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Product Market Competition, Skill Shortages and Productivity: Evidence from Canadian Manufacturing Firms

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Abstract

In this paper, we estimate the impacts of product market competition and skill shortages on the productivity level performance of Canadian manufacturing firms. We use firms' perceptions of their competitive environment from the Statistics Canada 1999 *Survey of Innovation* to measure product market competition and skill shortages. We argue in the paper that such perceptions are important for productivity level performance. After controlling for other factors, we find that product market competition has a positive impact on the performance of medium-sized and large-sized firms, and that skill shortages have a negative impact on the performance of small-sized and medium-sized firms.

JEL Classification: L0, O0

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1. Introduction

Many policy makers and researchers believe that product market competition not only increases the pressure for firms to develop and adopt new technologies,[1] but also induces innovative managerial effort. And, they believe that all these innovation activities lead to improvements in efficiency.

Is the Canadian experience consistent with this belief? In this paper, we examine the effect of product market competition, together with skill shortages, on the productivity level performance of Canadian firms.[2] We use data from the Statistics Canada 1999 *Survey of Innovation*, which was linked to the Statistics Canada 1997 *Annual Survey of Manufacturers*. The latter contains necessary production data for productivity analysis.

The theoretical research about the relationship between product market competition and productivity performance is mixed, as indicated in Nickell (1996). Supporters of a positive relationship argue that product market competition reduces managerial slack introduced by monopoly power, and generates incentives to improve efficiency through product, process or organizational innovation. Baily and Gersbach (1995) state that:

> "Vigorous global competition against the best-practice companies not only spurs allocative efficiency, it can also force structural change in industries and encourage the adoption of more efficient product and process designs."

The argument for a positive relationship between product market competition and productivity is often based on two observations. First, product market competition means that there is more than one firm in the same market. The performance of firms in a given market can be compared with one another. The comparable performance helps investors reward "highly performing" firms and punish "poorly performing" firms by providing financial capital at a relatively low cost to the former while withdrawing capital from the latter. This increases the pressure on firms to perform better than their counterparts, leading to efforts to improve efficiency, as shown by Meyer and Vickers (1997) in a two-period model.[3] Second, an increase in product market competition raises the demand elasticity. Higher demand elasticity implies that improvements in productivity will generate larger profits. The potentially larger profits induce higher managerial effort (Willig, 1987), creating incentives for efficiency-enhancing activities such as innovation.[4] Furthermore, higher demand elasticity can quickly reduce the demand for the products of poor performers, which increases the probability of bankruptcy. To reduce the probability of facing bankruptcy, firms have to be innovative and improve their efficiency (Schmidt, 1994).

However, there are also some theoretical arguments in the literature for a negative relationship between product market competition and productivity performance. Hermalin (1992) and Horn et al. (1994) claim that increased competition lowers managers' expected income, and hence reduces their managerial effort. It has also been argued along the line of the Schumpeterian hypothesis that monopoly power enables firms to spend more on innovation activities. According to Kamien and Schwartz (1982), a firm that has monopoly power is more likely to be able to finance innovative activities and use its present monopoly power to strive for persistent dominance in its market than a firm without monopoly power.

Despite the theoretical debate, many empirical studies suggest that product market competition raises productivity. Based on cross-sectional data, Caves and Barton (1990), Caves (1992) and Green and Mayes (1991) link technical efficiency to market structures. They find that an increase in market concentration above a certain threshold tends to reduce technical efficiency. Using survey data on 58 countries, Porter (2000) finds that the intensity of local competition is the single most influential variable on the growth of GDP per capita. Nickell (1996) confirms the effect of product market competition on productivity with panel data on 670

U.K. companies. He finds that competition, measured either by increased numbers of competitors or by lower levels of rents, is associated with higher rates of total factor productivity growth. In addition, he finds that market power, as captured by market share, leads to a lower level of productivity. These results are consistent with the findings of Lever and Nieuwenhuijsen (1999) who use panel data on nearly 2000 Dutch manufacturing firms. Similar results are also obtained by Gort and Sung (1999) who compare the experience of AT&T long lines, operating in an increasingly competitive market, with those of eight local telephone monopolies.

Besides product market competition, this paper also examines the impact of skill shortages on productivity level performance.[5] Skilled workers have long been recognized as a crucial input to the production process. First, they tend to produce more than non-skilled workers, which is relevant since productivity is commonly defined as output per worker. Second, skill shortages mean high turnover rates among skilled labour, which necessarily increases replacement costs such as transaction and learning costs. Sometimes, skilled labour turnover may delay or even discontinue projects. Finally, skills play an important role in the development and use of new technologies (Griliches, 1969; Nelson and Phelps, 1966). Findings by Foley et al. (1993) suggest that skill shortages associated with craft workers can act as a barrier to the use of new technologies and lead to lower productivity. After analyzing survey data on over 700 U.K. companies, together with a number of in-depth cases, Bosworth and Wilson (1993) show that there is a strong relationship between the deployment of highly qualified employees, their role in the strategic management of companies, and dynamic economic performance.

The data used in this study to measure product market competition and skill shortages come from the Statistics Canada 1999 *Survey of Innovation*. This survey was conducted in 1999 among all Canadian manufacturing and selected natural resources industries. It probed firms' innovation environment and related activities over the period 1997–1999. There are several advantages in using this database. First, it had a response rate of 95%, which is probably one of the best response rates to an innovation survey in the world. The very high response rate certainly eliminates potential sampling biases. A detailed description of the survey is given in the Section 2.

Second, unlike most previous studies using market share or other indicators based on industrial statistics to measure competition (e.g., Green and Mayes, 1991; Nickell, 1996; Pilat, 1996), this study uses firms' perceptions about the degree of competition. This is a significant departure from the literature. Competition is often characterized by the presence of a large number of firms in a given product market. However, the degree of competition is not necessarily related to the number of rivals against which a firm competes, but rather to the ever-present possibility that competitors may innovate and gain a decisive cost or product-quality advantage (Metcalfe and Boden, 1993). We argue here that firms' perceptions about their competitive environment are important for their efficiency-improving effort. In a given competitive environment, different firms will have different perceptions about the degree of competition they are facing. The differences in perceptions are important since they lead to different innovation efforts, which may partly explain why some firms undertake more innovation activities and are more productive than others in the same product market and competitive environment.

Third, the perception-based measure captures firm-specific competition. Even in the same industry, firms may produce different products or compete in different product markets, and thus face different degrees of competition. Importantly, only firms themselves have first-hand information in this regard. In contrast, market share or other competition measures based on industrial statistics can be misleading since firms belonging to the same industry classification group are not necessarily competing against each other.[6]

Fourth, the perception-based measure reflects not only competition from domestic markets but also competition from overseas markets. Foreign competition is important, especially for Canadian manufacturing firms, which sell 60% of their production on foreign markets.[7] In contrast, market share or other measures based on industrial statistics are often calculated from national industry statistics and, atmost, capture only competition from domestic markets. In order to capture foreign competition, market shares have to be calculated on a global scale, taking into account industry statistics in all major markets where a firm competes. This is a daunting task.

Finally, the survey allows us to measure product market competition and skill shortages and to examine simultaneously their effects on firms' productivity performance, which usually cannot be done with measures based on industrial statistics. The former represents competition in the sale of products while the latter represents competition for labour input. Their implications for productivity can be very different, as will be seen later. This study focuses on two types of skill shortages: the *difficulty of hiring qualified workers* and the *difficulty of retaining qualified workers*, and explores four types of product market competition: *easy substitution of products*, *constant arrival of competing products, constant arrival of new competitors*, and *quick obsolescence of products*.

The production data used to measure labour productivity levels come from Statistics Canada's 1997 *Annual Survey of Manufacturers*, which was linked to the *Innovation Survey*. An important assumption for our empirical analysis is that firms' perceptions of product market competition and skill shortages did not change significantly from 1997 to 1998–1999. This assumption is important since the dependent variable was valued in 1997 while the independent variables were valued over the period 1997–1999. The assumption may be valid for two reasons. First, the competitive environment does not change dramatically from one year to the next over this period, except for the computer and electronics industry. Also, the presence of industry dummies minimizes any adverse impact on our regression results of industry-specific changes in the competitive environment. Second, the significance of product market competition and skill shortages, as shown below, indicates a strong correlation between these variables and productivity performance. Nonetheless, these results should be interpreted with caution. Further study of the dependent variable (labour productivity) valued in 1999 would be highly desirable.[8]

In the remainder of the study, the regression model linking product market competition, skill shortages and other control variables to labour productivity is developed in the Section 2. Section 3 describes the micro data, the linked Statistics Canada 1999 *Survey of Innovation*, and, briefly, the sample profile. Section 4 discusses the empirical results. Section 5, the final section ends the paper with some concluding remarks.

2. The Regression Model

To estimate the impacts of product market competition and skill shortages on labour productivity level performance, we first develop a regression model. Our regression model is an extension of the Cobb–Douglas production function with constant return to scale:[9]

$$LP_j = \beta_0 + \beta_1 LF_j + \sum_{i=1}^{4} \beta_{2,i} CP_{i,j} + \sum_{k=1}^{2} \beta_{3,k} SK_{k,j} + \beta_4 SM_j + \beta_5 SL_j + \sum_{n=1}^{20} \alpha_n I_{nj} + \varepsilon_j \quad (1)$$

where LP_j, is labour productivity (in logarithm), defined as current value added per employed person in firm j; LF_j is fuel and power consumption per employed person (in logarithm) in firm j; $CP_{i,j}$ is type i product market competition for firm j, representing *easy substitution of products, constant arrival of competing products, constant arrival of new competitors*, and *quick obsolescence of products*; $SK_{k,j}$ is type k skill shortages for firm j, representing the *difficulty of hiring qualified workers* and the *difficulty of retaining qualified workers*; SM_j is a size dummy for medium-sized firms, 1 for firm j being medium-sized and otherwise; SL_j is a size dummy for large-sized firms, 1 for firm j being large-sized and 0 otherwise; I_{nj} is a binary industry dummy, 1 for firm j belonging to industry n and 0 otherwise; ε_j and is the error term for firm j.

Variables for product market competition and skill shortages will be elaborated in the Section 3. As discussed in the Section 1, the impact of product market competition on productivity could occur through technological or organizational innovation, or directly through increased effort such as working hard during a given number of hours worked. For skill shortages, some of the impacts could come from delayed innovation projects, reduced technology development and adoption, and a low capacity utilization of current investments. It should be noted here that no efforts are made in the study to identify the actual mechanisms that may be responsible for any observed productivity effects.

Fuel and power consumption per employed person is a proxy variable for capital intensity, defined as the capital stock per employed person. We use this proxy since there is no capital stock or investment data in the linked Statistics Canada 1999 *Survey of Innovation*. The proxy variable rests on the observation that the working capital stock is highly correlated with fuel and power consumption, and that industry differences in energy intensity are accounted for by industry dummies. In fact, fuel and power consumption is used as a proxy for the same purpose by Globerman et al. (1994).

Firm size and industry dummies are introduced to capture size-related and industry-related specific residuals that are due to differences in financial and technological opportunities not captured by other variables.

To capture the size effect, we divide firms into three groups according to their size. The small-sized group, which is the reference group in the regression model, consists of firms with 100 employees or less. Medium-sized firms are those with over 100 but less than 501 employees. Large-sized firms are those with over 500 employees.

Industry dummies are mainly designed to capture differences in industry characteristics, after controlling for the variables present in the regression model. One such characteristic is the variation in energy intensity across industries. Some industries are more energy intensive than others for a given capital intensity. The industry dummies will capture these differences, which is beneficial since it will minimize the inaccuracy of using energy consumption as a proxy for the capital stock. Industries are grouped at the 3-digit NAICS level. The reference industry in the regression model is Wood (NAICS 321) since it tends to be less productive (or to have a lower level of current value added per employed person) than others.

3. The Data and Sample Profile

The data used in the study come from Statistics Canada's 1999 *Survey of Innovation* (SI). That survey was conducted in 1999 among all Canadian manufacturing and selected natural resources industries, and was linked to production data from the 1997 *Annual Survey of Manufacturers* (ASM). The sample unit is the provincial enterprise. A provincial enterprise ("firm" hereafter) includes all its establishments with the same 4-digit NAICS codes in a province. To reduce the response burden, the SI surveyed only firms with atleast $250,000 in gross business income and more than 19 employees in 1999.[10] All information in the SI concerns the firms' innovation environment and related activities during the period of 1997–1999.[11] After its linkage to the 1997 ASM, the SI incorporates additional information on firms' production activities such as value added and employment in 1997.

The linked SI database contains data on 5,455 in-sample manufacturing firms. Each firm carries a weight. The weight given to each in-sample firm allows that firm to represent other firms in the population having similar characteristics. Thus, if the weight given to firm X is 5, firm X represents five firms in the population. The total population is made out of 8,921 manufacturing firms, which is equal to the sum of population weights of the in-sample firms. For the purpose of this study, however, we exclude 125 in-sample firms that either have incomplete information or are considered to be outliers.[12] Thus, the final sample used for the study contains data on 5320 in-sample manufacturing firms, representing a sub-population of 8682 manufacturing firms. [13]

The first question asked in the Survey deals with the competitive environment faced by firms. The actual question is: "For your firm, how strongly do you agree or disagree with each of the following statements?" We identify four statements that are indicators for product market competition and two statements that are indicators for skill shortages:

CP_1: *Easy substitution of products*, standing for "My clients can easily substitute my products for the products of my competitors",

CP_2: *Constant arrival of competing products*, standing for "The arrival of competing products is a constant threat",

CP_3: *Constant arrival of new competitors*, standing for "The arrival of new competitors is a constant threat",

CP_4: *Quick obsolescence of products*, standing for "My products quickly become obsolete",

SK_1: *Difficulty of hiring qualified workers*, standing for "It is difficult to hire qualified staff and workers",

SK_2: *Difficulty of retaining qualified workers*, standing for "It is difficult to retain qualified staff and workers".

Firms were asked to note their perceptions on each of those statements using a scale from 0 to 5, where 0 stands for not relevant, 1 for strongly disagree and 5 for strongly agree. We use the perceptions on those statements to form the basis for measuring product market competition and skill shortages.

The four measures of product market competition tend to represent four different types of product market competition faced by firms, as revealed by the weak correlation between those indicators. The correlation coefficients between them are very small, except for the coefficient (0.54) between *constant arrival of competing products* and *constant arrival of new competitors* (Table 1). In particular, *easy substitution of products* represents product competition that arises when a firm's clients can easily substitute the products of the firm for the products of its competitors. One possible reason for this situation is the ineffectiveness of market framework laws in the area of intellectual property protection policy. [14] *Constant arrival of competing products* represents general product market competition among identical or very similar products. *Constant arrival of new competitors* seems to be broader than *constant arrival of competing products*. It may include competition for general inputs in the production process.[15] *Quick obsolescence of products* represents product market competition between old and new technologies (e.g., VCR versus DVD).

There are two indicators for skill shortages: the *difficulty of hiring qualified workers* and the *difficulty of retaining qualified workers*. These are indicators for skill

Table 1. Correlation coefficients between indicators of competition and skill shortages.

Indicators	CP_1	CP_2	CP_3	CP_4	SK_1	SK_2
CP_1: easy substitution of products	1.00					
CP_2: constant arrival of competing products	0.24	1.00				
CP_3: constant arrival of new competitors	0.20	0.54	1.00			
CP_4: quick obsolescence of products	0.04	0.18	0.12	1.00		
SK_1: difficulty of hiring qualified workers	0.04	0.11	0.14	0.07	1.00	
SK_2: difficulty of retaining qualified workers	0.06	0.14	0.16	0.13	0.43	1.00

Source: The linked *Survey of Innovation*, Statistics Canada.

shortages since in a tight labour market, firms will experience difficulty in hiring and retaining qualified workers.[16] Although the two are correlated (Table 1), they are different since the former concerns hiring labour while the latter concerns retaining labour, which may have different implications for productivity.

The sample for our analysis contains data on 5320 in-sample manufacturing firms, of which there are 3110 small-sized firms, 1860 medium-sized firms and 350 large-sized firms. Table 2 shows the percentage of firms that highly agree[17] with a statement regarding the competitive environment, by size[18] and by industry. Among the four product market competition and the two skill shortage indicators, the leading indicator for the manufacturing sector is the *difficulty of hiring qualified workers*, which is highly agreed with by 61.8% of firms,[19] followed by the *easy substitution of products*, which is highly agreed with by 59.4% of firms. The statement gathering the least support is *quick obsolescence of products*, which is highly agreed with by only 11.3% of firms.

The profile at the industry level is significantly different. Beverages and Tobacco, and Paper are leading for the *easy substitution of products*. Leather and Apparel have the highest scores for the *constant arrival of new competitors*. Leather and Beverage and Tobacco are leading for the *constant arrival of competing products*. Apparel and Computer and Electronics have the highest scores for the *quick obsolescence of products*. Machinery and Furniture are leading for the *difficulty of hiring qualified workers*. Finally, Furniture and Computer and Electronics have the highest scores for the *difficulty of retaining qualified workers*.

In the manufacturing sector as a whole, the profile for small-sized firms is very similar to that of medium-sized and large-sized firms. But in some industries, their profiles are significantly different. For example, in the Textile Products industry, small-sized firms are less threatened than medium-sized and large-sized firms by the *constant arrival of competing products*, but they have more difficulty in retaining qualified workers.

4. Empirical Results

We estimated regression model (1), described in Section 2, with data from the linked Statistics Canada 1999 *Survey of Innovation*. We first deal with heteroscedasticity,

Table 2. Percentage of manufacturing firms that highly agree[a] with a statement.

		Easy substitution of products			Constant arrival of new competitors			Constant arrival of competing products		
NAICS	Industry	Small[b]	M&L[c]	Total	Small[b]	M&L[c]	Total	Small[b]	M&L[c]	Total
311	Food	66.5	60.6	63.9	48.9	59.6	53.6	56.7	63.9	59.9
312	Beverage and tobacco	66.1	83.3	75.5	48.0	45.6	46.7	67.0	64.7	65.8
313	Textile mills	65.2	64.8	65.0	43.9	62.9	52.5	55.4	71.5	62.6
314	Textile products	55.9	67.0	59.3	46.2	45.1	45.9	55.5	66.2	58.8
315	Apparel	48.6	59.4	52.6	52.6	56.2	53.9	62.8	66.2	64.1
316	Leather	57.3	49.5	53.5	54.2	74.8	64.2	72.2	62.6	67.6
321	Wood	62.5	67.7	64.3	51.5	51.7	51.6	54.9	54.3	54.6
322	Paper	63.1	80.0	73.5	30.2	52.1	43.6	40.7	55.6	49.9
323	Printing	65.9	59.4	64.3	50.1	40.9	47.8	52.3	48.7	51.4
324	Petroleum and coal	56.9	80.0	68.3	33.3	48.0	40.6	45.1	52.0	48.5
325	Chemicals	62.7	57.5	60.6	43.3	52.4	46.9	49.7	58.2	53.1
326	Plastics and rubber	58.5	51.8	55.8	49.6	42.3	46.6	57.0	55.9	56.5
327	Nonmetallic minerals	63.4	67.4	64.3	44.8	43.3	44.4	47.6	53.0	48.8
331	Primary metals	66.1	59.7	62.4	51.5	41.9	46.0	56.3	50.8	53.1
332	Fabricated metals	59.2	47.2	56.8	48.5	55.0	49.8	41.7	49.0	43.2
333	Machinery	54.4	66.6	58.1	42.9	47.8	44.4	47.8	50.2	48.5
334	Computer and electronics	46.2	46.6	46.4	42.4	46.8	44.4	55.7	64.5	59.8
335	Electrical equipment	54.6	68.9	61.6	49.4	46.1	47.7	55.5	54.2	54.9
336	Transportation equipment	49.7	51.3	50.6	40.9	44.3	42.8	46.5	44.9	45.6
337	Furniture	55.4	55.5	55.4	44.8	51.5	46.7	48.5	53.0	49.8
339	Miscellaneous manufactory	57.9	53.9	57.0	47.7	61.0	50.7	56.5	58.8	57.0
Total Manufacturing		59.0	60.0	59.4	47.0	50.7	48.3	51.1	55.9	52.8

Table 2. Continued.

NAICS	Industry	Quick obsolescence of products			Difficulty of hiring qualified workers			Difficulty of retaining qualified workers		
		Small[b]	M&L[c]	Total	Small[b]	M&L[c]	Total	Small[b]	M&L[c]	Total
311	Food	16.8	15.5	16.3	54.2	47.8	51.4	34.1	36.1	35.0
312	Beverage and tobacco	12.4	10.3	11.3	26.4	54.4	41.6	31.4	25.7	28.3
313	Textile mills	13.4	16.6	14.8	62.4	60.7	61.6	38.1	37.3	37.8
314	Textile products	11.0	18.9	13.4	67.9	70.6	68.7	31.2	20.6	28.0
315	Apparel	22.3	33.3	26.4	60.3	69.3	63.6	38.9	30.7	35.8
316	Leather	17.6	16.8	17.2	70.5	53.3	62.1	54.6	24.3	39.9
321	Wood	9.5	7.8	8.9	59.7	52.0	57.0	32.5	34.2	33.1
322	Paper	9.4	7.8	8.4	46.8	53.6	51.0	20.3	27.1	24.5
323	Printing	18.2	22.6	19.3	72.3	60.8	69.4	33.2	29.4	32.3
324	Petroleum and coal	23.5	12.0	17.8	60.8	48.0	54.5	13.7	20.0	16.8
325	Chemicals	11.1	5.8	9.0	46.5	49.5	47.7	27.2	28.6	27.8
326	Plastics and rubber	12.5	6.8	10.2	62.8	65.9	64.1	37.3	36.7	37.1
327	Nonmetallic minerals	7.2	6.0	6.9	53.1	52.3	52.9	27.0	28.9	27.5
331	Primary metals	7.7	2.6	4.8	63.1	46.2	53.5	28.6	29.1	28.9
332	Fabricated metals	4.4	9.5	5.4	70.1	60.5	68.3	31.2	21.2	29.3
333	Machinery	6.6	9.5	7.5	73.7	68.0	71.9	34.7	34.2	34.5
334	Computer and electronics	20.2	20.1	20.2	59.4	68.3	63.5	42.4	43.6	43.0
335	Electrical equipment	9.8	9.4	9.6	54.4	59.8	57.1	34.4	29.9	32.2
336	Transportion equipment	9.7	7.4	8.4	60.6	60.0	60.2	37.8	33.6	35.5
337	Furniture	12.5	7.3	11.0	70.1	72.0	70.7	46.2	40.9	44.7
339	Miscellaneous manufactory	8.3	12.4	9.2	71.7	57.0	68.4	34.6	35.6	34.8
Total Manufacturing		11.0	11.8	11.3	63.6	58.6	61.8	34.0	32.2	33.4

[a] A statement is highly agreed with by a firm if the firm scores 4 or 5.
[b] Small-sized firms.
[c] Medium-sized and large-sized firms.
Source: The linked *Survey of Innovation*, Statistics Canada.

which is common in cross-sectional data. When heteroscedasticity is present, the estimation is no longer efficient and the inferences are inappropriate. We tested for heteroscedasticity across firm sizes, industries,[20] and for all independent variables. We only found evidence that the variance of the disturbance of small-sized firms is significantly larger than that of medium-sized or large-sized firms.[21] The regressions in our study were therefore conducted by using the generalized least squares (GLS) method under the variance structure. The variances for small-sized firms and for medium-sized or large-sized firms were estimated by running regressions independently for the two groups of firms.

Table 3 shows our first set of estimation results. As expected, fuel and power consumption per employed person, as a proxy for capital intensity, is the most significant factor for labour productivity after the dummy variables for firm size. This is consistent with the fact that the higher the capital intensity, the higher the level of labour productivity.

The most interesting results for our purposes, however, are those associated with the product market competition and skill shortages indicators. The indicator of *constant arrival of competing products* is positive and significant. This is an important empirical result since it supports the view that a higher degree of product market competition leads to a higher level of productivity. Product market competition increases the pressure for firms to develop and adopt new technology and induces managerial effort, which in turn improves productivity. This result is consistent with the findings of Baily and Gersbach (1995), Nickell (1996), Pilat (1996) and Rao and Ahmad (1996) that productivity is strongly correlated with the exposure to competition with best-practices firms.

The estimation results also indicate that the *difficulty of retaining qualified workers* has a negative and significant impact on firms' productivity levels. Surely, firms with an acute perception of the difficulty of retaining qualified workers face high labour turnover. Labour turnover not only affects efficiency but it also increases the costs associated with hiring and training workers. According to Martin and Porter (2001), productivity is determined by the interplay of three broad influences: a nation's political, legal and macro-economic context, the quality of the micro-economic business environment, and the sophistication of company operations and strategies. Firms require skilled and experienced workers to develop systems associated with sophisticated products or production processes. And, they rely on those workers to operate sophisticated systems effectively. In other words, failing to retain qualified workers will disrupt and reduce the effectiveness of a firm's operating systems, leading to low productivity.

The estimation shows that all other indicators are insignificant. *Easy substitution of products* and *quick obsolescence of products* are not significant because firms with these perceptions have little incentive to undertake innovation activities in order to improve their productive efficiency (Tang, 2003). The insignificant results for *constant arrival of new competitors* and *difficulty of hiring qualified workers* are somewhat surprising, and are discussed in depth below.

Our estimation results also show that small-sized firms are less productive than medium-sized and large-sized firms, revealed by the highly significant coefficients

Table 3. GLS Estimation results of the effects of competition and skill shortage indicators on productivity.

Variables	Parameter estimates	*t*-values
Intercept	6.152	78.91*
Fuel and power consumption per worker	0.237	25.83*
Easy substitution of products	0.001	0.21
Constant arrival of competing products	0.019	2.55*
Constant arrival of new competitors	−0.006	−0.86
Quick obsolescence of products	−0.005	−0.62
Difficulty of hiring qualified workers	−0.007	−0.93
Difficulty of retaining qualified workers	−0.042	−5.09*
Medium-sized firms	0.665	36.12*
Large-sized firms	0.797	23.45*
Food	0.050	1.28
Beverage and tobacco	0.698	9.76*
Textile mills	−0.070	−1.15
Textile products	−0.060	−0.81
Apparel	0.015	0.31
Leather	−0.086	−0.99
Paper	0.121	2.51*
Printing	0.221	4.41*
Petroleum and coal	0.534	5.89*
Chemicals	0.660	15.30*
Plastics & rubber	0.122	2.83*
Nonmetallic minerals	0.085	1.73**
Primary metals	0.189	3.54*
Fabricated metals	0.214	5.33*
Machinery	0.414	10.16*
Computer and electronics	0.551	10.86*
Electrical equipment	0.317	5.60*
Transportation equipment	0.277	6.11*
Furniture	0.104	2.14*
Miscellaneous manufacturing	0.266	4.86*

Note: * and ** denote significance at the 5% and 10% levels, respectively.

on the two size variables. This result is consistent with the findings of Lee and Tang (2001).

As for the insignificance of *constant arrival of new competitors* and *difficulty of hiring qualified workers*, it may be argued that multicollinearity plays a role here. Multicollinearity arises when an explanatory variable is nearly a linear combination of other explanatory variables. The high intercorrelation between those variables may produce very high standard errors for the same variables and lead to inaccurate analyses of their individual effects. One possible reason for the presence of multicollinearity in our analysis is a high correlation between two indicators. As shown in Table 1, the largest correlation coefficient is 0.54

Table 4. GLS estimation results of the effects of competition and skill shortage indicators on productivity.

	Reg. A1		Reg. A2	
Variables	Estimates	*t*-values	Estimates	*t*-values
Intercept	6.143	79.53*	6.181	80.09*
Fuel and power consumption per worker	0.238	25.83*	0.237	25.79*
Easy substitution of products	0.001	0.14	0.004	0.59
Constant arrival of competing products	0.016	2.45*	–	–
Constant arrival of new competitors	–	–	0.003	0.46
Quick obsolescence of products	−0.005	−0.64	−0.002	−0.34
Difficulty of hiring qualified workers	−0.008	−0.97	−0.007	−0.86
Difficulty of retaining qualified workers	−0.043	−5.16*	−0.042	−5.02*

Notes: * denotes significance at the 5% level. The coefficient estimates for the industry and firm size dummy variables are not reported. They are available upon request.

Table 5. GLS estimation results of the effects of competition and skill shortage indicators on productivity.

	Reg. A3		Reg. A4	
Variables	Estimates	*t*-values	Estimates	*t*-values
Intercept	6.083	79.05*	6.128	83.32*
Fuel and power consumption per worker	0.238	25.86*	0.238	25.94*
Easy substitution of products	0.000	0.06	0.001	0.20
Constant arrival of competing products	0.018	2.41*	0.019	2.53*
Constant arrival of new competitors	−0.009	−1.18	−0.007	−0.91
Quick obsolescence of products	−0.008	−1.06	−0.005	−0.62
Difficulty of hiring qualified workers	−0.024	−3.27*	–	–
Difficulty of retaining qualified workers	–	–	−0.046	−5.98*

Notes: * denotes significance at the 5% level. The coefficient estimates for the industry and firm size dummy variables are not reported. They are available upon request.

between *constant arrival of competing products* and *constant arrival of new competitors*, followed by 0.43 between *difficulty of hiring qualified workers* and *difficulty of retaining qualified workers*. To obtain more evidence of multicollinearity problems, we conducted a formal collinearity diagnostic following Belsley et al. (1980).[22] The test statistics could not exclude the possibility that these two pairs may cause multicollinearity problems in our model. For instance, we found that there are two principal components associated with a high condition index. One component contributes strongly to the variance of the *constant arrival of competing products* and the*constant arrival of new competitors*, while the other contributes strongly to the variance of the *difficulty of hiring qualified workers* and the *difficulty of retaining qualified workers*.[23]

Table 6. Indicator weights for product market competition and skill shortages.

Indicators	Product market competition	Skill shortages
CP_1: easy substitution of products	0.007	–
CP_2: constant arrival of competing products	0.243	–
CP_3: constant arrival of new competitors	0.030	0.057
CP_4: quick obsolescence of products	0.006	–
SK_1: difficulty of hiring qualified workers	–	0.247
SK_2: difficulty of retaining qualified workers	–	0.350

Given this evidence, the model was re-estimated. For product market competition, we estimated the model by dropping out either the *constant arrival of competing products* or the *constant arrival of new competitors*. The new estimation shows that the absence of one of the variables does not significantly affect the significance of the other (Table 4). Thus, we conclude that there is no multicollinearity problem for this pair of variables. What could then explain the non-significance of the *constant arrival of new competitors*? One possible reason is that this indicator is broader than the *constant arrival of competing products*. It may be not only associated with product market competition, but also related to competition for resources, as discussed in the Section 3. Product market competition tends to have a positive effect on productive efficiency, while competition for resources tends to have the opposite effect. The two effects offset each other, leading to insignificant results. The non-significance is also consistent with the finding of Metcalfe and Boden (1993) that the degree of competition may not necessarily be related to the number of rivals against which a firm competes, but rather to the ever-present possibility that its rivals may innovate and gain a decisive cost or product-quality advantage.

Similarly, for skill shortages, we estimated the model by dropping out either the *difficulty of hiring qualified workers* or the *difficulty of retaining qualified workers*. The estimation shows that the absence of one of the variables significantly increases the impact of the other (Table 5). Thus, the evidence indicates a multicollinearity problem caused by this pair of variables.

Partly as an effort to deal with the multicollinearity problem, we developed indexes for both product market competition and skill shortages. The indexes are also interesting for other reasons. As discussed earlier, although some indicators of product market competition and skill shortages are insignificant in explaining productivity performance, they represent different aspects of product market competition and skill shortages. To take into account these different aspects, we calculate an index for product market competition and skill shortages. An index of product market competition or skill shortages is a weighted sum of its indicators. For skill shortages, we also include the *constant arrival of new competitors* as the indicator, mainly for technical convenience.[24] This indicator is chosen over other market product competition indicators because it is slightly more correlated with skill variables, as shown in Table 1. But, as mentioned below, it has no significant impact on the estimation of the latent variable for skill shortages.

To avoid subjectivity in determining the weights of each index, we use a latent variable approach in our study. Basically, the latent variable approach models product market competition and skill shortages as latent variables, and uses variance analyses to determine the weights of their indicators. A latent variable is not observable, but is estimated as a weighted index of its indicators. This approach is similar to the method used by Lanjouw and Schankerman (1999) to measure innovation. As discussed in the Appendix, the latent variable approach offers three main advantages. First, it can provide us with a more comprehensive measure of product market competition or skill shortages than a single indicator, since different indicators measure product market competition or skill shortages from different perspectives. Second, it resolves multicollinearity problems caused by directly using multiple indicators in a regression. Finally, it reduces the number of variables in the analysis and helps us to summarize the data.

The estimated weights for product market competition or skill shortages, based on the latent variable model, are reported in Table 6.[25] As can be seen, the *constant arrival of competing products* takes almost all the weight 0.24, against 0.01 for the *easy substitution of products* and the *quick obsolescence of products* and 0.03 for the *constant arrival of new competitors*. Thus, product market competition is well represented by the indicator *constant arrival of competing products*. Similarly, for skill shortages, the *difficulty of retaining qualified workers* is most heavily weighted, followed by the *difficulty of hiring qualified workers*. Their weights are 0.35 and 0.25, respectively. In contrast, the "*constant arrival of new competitors*" has a negligible weight of 0.06 and has no significant impact on the latent variable for skill shortages.

With those two indexes, we re-estimated our regression model (1). As expected, the index of product market competition is positive and significant, and the index of skill shortages is negative and significant (Table 7). The estimated effects of other variables are very similar to those presented before. The results obtained with the latent variable approach are thus consistent with the previous results.

Finally, we allowed different effects by firm size and re-estimated the regression of Table 7. The results are reported in Table 8. They are generally consistent with previous findings. The regression shows that the impact of product market competition on productivity levels of medium-sized firms is positive and significant. The impact on large-sized firms is also sizable, although only marginally significant.[26] The impact on small-sized firms is insignificant. The non-significance is surprising and interesting. It may be due to the fact that these firms are often serving niche or specialized markets and are less involved in international markets than medium-sized or large-sized firms. So product market competition is less important to their business operations.[27] In addition, the estimation of Table 8 shows that productivity levels of large-sized firms are not affected by skill shortages. The non-significance may be due to the fact that large-sized firms have fewer skill shortage problems than small-sized or medium-sized firms.[28] It may be also because large-sized firms are relatively less affected by skill shortages than

Table 7. GLS estimation results of the effects of product market competition and skill shortages on productivity: a latent variable approach.

Variables	Parameter Estimates	*t*-values
Intercept	6.166	86.88*
Fuel and power consumption per worker	0.237	25.86*
Product market competition	0.069	2.80*
Skill shortages	−0.088	−6.04*
Medium-sized firms	0.666	36.74*
Large-sized firms	0.796	23.54*
Food	0.045	1.17
Beverage and tobacco	0.696	9.75*
Textile mills	−0.070	−1.16
Textile products	−0.059	−0.80
Apparel	0.011	0.24
Leather	−0.089	−1.02
Paper	0.121	2.51*
Printing	0.224	4.48*
Petroleum and coal	0.538	5.94*
Chemicals	0.658	15.30*
Plastics and rubber	0.124	2.87*
Nonmetallic minerals	0.085	1.75**
Primary metals	0.192	3.61*
Fabricated metals	0.217	5.41*
Machinery	0.415	10.19*
Computer and electronics	0.546	10.86*
Electrical equipment	0.315	5.57*
Transportation equipment	0.276	6.11*
Furniture	0.104	2.14*
Miscellaneous manufacturing	0.267	4.88*

Note: * and ** denote significance at the 5% and 10% levels, respectively.

small-sized or medium-sized firms due to their larger workforce. However, further studies are required in order to come up with sound or definitive explanations.

5. Concluding Remarks

Productivity is one of the fundamental determinants of differences in the standard of living across countries and regions within a country. Over the longer term, productivity growth is the only way to sustain improvements in the standard of living (Krugman, 1994). Thus, improving productivity has become part of the national agenda in several countries.

Many policy makers and researchers believe that product market competition increases the pressure for firms to undertake product, process or organizational

Table 8. GLS estimation results of the effects by firm size of product market competition and skill shortages on productivity: a latent variable approach.

Variables	Parameter Estimates	t-values
Intercept	6.230	73.47*
Fuel and power consumption per worker, small–sized	0.220	17.93*
Fuel and power consumption per worker, medium-sized	0.267	21.80*
Fuel and power consumption per worker, large-sized	0.191	8.09*
Product market competition, small–sized firms	0.016	0.47
Product market competition, medium-sized firms	0.130	3.37*
Product market competition, large-sized firms	0.143	1.54
Skill shortages, small–sized firms	−0.080	−4.07*
Skill shortages, medium-sized firms	−0.106	−4.54*
Skill shortages, large-sized firms	−0.035	−0.60
Medium-sized firms	0.583	8.05*
Large-sized firms	0.632	3.88*
Food	0.049	1.27
Beverage and tobacco	0.696	9.76*
Textile mills	−0.075	−1.25
Textile products	−0.056	−0.76
Apparel	0.014	0.30
Leather	−0.076	−0.88
Paper	0.127	2.61*
Printing	0.227	4.56*
Petroleum and coal	0.535	5.91*
Chemicals	0.659	15.33*
Plastics and rubber	0.130	3.03*
Nonmetallic minerals	0.095	1.94**
Primary metals	0.200	3.74*
Fabricated metals	0.217	5.43*
Machinery	0.417	10.25*
Computer and electronics	0.546	10.86*
Electrical equipment	0.322	5.70*
Transportation equipment	0.278	6.14*
Furniture	0.105	2.17*
Miscellaneous manufacturing	0.267	4.89*

Note: * and ** denote significance at the 5% and 10% levels, respectively.

innovation, which improves productivity. The empirical evidence from our study is consistent with this view. It shows that, firms – especially medium-sized ones – that perceive a higher degree of product market competition tend to have higher productivity levels.

This study also found that small-sized and medium-sized firms that perceive a higher degree of skill shortages have significantly lower productivity levels. This result implies that skills and productivity go hand in hand, and that skill shortages weaken productivity level performance. This result is consistent with the findings of Rao et al. (2002) showing that productivity performance is positively correlated with the education attainment of employees. They demonstrate that skilled workers, especially those with a university education or above, contribute significantly to differences in productivity performance in Canadian manufacturing industries.

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Notes

1. For instance, Porter (1990), Nickell (1996), Van de Klundert and Smulders (1997), Boone and Van Dijk (1998) and Tang (2003) show that competition leads to innovation.
2. Note that this paper makes no attempt to identify the actual mechanisms through which product and labour market conditions would affect productivity, although it will suggest possible mechanisms (found in the literature) that may be responsible for any productivity effect.
3. Clearly, the argument requires some sort of failure in financial markets such as the inability to observe managerial effort or performance, or incomplete contingent financial or managerial markets.
4. Jagannathan and Srinivasan (1999), using panel data on 2970 U.S. firms over the period 1973–1990, find that product market competition reduces managerial slack.
5. For most firms, skill shortages exist because they are unwilling or unable to afford higher wages. Why do firms with skill shortages not raise wages to address the problem? This is an interesting question, but out of the scope of this paper.
6. For instance, JDS Uniphase Corp. and Texas Instruments Inc. are both classified in Semiconductor and Related Device Manufacturing. Their primary SIC (Standard Industrial Classification) number is 3674 and their primary NAICS (North American Industry Classification System) number is 334413. However, they are not competing against each other. JDS Uniphase Corp. designs, develops, manufactures and distributes fiber optic components, modules and subsystems for the fiber optic communications industry. For its part, Texas Instruments Inc. develops, manufactures and sells semiconductors (such as digital signal processors, analog integrated circuits and computing microprocessors), sensors and controls (such as electrical and electronic controls, sensors and ratio frequency identification systems), as well as educational and productivity solutions (such as graphing and educational calculators) for both industrial and consumer markets.
7. In 1999, the export-sales ratio of Canada's manufacturing sector was 57%.
8. Statistics Canada planned to link the 1999 *Survey of Innovation* to the 1999 *Annual Survey of Manufacturers*. Unfortunately, due to resource limitations and other complex issues, this project was postponed.
9. The Cobb–Douglas production function with constant return to scale can be expressed as $Y = AK^{\alpha}L^{1-\alpha}$, where Y is output, A is the efficiency parameter, K is the capital stock and L is the labour input (the number of employed persons). The labour productivity function, based on the Cobb–Douglas production function is $\ln(LP) = \alpha_0 + \alpha\ln(k)$, where LP is labour productivity, defined as output per employed person, and k is capital intensity, defined as the capital stock per employed person.
10. In the linked database, employment data are based on the 1997 ASM and some firms had less than 20 employees in 1997.
11. For methodological issues and the overall description of the survey, please see Schaan and Anderson (2001).

12. For instance, several in-sample firms have no employment information. We also exclude firms with negative value added.
13. Empirical results in this paper are weighted, and they are very similar to those unweighted.
14. Presumably, in a country with an ineffective intellectual property protection system, cheaper and unauthorized copies of an innovation product can quickly flood the market and make it impossible for its innovator to recover the costs of the innovation. The perception of easy substitution of products reduces anticipated returns and thus the incentive for a firm to undertake such innovation.
15. Note, however, that there is no strong evidence showing that *constant arrival of new competitors* indicates competition for skills. Compared to *constant arrival of competing products*, *constant arrival of new competitors* is slightly more correlated with both difficulties of hiring and retaining qualified workers, but the differences are insignificant (Table 1).
16. It should be noted that skill shortages are conditional on labour compensation. Firms can always compete against each other for skills by using all kinds of incentives related to labour compensation.
17. A firm highly agrees with a statement if is scores 4 or 5 for that statement.
18. Due to confidentiality, medium-sized and large-sized firms are combined.
19. This result is consistent with the *Workplace and Employee Survey* of Statistics Canada showing that about 45% of jobs were found in locations with vacancies in 1999 (Morissette and Zhang, 2001). It is also consistent with the results from the Canadian Labour and Business Centre's Viewpoints 1998 Survey showing that about 50% of business leaders viewed skill shortages as being a "serious problem" (CLBC, 1999).
20. Based on the OECD definition (Le, 2001), industries are divided into two groups: low-tech industries and medium- or high-tech industries.
21. The variances of the disturbance differ between medium-sized and large-sized firms, but they are statistically insignificant.
22. The diagnostics are conducted with variance inflation factors, tolerance values for parameter estimates, and condition indexes based on principal component analyses (see Belsley et al., 1980 for details).
23. A collinearity problem may occur when a principal component associated with a high-condition index contributes strongly to the variance of two or more variables (SAS Institute, 1994, p. 1417).
24. At least three indicators are required to estimate a latent variable model.
25. The weights are not normalized. They can be normalized to one for each latent variable, but the normalization will not affect the estimation.
26. Note that the inference for the large-sized group is less reliable than those for the small-sized or medium-sized group since the large-sized group has the smallest sample size (350 versus 3,110 for the small-sized group and 1860 for the medium-sized group).
27. This conjecture is consistent with the evidence from Table 2. Although the difference is not highly significant, the evidence shows that 51% of small-sized firms highly agree with the statement that "the arrival of competing products is a constant threat" compared to 56% for medium-sized and large-sized firms.
28. This is consistent with the evidence from the 1999 *Survey of Innovation*, although the difference is not highly significant.
29. In the study, the estimation is done with generally weighted least squares since all observed variables are ordinal. The weight matrix is the inverse of the estimated asymptotic covariance matrix of the polychoric correlations of the observed variables. It is important to use the generally weighted least squares method here. When other methods such as the maximum likelihood or generalized least squares are used, parameter estimates may be distorted and the chi-square goodness-of-fit measure and standard errors may not be reliable (Jöreskog and Sörbom, 1996).

Appendix: Measuring Product Market Competition and Skill Shortages as Latent Variables

In this appendix, we measure product market competition and skill shortages using a latent variable model. A latent variable is not observable, but estimated as the weighted sum of its multiple indicators. The latent variable approach has three main advantages. First, it can provide us with a more comprehensive measure of product market competition or skill shortages than a single indicator since different indicators measure product market competition or skill shortages from different perspectives. Second, it solves multicollinearity problems associated with directly using multiple indicators in a regression. Finally, it reduces the number of variables in the analysis and helps us to summarize the data.

Latent Variable Model

Let ξ denote an unobservable latent variable that is to be estimated from its n indicators. The empirical relationship between the latent variable and its indicators can be written as:

$$\mathbf{x} = \boldsymbol{\lambda}\xi + \boldsymbol{\delta}, \tag{A.1}$$

where $\mathbf{x} = (x_1, x_2, \ldots, x_n)$ is the vector of indicators, $\boldsymbol{\lambda} = (\lambda_1, \lambda_2, \ldots, \lambda_n)$ is the vector of coefficients of $\mathbf{x}$ on ξ, and $\boldsymbol{\delta} = (\delta_1, \delta_2, \ldots, \delta_n)$ is the vector of error terms.

Assume that the error terms are orthogonal to the latent variable ξ. The covariance matrix of $\mathbf{x}$ can be written as:

$$\mathbf{x}\mathbf{x}^T \equiv \sum = \boldsymbol{\lambda}\xi\xi^T\boldsymbol{\lambda}^T + \boldsymbol{\delta}\boldsymbol{\delta}^T. \tag{A.2}$$

Normalize the variance of ξ to 1, i.e., $\mathrm{var}(\xi) \equiv \xi\xi^T = 1$. As $\sum$ is known, we can derive the estimate of $\boldsymbol{\lambda}$, denoted $\hat{\boldsymbol{\lambda}}$, by minimizing the determinant of

$$\boldsymbol{\Theta} \equiv \boldsymbol{\delta}\boldsymbol{\delta}^T = \sum - \boldsymbol{\lambda}\boldsymbol{\lambda}^T. \tag{A.3}$$

Thus, the parameters of the model are estimated by minimizing the difference between the sample covariances of all indicators and the covariances predicted by the model.[29]

Following Lanjouw and Schankerman (1999) and Jöreskog and Sörbom (1996), the estimate of the latent variable, ξ, is

$$\hat{\xi} = \hat{\mathbf{w}}\mathbf{x}, \tag{A.4}$$

where $\hat{\mathbf{w}} = \hat{\boldsymbol{\lambda}}^T \sum^{-1}$.

It is clear from equation (A.4) that the weight of an indicator depends not only on its correlation with the latent variable, reflected by $\hat{\boldsymbol{\lambda}}$, but also on its variance and its covariance with other indicators. The smaller the variance of the indicator, the higher is its weight.

Product Market Competition

As discussed in the text, there are four indicators for product market competition: *easy substitution of products, constant arrival of competing products, constant arrival of new competitors*, and *quick obsolescence of products*. We model product market competition as a latent variable. The latent variable is not observable itself but underlies the four indicators. Let ξ_p denote our measure of product market competition. The estimate of ξ_p, $\hat{\xi}_p$ can be written as the weighted sum of the four indicators:

$$\hat{\xi}_p = \hat{w}_1 CP_1 + \hat{w}_2 CP_2 + \hat{w}_3 CP_3 + \hat{w}_4 CP_4, \tag{A.5}$$

where $\hat{w}_i$ is the weight for indicator CP_i with $i = 1, 2, 3, 4$, and is estimated based on the latent variable model, described earlier.

Skill Shortages

The *difficulty of hiring qualified workers* and the *difficulty of retaining qualified workers* are two indicators of skill shortages, as discussed earlier. To estimate the latent variable, we need at least three indicators, for technical reasons. So, we also include the *constant arrival of new competitors* as an indicator of skill shortages. We chose this indicator over other product competition indicators since it is slightly more correlated with the first two skill shortages indicators than others.

Like product market competition, skill shortages are also modeled as a latent variable. Let ξ_w denote our measure of skill shortages. The estimate of ξ_w, $\hat{\xi}_w$, can be written as a weighted sum of the three indicators,

$$\hat{\xi}_w = \hat{w}_1 SK_1 + \hat{w}_2 SK_2 + \hat{w}_3 CP_3, \tag{A.6}$$

where $\hat{w}_i$, with $i = 1, 2, 3$ is the weight for indicator SK_i, SK_2, or CP_3.

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