the review of income and wealth

Review of Income and Wealth
Series 59, Number 4, December 2013
DOI: 10.1111/roiw.12028

EXPORT GROWTH, CAPACITY UTILIZATION, AND PRODUCTIVITY GROWTH: EVIDENCE FROM THE CANADIAN MANUFACTURING PLANTS

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Aggregate labor and multifactor productivity growth slowed substantially post-2000 in the Canadian manufacturing sector. To examine the source of the decline, this paper proposes a decomposition method that delves deeper into the two micro-components of aggregate productivity growth: a within-plant component and a between-plant component. The decomposition builds on earlier work by Jorgenson and his collaborators that decomposes aggregate productivity growth into its industry components, but applies it to the plant level and introduces non-neoclassical features of the plant-level economic environment. It finds that the preponderance of the aggregate labor and multifactor productivity growth slowdown is due to the pro-cyclical nature of productivity growth arising from capacity utilization. Almost all of the aggregate productivity growth slowdown is driven by exporters, as exporters experienced large declines in labor productivity growth in the post-2000 period as a result of large declines in their capacity utilization.

JEL Codes: D24, O47

Keywords: excess capacity, export growth, productivity

1. Introduction

Growth in labor and multifactor productivity in the Canadian manufacturing sector declined sharply after 2000. This post-2000 decline accounted for most of the slower productivity growth of the business sector in Canada (Baldwin and Gu, 2009).

The economic environment post-2000 differed markedly from the previous decade. During the period from 1990 to 1996, average tariff reductions between Canada and the U.S. were large, with an annual average rate of decline of 0.60 percentage points (Baldwin and Yan, 2012). In addition, the Canada/U.S. exchange rate depreciated at an average annual rate of 2.0 percentage points from 1990 to 1999. As a result, total merchandise exports (mostly going to the U.S. market) as a proportion of gross domestic product (GDP) in Canada increased. The trading environment post-2000 was very different. Most of the tariff reductions pursuant to the Canada–U.S. free trade treaties had already been implemented. At the same time, trade costs rose due to post-9/11 border frictions.

Note: We would like to thank Isabelle Amano, Claude Lavoie, Alla Lileeva, Annette Ryan, Jianmin Tang, Ben Tomlin, and seminar participants at Industry Canada and Statistics Canada for comments, and Danny Leung for his help with GMM estimation. We would also like to thank two anonymous referees and an editor for their helpful comments.

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Moreover, the Canadian dollar appreciated steeply from US$0.67 in 2000 to US$0.88 in 2006, an average annual appreciation of 3.5 percentage points, powered by the worldwide resource boom that led to a dramatic expansion of the resource-based Western Canadian economy. During that period, total merchandise exports as a proportion of gross domestic product in Canada declined.

The post-2000 period was also characterized by the development of excess capacity in the Canadian manufacturing sector. Capacity utilization declined in 16 out of the 20 manufacturing industries in that period. The emergence of excess capacity post-2000 mainly originated from the large decline in exports as a result of the change in the trade environment during that period.[1] This paper examines how changes in the environment post-2000 are related to slower productivity growth in the Canadian manufacturing sector. It examines how this slowdown in productivity growth post-2000 was associated with the increase in excess capacity.

To understand how changes in the economic environment are related to slower productivity growth, we decompose changes in aggregate productivity growth into underlying micro-components to examine whether differences in these components suggest causes that relate to changes in the economic environment. Previous empirical studies have decomposed aggregate productivity growth into the effect of reallocation and the effect of within-plant growth (Griliches and Regev, 1995; Bartelsman and Doms, 2000; Foster *et al.*, 2001; Bartelsman *et al.*, 2005). The original decomposition methods used in those studies focused only on the extent to which growth taking place at individual firms contributed to overall productivity growth (within-plant component) and the extent to which shifts in output and inputs across firms enhanced productivity growth (between-plant component or the effect of reallocation).

This paper proposes a decomposition method that delves deeper into these two micro-components of aggregate labor and multifactor productivity (MFP) growth. The within-plant component for aggregate MFP growth is further decomposed into the effect of technological progress, scale economies, and variable input utilization at the plant level; for aggregate labor productivity growth, the within-plant component is decomposed into those effects plus the effect of capital deepening. The between-plant component for aggregate MFP growth captures the effect of reallocation across plants on aggregate MFP growth; for aggregate labor productivity growth, the between-plant component is further decomposed into the effect of reallocation on aggregate MFP growth plus the effect of reallocation on aggregate capital deepening. The question of interest is the extent to which most of the decline in productivity growth came from a decline in capacity utilization or whether it came from other sources—a decline in production efficiency (MFP growth) or a decline in the impact of the reallocation of resources that generally tends to contribute to productivity growth.

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 to the plant level. It also introduces

[1]Excess capacity also developed in several industries as they experienced dramatic declines in demand after 2000 that were related to structural adjustments. For example, the large decline in production in the electronic product manufacturing sector after 2000 was related to the burst of the dot-com bubble in that period.

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non-neoclassical features of the plant-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.[2]

Labor and multifactor productivity measures are both examined here. Labor productivity is used to tell us how efficiently labor is transformed in the production process. It is of interest because of its close connection with the growth in real wage rates. Multifactor productivity is a more comprehensive weighted average of both labor and capital productivity. It is calculated as the difference between the growth of output and the growth in expected output from the application of labor and capital inputs using assumptions about production technology—that is, how much output additional units of labor and capital might be expected to have produced. It is of interest because of its interpretation as capturing all unmeasured factors including disembodied technical progress. But more importantly for our purposes, labor productivity growth can be decomposed into multifactor productivity growth and a term involving the growth in capital/labor intensity. Thus, underlying changes in the economy that affect labor productivity will be found both in those that affect multifactor productivity growth and in those that affect changes in capital intensity.

2. Methodology

A number of empirical studies have decomposed aggregate productivity growth into the effect of reallocation and the effect of within-plant growth (Griliches and Regev, 1995; Foster *et al.*, 2001; Bartelsman *et al.*, 2005; Baldwin and Gu, 2006). The decomposition methods used in these studies focused on aggregate labor productivity or aggregate multifactor productivity and the extent to which shifts in output and inputs across firms enhanced productivity growth.

However, previous empirical studies did not focus on the underlying causes of changes in labor and multifactor productivity at the plant level arising from factors such as investment, technological progress, scale economies, or variable input utilization—only on whether changes were internal to the plant or were caused by reallocation of outputs across plants that arise from the dynamic competitive process. In order to proceed further, it is necessary to introduce production functions at the plant level to improve our understanding of the sources of the within-plant growth effect and the between-plant reallocation effect on overall productivity growth.

This paper extends the previous work that just examined the size of within- and between-plant components to allow us to delve deeper into these components using the methodologies of Jorgenson and his collaborators.[3] The methodologies of Jorgenson and his collaborators were developed under the assumption of

[2]A number of recent papers have presented a decomposition of aggregate multifactor productivity growth (Basu and Fernald, 2002; Petrin and Levinsohn, 2012). Similar to this paper, these papers can be seen as an extension of the Jorgenson decomposition to a non-neoclassical framework.

[3]Previous work also extends that analysis by not just examining the effects of the reallocation of labor or other inputs (as is done here) to investigating the impact of shifting market share—in order to quantify the impact of competition on productivity growth.

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perfect competition and constant returns to scale. This paper introduces non-neoclassical features of the plant-level economic environment such as imperfect competition and increased returns to scale, as in Hall (1988, 1990), Basu and Fernald (2002), and Petrin and Levinsohn (2012). It also takes into account the effect of changes in capacity utilization.

Jorgenson (1966) and Jorgenson *et al.* (2005) developed two alternative approaches for constructing the aggregate estimates of labor and multifactor productivity growth—a production possibility frontier approach and the direct aggregation across micro-producers (firms or plants).[4] The former is the traditional approach used to estimate productivity when only aggregate data are available. The latter allows for a decomposition of the within- and between-plant components.

For the empirical analysis below, value-added will be used to measure output at both aggregate industry level and plant level. As such, the decomposition in this paper will be presented using the value-added output concept. Alternatively, gross output can be used to measure output at aggregate industry and plant levels. The gross output of an aggregate industry is defined as the sum of gross output of individual plants. The gross output approach is presented and applied in Gu and Lafrance (2012) in their study on the dynamics of productivity growth in the broadcasting and telecommunication industry in Canada.[5]

The value-added approach used in this paper imposes a separability assumption necessary for the existence of value-added production at the plant level; the gross output approach, while it captures more of the production process by taking into account the role of intermediate inputs at the plant level, may suffer from the double counting of intermediate inputs transactions among plants within an industry.[6] In addition, as shown by Basu and Fernald (2001), the chained-Torqvist aggregation method used in statistical agencies for calculating valued added as the difference between gross output and intermediate inputs implies that value-added growth is not, in general, a function of capital and labor inputs alone. It is also affected by intermediate input growth when there is imperfect competition. With imperfect competition, value-added growth is a function of capital and labor alone when the ratio of intermediate inputs to gross output is constant. Basu and Fernald (2001) also show that the value-added approach is expected to yield a higher MFP growth and larger effect of capacity utilization on MFP growth. But the value-added approach and gross output approach often yield similar trends in aggregate labor and multifactor productivity growth.

In addition to the value-added and gross output approaches, the third alternative is to use the gross output concept at the plant level and the value-added concept at the aggregate level. That framework will be appropriate to examine the

[4]Those two approaches are sometimes called top-down and bottom-up approaches.

[5]The decomposition methodology based on gross output concept is a straightforward extension of the methodology based on the value-added concept used in this paper from two inputs (capital and labor) to three inputs (capital, labor, and intermediate inputs).

[6]As a result of the double counting of intermediate inputs, a reorganization of production that resulted in increased use of intermediate inputs would count as an increase in productivity even though the amount of production for use outside of the industry would not be increased by this reorganization. We thank an anonymous referee for making this point.

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dynamics of productivity growth at the total economy level where the appropriate output concept is value-added (Basu and Fernald 2001; Jorgenson *et al.*, 2005).[7]

2.1. *Production Possibility Frontier*

The production possibility frontier approach assumes that capital and labor inputs receive the same price in all plants, but plants have different production functions that relate value-added output (V) to capital, and labor inputs at the plant level and the price of output differs across plants.[8] Under these assumptions, aggregate value-added can be expressed as a function of aggregate capital, aggregate labor, and a time variable that proxies technology (T). The aggregate value added is defined as a Tornqvist index of plant value-added:

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

where $\Delta\ln$ denotes the change between periods $t-1$ and t in logarithm, and $\bar{w}_i$ is the share of plant i in aggregate nominal value-added, averaged over the two periods.

Aggregate labor productivity growth, defined as the difference between growth in aggregate value added and growth in aggregate labor input, can be written as:

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

where $\Delta\ln P_i = \Delta\ln V_i - \Delta\ln L_i$ is labor productivity growth at plant i defined as difference between value-added growth $\Delta\ln V_i$ and labor input growth $\Delta\ln L_i$.

The growth on aggregate labor productivity in equation (2) is decomposed into two components: the within-plant effect and between-plant reallocation effect. The within-plant effect measures the contribution to overall productivity growth of growth within individual plants, holding their shares of output constant. The second term is the between-plant effect that represents the effect of reallocation of labor input on aggregate labor productivity growth. The reallocation effect is positive if plants with higher average labor productivity level have faster growth in labor input.[9] To see that, aggregate growth in labor input can be approximated as the weighted average of labor input growth across plants using labor input shares of plants as weights, i.e. $\Delta \ln L = \sum_i \bar{s}_i \Delta \ln L_i$. Aggregate labor productivity

[7]The framework requires Domar aggregation (Domar, 1961).

[8]The existence of value-added production function at the plant level requires the assumption that intermediate inputs are separable from capital, labor, and technology variables (Jorgenson *et al.*, 2005).

[9]The equation has been applied to industry level data by Jorgenson *et al.* (2005). The economic interpretation of the reallocation effect is valid when average labor productivity is equal to marginal labor productivity in the plants that are characterized by constant returns to scale. When there are increasing returns to scale and plants operate at different scales, average labor productivity is not proportional to marginal productivity across plants. In that case, a portion of the reallocation effect is included in the within-plant effect.

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rises and the reallocation effect is positive if plants whose value-added shares exceed their employment shares ($\bar{w}_i > \bar{s}_i$) (or plants with higher average labor productivity levels) experience faster growth in labor input (Jorgenson *et al.*, 2005).

The decomposition in equation (2) differs from the decomposition used in most empirical studies (Griliches and Regev, 1995; Foster *et al.*, 2001; Baldwin and Gu, 2006, 2011). Those studies start with the equation that aggregate labor productivity level is a weighted sum of labor productivity level across plants using employment shares s_i as weights: $P = \sum_i s_i P_i$. First-differencing the equation provides a decomposition of aggregate labor productivity changes into a within-plant component and a between-plant component: $\Delta P = \sum_i \bar{s}_i \Delta P_i + \sum_i \Delta s_i \bar{P}_i$, where a bar over a variable denotes average values over two periods.

The decomposition in those previous empirical studies is valid when the price of output is the same across all plants. When that is true, aggregate output can be expressed as the sum of output across plants and aggregate labor productivity level is equal to a weighted sum of plant labor productivity using plant employment share as weights. However, when the price of output differs across plants as is the case for the production possibility frontier approach, the decomposition in those previous studies only provides an approximation to the correct decomposition in equation (2).

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 labor productivity growth and the effect of capital deepening:

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

where v_T is multifactor productivity growth, and $\bar{\alpha}_K$ is the share of capital cost in nominal output, averaged over the two periods.

2.2. *Direct Aggregation Across Plants*

The alternative approach for estimating aggregate labor and multifactor productivity is direct aggregation across plants (Jorgenson *et al.*, 1987, 2005). The approach relaxes the assumption adopted in the production possibility frontier approach that all inputs receive the same price among all plants. Instead, it assumes that the prices of capital and labor inputs differ across plants. For the purpose of this paper, the direct aggregation approach is extended to take into account non-neoclassical features of the economic environment facing plants. More specifically, it is assumed that the plant production function is characterized by increasing returns to scale and there is imperfect competition in the product market.

Plant *i* is assumed to have a production function that expresses output (V_i) as a function of capital (K_i), labor (L_i), and technology (T_i):

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

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where e_{Ki}, e_{Li} denote the unobserved utilization of capital, labor, and T_i indexes technology. The production function exhibits increasing return to scale γ_i.

Following Hall (1990) and Basu and Fernald (2001, 2002), output growth can be written as:[10]

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

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

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

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

$$\Delta \ln e_i = \bar{\alpha}_{Ki} \Delta \ln e_{Ki} + \bar{\alpha}_{Li} \Delta \ln e_{Li}. \tag{7}$$

$\bar{\alpha}_{Ki}$ and $\bar{\alpha}_{Li}$, are the average shares of capital and labor in nominal output. The sum of those input cost shares in nominal output is less than one if there is economic profit. $v_{T,I}$ is multifactor productivity growth. μ_i is the mark-up over marginal cost. The mark-up is related to the returns to scale γ_i and the ratio of economic profits to nominal output $s_{\pi i}$ by the following equation:

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

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 returns to scale 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, mark-up is equal to returns to scale and the sum of input costs share in nominal output is equal to one. Subtracting labor input growth from both sides of equation (5) yields the following equation that shows the source of growth in labor productivity at plant i:

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

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

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

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

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

where $\bar{w}_{Ji}$ is the share of plant i in the cost of input J averaged over two periods, P_{Ji} is the price that input J receives at a plant, and P_J is the price of input J in the production possibility frontier approach.[11]

Aggregate multifactor productivity growth is decomposed into a within-plant component and a between-plant component. The within-plant component captures the effect of changes taking place at individual plants 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-plant component that measures the effect of reallocation of capital and labor on aggregate multifactor productivity growth. The reallocation of an input contributes positively to aggregate MFP growth if the input is shifted toward those plants 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.

Previous empirical studies also decomposed aggregate MFP growth into within-plant and between-plant components. The within-plant component was estimated as a weighted sum of MFP growth across plants using their output shares as weights. The between-plant component was calculated as the change in the output share of a plant times the average MFP level of the plant, summed over all plants. Our contribution here is to delve deeper into those two components and provide a richer understanding of the sources of within-plant growth effect and between-plant reallocation effect.[12]

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

$$\Delta \ln P = \sum_i \bar{w}_i \Delta \ln P_i + \left(\sum_i \bar{w}_i \Delta \ln L_i - \Delta \ln L\right), \tag{11}$$
$$\sum_i \bar{w}_i \Delta \ln P_i = \sum_i \bar{w}_i(\mu_i - 1)\Delta \ln X_i + \sum_{J=K}\sum_i \bar{w}_i \bar{\alpha}_{Ji}\Delta \ln(J_i/L_i) + \sum_i \bar{w}_i a_i \Delta \ln e_i + \sum_i \bar{w}_i v_{T,i},$$
$$\left(\sum_i \bar{w}_i \Delta \ln L_i - \Delta \ln L\right) = \sum_{J=K,L} REALL_J + \bar{\alpha}_K\left(\Delta \ln(K/L) - \sum_i \bar{w}_{Ki}\Delta \ln(K_i/L_i)\right).$$

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

[12]A number of recent studies have proposed a similar decomposition of aggregate multifactor productivity growth (Basu and Fernald, 2002; Petrin and Levinsohn, 2012). These papers, like this one, can be seen as extension of the Jorgenson decomposition to a non-neoclassical framework. For example, the MFP decomposition in Basu and Fernald (2002) (equation 28) and Petrin and Levinsohn (2012) (equation 9) are variants of the decomposition (12) in this paper.

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Aggregate labor productivity growth is decomposed into a between-plant and a within-plant component. The within-plant effect in equation (11) is the sum of the following components: scale effect, capital deepening effect, variable input utilization effect, and technical progress. The between-plant reallocation effect is traced to the effect of the reallocation of labor and capital inputs on aggregate MFP growth $\left(\sum_{J=K,L} REALL_J\right)$ and the effect of reallocation on capital deepening.

To complete the decomposition, it can be shown that the aggregate capital deepening effect can be decomposed into the effect of capital deepening at the plant level and the effect of input reallocation across plants on aggregate capital deepening.

$$(12)\quad \bar{\alpha}_K \Delta \ln(K/L) = \sum_i \bar{w}_i \bar{\alpha}_{Ki} \Delta \ln(K_i/L_i) + \bar{\alpha}_K \left(\Delta \ln(K/L) - \sum_i \bar{w}_{Ki} \Delta \ln(K_i/L_i) \right).$$

The between-plant reallocation effect is positive if labor moves toward those plants with higher capital costs and higher marginal products of capital.

The decomposition of aggregate MFP growth, aggregate labor productivity growth, and aggregate capital deepening effects can be extended to estimate the effect of entrants and exiters. 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 plants and ignored the effect of entry and exit (Basu and Fernald, 2002; Petrin and Levinsohn, 2012).

In order to estimate the effect of entry and exit, it is assumed that a hypothetical plant exists whose inputs and outputs at the start of the period is set equal to those of exiters, and whose inputs and outputs at the end of the period is set equal to those of entrants at the end of the period. The contribution of entry and exit to aggregate MFP growth, labor productivity growth, and capital deepening effect can be measured as the contribution of the hypothetical plant to the within-plant component in the decomposition. For example, the contribution of entry and exit to aggregate labor productivity is estimated as the difference between the average labor 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. This approach for estimating the effect of entry and exit is consistent with the approach proposed by Baldwin (1995) to estimate the effect of entry and exit. Baldwin argues that if the entrants essentially displace the exiters, the effect of entry and exit should be evaluated by comparing entrants and exiters.[13]

[13]Alternatively, the effect of entry and exit is estimated separately (e.g., Griliches and Regev, 1995; Foster *et al.*, 2001). The effect of entry on productivity is estimated from a comparison of an entry cohort with average continuing plants or plants at the end of a period and the effect of exit is obtained from a comparison of an exit cohort with average continuers or plants at the start of a period. The methods are equivalent to a method suggested by a referee that the effect of entry and exit can be derived by comparing aggregate productivity growth with and without entry and exit. Baldwin and Gu (2011) show that the combined effects of entry and exit from those different approaches are similar for Canadian manufacturing, since the size of entry cohort is often similar to the size of exit cohort.

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3. Data

This paper examines productivity growth in the Canadian manufacturing sector over two periods: 1990–99 and 2000–06, and the causes of the slowdown that occurred. The plant-level data used in this study come from Statistics Canada's Annual Survey of Manufacturers' (ASM) longitudinal file, a database that covers the entire Canadian manufacturing sector using both survey and administrative data, and permits plants to be tracked over time.

The ASM database has information on shipments, value-added, employment, labor cost, heat and power costs, material costs, exports, ownership, and industry affiliation. Industry affiliation is at the 1980 4-digit Canadian Standard Industrial Classification (SIC) from 1979 to 1999, and at the 6-digit North American Industry Classification System (NAICS) from 1997 onwards. The two industry classifications are mapped to the 3- and 4-digit NAICS industry classification.

For the empirical analysis, we use value-added as a measure of output.[14] This value-added approach requires the assumption that time (used to proxy technology) and capital and labor inputs are separable from intermediate inputs.[15] The real value-added at a plant is derived by deflating the nominal value-added by a value-added deflator at industry level taken from the Productivity Accounts of Statistics Canada (Baldwin and Gu, 2009). The value-added deflator in the Productivity Accounts of Statistics Canada is in turn constructed from a double deflation of output and intermediate inputs using the chained-Tornqvist index.[16]

Labor input in the ASM file is calculated as the sum of production and non-production workers. Capital input is not available from the ASM file, and it is estimated using the assumption that energy cost is proportional to capital input. Specifically, it is estimated by allocating capital input of an industry at the 4-digit NAICS industry classification among the plants according to their shares of heat and power costs.[17,18]

Figure 1 shows the number of plants, capital, labor, and real value-added in the total manufacturing sector from the ASM longitudinal plant file. There were about 30,000 plants a year in the ASM file before 2000. The number of plants in the ASM file increased after 2000, as a result of the redesign of the Annual Survey of

[14]The value-added estimate constructed from the ASM file used here includes the costs of purchased services. This may generate an upward bias in the estimated labor productivity growth as purchased services are increasingly substituted for labor. But as shown in Table 1, the value added and labor productivity estimates from the ASM file and the Productivity Program of Statistics Canada show similar trends over time, and therefore the bias is likely to be small and will not affect our results on the sources of the decline in productivity growth after 2000.

[15]While the assumption is restrictive, decomposition results based on gross output and value-added are similar.

[16]The data are available from Statistics Canada CANSIM table 383-0022.

[17]Tomlin (2010) used a similar procedure to estimate capital stock of individual plants. Estevadeordal and Taylor (2002) constructed a proxy for capital stock based on energy consumption in their empirical test of factor abundance theory of trade. Energy costs are found to be highly correlated with capital costs across the manufacturing plants in the ASM micro-file, which provides empirical support for the assumption that energy costs are proportional to capital stock.

[18]Previous studies assumed that energy costs are related to capacity utilization and used energy costs to proxy capacity utilization. According to that assumption, the variation of capital stock estimated here may include the variation of capacity utilization resulting in biased parameter estimates. But as shown in the paper, energy costs are not related to capacity utilization and therefore the potential bias should be small.

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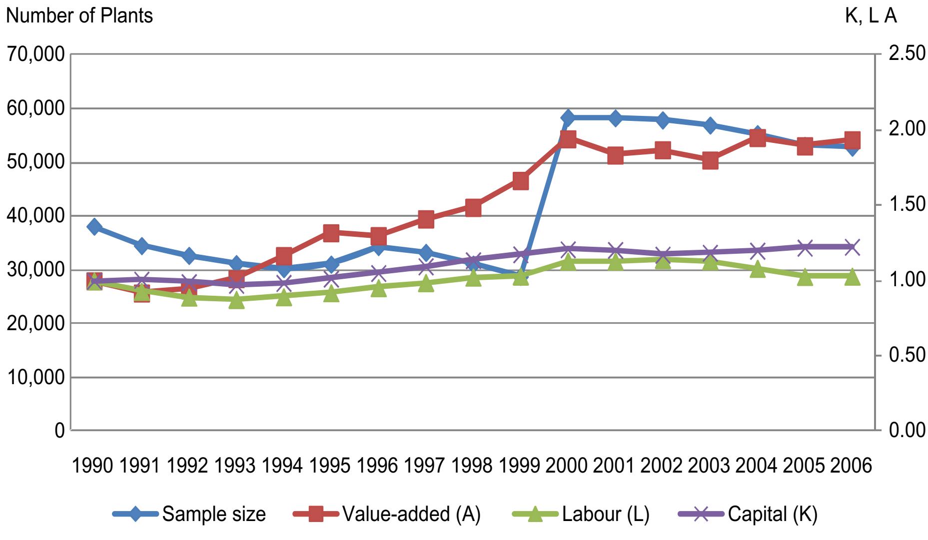

Figure 1. Capital, Labor, Value-Added, and Number of Plants in Manufacturing

Manufacturers over that period. For the period after 2000, there were between 50,000 and 60,000 plants a year in the ASM file. The ASM survey now captures more small plants, whose data are derived from tax forms.

The additional plants that the ASM captured after 2000 had a negligible effect on the estimate of output and inputs, as shown in Figure 1. To remove any potential bias that the ASM redesign may have on the results, the decomposition of aggregate productivity growth into within- and between-plant components and the effect of net entry is carried out separately for the two periods 1990–99 and 2000–06. Each period is consistent with regard to sample coverage.

The growth rates of output, inputs, and productivity derived from the ASM micro-file are compared with the aggregate statistics from the KLEMS productivity database of Statistic Canada in Table 1. The ASM data and the KLEMS data exhibit similar output and labor productivity growth rates during the 1990s, and slightly different growth rates during the post-2000 period. They both show the same decline in labor productivity growth after 2000. The data from the ASM show that labor productivity growth declined from 3.7 percent per year to 1.7 percent per year from the 1990–99 period to the 2000–06 period.[19] The data from the KLEMS database show that labor productivity growth declined from 3.3 percent per year to 1.0 percent per year between those two periods.

3.1. *Measures of Capacity Utilization*

To examine the extent to which the decline in productivity growth came from a decline in capacity utilization, a measure of capacity utilization needs to be

[19]The part of the difference in the growth of value-added is due to the difference in treatment of purchased services. The value-added estimate from the ASM file includes purchased services, while that form the Productivity Program of Statistics Canada does not.

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TABLE 1
Annual Growth Rates of Output, Capital, and Labor in Total Manufacturing

	ASM		KLEMS	
	1990–99	2000–06	1990–99	2000–06
Labor productivity	3.7	1.7	3.3	1.0
Real value added	4.0	0.2	3.4	–0.3
Capital input	1.8	0.2	2.3	0.3
Labor input	0.3	–1.5	0.2	–1.2
Nominal value added	5.7	–0.1	5.6	–0.4
Capital income	8.9	–3.7	8.8	–3.9
Labor income	2.8	2.2	3.3	2.4

Source: The authors' tabulation from the Annual Survey of Manufacturers and CANSIM table 383-0022.

constructed. As direct measures of capacity utilization are often not observable, previous empirical studies have used a number of proxies. Solow (1957) used unemployment rates for adjusting the changes in the utilization of both capital and labor. Jorgenson and Griliches (1967) used an index of electric motor utilization in U.S. manufacturing to adjust capital utilization in the U.S. private economy. Other measures used include growth of materials (Basu, 1996), hours worked per worker (Basu and Fernald, 2001), the ratio of energy costs to capital stock (Burnside *et al.*, 1995), and profit shares (Denison, 1979). As noted in Berndt and Fuss (1986), the use of ad-hoc proxies is unsatisfactory since it lacks adequate theoretical framework.

An alternate measure has been developed by Berndt and Fuss (1986) and Hulten (1986) who show that the ex-post capital income compared with ex-ante capital cost provides a good measure of the utilization of capital.[20] They argue that an adjustment should be made to the price of capital input in the traditional growth accounting framework to take into account the changes in capacity utilization. They show that the ex-post return on capital captures the effect of changes in capacity utilization. When the ex-post return on capital is used to measure the contribution of capital to output growth, MFP growth calculated as the difference between output growth and the contributions of capital and other inputs is adjusted for changes in capacity utilization. As noted in a number of previous studies, the procedure by Berndt and Fuss does not completely remove the cyclical fluctuations in the MFP growth associated with variable capacity utilization (e.g., Basu and Fernald, 2001).

Gu and Wang (2012) build upon the idea in Berndt and Fuss (1986) that the variation in ex-post return to capital reflects the variation in capacity utilization and argue that the ex-post return to capital should be used to adjust the quantity of capital input rather than the price of capital input as in Berndt and Fuss (1986). They show that when the ratio of ex-post to ex-ante return to capital is used to adjust the quantity of capital input, the estimated MFP growth takes into account the rate of capital utilization.

[20]In rapidly growing industries, the value of marginal product of capital can be higher than the ex-ante capital costs (Hulten, 1986).

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The approach developed by Berndt and Fuss (1986), Hulten (1986), and Gu and Wang (2012) requires an estimate of ex-ante return to capital at the plant level which is not easy to construct. Therefore, the share of capital income in total value added will be used here instead. The alternative used here should bear a close relationship to the Berndt–Fuss measure since the share of capital income will be highly correlated with the ratio of ex-post capital to ex-ante capital income. It is also related to Denison (1979) who used an index of corporate profit share in corporate national income to adjust capital input for fluctuations in intensity of use.

The log changes in capacity utilization rates as measured by the share of capital income in value added from the ASM are found to be positively correlated with the log changes in capacity utilization rates as measured by the ratio of actual output to potential output from a survey of manufacturing firms across industries.[21] The correlation is large and statistically significant. The two capacity utilization rates also showed a similar trend for the total manufacturing sector. It increased in the 1990s as manufacturing firms increased output to meet the increasing demand for their outputs arising from the implementation of the North American Free Trade Agreement. It then declined after 2000 and the decline coincided with the appreciation of the Canadian dollar relative to the U.S. dollar, which made Canadian products more expensive in the U.S. markets, and with the U.S. recession, which resulted in lower demand for imported goods.

As noted above, previous studies used alternative proxies for capacity utilization such as the ratio of energy costs to capital stock and hours worked per worker. However, those proxies are found to be a poor measure of capacity utilization for the Canadian manufacturing plants over the last 20 years. The ratio of energy costs to capital stock in the manufacturing sector increased during the early 1990s when there was a deep recession and declines in capacity utilization. The hours worked per worker showed little fluctuations over time in the Canadian data. While not perfect, the ratio of capital income to value-added proposed in this paper provides a good measure of capacity utilization based on the empirical evidence presented here, and the theoretical development of Berndt and Fuss (1986), Hulten (1986), and Gu and Wang (2012).

4. Empirical Results

This section reports the results from the decomposition of aggregate labor and multifactor productivity growth for the total manufacturing sector. In the first step, the parameters of the production function are estimated using plant-level data to obtain estimates of the economies of scale and the effect of variable capacity utilization on labor productivity growth. In the second step, these parameter estimates are used in the decomposition formulae to break down aggregate productivity growth into its components.

Alternative econometric techniques are used to estimate the parameters—to assess the sensitivity of the results to alternative estimation techniques. Finally, the relative contributions of exporters and non-exporters, and foreign- and domestic-controlled plants to aggregate labor productivity growth are measured in

[21]The ratio of actual output to potential output is taken from CANSIM table 028-0002.

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order to see whether the impact of capacity utilization was greater in those producers most affected by the appreciation of the Canadian dollar.

4.1. *Production Function Estimation*

This section reports parameter estimates of scale economies and capacity utilization 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:

$$\ln V_{it} = \alpha_K \ln K_{it} + \alpha_L \ln L_{it} + a \ln e_{it} + \delta_t + (\eta_i + v_{it} + m_{it}), \tag{13}$$

where δ_t is a year effect. The equation includes three error terms. η_i is an unobserved plant effect, v_{it} is a possibly autoregressive productivity shock, and m_{it} reflects serially uncorrelated measurement errors. The estimate of returns to scale is derived as the sum of the coefficients on capital and labor inputs, α_K and α_L. As output is measured by value-added, only capital, labor, and capacity utilization are included as independent variables.

The equation is estimated for each of 20 manufacturing industries using the 3-digit NAICS industry classification. The SYS-GMM and Difference-GMM estimation methods are used to address the effect of the possible endogeneity of the independent variables in the production function (Arellano and Bond, 1991; Blundell and Bond, 1998). For example, the endogeneity of the capacity utilization variable arises when a negative productivity shock leads to a loss in market shares of Canadian firms in international markets, which in turn leads to the decline in input utilization. Difference-GMM transforms all variables by differencing, and uses lagged levels of the independent variables (capital, labor, and capacity utilization variables) as instruments for first-differenced variables. SYS-GMM makes an additional assumption on the initial condition process that is designed to allow the introduction of more instruments and improves the properties of the Difference-GMM estimator.

The discussion in Section 3.1 suggests that it is the change in the share of capital income in value added over time that captures the change in capacity utilization. The cross-sectional differences in the share of capital income in value added may not necessarily reflect the differences in capacity utilization. The capacity utilization variable and all other variables are therefore demeaned at the individual plants before the estimation.

The sample used for estimation consists of all plants in the ASM longitudinal file that existed for at least five years in the period 1990–2006. The sample of plants that existed for at least 2 years, 10 years, or in all years during the sample period is also employed; the resulting estimates are similar.

The estimates of the degree of returns to scale and the effect of capacity utilization are presented in Table 2. The estimates are derived using SYS-GMM and Difference-GMM allowing for AR(1) error in the level equation.[22] The

[22]SYS-GMM and Difference-GMM with AR(1) error were employed. The Arellano–Bond test does not reject the second-order and third-order serial correlation in the differenced equation. The Levinsohn–Petrin estimation technique (Levinsohn and Petrin, 2003) was also employed. But the estimated degree of returns to scale was unreasonably low in the latter. This may be due to the collinearity problem associated with Levinsohn–Petrin estimation as shown by Ackerberg *et al.* (2006).

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TABLE 2
GMM Estimates of Returns to Scale and the Effect of Capacity Utilization on Output Growth

	SYS-GMM		DIFF-GMM	
Industry	Returns to Scale	Effect of Utilization	Returns to Scale	Effect of Utilization
Food manufacturing	1.07	0.88	1.04	0.86
Beverage and tobacco	0.93	0.90	0.95	0.93
Textile and textile products	0.94	0.69	0.90	0.66
Clothing manufacturing	0.86	0.45	0.91	0.54
Leather and allied products	0.80	0.35	0.84	0.39
Wood products	1.03	0.77	1.03	0.77
Paper manufacturing	0.91	0.56	0.88	0.53
Printing and related activities	0.99	0.73	1.00	0.84
Petroleum and coal products	0.85	0.80	0.84	0.78
Chemical manufacturing	0.87	0.74	0.85	0.70
Plastics and rubber products	0.97	0.83	0.96	0.78
Non-metallic mineral products	1.03	0.57	1.04	0.60
Primary metal manufacturing	0.95	0.68	0.90	0.73
Fabricated metal products	1.08	0.87	1.03	0.89
Machinery manufacturing	1.14	0.85	1.03	0.76
Computer and electronic products	1.06	0.74	0.85	0.63
Electrical equipment	0.95	0.70	0.93	0.63
Transportation equipment	1.02	0.88	1.00	0.82
Furniture and related products	1.05	0.70	1.01	0.62
Miscellaneous manufacturing	1.06	0.82	1.02	0.76
Average	0.98	0.73	0.95	0.71

Arellano and Bond test of second-order and third-order serial correlation both reject serial correlation in the differenced equation in most industries. But the Sargan test rejects the null hypothesis that the overidentifying restrictions are valid. As the Sargan test is prone to weakness, the results from the Sargan test may not necessarily mean that the instruments in the GMM estimator are invalid.

The average returns to scale is about 0.98 in the 20 manufacturing industries, indicating that, on average, constant returns to scale are present. Our estimates of returns to scale are similar to the evidence from previous studies (Basu *et al.*, 2009; Diewert *et al.*, 2011). The coefficients on the input utilization variable are all positive and statistically significant at the 5% level. A higher utilization of capital and labor inputs results in higher output.[23]

Equation (13) is also estimated using OLS. The OLS estimates are reported in Baldwin *et al.* (2012).[24] The estimated coefficient on the capacity utilization variable is lower than the GMM estimate presented in Table 2. That is, the OLS estimator underestimates the coefficient on the capacity utilization variable. As shown in Levinsohn and Petrin (2003), the direction of bias in the estimated coefficient on a variable (capacity utilization) from the OLS depends on the

[23]When the unobserved productivity shocks are correlated with capacity utilization, scale economies, and other independent variables, it is difficult to separately indentify those effects. The GMM estimate provides an identification of those effects by imposing appropriate moment restrictions.

[24]The OLS estimates in Baldwin *et al.* (2012) are obtained using a slightly different sample. When the same sample as the one used for the GMM estimation is used, the results are similar.

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TABLE 3
Sources of Aggregate Labor Productivity Growth, Production Possibility Frontier Approach

	1990–99	2000–06	2000–06 less 1990–99
Annual average labor productivity growth	3.7	1.7	–2.0
Contribution from:			
Capital deepening	0.8	1.2	0.3
MFP growth	2.9	0.5	–2.4
Reallocation of labor across industries	–0.1	0.0	0.1

Source: Authors' tabulation from the ASM file.

relative strength of correlation between productivity shocks and the capacity utilization variable and other variables including capital and labor input. The downward bias for the capacity utilization variable generated by OLS occurs when the correlation between productivity shocks and the capacity utilization is lower than the correlation between the productivity shocks and the other variables.

For the rest of the paper, we will present decomposition results using the parameter estimates from the SYS-GMM estimation technique. The decomposition results based on alternative parameter estimates are very similar.[25]

4.2. *Decomposition Results for Total Manufacturing*

This section reports the decomposition estimates for aggregate labor and multifactor productivity growth and examines the sources of the decline in aggregate productivity growth in the total manufacturing sector.

Table 3 presents a decomposition of the aggregate labor productivity growth from the production possibility frontier approach into two main sources: the effect of aggregate capital deepening, and the effect of aggregate multifactor productivity growth. Aggregate labor productivity growth in manufacturing declined from 3.7 percent per year during the period 1990–99 to 1.7 percent per year during the period 2000–06. The deceleration in labor productivity growth can be attributed to the decline in MFP growth. The contribution of capital deepening increased slightly between the two periods.

Table 4 presents the decomposition results for aggregate MFP growth and aggregate capital deepening effect, while Table 5 presents decomposition results for aggregate labor productivity growth. They are each decomposed into the within-plant effect, the between-plant reallocation effect, and the effect of entry and exit. The decomposition is carried out for the 20 industries at 3-digit NAICS industry classification, and then aggregated to the total manufacturing sector, using their shares of total nominal value-added as weights.

Previous empirical studies have decomposed aggregate labor and multifactor productivity growth into the effect of within-plant growth, between-plant reallocation, and net entry. The decomposition results in Tables 4 and 5 extend those empirical studies to provide a richer understanding of the between- and within-plant components.

[25]Those results are presented in Baldwin *et al.* (2012).

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TABLE 4

Decomposition of Aggregate MFP Growth and Aggregate Capital Deepening Effect

	1990–99	2000–06	2000–06 less 1990–99
Decomposition of aggregate MFP growth			
Aggregate MFP growth	2.9	0.5	–2.4
Contribution of:			
Within-plant effect	2.6	0.1	–2.5
Within-plant MFP growth	1.3	0.8	–0.5
Scale economies	0.1	0.0	–0.1
Input utilization	1.2	–0.7	–1.9
Between-plant effect	0.1	0.4	0.3
Reallocation of capital	0.1	0.3	0.2
Reallocation of labor	–0.1	0.1	0.2
Net entry	0.4	0.0	–0.4
Decomposition of aggregate capital deepening effect			
Aggregate capital deepening effect	0.8	1.2	0.3
Contribution of:			
Within-plant effect	1.0	1.2	0.2
Between-plant effect	–0.3	0.0	0.3
Net entry	0.2	0.0	–0.2

Notes: Aggregate MFP growth is the sum of direct effect and reallocation effect where the direct effect is the sum of within-plant MFP growth, the effect of scale economies and input utilizations at individual plants, and the reallocation effect includes the effect of reallocation of labor and the effect of reallocation of capital.

Source: Authors' tabulation from the ASM file.

TABLE 5

Decomposition of Aggregate Labor Productivity Growth

	1990–99	2000–06	2000–06 less 1990–99
Aggregate labor productivity growth	3.7	1.7	–2.0
Within-plant effect	3.6	1.3	–2.2
MFP growth	1.3	0.8	–0.5
Scale economies	0.1	0.0	–0.1
Input utilization	1.2	–0.7	–1.9
Capital deepening	1.0	1.2	0.2
Between-plant effect	–0.3	0.4	0.6
Reallocation of capital on MFP	0.1	0.3	0.2
Reallocation of labor on MFP	–0.1	0.1	0.2
Reallocation effect on capital deepening	–0.3	0.0	0.3
Net entry	0.6	0.0	–0.6

Notes: Aggregate labor productivity growth is the sum of within-plant effect, between-plant effect, and the effect of net entry. The aggregate labor productivity growth may differ from the sum of those three components. The difference reflects the effect of reallocation of labor across industries on aggregate labor productivity growth.

Source: Authors' tabulation from the ASM file.

Consistent with the empirical evidence from the previous studies, the results in Tables 4 and 5 show that the aggregate labor and multifactor productivity growth can mainly be attributed to the growth occurring within individual plants, but reallocation is important. The between-plant reallocation is especially important for the aggregate MFP growth in the period 2000–06, accounting for more than half of the 0.5 percent growth in the aggregate MFP growth for that period. The

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post-2000 period when the manufacturing sector was facing adjustment challenges, in part, to the Canada/U.S. exchange-rate appreciation, was one where considerably more impact of reallocation was felt.

Aggregate labor productivity went from 3.7 percent per year in the 1990–99 period to 1.7 percent per year in the 2000–06 period, a decline of 2.0 percentage points. The last column of Table 5 provides a decomposition of that decline.

The decline in labor productivity growth within individual plants during the post-2000 period compared to the pre-2000 period accounted for most of the decline in aggregate labor productivity growth. Net entry also contributed to the decline. But the reallocation among continuing plants raised the labor productivity growth in the post-2000 period.[26] Its impact is larger in the post-2000 period when the manufacturing sector was adjusting to exchange rate appreciation than during the 1990s, when it was expanding in response to the implementation of the North American Free Trade Agreement. The large between-plant reallocation effect in the 2000–06 period reflects the sum of the effect of reallocation of inputs on MFP growth (0.4 percentage points) and the effect of reallocation of inputs on capital deepening (0.3 percentage points).

Of the contribution from the within-plant effect to the decline in aggregate labor productivity growth (–2.2 percentage points), –1.9 percentage points come from declines in capacity utilization, –0.5 percentage points from declines in multifactor productivity growth, and the remaining –0.2 percentage points from scale economies and capital deepening. Scale economies and capital deepening made little contribution to the decline in the within-plant effect. The results suggest that the slowdown in aggregate labor productivity growth during the 2000–06 period is driven by significant under-utilization of production capacity and a slight worsening of MFP growth.

Around 90 percent or 1.9 percentage points of the 2.0 percentage-point decline in aggregate labor productivity is due to the pro-cyclical nature of productivity arising from capacity utilization. In the post-2000 period, the economy grew more slowly: the Canadian manufacturing sector contracted at an annual average rate of –0.3 percent in the 2000–06 period compared to average growth of 3.4 percent in the 1990–99 period. The non-instantaneous adjustment of production inputs such as capital and labor led to excess capacity and lower productivity estimates (unobservable capacity utilization results in over-measurement of variable production inputs). In addition, the sharp increase in energy prices following the commodity boom in the post-2000 period may have made capital of earlier vintages obsolete—much as occurred in the 1970s with the first oil shock.[27]

The other contributor to aggregate labor productivity change was capital deepening. It contributes 1.0 percentage points of the 3.7 percentage points growth in labor productivity in the 1990s and 1.2 of the 1.7 percentage points growth in the post-2000

[26]Chan *et al.* (2012) used the data from the ASM longitudinal file to decompose the aggregate labor productivity growth in the electronic and electrical products manufacturing into the with-plant growth effect and between-plant reallocation effect. They found that the decline in within-plant growth is the dominant factor behind the slow labor productivity growth in that sector. The between-plant reallocation among incumbents and entry and exit is not a significant factor.

[27]Berndt and Wood (1984) examined the impact of energy prices on the flow of services from a given stock of capital in this earlier period and argued that the earlier energy price shock led to the obsolescence of capital.

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period (Table 5). While the appreciation of the Canada/U.S. dollar in the post-2000 period made imported capital less expensive, and was associated with more capital deepening, this source of improvement in labor productivity was not sufficient to offset the effect of declining MFP growth and declining capacity utilization.

4.3. *Contribution of Exporters vs. Non-Exporters and Foreign- vs. Domestic-Controlled Plants*

The evidence on the importance of excess capacity in the post-2000 decline in aggregate productivity growth suggests that changes in the trading environment are a primary cause behind the slower productivity growth post-2000. To corroborate this interpretation, the between-plant component of aggregate labor productivity growth is decomposed into the contribution of exporters versus non-exporters and that of foreign- versus domestic-controlled plants. The exporters and foreign-controlled plants are expected to experience a larger decline in productivity growth compared with non-exporters and domestic-controlled plants in the post-2000 period as the effect of the unfavorable trading environment would likely to have been felt more by these trade-oriented plants.

Canada is a trade-dependent country. In 2006, the ratio of the merchandise exports to gross domestic product was 0.33; some 84 percent of merchandise exports were destined for the U.S. market. To investigate how the expansion and contraction in export markets affected aggregate productivity growth, continuers in a period are classified into four types according to their export status over the period: continuers that exported throughout the period; continuers that entered export markets over the period; continuers that exited from export markets; and continuers that did not export in the period.

The within-plant component of aggregate labor productivity growth is decomposed into the contributions from those four types of continuers in Table 6. The decomposition reveals that the slowdown in labor productivity was entirely driven by continuing exporters. During the more favorable export market conditions in the 1990s, continuing exporters experienced rapid growth in labor productivity, accounting for about 3.1 percentage points of the 3.7 percent annual labor productivity growth. Their contribution dropped to 0.2 percentage points during the post-2000 period as export markets contracted and exporters experienced little productivity growth over that period. Continuing exporters contributed 2.9 percentage points to the decline in annual labor productivity growth between those two periods. Around 50 percent of the slowdown was due to the under-utilization of production capacity, 25 percent was due to slower growth in multifactor productivity, 15 percent was due to a slowdown in capital deepening between the two periods, and the remaining 10 percent was due to changes in scale economies.

Rising commodity prices, the appreciation of the Canadian dollar, and the resulting gains in the terms of trade offered new opportunities in expanding domestic markets due to a resource-led domestic boom that benefited manufacturing firms serving the domestic market in the post-2000 period (Baldwin and Yan, 2012). During this period, plants that exited export markets and began to serve domestic markets performed much better during the post-2000 period compared to the pre-2000 period, posting a gain in their contributions to aggregate

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TABLE 6

Direct Contribution of Exporters and Non-Exporters to Aggregate Labor Productivity Growth

	Different Types of Continuers				
	CX	EX	DX	NX	All
1990–99					
Aggregate labor productivity growth					3.7
Within-plant effect	3.1	0.3	0.0	0.2	3.6
MFP growth	1.3	0.0	–0.1	0.0	1.3
Scale economies	0.1	0.0	0.0	0.0	0.1
Input utilization	1.0	0.1	0.0	0.1	1.2
Capital deepening	0.8	0.1	0.1	0.1	1.0
Between-plant effect					–0.3
Net entry					0.6
2000–06					
Aggregate labor productivity growth					1.7
Within-plant effect	0.2	0.1	0.9	0.2	1.3
MFP growth	0.5	0.1	0.1	0.0	0.8
Scale economies	0.0	0.0	0.0	0.0	0.0
Input utilization	–0.6	0.0	0.0	–0.1	–0.7
Capital deepening	0.3	0.0	0.7	0.2	1.2
Between-plant effect					0.4
Net entry					0.0
2000–06 less 1990–99					
Aggregate labor productivity growth					–2.0
Within-plant effect	–2.9	–0.1	0.8	0.0	–2.2
MFP growth	–0.8	0.1	0.1	0.0	–0.5
Scale economies	–0.1	0.0	0.0	0.0	–0.1
Input utilization	–1.6	–0.1	0.0	–0.2	–1.9
Capital deepening	–0.5	–0.1	0.7	0.2	0.2
Between-plant effect					
Net entry					0.6
					–0.6
Addendum: Share of different types of plants in total value added					
1990–99	55.4	9.7	5.7	9.7	80.5
2000–06	53.3	6.3	7.6	8.1	75.3

Notes: The continuing plants are classified into four types: continuers that exported throughout the period (denoted by CX); continuers that entered export markets (EX); continuers that exited from exports (DX); and continuers that did not export in the period (NX). The within-plant effect is the sum of the contributions of those four types of continuing plants.

Source: Authors' tabulation from the ASM file.

labor productivity growth of 0.8 percentage points annually. The gain mainly came from capital deepening (0.7 percentage points) and improvements in multifactor productivity (0.1 percentage points).

Because of differences in export-market participation, it is hypothesized that productivity growth for foreign-controlled plants slowed much more in the post-2000 period compared to that for domestic-controlled plants. The discrepancy, however, should not have been as sharp as that between exporters and non-exporters because some domestic firms were also exporters.

The decomposition results in Table 7 indicate that foreign-controlled continuing plants contributed 1.8 percentage points to the deceleration in aggregate labor productivity growth between 1990–99 and 2000–06, compared to –0.4 percentage

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TABLE 7

Direct Contribution of Foreign- and Domestic-Controlled Plants to Aggregate Labor Productivity Growth

	Different Types of Continuers		
	Foreign Plants	Domestic Plants	All
1990–99			
Aggregate labor productivity growth			3.7
Within-plant effect	2.5	1.1	3.6
MFP growth	1.1	0.2	1.3
Scale economies	0.0	0.1	0.1
Input utilization	0.7	0.5	1.2
Capital deepening	0.7	0.3	1.0
Between-plant effect			–0.3
Net entry			0.6
2000–06			
Aggregate labor productivity growth			1.7
Within-plant effect	0.7	0.6	1.3
MFP growth	0.3	0.5	0.8
Scale economies	0.0	0.0	0.0
Input utilization	–0.4	–0.2	–0.7
Capital deepening	0.9	0.3	1.2
Between-plant effect			0.4
Net entry			0.0
2000–06 less 1990–99			
Aggregate labor productivity growth			–2.0
Within-plant effect	–1.8	–0.4	–2.2
MFP growth	–0.8	0.4	–0.5
Scale economies	0.0	0.0	–0.1
Input utilization	–1.1	–0.8	–1.9
Capital deepening	0.2	0.0	0.2
Between-plant effect			0.6
Net entry			–0.6
Addendum: Share of different types of plants in total value added			
1990–99	45.9	34.6	80.5
2000–06	41.5	33.6	75.3

Notes: The within-plant effect is the sum of the contributions of foreign- and domestically-controlled plants.

Source: Authors' tabulation from the ASM file.

points for domestic-controlled plants.[28] The foreign sector's contribution to this slowdown in aggregate labor productivity growth is larger than its share of nominal value added (between 40 and 45 percent in the two periods) as foreign-controlled plants showed a larger decline in labor productivity growth than domestic-controlled plants. But, as expected, the discrepancy between foreign- and domestic-controlled plants is not as large as that between exporters and non-exporters.

The common source of slowdown for both domestic- and foreign-controlled plants is excess production capacity. Slower MFP growth is the other important contributing factor for foreign-controlled plants. In contrast, MFP growth in

[28]Domestic-controlled plants and foreign-controlled plants are defined based on their status at the start of a period. Foreign-controlled plants made a large contribution to productivity growth in the Canadian manufacturing industry (Baldwin and Gu, 2006; Ng and Souare, 2010).

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domestic-controlled plants experienced little change over time. The capital deepening effect increased in foreign-controlled plants, while it was unimportant in domestic-controlled plants. The declines in capital costs associated with the appreciation of the exchange rate were exploited more by foreign-controlled than domestic-controlled plants.

5. Conclusion

The Canadian manufacturing sector underwent considerable restructuring as a result of changes in the economic environment and the development of excess capacity in the post-2000 period. This paper demonstrates the close connection between changes in the economic environment, increases in excess capacity, and the slowdown in productivity growth for that period.

The decomposition of overall productivity growth into its components reveals that most, if not all, of the decline in aggregate labor productive growth was due to the decline in labor productivity growth within plants. And most of this decline came from an emergence of excess capacity. The deterioration in productivity performance during the 2000s in manufacturing stems in large part from the economic conditions that led to the development of excess capacity.

The effect of net entry on productivity growth also fell in the post-2000 period, contributing to the post-2000 labor productivity growth slowdown. In a related paper, Baldwin and Yan (2012) demonstrate that much of this decline in the effect of net entry was also associated with the appreciation of the Canadian dollar in that period. The appreciation of the Canadian dollar in the post-2000 period led to the exit of many large exporters that were relatively more productive. As a result, the exiters in the post-2000 period were as productive as entrants and the process of entry and exit made little contribution to productivity growth, whereas it did so in the 1990s. The reallocation of inputs within continuing plants did not decline during the post-2000 period, and was not a factor in the decline in labor productivity growth in the post-2000 period. Indeed, the positive impact of reallocation increased post-2000, but not sufficiently to offset the impact of increases in excess capacity.

The source of this excess capacity mainly originated in export markets. Almost all of the aggregate labor productivity growth slowdown after 2000 was driven by exporters, as exporters experienced large declines in labor productivity growth after 2000 as a result of large declines in capacity utilization arising from lower demand in the export markets. The decline in labor productivity growth was more pronounced in foreign-controlled plants than domestic-controlled plants as foreign-controlled plants are more export oriented.

References

Ackerberg, D. A., K. Caves, and G. Frazer, "Structural Identification of Production Functions," MPRA Paper 38349, University Library of Munich, Germany, 2006.

Arellano, M. and S. Bond, "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *Review of Economic Studies*, 14, 328–52, 1991.

Baldwin, J. R., *Dynamics of Industrial Competition*, Cambridge University Press, Cambridge, 1995.

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Baldwin, J. R. and W. Gu, “Plant Turnover and Productivity Growth in Canadian Manufacturing,” *Industrial and Corporate Change*, 5, 417–65, 2006.

———, “Productivity Performance in Canada, 1961 to 2008: An Update on Long-Term Trends,” *Canadian Productivity Review*, Catalogue 15-206, No. 25, Statistics Canada, Ottawa, 2009.

———, “Firm Dynamics and Productivity Growth: A Comparison of the Retail Trade and Manufacturing Sectors,” *Industrial and Corporate Change*, 20, 367–95, 2011.

Baldwin, J. R. and B. Yan, “Export Market Dynamics and Plant-Level Productivity: Impact of Tariff Reductions and Exchange Rate Cycles,” *Scandinavian Journal of Economics*, 114, 831–55, 2012.

Bartelsman, E. J. and M. Doms, “Understanding Productivity: Lessons from Longitudinal Microdata,” *Journal of Economic Literature*, 38, 569–94, 2000.

Bartelsman, E., J. S. Scarpetta, and F. Schivardi, “Comparative Analysis of Firm Demographics and Survival: Evidence from Micro-Level Sources in OECD Countries,” *Industrial and Corporate Change*, 14, 365–95, 2005.

Basu, S., “Procyclical Productivity: Increasing Returns or Cyclical Utilization?” *Quarterly Journal of Economics*, 111, 719–51, 1996.

Basu, S. and J. G. Fernald, “Why is Productivity Procyclical? Why do We Care?” in C. R. Hulten, E. R. Dean, and M. J. Harper (eds), *New Development in Productivity Analysis*, The University of Chicago Press, Chicago, IL, 225–302, 2001.

———, “Aggregate Productivity and Aggregate Technology,” *European Economic Review*, 46, 963–91, 2002.

Basu, S., L. Pascali, F. Schiantarelli, and L. Serven, “Productivity, Welfare and Reallocation: Theory and Plant-Level Evidence,” NBER Working Paper 15579, 2009.

Berndt, E. R. and M. A. Fuss, “Productivity Measurement with Adjustment for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium,” *Journal of Econometrics*, 33, 7–29, 1986.

Berndt, E. R. and D. O. Wood, “Energy Price Changes and the Induced Revaluation of Durable Capital in U.S. Manufacturing during the OPEC Decade,” MIT Center for Economic Policy Research, Cambridge, MA, 1984.

Blundell, R. and S. Bond, “Initial Conditions and Moment Restrictions in Dynamic Panel Data,” *Journal of Econometrics*, 87, 115–43, 1998.

Burnside, C., M. Eichenbaum, and S. Rebelo, “Capital Utilization and Returns to Scale,” in B. S. Bernanke and J. J. Rotemberg (eds), *NBER Macroeconomics Annual 1995*, MIT Press, Cambridge, MA, 67–110, 1995.

Chan, K., W. Gu, and J. Tang, “Industry Mix, Plant Turnover and Productivity Growth: A Case Study of the Electronic and Electrical Product Manufacturing,” *Transnational Corporations Review*, 4, 11–37, 2012.

Denison, E. F., *Accounting for Slower Economic Growth: The United States in the 1970's*, The Brookings Institution, Washington DC, 1979.

Diewert, E. W., T. Nakajima, A. Nakamura, E. Nakamura, and M. Nakamura, “Returns to Scale: Concept, Estimation and Analysis of Japan's Turbulent 1961–88 Economy,” *Canadian Journal of Economics*, 44, 451–85, 2011.

Domar, E., “On the Measurement of Technological Change,” *Economic Journal*, 7, 709–29, 1961.

Estevadeordal, A. and A. M. Taylor, “Testing Trade Theory in Ohlin's Time,” NBER Working Paper 8842, 2002.

Foster, L., J. Haltiwanger, and C. J. Krizan, “Aggregate Productivity: Lessons from Microeconomic Evidence,” in C. R. Hulten, E. R. Dean, and M. J. Harper (eds), *New Developments in Productivity Analysis*, University of Chicago Press, Chicago, IL, 303–72, 2001.

Griliches, Z. and H. Regev, “Productivity and Firm Turnover in Israeli Industry, 1979–1988,” *Journal of Econometrics*, 65, 175–203, 1995.

Gu, W. and A. Lafrance, “Productivity Growth in the Canadian Broadcasting and Telecommunication Sector,” Paper presented at the 32nd International Association of Research on Income and Wealth (IARIW) General Conference, Boston, MA, 2012.

Gu, W. and W. Wang, *Productivity Growth and Capacity Utilization*, Economic Analysis Division, Statistics Canada, 2012.

Hall, R. E., “The Relation between Price and Marginal Cost in U.S. Industries,” *Journal of Political Economy*, 96, 921–47, 1988.

———, “Invariance Properties of Solow's Productivity Residual,” in P. Diamond (ed.), *Growth–Productivity–Employment: Essays to Celebrate Bob Solow's Birthday*, MIT Press, Cambridge, MA, 71–112, 1990.

Hulten, C. R., “Productivity Change, Capacity Utilization, and the Sources of Productivity Growth,” *Journal of Econometrics*, 33, 31–50, 1986.

Jorgenson, D. W., “Embodiment Hypothesis,” *Journal of Political Economy*, 74, 1–17, 1966.

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Jorgenson, D. W. and Z. Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, 34, 249–83, 1967.

Jorgenson, D. W., F. M. Gollop, and B. M. Fraumeni, *Productivity and U.S. Economic Growth*, Harvard University Press, Cambridge, MA, 1987.

Jorgenson, D. W., M. S. Ho, and K. J. Stiroh, *Information Technology and the American Growth Resurgence*, MIT Press, Cambridge, MA, 2005.

Levinsohn, J. and A. Petrin, "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, 70, 317–41, 2003.

Ng, E. C. Y. and M. Souare, "Inward FDI and Productivity Performance in Canadian Industries: Does the Country of Origin Matter?" *Transnational Corporations Review*, 3, 72–90, 2010.

Petrin, A. and J. Levinsohn, "Measuring Aggregate Productivity Growth using Plant-Level Data," *Rand Journal of Economics*, 43, 705–25, 2012.

Solow, R. M., "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39, 312–20, 1957.

Tomlin, B., "Exchange Rate Volatility, Plant Turnover and Productivity," Bank of Canada Working Paper 18, 2010.

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