growth in the broadcasting and telecommunication industry over the period 1984 to 2008, particularly for the period before 1998. It increased at 6.4% per year for the period 1984 to 1998 and at 3.2% per year for the period 1998 to 2008.

Aggregate labour productivity growth declined after 1998. The decline was due to the decline in the effect of capital deepening and intermediate input deepening. Aggregate MFP growth increased after 1998. It increased from 2.7% per year over the period 1984 to 1998 to 3.5% per year for the period 1998 to 2008.

Table 5 presents the decomposition results for aggregate labour productivity growth, while Table 6 presents decomposition results for aggregate multifactor productivity growth. They are each decomposed into the within-firm effect, the between-firm reallocation effect, and the effect of entry and exit. The decomposition is carried out for NAICS 4-digit industries, and then aggregated to the broadcasting and communication sector, using their shares of total nominal gross output as weights.

The results in Table 4 and 5 show that the aggregate labour and multifactor productivity growth stems mainly from the productivity growth occurring within individual firms.

The between-firm reallocation was important contributor to aggregate labour and multifactor productivity growth in the period 1984 to 1998. It contributed 2.2 percentage points or 34 percent of the aggregate labour productivity growth. There was major restructuring in the telecommunication industry before 1998 which contributed to the overall productivity growth. But after 1998, the reallocation across firms was not a major contributing factor to aggregate productivity growth.

Entry and exit did not significantly contribute to overall labour productivity growth in the broadcasting and communication industry over the period. For the period 1998 to 2008, entry and exit made a positive contribution to overall MFP growth, but the contribution was small and it only accounted for about 10% of the overall MFP growth in that period.

The results from the production possibility frontier approach are presented in Table 4. While labour productivity slowed after 1998, aggregate MFP growth increased. The results from direct aggregation across firms in Table 5 show that most of the acceleration in MFP growth was due to technical progress at the firm level. The broadcasting and telecommunication services introduced major innovations and experienced rapid technical progress in voice, data and video communications over that period (Jorgenson et al. 2010). The impact of scale economies declined for the post-1998 period due to slower growth in the industry.

The between-firm reallocation made a positive contribution to aggregate MFP growth in the period 1984 to 1998, but it made negative contribution to aggregate MFP growth in the period 1998 to 2008. The decline in the contribution of between-firm reallocation is a significant factor behind slower overall labour productivity growth during the latter period.

6. Conclusions

In this paper, we have examined sources of productivity growth in the broadcasting and telecommunication services industry. The paper relaxed the assumption of constant returns and perfect competition adopted in the standard growth accounting framework, and provided a decomposition of multifactor productivity growth into the effect of scale economies and technical progress. It also constructed the aggregated productivity growth measures from direct aggregation across firms to provide a decomposition of aggregate productivity growth into a within-firm component, a between-firm component and the effect of net entry of firms.

The paper finds that aggregate labour and multifactor productivity growth can be mainly attributed to the growth occurring within individual firms. The between-firm reallocation was important contributor to aggregate labour and multifactor productivity growth in the period 1984 to 1998. But after 1998, the reallocation across firms was not a factor behind the aggregate productivity growth. The effect of entry and exit was not significant factor for the overall labour productivity growth in the broadcasting and communication industry.

Aggregate multifactor productivity growth mainly came from technical progress. Scale economies made a small and positive contribution to aggregate multifactor productivity growth. Technical progress accelerated in the Canadian broadcasting and telecommunication services industry after late 1990s.

In spite of the acceleration of technical progress, aggregate labour productivity growth in the broadcasting and telecommunication service industry declined after 1998. The decline can be attributed to the decline in capital deepening effect and the decline in the effect of reallocation between firms in the recent period.

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Table 1. Annual growth rates of output, capital and labour in the broadcasting and telecommunications industry, 1984 to 2008

	T2-LEAP	KLEMS
	percent	
Labour productivity	5.4	3.9
Real output	6.0	5.5
Capital input	9.8	3.2
Labour input	0.6	1.6
Labour income	4.7	4.5

Sources: Statistics Canada, KLEMS database and Longitudinal Employment Analysis Program database; and Canada Revenue Agency, Corporate Tax Statistical Universe File

Table 2. Average annual entry and exit rates in the broadcasting and telecommunications industry, 1986 to 2008.

	Entry rate	Exit rate	Total turnover
		percent	
1986 to 1998	12.6	5.9	18.5
1999 to 2008	15.4	11.1	26.5

Sources: Statistics Canada, Longitudinal Employment Analysis Program database; and Canada Revenue Agency, Corporate Tax Statistical Universe File

Table 3. Estimates of production parameters and economies of scale

	Model	
	1	2
Capital	0.71	0.89
	(14.38)	(10.17)
Labour	0.10	0.07
	(7.91)	(3.40)
Intermediate Inputs	0.24	0.21
	(25.79)	(20.55)
Capital Utilization	0.05	
	(3.20)	
# Obs.	6528	6382
Scale economies	1.05	1.17

Note. All regressions include year fixed effects. Robust t-statistics are in parentheses.

Table 4. Decomposition of aggregate labour productivity growth – results from growth accounting

	1984-1998	1998-2008	1998-2008 less 1984-1998
Aggregate labour productivity growth	6.4	3.2	-3.2
Contribution from			
Capital deepening	2.5	-0.8	-3.4
Intermediate input deepening	1.2	0.6	-0.6
MFP growth	2.7	3.5	0.8

Table 5. Decomposition of aggregate labour productivity growth- results from direct aggregation across firms

	1984-1998	1998-2008	1998-2008 less 1984-1998
Aggregate labour productivity growth	6.4	3.2	-3.2
Within-firm growth	4.4	3.4	-1.0
MFP growth	1.1	3.5	2.4
Scale economies	0.4	0.2	-0.2
Capital deepening	1.8	-1.0	-2.9
Intermediate input deepening	1.0	0.7	-0.3
Between-firm reallocation	2.2	-0.3	-2.6
Reallocation on MFP	1.3	-0.7	-2.0
Reallocation on input deepening	0.9	0.4	-0.5
Net entry	-0.2	0.2	0.4

Table 6. Decomposition of aggregate multifactor productivity growth- results from direct aggregation across firms

	1984-1998	1998-2008	1998-2008 less 1984-1998
Aggregate MFP growth	2.7	3.5	0.8
Within-firm growth	1.5	3.8	2.2
MFP growth	1.1	3.5	2.4
Scale economies	0.4	0.2	-0.2
Between-firm reallocation	1.3	-0.7	-2.0
Net entry	-0.2	0.4	0.6

Figure 1. Output, inputs and number of firms in Broadcasting and Telecommunication

(1984 = 100 except for # of firms)