ASSESSING THE PERFORMANCE OF CANADA'S MANUFACTURERS: FIRM LEVEL EVIDENCE FROM 1902-1990

by

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Abstract

This thesis uses data collected from a sample of thirty-nine Canadian and thirty-nine American manufacturing firms to provide an empirical foundation for the assessment of the performance of Canadian manufacturers through most of the twentieth century. The unbalanced panel of Canadian firms covers the years 1907-1990. The unbalanced panel of American firms covers the years 1902-1990.

To quantify the performance of Canadian manufacturers I measure relative technical efficiency by calculating the total factor productivity (T.F.P.) and labour, capital and intermediate input partial factor productivities of the Canadian firms in my sample relative to the American firms. On average I find that the Canadian firms have had lower labour productivity and intermediate input productivities, but superior capital productivity. When measuring the productivity of the entire production process simultaneously there appears to have been no consistent and substantial T.F.P. difference between the Canadian and American firms, on average.

To explain the variation in the partial factor productivities between my Canadian and American firms I disaggregate the total variation into differences due to domestically unique input prices, output levels, biased technology and neutral technology. In general the Canadian firms appear to have been responding to lower labour and intermediate input prices and higher capital costs by using the relatively expensive inputs conservatively and the relatively inexpensive inputs liberally. The Canadian firms also appear to have been adapting their technology in response to the unique input market conditions they faced. The evidence that the Canadian firms in my sample were choosing input combinations and technology which reflected the domestic input prices they faced indicates behaviour consistent with competent entrepreneurship. Additional evidence illustrating the Canadian producers' responsiveness to idiosyncratic and continental changes in their input market conditions reinforces the partial factor productivity evidence.

The performance of the Canadian manufacturers' in my sample of firms, with respect to total factor productivity and responsiveness to domestic input market conditions, suggests that on average Canadian manufacturers have traditionally performed at least as well as their American counterparts.

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Chapter 1
Introduction

Robert Solow (1957) argued that technical change was the largest contributor to the growth of income per capita in the United States (U.S.) between the years 1909 and 1949. During the twentieth century nations' manufacturing sectors have been the source of the majority of the technical change they experience. This implies that in searching for explanations for cross country variations in income per capita we should expect to find that an important role has been played by the performance of nations' manufacturing sectors. More recent research on endogenous growth, while down playing the impact of pure technical change, has further strengthened the link between human and physical capital accumulation, nations' manufacturing sectors and their ability to generate income per capita.[1]

Canadian income per capita has traditionally been and continues to be lower than U.S. income per capita. The ratio of Canadian to American G.N.P. per capita, deflated by a wholesale price index which has been adjusted for price differences and exchange rates using a 1990 purchasing power parity measure, has averaged 0.729 between the years 1900 and 1990. Explaining this gap has occupied Canadian economists for many years and both empirical and theoretical work addressing the issue continues. Not surprisingly much of this work has focused on the performance of Canadian manufacturers.

1.1 The Canadian Manufacturing Sector: 1900-1990

At the turn of the twentieth century the Canadian economy was industrializing rapidly. Unprecedented inflows of labour in the form of both rural and urban immigration were accompanied by an investment boom driven by residential and urban capital formation.[2]

[1]The classic endogenous growth references include Romer, 1986 and Lucus, 1990.

[2]Green and Urquhart, 1987, Table 4 and Pg. 198.

The period from 1896 to WWI has been called the Wheat Boom by Canadian economic historians because it saw the settlement of the prairies and a dramatic increase in acreage under cultivation, agricultural output and agricultural exports. Although this period has traditionally been known for the agricultural expansion which occurred in Canada, it was also an era of industrialization driven by the investment boom which accompanied the influx of new immigrants.[3] This industrialization phase was led by industries such as iron and steel, transportation equipment, non-ferrous metals and electrical equipment. The majority of the output of these industries was produced in southern Ontario and southwestern Quebec.[4]

During the burst of industrialization which coincided with the Wheat Boom the National Policy tariff structure became a key feature of western Canadian grievances against central Canadian manufacturers and power elites. The National Policy tariffs placed high nominal and effective rates on imported manufactured goods and low rates on raw materials and manufactured intermediate inputs. The traditional argument claims that this tariff structure forced agricultural interests to pay higher prices for domestically produced manufactured goods, thereby transferring income from the agricultural sector to the manufacturing sector.[5]

During WWI government contracts provided further impetus for Canadian manufacturing industries to continue their expansion. Although the decrease in demand during the immediate post-WWI period, coupled with the dramatic increases in capacity which had been encouraged during the war, led to a number of years of falling profits, output and employment for many Canadian firms[6], by the mid-1920s Canadian manufacturing output was well over its pre-war levels. The continued growth of the sector during the 1920s was fueled by dramatic increases in the exports of a number of primary manufacturing industries. These included pulp and paper mills, in particular the firms which produced

[3] Ibid, Table 5.
[4] Norrie and Owram, 1996, Pg. 252.
[5] Marr and Paterson, 1980, Pg. 379.
[6] Kilbourn, 1960, Pg. 129.

newsprint for U.S. customers, and non-ferrous metal extraction and refining.[7]

At the depth of the Great Depression (1929-1939) Canadian manufacturing output had fallen by over forty percent, manufacturing employment decreased by almost one third, over a wide range of industries capacity utilization had dropped below fifty percent and net investment for the sector was negative.[8] With the declaration of war in 1939 Canadian manufacturing output had only just recovered to its 1928 peak and in many industries output and employment continued to be below the pre-Depression levels.[9] There were increases in both nominal and effective tariff rates on virtually all finished manufactured goods during the Depression in Canada and most western industrialized nations.

Increased demand during WWII led to increasing output, employment, profits and net investment across a broad range of Canadian manufacturing industries. This widespread expansion of the manufacturing sector continued under domestic government demand management policies and the introduction of multilateral trade and capital institutions during the post-1945 period. Perhaps the most significant of the post-war changes to the economic environment for Canadian manufacturers was the introduction of the General Agreement on Tariffs and Trade (G.A.T.T.). Under the influence of G.A.T.T. Canada lowered its nominal tariff rates repeatedly through the 1950s, 1960s and 1970s. There is some question about the change in effective tariff protection enjoyed by Canadian manufacturers, particularly due to the introduction of a wide range of non-tariff barriers to trade.[10]

The twenty-five years after the end of WWII has become known as the Long Boom. It was a period of continued growth and prosperity throughout the Canadian economy and the manufacturing sector in particular. While industries such as automobile production and petroleum refining were showing dramatic increases in output and exports some Canadian firms continued to struggle against foreign competition, even with the aid of high effective tariff protection. Cotton textile mills and food and beverage industries were among the

[7]Norrie and Owram, 1996, Pg. 254 and 260.

[8]Ibid, Table 17.2 and Kilbourn, 1960, Pg. 142.

[9]Examples of the hardest hit industries include animal products, wood products and food and beverages. Marr and Paterson, 1980, Pg. 393.

[10]Ibid, Pg. 398.

weaker Canadian industries at this time.[11] In 1965 the Auto Pact was signed between Canada and the U.S.. This agreement managed Canada-U.S. trade in automobiles and automobile parts. The key feature of the pact, from Canadian firms' points of view, was a guaranteed share of the production of the U.S. automobile industry for Canadian producers and parts suppliers, such as silk and synthetic fibre textile mills.

The dramatic increases in imported oil prices in 1973 and 1979 clearly had a negative impact on the Canadian manufacturing sector. The Long Boom ended during the early 1970s. Falling domestic and international demand, rising inflation rates and rapidly increasing government deficits resulted in a slowing of the rate of expansion and in a number of years an actual decline in the output of the Canadian manufacturing sector. Decreases in employment in manufacturing firms, particularly in central Canada, became a primary policy concern of the federal and provincial governments during the late 1970s and early 1980s.

In 1984 the federal government in Canada embarked on a series of policy changes designed to alter the economic environment in which Canadian manufacturers operated.[12] These policy changes were drawn from the Economic Continentalist platform. This platform called for less government involvement, lower trade barriers and increased foreign investment. It was hoped that these industrial and taxation policy changes would result in a rationalization of the Canadian manufacturing sector and an improvement in their output, employment and export performance.

After a slow recovery process during the mid-1980s Canadian manufacturers showed signs of accelerating growth in output and investment levels heading into the 1990s. The federal government's drive to adopt the Continentalist platform reached its climax with the signing of the Free Trade Agreement (F.T.A.) between Canada and the U.S. in 1988 and the North American Free Trade Agreement (N.A.F.T.A.), which included Mexico, in 1992. These agreements put in place a process designed to remove virtually all tariffs on

[11] Ibid, Pg. 396.
[12] Norrie and Owram, 1996, Pg. 451-54.

finished manufactured goods traded between Canada, the U.S. and Mexico. The efficacy of these radical policy changes is still a matter of considerable debate amongst economists in Canada.

1.2 The Contribution of This Thesis

At the opening of this chapter I mentioned that there has been considerable effort devoted to the study of the performance of the Canadian manufacturing sector. In much of this work the Canadians' performance has been found to be lacking relative to some international, usually American, standard. The traditional argument claims that relatively low labour productivity in the Canadian manufacturing sector has led to relatively low real wages and, hence, relatively low income per capita. Explanations for the relatively low Canadian labour productivity often implicate the tariff structure under which Canadian manufacturers have operated through most of the twentieth century.

The most compelling argument in favour of a causal link between tariffs, labour productivity and income per capita suggests that high tariffs on finished manufactured goods, coupled with Canada's relatively small domestic market led to the prevalence of small manufacturing firms, which produced widely diversified product lines. These two features of the Canadian manufacturing sector imply that Canadian manufacturers were not taking advantage of potential returns to scale inherent in their technology. Therefore, labour productivity in Canadian manufacturing firms was not as high as it could have been and this low productivity was responsible for low real wages in Canada and low income per capita. In addition to scale disadvantages, the Canadian tariff structure is often accused of reducing the competitive pressures within the Canadian economy, such that Canadian manufacturers could be unresponsive, inflexible and myopic, yet continue to operate profitable firms.

The empirical work on which the traditional explanations for Canada's low income per capita are based identifies a persistent and substantial shortfall in Canadian manufacturers' labour productivity, relative to U.S. manufacturers' labour productivity. The fact that the productivity performance of other inputs and the factor payments these inputs earn are ignored in virtually all of the Canadian labour productivity literature suggests that there is an implicit assumption within this literature that lower labour productivity reflects lower capital and intermediate input productivities as well. In other words, it is assumed that labour productivity is an accurate proxy for the productivity of the entire production process.

The empirical and theoretical literature articulating the perceived connections between the Canadian tariff structure, low labour productivity within the manufacturing sector and low Canadian income per capita was rejected by Canadian Economic Nationalists. Canadian Economic Nationalists accepted the evidence of low labour productivity within the Canadian manufacturing sector. However, Kari Levitt (1970), Wallace Clement (1977) and Glen Williams (1994) explicitly blame unresponsive and myopic Canadian entrepreneurs for the poor output, export and productivity performance of Canadian manufacturers, rather that the Canadian tariff structure.

The Economic Nationalist literature which embraces the low labour productivity-unresponsive entrepreneur argument contributed to the policy debate which was carried on in Canada during the twenty-five years prior to the signing of the F.T.A. in 1988. This policy debate pitted the Economic Nationalists, who felt that increased government regulation and increased trade and foreign investment barriers would lead to improved productivity and increased income per capita in Canada, against Continentalists. As I have briefly mentioned, the Continentalists argued that the competitive pressures which would result from less government involvement, lower trade barriers and increased foreign investment would lead to a rationalization of Canadian business, improved productivity and higher income per capita in Canada.

The Continentalists generally accepted the view that Canadian producers had lower productivity than their international competition, but they felt that the solution to this problem lay not in more government control, but in a more competitive market in which only the strong would survive. Implicit in this argument was the belief that once Canadian producers were forced to compete they would prove themselves capable. Since 1984 Canada has embarked on a program drawn from the Continentalist platform; hemispheric free trade zones, continued reduction in investment restrictions and a general decline in government activity in the Canadian business environment.

More quantitative evidence is needed to assess the competing views regarding the traditional performance of the Canadian manufacturing sector, the role this performance played in determining Canadian income per capita and the effects of the Canadian tariff structure and firm size on this performance. The work in this thesis is primarily concerned with addressing the first of these issues.

The performance of any production unit is reflected in its ability to generate employment, value added, economic profit or export revenue. These indicators, while they are easily measured, are only proxies for the efficiency of a production unit.[13] Economists have very specific definitions in mind when they refer to efficiency. Economic efficiency refers to two concepts; allocative efficiency and technical efficiency. Allocative efficiency measures a production unit's ability to chose optimal (ie. cost minimizing) input combinations, given the input prices and technology faced by that production unit. Technical efficiency measures a production unit's ability to convert inputs into outputs, independent of conditions in their input markets.[14]

In this thesis I empirically measure the performance of Canadian manufacturers through most of the twentieth century by calculating relative levels of technical efficiency and by searching for evidence of weak entrepreneurial performance. I measure relative technical efficiency by comparing the total factor productivity (T.F.P.) of Canadian manufacturers to the T.F.P. of American manufacturers. This measurement technique allows me to determine relative technical efficiency and investigate the appropriateness of using labour productivity as a proxy for the productivity of an entire production process.

Measures of relative technical efficiency compare production units' abilities to convert

[13] McCloskey and Sandberg, 1971, Pg. 163.
[14] Allen, 1991, Pg. 203-4.

inputs into outputs at a given point in time. However, production units change the technology they employ over time and these decisions influence their overall productivity. The theory of induced innovation suggests that facing a given set of available technological options a production unit should choose the technology which reflects the current and anticipated conditions in its input markets and then adapt this chosen technology to further conserve on its expensive inputs and use liberally its inexpensive inputs.[15] We can derive a measure of this process of induced innovation in the adoption, adaptation and development of technology by estimating biases in production units' technical choices. If a production unit is adopting, adapting or developing its technology in response to, or in anticipation of, the input market conditions it faces, than it does not conform to a view which argues in favour of myopia and inflexibility on the part of the production unit's management. In this thesis I determine the degree to which the technology employed by Canadian manufacturers was biased in a manner consistent with innovations and adaptations which have been induced by input market conditions.

The technique I employ in the measurement of relative T.F.P. requires that I assume that both Canadian and American manufacturers have been allocatively efficient. Therefore, I do not measure allocative efficiency in this thesis. However, if a production unit is allocatively efficient it must be minimizing costs at each point in time. This suggests that production units which behave in a manner consistent with cost minimization must also be behaving in a manner consistent with allocative efficiency. In this thesis I investigate the degree to which Canadian manufacturers were adjusting their input combinations in response to changes in their input markets. This allows me to determine the extent to which Canadian manufacturers have been behaving in a manner consistent with cost minimization.

The evidence I present does not support the view that Canadian manufacturers have traditionally been technically inefficient relative to American manufacturers, if we measure

[15]Hicks (1968; Pg. 124) was the first to articulate this notion of induced innovation. A review of the theoretical work on induced innovation and biased technical change can be found in Binswanger and Ruttan, 1978, Chap. 2.

technical efficiency as relative T.F.P. performance. In addition, the evidence in this thesis does not support the view that Canadian manufacturers have traditionally been unresponsive, inflexible and myopic. I measure responsiveness as the employment of technology reflecting biased technical change induced by anticipated or observed conditions in domestic input markets and alterations in input combinations in response to changes in domestic input market conditions which are consistent with cost minimizing behaviour.

The data on which the measured performance indicators are based has been drawn from a sample of thirty-nine Canadian and thirty-nine American manufacturing firms. These firms represent nine industries. The Canadian data covers the years 1907-1990, while the U.S. data spans the years 1902- 1990. Using these data I have calculated Canadian relative to American T.F.P. and labour, capital and intermediate input partial factor productivities. On average there is no evidence of substantial, consistent weak Canadian T.F.P. performance. However, it does appear that on average the Canadian firms in my sample had consistently lower labour and intermediate input partial factor productivities and higher capital productivity, relative to the American firms. Therefore, Canadian labour productivity does appear to have traditionally been lower than American labour productivity, but this does not necessarily imply low Canadian technical efficiency.

If the Canadian firms in my sample were enjoying competent entrepreneurship they should have been employing input combinations which reflected cost minimizing decisions, given the conditions in Canadian input markets. These unique input combinations would lead to unique partial factor productivities. To identify the differences between the Canadian and American industries' partial factor productivities which were due to differences in their input prices I have estimated input demand functions for all eighteen industries represented in my sample. The estimated parameters from these input demand functions have been used to conduct counterfactual experiments in which I disaggregate the cross country variation in the partials into the variation due directly to different input prices, variation due to scale differences, variation due to technological biases and variation due to neutral technological differences. The results from the counterfactuals indicate that even after controlling for technological and scale differences the Canadian firms in my sample were choosing domestically unique input combinations, implying domestically unique partial factor productivities. The Canadian counterfactual partials reflect behaviour consistent with cost minimization, given the domestic input prices the Canadian firms faced.

The Canadian firms appear to have been sensitive to domestic input prices not only in their choice of input combination, but also in their adoption, development and adaptation of technology. After controlling for input price differences, scale differences and neutral technological differences the remaining cross country variation in partial factor productivities must be due to domestically unique technological biases. In general, the Canadian technological biases led to the use of the relatively expensive Canadian inputs conservatively and the relatively inexpensive Canadian inputs liberally. This is further evidence that the Canadian firms in my sample were not myopic, nor unresponsive to domestic input market conditions.

Domestically unique input prices faced by the Canadian firms in my sample are reflected in domestically unique input combinations and technological biases. However, these input price reactions only explain part of the cross country variation in the partial factor productivities of the inputs employed. The remaining difference must be due to scale differences and neutral technological differences. If the technology employed by the industries represented in my sample had non-constant returns to scale, then we would expect that differences in output levels would have had an effect on the partial and total factor productivities of the Canadian and American firms in my sample. If there were unbiased technological differences or differences in the quality of measured inputs, then we would expect that there should be additional cross-country variation in total and partial factor productivities. In general, the variation due to input price differences and technological biases offset the effects of scale and neutral technological differences.

In explaining the cross country variation in partials, my counterfactual experiments suggest that the Canadian firms in my sample were responding in a cost minimizing way to domestic input prices, on average, over time. However, the counterfactual results do not indicate the Canadian firms' relative responsiveness to changes in their input prices. To determine the relative responsiveness of the Canadian firms in my sample to changes in their input prices, and to add robustness to the counterfactual results, I present evidence relating input combinations to relative input prices and own price input demand elasticities for the Canadian and American firms. This evidence reenforces the view that the Canadian firms in my sample appear to have been choosing their input combinations in a manner consistent with cost minimization. The Canadian industries' own price input demand elasticities are comparable to, and often greater than the U.S. industries' own price input demand elasticities. These results indicate that the Canadian firms were at least as responsive as the American firms to changes in their input prices.

The Economic Nationalists claim that Canadian manufacturers were heavily influenced by U.S. market conditions. This tended to make them insensitive to changes in Canadian markets which were idiosyncratic to Canada. Therefore, the Canadian firms' responsiveness to domestic input market conditions may reflect their sensitivity to continental input market fluctuations, not strictly Canadian input market fluctuations. I have tested this hypothesis by identifying idiosyncratic changes in Canadian input prices and the Canadian firms' responses to these changes. My tests provide very little empirical support for the view that input market changes which were idiosyncratic to Canada did not illicit a response from Canadian firms which was consistent with cost minimizing behaviour.

If performance is assessed by measuring technical efficiency, the selection of appropriate technology and the choice of input combination in response to changes in input prices, then the evidence in this thesis supports the view that, on average, Canadian manufacturers have not traditionally been ineffective, weak nor incompetent, relative to American manufacturers. I argue that the Canadian manufacturers in my sample have not been consistently and substantially less technically efficient than American manufacturers in the same industries, nor less responsive and flexible that American manufacturers in the same industries.

The second chapter of this thesis presents the evidence on relative T.F.P. and relative labour, capital and intermediate input partial factor productivities. Chapter 3 discusses the disaggregation of the cross country variation in the partials. In Chapter 4 further evidence on the responsiveness of the Canadian firms in my sample is reviewed. The final chapter contains a brief summary of the results, mentions some of the conclusions implied by the results and suggests some potential questions for further research.

Chapter 2
Measuring the Technical Efficiency of Canada's Manufacturers

> "...Canada's secondary manufacturing was less efficient than that of its trading partners as a result (depending on the writer) of its tariff policies and those of its trading partners, of government sponsorship, of foreign ownership, or even of the conservatism and myopia of the Canadian business class."[1]

The notion that Canadian manufacturers have traditionally been technically inefficient relative to their counterparts in other countries has become a stylized fact in the literature on Canadian manufacturing productivity. The majority of this literature deals with explanations for Canada's poor productivity performance. This performance, when it is measured at all, not just assumed, is most often measured in terms of labour productivity relative to Canada's largest trading partner, the United States, at an aggregate level for some year(s) after WWII. After determining that, on average, Canadian manufacturing industries have lower output per worker than U.S. manufacturing industries the writers on the subject then spend the preponderance of their time chronicling the reasons for the Canadian shortfall. Only rarely are any attempts made to adjust the relative labour productivity figures so they reflect the technical efficiency of the entire production process.

The main goal of this chapter is to illustrate that the notion that Canada's manufacturers have traditionally been technically inefficient does not hold when long run relative total factor productivity (T.F.P.), rather than post-WWII relative labour productivity, is used to gauge relative inefficiency. Technical efficiency measures a production unit's ability to convert inputs into outputs, independent of input market conditions. Using data from a sample of thirty-nine Canadian and thirty-nine U.S. firms, in nine manufacturing

[1] Norrie and Owram, 1996, Pg. 441.

industries, which span the years 1907-90 and 1902-90 respectively, I can find very little evidence of Canadian technical inefficiency after 1925. For the seventy-eight firms in my sample, between 1907 and 1990, the weighted average of the Canadian firms' T.F.P. over the weighted average of U.S. firms' T.F.P. is between 1.034 and 1.137, depending on aggregation scheme. This result may seem quite surprising to those familiar with the labour productivity performance of Canadian manufacturing firms.

Measures of relative T.F.P. between the Canadian and American manufacturing sectors by Green and Baldwin (1987) for 1929, Baldwin and Gorecki (1986) for 1970 and 1979 and Bernstein, Denny, Fuss, Nakamura and Waverman (1992) for 1964-66, 1974-76 and 1983-85 are more optimistic about Canada's productivity performance than virtually all the measures of relative labour productivity in the literature. Green and Baldwin suggest that the reliance on relative labour productivity rather than relative T.F.P. evidence is responsible for the poor reputation of Canadian manufacturing. The relative T.F.P. results from my sample of firms for the years 1929, 1970 and 1979 and 1964-66, 1974-76 and 1983-85 are very similar to those reported by Green and Baldwin, Baldwin and Gorecki and Bernstein et al.. My results also support the hypothesis that relative labour productivity underestimates relative T.F.P. between Canadian and American manufacturing firms. It appears that labour productivity may not be a good proxy for the technical efficiency of the entire production processes of Canadian manufacturing firms.

A unique feature of the evidence presented in this chapter is the construction of relative T.F.P. ratios from firm level data sources. The use of firm level data means that sources of productivity in administration, distribution and procurement, which are missing in plant level studies, have been measured here.

The firms in the sample have a wide variety of sizes, locations, input markets and output markets. However, the Canadian and American firms have been carefully matched such that all firms in any given industry could potentially have been competitors with their cross border counterparts. In other words, their products were similar enough to be potential substitutes. Although other studies have attempted to match Canadian and U.S.

industries at the two or even three digit level of aggregation this matching process cannot be as fine as at the firm level.

The T.F.P. results in this chapter do not support the notion perpetuated in much of the labour productivity literature, that Canadian manufacturers have traditionally been technically inefficient relative to U.S. manufacturers. In an effort to reconcile my T.F.P. results and existing labour productivity results I present evidence on the relative labour, capital and intermediate input partial factor productivities of the Canadian and American firms in my sample. A weighted average of these relative partials provides me with an alternate set of T.F.P. ratios with which the assumptions required to implement the primary T.F.P. calculation methodology may be tested. On average the Canadian firms in my sample appear to have had slightly lower labour and intermediate input productivities, but higher capital productivity. Where the higher relative capital productivity compensated for the lower relative labour and intermediate input productivities, T.F.P. was roughly equal between the Canadian and American firms. This pattern amongst the partials helps to explain the contrast between the T.F.P. and labour productivity results.

In Section 2 of this chapter a brief review of the literature on the technical efficiency of the Canadian manufacturing sector is presented. The third section discusses the selection criteria and characteristics of the firms included in my sample. An explanation of the relative T.F.P. calculation methodology and the results from these calculations are presented in Section 4. Section 5 reviews the evidence on the firms' relative partial factor productivities. The final section offers a brief summary and some conclusions. A data appendix and a graphical appendix have been included at the end of the chapter.

2.2 Canadian Manufacturers' Productivity Performance: The Literature

Textbooks on Canadian economic history often refer to technical inefficiency amongst Canadian manufacturers because there is a substantial body of empirical and theoretical work in support of this view.[2] Eastman and Stykolt's (1967) seminal work on Canadian firm size played a key role in establishing the belief in Canadian technical inefficiency. Relative inefficiency was never measured explicitly by Eastman and Stykolt, but it was a strong implication in their work. Using data from sixteen manufacturing industries between 1955 and 1960 Eastman and Stykolt sought to determine the share of these industries' output which was produced in plants that were of minimum efficient scale. If a plant is not producing at minimum efficient scale, it is not at the lowest point on its average cost curve. This implies that there are unrealized economies of scale and productivity could potentially be increased by increasing the output of each inefficiently small plant. Eastman and Stykolt determined the minimum efficient scale of plants in each of their sixteen industries by, "... the size of the unit of equipment that had the largest minimum efficient output of all the stages in the manufacturing process..."[3] For some industries, "...the sources of economies of scale were less readily identifiable. The economies depended on the capacity of several different pieces of equipment on a single processing or assembly line and on balance between them."[4]

Eastman and Stykolt suggest that much of the Canadian manufacturing sector was inefficient because Canadian plants were too small or Canadian production runs were too short. However, no attempt was made to directly compare Canadian and U.S. firm size, to explicitly calculate relative productivity or to estimate returns to scale. Eastman and Stykolt (1967; Pg. 104) also point out that, "(t)he efficiency of firms depends not only on the size of their plant in relation to the lowest point on a plant long- run average cost curve, but also on the number of plants operated by the firm because of the existence of economies that are external to plants, but internal to firms."

Eastman and Stykolt's results indicate that five of their industries produced between 75 and 100 percent of their output in plants of minimum efficient scale. These industries

[2] In addition to Norrie and Owram see Marr and Paterson, 1980, Pg. 394, or Easterbrook and Aitken, 1956, Pg. 504.

[3] Eastman and Stykolt, 1967, Pg. 56.

[4] Ibid, Pg. 56.

produced cement, liquid detergents, solid detergents, newsprint and wringer-type washing machines. The vegetable canning, containerboard, containers and beef packing industries produced between 50 and 75 percent of their output at minimum efficient scale. Less than 25 percent of the output of the fruit canning and pork packing industries and none of the output of the electrical refrigerator and range, petroleum refining, basic steel or tire industries was produced at minimum efficient scale.[5] All sixteen of Eastman and Stykolt's industries accounted for approximately one quarter of the value added generated by Canadian manufacturers in 1960.[6]

In the introduction to *The Tariff and Competition in Canada* Eastman and Stykolt (1967; Pg. 7) state that, "...the tariff has given rise to inefficiently small scale of plant and therefore to unnecessarily high costs in protected industries..." Dales (1966) was the first to formally model a link between trade barriers, the productivity of Canadian manufacturing and Canadian income per capita. He argued that, "... the tariff ... reduces G.N.P. per capita in Canada by reducing the efficiency of the economy ..."[7]

In *The Protective Tariff in Canada's Development* Dales constructed a model in which Canadian tariff protection, in combination with immigration policies designed to maintain a constant nominal wage, leads to increased G.N.P., but falling G.N.P. per capita. Dales claimed that this model effectively captured the Canadian situation in the mid 1950s. In support of his view that Canada suffered from a productivity shortfall due to the tariff, G.N.P. per capita in Canada and the U.S. was compared from 1870-1955.[8] Canadian G.N.P. per capita appears to have averaged less than 80 percent of American G.N.P. per capita over the entire period. Dales also measured real net value added per employed worker in Canadian secondary manufacturing, relative to U.S. total manufacturing. He found that between 1926-55 Canadian labour productivity averaged slightly less than 80

[5] Ibid, Pg. 62-63.

[6] The "small Canadian plant" theme was taken up and further articulated in work by Daly, Keys and Spence (1968), Stykolt (1969) and Gorecki (1976).

[7] Dales, 1966, Pg. 7.

[8] Ibid, Pg. 111. Dales used Firestone's (1958) G.N.P. figures for years prior to 1926 and standard D.B.S. figures for the years 1926-55.

percent of American labour productivity.[9] Dales made no adjustments for differences in input or output prices between Canada and the U.S.. Dales' model and his empirical support for the conclusions implied by this model appear to have had a significant impact on the formation of the belief that Canadian manufacturers were relatively inefficient and that this inefficiency was at least partially responsible for relatively low Canadian income per capita.

Dales' attempt to quantify the technical efficiency gap between Canadian and American manufacturing sectors may have been the most influential work on the subject but it was not the first nor the last. For the *Royal Commission on Canada's Economic Prospects* Fullerton and Hampson (1957) measured Canadian value added per man-hour relative to American value added per man hour in secondary manufacturing in 1953. After adjusting Canadian value added downwards 10 percent to compensate for differences in the measurement of net value added and a further downward adjustment of Canadian value added to compensate for tariff inflated Canadian output prices, Fullerton and Hampson found that Canadian labour productivity in secondary manufacturing was almost 40 percent less than American labour productivity in total manufacturing in 1953.[10]

This labour productivity gap was also identified by West (1971). He found that Canadian gross output per employee in total manufacturing in 1963, relative to U.S. gross output per employee (measured in Canadian dollars) was only 0.72.[11] Frank (1977) measured Canadian and American value added per man hour in thirty-three manufacturing industries. After adjusting for input and output price differences he found that Canadian labour productivity in 1967 was 62 percent of American labour productivity and by 1974 Canadian labour productivity had risen to 77 percent of the American productivity measure.[12] Caves, Porter, Spence, and Scott (1980) expanded Frank's sample of manufacturing industries to 84 and again found a substantial shortfall in Canadian value added per

[9]Ibid, Pg. 98.

[10]Fullerton and Hampson, 1957, Pg. 263.

[11]West, 1971, Pg. 26.

[12]Frank, 1977, Pg. 66.

worker relative to the U.S.. According to Caves et al. Canadian value added per worker, adjusted for inflated Canadian output prices (assuming "up-to-the-tariff" pricing policies by Canadian industries), in 1975-76 was only 79.6 percent of American value added per worker.[13]

Fullerton and Hampson, Dales, West, Frank and Caves, Porter, Spence and Scott all reported partial factor productivity comparisons derived from aggregate data. These measures do not capture the productivity of an entire production process. The productivity of other inputs in the production process as well as firms' substitution possibilities between inputs are not captured. Partial factor productivity measures are good representations of a firm or industry's total technical efficiency only if the relationship between the measured factor and unmeasured factors in the production process do not change. It is because partial factor productivity measures are incapable of measuring the efficiency of the entire production process of a production unit through time that total factor productivity measures are theoretically superior. However, because all factors must be measured to calculate T.F.P. there are greater data requirements and more opportunities for error. In particular, the measurement of capital stocks on a time and cross country consistent basis has proven problematic.[14] Often researchers have been forced to rely on proxies for the capital input. These measurement issues have not dissuaded all writers from tackling the problem of Canadian relative T.F.P. performance.

West (1971) and Frank (1977) adjusted their labour productivity measures for different intensities of capital and materials usage between Canada and the U.S. in an attempt to measure a form of "output per unit of total resource use".[15]

Baldwin and Gorecki (1986) contributed a volume to the *Royal Commission on Economic Union and the Development Prospects for Canada* in which they sought to measure relative T.F.P. between matched Canadian and U.S. manufacturing industries in 1970 and

[13]Caves, Porter, Spence and Scott, 1980, Pg. 262.

[14]See Hood and Scott, 1956 Pg. 231-46 for a discussion of different methods of capital stock measurement and their short comings.

[15]See West, 1971, Pg. 45.

1979. By assuming a Cobb-Douglas production function for 107 four digit manufacturing industries, estimating input shares and aggregating the four digit industry results, Baldwin and Gorecki found that Canadian manufacturing T.F.P. in 1970 averaged 77.06 percent of U.S. manufacturing T.F.P.. By 1979 the ratio had risen to 92.50 percent.[16] These results indicate that Canadian manufacturing industries were performing better, relative to U.S. manufacturing industries, when T.F.P. is the productivity measure being compared, rather than labour productivity.

In a paper written for the Bellagio Conference (March, 1986) Green and Baldwin (1987) expressed concern that the accepted wisdom that Canadian manufacturing has traditionally been technically inefficient relative to American manufacturing prior to WWII was based on fairly weak empirical evidence. They estimate relative T.F.P. for fifty-one Canadian and American manufacturing industries in 1929 for which differences in output and input prices can be accounted for. Stressing the observation that Canadian relative to American value added per worker under represents relative T.F.P., Green and Baldwin found that the median ratio of Canadian to American T.F.P. from their sample of fifty-one industries ranged from 0.89 to 0.96, depending on output measurement and capital proxies.[17] These results indicate that as early as 1929 Canadian manufacturing was not significantly less technically efficient than U.S. manufacturing if one uses T.F.P. as the relative productivity measure.

The most recent work that explicitly addresses Canadian relative T.F.P. performance is by Bernstein, Denny, May, Nakamura and Waverman (1992). In this paper Canadian relative to U.S. and Japanese T.F.P. is measured in twelve two digit industries in 1964-66, 1974-76 and 1983-85. Bernstein et al. find that the median T.F.P. ratio between Canada and the U.S., of the twelve manufacturing industries in the sample, is 0.867 in 1964-66. This ratio increases to 0.898 in 1974-76 and to 0.938 in 1983-85.[18] Again there appears to be little evidence of significant Canadian technical inefficiency.

[16]Baldwin and Gorecki, 1986, Pg. 137. I have noted the results for their TFP4 measure.

[17]Green and Baldwin, 1987, Table 7.

[18]Bernstein, Denny, May, Nakamura and Waverman, 1992, Pg. 600.

Dales, Eastman and Stykolt, Baldwin and Gorecki and the literature on scale and relative labour productivity contributed to a larger debate that dominated Canadian economic policy discussions during the late 1960s, 1970s and into the early 1980s. This debate centred on the role Canada's tariff structure played in determining the performance of Canada's manufacturers and the effect this performance had on Canadian income per capita. The debate culminated in the negotiation of the Free Trade Agreement between Canada and the U.S. in 1988. The protagonists clearly fell into two camps. Economic Nationalists prescribed continued trade protection for Canadian manufacturers, increased regulatory control, particularly on foreign owned firms, and continued or increased control over foreign direct investment in the Canadian economy.[19] Continentalists argued that tariff protection was responsible for the low efficiency of Canadian producers and that a combination of free trade and the liberalization of foreign direct investment would result in the rationalization of Canadian manufacturing and improved productivity.[20] Both the Nationalists and Continentalists accepted the view that Canada's manufacturers have traditionally been technically inefficient relative to her trading partners'.[21]

From this brief review of the existing literature on the scale of Canadian manufacturing plants, Canadian and American manufacturing labour and total factor productivity and the role the Canadian tariff structure played in determining the performance of Canadian manufacturers, we can see that there has been very little empirical work done on Canadian relative productivity prior to 1950. A second potential concern is that the vast majority of the empirical work in this field relies on measures of labour productivity. This would not be very worrisome were it not for the fact that the ratio of Canadian to American labour productivity seems to be consistently below the ratio of Canadian to American T.F.P.. The reason more work has not been done to quantify Canadian and American relative T.F.P. for longer time periods is likely related to the problems associated with time and cross border consistent measurement of the outputs and inputs, particularly capital.

[19]Lumsden, 1970, presents the Nationalist platform.
[20]See Wonnacott and Wonnacott, 1982, for a description of the Continentalist platform.
[21]See Saunders, 1982, for a comparison of the Nationalist and Continentalist positions.

The remainder of this chapter presents a long annual time series of relative T.F.P. ratios for nine manufacturing industries which has been built up from firm level data sources. The firm level data allows for the outputs and inputs to be carefully constructed and closely matched over time and across countries. The results from this T.F.P. series are consistent with the existing T.F.P. results in the literature. I also present partial factor productivity results for my nine industries which indicate that, as Green and Baldwin have suggested was true for 1929, Canadian manufacturers' relative labour productivity under represents their relative T.F.P. performance. Prior to the presentation of my T.F.P. and partial factor productivity figures the selection criteria and characteristics of the firms from which the data has been compiled is reviewed.

2.3 Sample Selection Criteria and Sample Characteristics

The availability of data constrains much of the work that can be done on the assessment of Canadian manufacturer's relative technical efficiency. This is particularly true in the pre-WWII era. Measuring capital stocks, calculating purchasing power parity measures for inputs and outputs and international differences in input, output and value added definitions are just a few of the problems that must be addressed. Nadiri (1970) surveys many T.F.P. measurement techniques and reviews some of the methodological problems and data requirements for each of these techniques.

In an effort to measure Canadian relative to American manufacturers' technical efficiency over a long time period, on an annual basis, I have compiled data from both firm level and national statistical agency data sources. The firm level results have been aggregated up to the three digit S.I.C. industry level for presentation purposes. Firm level data allows me to assess Canadian manufacturing performance on an annual basis over a long time period, while closely matching the firms in terms of inputs, outputs and production technology within industries, across countries and over time.

Moody's, Poor's and The Financial Post publish annual industrial manuals which contain balance sheets and income accounts for firms which issue publicly traded debt or equity. These manuals, in combination with companies' annual reports, trade journals and aggregate statistical data sources, supply all the information required to generate the results presented in this thesis. A detailed discussion of the aggregate data sources used is provided in a data appendix at the end of this chapter.

The required firm level data was gathered for thirty-nine Canadian and thirty-nine U.S. firms in nine manufacturing industries. Firms were included in the sample if appropriate data existed for a long time period. This criteria was fairly flexible, but in most cases a minimum of twenty years of data was required for inclusion in the sample. The firms had to generate virtually all their revenue from one class of commodities. There are very few cases in which a firm in the sample generated less than 85 percent of its revenue from commodities which can be considered the output of the industry in which it has been grouped. To be included in the sample the firms were also required to generate virtually all their revenue from goods produced in their home country. Again, in only a very small number of cases did the firms in the sample generate less than 85 percent of their revenue from the sale of goods produced in their home country. These conditions on firms' inclusion imply that firms which did not issue publicly traded debt or equity and firms which failed quickly were excluded, as were firms which produced a widely diversified product line or were multinational in their production.

The nine industries represented are steel mills, cotton textile mills, silk and synthetic fibre textile mills, cement manufacturers, sugar refineries, oil refineries, paper mills, distilleries and wineries. In Canada these nine industries generated between 31.6 percent and 20.5 percent of manufacturing value added from 1907-90. From 1902-90 these nine industries generated between 33.7 and 8.9 percent of American manufacturing value added. Particularly in the U.S. these industries represented a declining share of total value added generated by the manufacturing sector. The decline in the contribution to aggregate value added was pronounced in U.S. steel mills and cotton textile mills. In Canada coverage of the manufacturing sector by the nine industries represented remained fairly high throughout the period of study. Canadian steel mills were the only industry for which there was a

Table 2.1: Canadian Industries' Share of Total Manufacturing Value Added

	1910	1920	1930	1940	1950	1960	1970	1980	1990
Steel	0.140	0.151	0.128	0.131	0.138	0.105	0.088	0.083	0.076
Textiles	0.040	0.052	0.042	0.069	0.055	0.035	0.036	0.033	0.027
Cement		0.001	0.008	0.005	0.004	0.007	0.006	0.005	0.005
Sugar		0.008	0.007	0.007	0.005	0.004	0.004		
Oil			0.011	0.011	0.018	0.026	0.017	0.021	0.016
Paper	0.071	0.090	0.073	0.081	0.086	0.079	0.066	0.081	0.076
Wine			0.001	0.001	0.001	0.001	0.001	0.001	0.001
Spirits			0.012	0.006	0.009	0.011	0.012	0.006	0.004
Total	0.251	0.302	0.283	0.311	0.316	0.267	0.230	0.231	0.205

Table 2.2: American Industries' Share of Total Manufacturing Value Added

	1909	1919	1929	1939	1950	1960	1970	1980	1990
Steel	0.167	0.103	0.107	0.121	0.099	0.082	0.071	0.062	0.040
Textiles	0.162	0.161	0.135	0.074	0.021	0.034	0.031	0.025	0.020
Cement		0.004	0.006	0.005	0.005	0.005	0.003	0.003	0.002
Sugar	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001	
Oil	0.005	0.026	0.020	0.022	0.027	0.027	0.025	0.029	0.014
Paper			0.013	0.014	0.025	0.011	0.009	0.010	0.012
Wine				0.001	0.001	0.001	0.001		
Spirits				0.005	0.005	0.003	0.003	0.002	0.001
Total	0.337	0.287	0.283	0.242	0.162	0.153	0.135	0.131	0.089

dramatic decline in the share of aggregate value added. (See Table 2.1 and 2.2.)

In addition to the fairly substantial quantitative coverage of the Canadian and American manufacturing sectors the industries represented also capture a number of the qualitative characteristics of the manufacturing sectors. Both durable and non-durable (steel mills and distilleries) and secondary and primary (cotton textile mills and oil refineries) manufacturing industries are represented and there are industries which have traditionally been identified as Canadian and American success stories (Canadian paper mills and U.S. steel mills) and typical Canadian and American failures (Canadian cotton textile mills and American paper mills) represented.

Establishing how much of the individual industries are covered by the firms in the sample is significantly more difficult to determine. Because the firm level data does not consistently report value of production, value of shipments, value added or even number of employees, these measures could not be used to establish firm coverage within the nine industries. Information on income paid to capital is available for all of the firms in the sample. However, the aggregate data do not report income going to capital. It is true that value added less income to labour is a measure of income paid to capital and services, at an aggregate level. The problem is that the aggregate measure of value added less labour income includes the payments to services. In the firm level data the payments to services are not included in the income paid to capital figures. Therefore, I cannot use (firm level income paid to capital)/(industry value added less labour costs) to measure the extent of firm coverage within the industries. For these reasons I can only broadly describe how extensive firm coverage is within the nine industries using value of production, value of shipments, value added, employees and income paid to capital when each, or all, are available for all the firms and the industry.

Four Canadian steel mills are included in the sample. They are Stelco (1910-90), Dofasco (1924-90), Dosco (1930-90) and Algoma (1936-90). When data exists for all firms industry coverage is virtually complete. The U.S. steel mills in the sample include U.S. Steel (1902 -90), Bethlehem Steel (1905-90), Inland Steel (1910-90), Republic Steel (1910-90), Armco (1917-90), Jones and Laughlin (1922-90) and National Steel (1930-90). These U.S. mills represent approximately 50-75 percent of the U.S. primary steel industry when all are included.

Turning to the cotton textile mills in the sample there are six Canadian firms to consider. The Canadian cotton textile mills which have been included are Penman's (1908-64), Dominion Textile (1910-79), Wabassco (1913-70), Wood's Manufacturing Company (1913-55), Hamilton Cottons (1927-62) and Dominion Fabrics (1942-70). These six mills accounted for between 25 and 50 percent of the Canadian cotton textile industry. The five U.S. cotton textile mills cover substantially less of the U.S. industry. American Thread (1902-69), Naumkeag Steam Cotton Company (1926-64), Cannon Mills (1930-80), Avondale Mills (1941-85) and Fieldcrest Mills (1961-90) cover less than 25 percent of the U.S. industry when all are included.

Four Canadian and three American silk and synthetic fibre textile mills are in the sample. The Canadian firms, Belding Cortecelli (1912-80), Bruck Silk Mills (1927-76), Riverside Mills (1929-81) and Consolidated Textile (1945-89) cover close to 50 percent of the Canadian industry. Belding Brothers (1912-90), Kayser-Roth (1912-74) and Stonecutter Mills (1923-68), like the cotton mills, cover less than 25 percent of the U.S. silk and synthetic textile industry.

Canada Cement (1910-90) had a virtual monopoly in the Canadian cement industry until the mid-1950s. The largest Canadian cement producers who challenged Canada Cement's hold on the domestic market were St. Lawrence Cement (1955- 90), Lafarge Cement (1957-69) and Lake Ontario Cement (1958-85). All of these firms are included in the sample. Coverage of the Canadian cement industry is nearly complete. Coverage of the U.S. industry is not as extensive. The four U.S. cement producers in the sample cover between 25-50 percent of the U.S. industry. The U.S. cement producers in the sample are Giant Portland Cement (1914-88), Missouri Portland Cement (1918-84), Alpha Portland Cement (1921-83) and Ideal Cement (1927-88).

Canadian sugar refineries were also dominated by a few large firms. Atlantic (-Acadia) Sugar (1917-64), Canada and Dominion Sugar (1934-67) and B.C. Sugar (1952-76) cover over 50 percent of the Canadian industry when they are all included. The U.S. sugar refineries, American Sugar Company (1909-67), (Imperial-) Holly Sugar (1922-86), National Sugar (1927-74) and Savannah Sugar (1944-67) represent coverage of the U.S. industry into the upper second quartile.

Coverage of oil refining for Canada and the U.S. is extensive. When all firms are included Canadian and U.S. coverage is well into the third quartile. The Canadian firms in the sample are North Star Oil (1922-59), McColl Frontenac (1923-88), Canadian Oil Companies (1925-61), Imperial Oil (1928-90), British-American Oil (1929-84) and Shell Canada (1960-90). The U.S. oil refineries in the sample are Union Oil Company (1911-90), Panhandle Oil Company (1919-55), Shell Oil (1922-90), Getty Oil (1929-82) and American Petrofina (1956-90)

Coverage of the Canadian paper industry by the mills included in the sample reaches almost fifty percent when data exists for all firms. The Canadian paper mills in the sample are Consolidated Paper (1907-63), St. Lawrence Corporation (1924-72), Rolland Paper (1928-90), Westminister (Scott) Paper (1928-90) and Donohue Brothers (1945-73). U.S. coverage of the paper industry is similar to the Canadian coverage. The U.S. paper mills in the sample are Neekosa-Edwards (1925-68), Moosinee Paper Mills (1926-74), Great Northern (1936-88), Southland Paper Mills (1941-74) and Hudson Pulp and Paper (1944-77).

Three Canadian distilleries are included in the sample of firms. They are Corby (1925-90), Melcher's (1929-75) and Potter (1966-82). These three firms cover roughly one quarter to one third of the Canadian spirits industry. U.S. distilleries were legally restricted to the production of industrial alcohol, or alcohol for medicinal purposes between 1920 and 1933. Therefore, data is not available for the U.S. industry until the end of the prohibition period. Data is available for Brown-Forman (1934-82) immediately after prohibition was repelled. However, data does not exist for the other two U.S. distilleries in the sample, Glenmore (1945-90) and James Beam (1948-65), until well after the prohibition period. Coverage of the U.S. spirits industry falls in the first quartile when all three firms are in the sample.

The final industry represented by firms in the sample is wineries. When all four Canadian firms, Chateau-Gai (1930-73), T.G. Bright (1934-90), Grower's Wineries (1947-71) and Andres (1969-90) are included coverage of the entire industry reaches over 50 percent. For the U.S., Pleasant Valley (1934-56), Lasalle Wines and Champagnes (1937-61) and Taylor Wines (1961-74) cover only approximately 10 percent of the U.S. wine industry. The regulation of Canadian wine sales, particularly in Ontario, and possible cross-country differences in the quality of measured inputs may be problematic. More than any other industry in the sample wineries display a divergence in potential market power and quality

Table 2.3: Mean Ratio Canadian : American Output Levels

	Q_{cda}/Q_{us}
Steel	0.087
Cotton	0.662
Silk	0.061
Cement	1.826
Sugar	0.521
Oil	0.412
Paper	0.376
Wine	0.534
Spirits	0.097
Cdn VAW	0.365
US VAW	0.346

variation between the Canadian and American firms.[22] For this reason results from the wine industry should be interpreted with care.

On average the Canadian firms in my sample were substantially smaller than the American firms, if we judge size by quantity of output.[23] However, in all nine industries represented there was at least one Canadian firm than was larger that the smallest U.S. firm in at least one year. This implies that in all nine industries represented in my sample the firm size distributions of the Canadian and American industries overlapped. In all of my industries, except cement producers, the average size of the Canadian firms was smaller than the average size of the American firms.[24] In the case of silk and synthetic fibre textile mills, steel mills and distilleries the Canadian firms in my sample had an average output level of less than ten percent of the average output level of the American firms in my sample. (See Table 2.3.)

The nine industries represented in the sample cover a substantial share of both Canadian and U.S. value added. The coverage by the firms in the sample of the industries they represent varies widely between the industries and within each industry over time. On the

[22]The effect of market power on my T.F.P. calculations is discussed in detail in Section 2.4.1.

[23]I have measured output as net sales deflated by nominal output prices. See the data appendix for further details.

[24]A weighted average of industry output has been calculated using shares in surplus as weights. See the data appendix for further details.

whole quantitative and qualitative coverage within the nine industries in both Canada and the U.S. is fairly substantial. There is no doubt that the ability of the firms in the sample to represent all of the Canadian and American manufacturing sectors is questionable. However, these firms were chosen for some specific reasons, not the least important of which was that the firms published data, produced goods and used production techniques, that matched their cross border counterparts. In other words, special care was taken in the firm selection and data construction to ensure that the results were comparing "apples to apples and oranges to oranges". The representativeness of these industries and firms is addressed further in Section 2.5.

2.4 The Measurement of Relative T.F.P.

2.4.1 Methodology

One category of T.F.P. measurement techniques uses ratios of index numbers rather than direct econometric estimation or calculation by simple growth accounting type procedures. Diewert (1976) is the theoretical work on which many of these techniques are based. Index number methods of measuring T.F.P. have been used extensively with aggregate data to calculate T.F.P. growth rates and relative levels.[25] There are some examples of index number methods being implemented with firm level data, but use of micro data is still quite rare.[26] Because index number techniques can be used with firm level data and can be used to calculate relative levels between firms, a novel, but not unique, T.F.P. measurement methodology drawing on these techniques has been used. The relative T.F.P. ratios generated reflect the relative technical efficiency of an entire production process, assuming both production units are allocatively efficient. The chosen methodology is a variant of that used by Allen (1982) to calculate the relative efficiency of open and enclosed farms in eighteenth century Britain.

The methodology I use to measure relative technical efficiency assumes that my firms

[25]See Denny and May, 1977 or Denny, May and Fuss, 1981, for some Canadian examples.

[26]See Caves and Christensen, 1980, for an example in which the productivity of the C.P.R. and C.N.R. is compared.

have translog cost functions with Hicks neutral multiplicatively separable productivity parameters. I also assume that their cost functions satisfy all the required properties and have been derived subject to constant returns to scale technology. The constant returns assumption implies that any scale effects will be captured by the productivity parameters. If:

$$lnC = ln\alpha_0 + \sum_{i=1}^{n} \alpha_i lnw_i + 0.5\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} lnw_i w_j + lnQ - lnA \tag{2.1}$$

Where:

$$i, j = L, K, M$$
$$\gamma_{ij} = \gamma_{ji}$$
$$\textstyle\sum_{i=1}^{n} \alpha_i = 1$$
$$\textstyle\sum_{i=1}^{n} \gamma_{ij} = \sum_{j=1}^{n} \gamma_{ji} = 0$$

And:

C =Total Cost

Q =Physical Output

A =Hicks Neutral Productivity Parameter

L =Labour Input

K =Capital Input

M =Intermediate Input (Materials, Fuel, Services)

w_L =Average Industry Wage Rate for Labour

w_M =Index of Industry Intermediate Input Prices

w_K =Total Return to Capital per Unit of Capital

Then we can write:

$$C(A, w_L, w_M, w_K, Q) = A^{-1} Q f(w_L, w_M, w_K)$$

The definition of w_K requires some elaboration. The total return to capital is the firm's variable profit, or surplus ($S = PQ - w_L L - w_M M$). The use of firm level data allows me to get a measure of the real capital input used by each firm. (See the data appendix at the end of this chapter.) Therefore, w_K is the variable profit generated by the firm divided by a measure of the real capital input used by the firm, in each year. Use of this definition for w_K requires the assumption that firms are using ex post capital cost in their cost minimizing decisions, rather than the typical assumption that firms are using ex ante capital cost, or user cost of capital, in their decisions. If we are assuming that w_K is the ex post cost of capital, then the cost function method of calculating T.F.P. becomes very similar to a variable profit function method.[27] The reason for using a cost function methodology rather than a variable profit function methodology, even though it requires a nonstandard assumption about cost minimizing behaviour, is the existence of negative variable profit. Economic theory suggests that firms will shut down when their variable profit drops below zero.[28] Empirically one year, or even a number of years, of negative variable profit does not necessarily cause firms to shut down. Instead, the owners of the firm, or those who rent capital to the firm, subsidize the firm during short periods of negative variable profit. During these times ex post capital cost becomes negative. In other words, during periods of negative variable profit ex post capital cost becomes an output price, rather than an input price. Negative ex post capital cost is treated as a positive output price in periods of negative variable profit. Hence, the assumption about ex post capital cost being used in the firm's cost minimizing decisions avoids the theoretical problems associated with a firm's continued operation during periods of negative variable profit.

If the definitions above are accepted Diewert (1976) has shown that we can express a ratio of the function $f(\cdots)$ in two time periods, or between two firms, as a Tornqvist index of input prices.

[27]See Allen, 1982.

[28]Negative variable profit is equivalent to price being less than average variable cost.

$$\frac{f(w_L^1, w_M^1, w_K^1)}{f(w_L^0, w_M^0, w_K^0)} = \left(\frac{w_L^1}{w_L^0}\right)^{0.5(sl^1+sl^0)} \left(\frac{w_M^1}{w_M^0}\right)^{0.5(sm^1+sm^0)} \left(\frac{w_K^1}{w_K^0}\right)^{0.5(sk^1+sk^0)} \tag{2.2}$$

Where:

$$si^t = \frac{w_i^t * i^t}{C^t(\cdots)} \tag{2.3}$$

Therefore:

$$\frac{C^1(\cdots)}{C^0(\cdots)} = \left(\frac{A^0}{A^1}\right)\left(\frac{Q^1}{Q^0}\right)\left(\frac{w_L^1}{w_L^0}\right)^{0.5(sl^1+sl^0)} \left(\frac{w_M^1}{w_M^0}\right)^{0.5(sm^1+sm^0)} \left(\frac{w_K^1}{w_K^0}\right)^{0.5(sk^1+sk^0)} \tag{2.4}$$

If total cost equals total revenue, which will be true under my definition of w_K, then we can write:

$$\frac{C^1(\cdots)}{C^0(\cdots)} = \frac{P^1 * Q^1}{P^0 * Q^0} \tag{2.5}$$

Where:

P =Index of Industry Output Prices

Canceling the appropriate variables and rearranging yields:

$$\frac{A^1}{A^0} = \left(\frac{w_L^1}{w_L^0}\right)^{0.5(sl^1+sl^0)} \left(\frac{w_M^1}{w_M^0}\right)^{0.5(sm^1+sm^0)} \left(\frac{w_K^1}{w_K^0}\right)^{0.5(sk^1+sk^0)} \left(\frac{P^0}{P^1}\right) \tag{2.6}$$

Intuitively this technique relies on the notion that changes in output prices which are not due to changes in input prices must be the result of changing T.F.P..

The most attractive feature of this methodology is that the information required is available from the firm level and aggregate data sources which I have access to. The labour and intermediate input and output prices can be gathered from aggregate industry level sources if we assume perfect competition in input and output markets. For w_K the surplus and investment data can be gathered from firm level financial data which is very plentiful. The share parameters can be calculated with a combination of firm and aggregate level data.

One of the least attractive features of this technique is the restrictive assumptions required. I must assume not only very specific functional forms, but also perfect competition in input and output markets. These assumptions are required for virtually all T.F.P. calculation techniques.[29]

Another serious concern in applying this cost function methodology to the measurement of Canadian relative to American technical efficiency is the existence of nation specific market power. Market power may be due to factors such as tariff protection or government regulations. The translog cost function T.F.P. calculation method requires that output prices represent average costs and input prices represent the value of the marginal products of the inputs. The presence of market power drives a wedge between output prices and average costs. Under my definition of ex post capital cost any economic rents earned as a result of market power are also reflected in higher returns paid to capital. This implies that market power also drives a wedge between ex post capital cost and the value of the marginal product of capital. Without specific knowledge of the output demand elasticity for an industry and the share of total cost going to capital in an industry I cannot predict the direction of bias the presence of market power introduces into my relative T.F.P. figures.

I can say that if an industry faces an inelastic demand function, then effective tariff protection or market power as a result of government regulation will result in output prices rising above average costs. These inflated output prices will raise the ex post capital cost above the value of the marginal product of capital. Therefore, both the numerator and denominator of the relative T.F.P. ratios I calculate using the translog cost function method will increase. The more inelastic the demand functions are, and the smaller the capital cost shares are, the larger the increases in ex post capital costs will be. Therefore, it is possible that if a Canadian industry represented in my sample of firms had a very inelastic demand function, a small share of total cost paid to capital and significantly more

[29]A production function methodology, which does not require any assumptions about market structure because it uses only physical quantities of inputs and outputs, has been applied using a subset of the firm year observations on which the cost function T.F.P. results are based. The production function methodology involves the aggregation of relative partial factor productivities to measure relative T.F.P.. On average the two alternate techniques generate very similar results. See Table 2.11.

market power than its American counterpart, then the relative technical efficiency measure reported may be biased in favour of the Canadian industry. However, under most elasticity, cost share and relative market power assumptions any biases introduced into my relative T.F.P. figures due to asymmetric tariff protection or cross-country variation in market power due to government regulation would be small and the direction of bias would be dependent on exogenous factors within an industry's economic environment.

2.4.2 T.F.P. Results

Annual T.F.P. growth rates have been calculated using the cost function index number technique for each of the seventy-eight firms in my sample. These calculations employ approximately 5500 firm-year observations. A weighted average of the firm level growth rates was calculated for each industry. Each firm's weight was determined by its share in the surplus generated by all the firms in its industry. Surplus has been used as weights because it is the only figure available for all firms for all years. Nominal input and output prices, expressed in Canadian dollars, were used to calculate the relative level of T.F.P. between the Canadian and American industries in all years for which data was available for both industries. Using the growth rate results with the first available relative T.F.P. figure, relative T.F.P. levels were generated annually for the entire period for which data was available for both countries' industries. The relative level ratios generated in this manner are very close to relative T.F.P. ratios which have been calculated for those years for which nominal prices were available for the Canadian and American industries. The industry results have been aggregated into a summary measure using each industry's share of the total value added generated by all nine industries as weights. Canadian and American value added weights have been used. As a check on these weighting schemes the median industry's relative T.F.P. has also been calculated.[30] Table 2.4 contains these weighted average relative T.F.P. figures.

From Table 2.4 we can see that between 1911-20 the T.F.P. of the nine Canadian

[30] An appendix to this chapter contains a graphical presentation of the results discussed in this subsection.

Table 2.4: Canadian Relative to American T.F.P.

	Cdn VA Weights	U.S. VA Weights	Median
1907-10	0.91	0.90	0.91
1911-20	0.86	0.83	0.91
1921-30	1.04	1.00	0.98
1931-40	1.44	1.23	1.00
1941-50	1.20	1.04	0.94
1951-60	1.18	1.07	1.05
1961-70	1.12	1.06	1.12
1971-80	1.13	1.10	1.15
1981-90	1.19	1.04	1.16
Mean	1.14	1.04	1.03

industries relative to the nine U.S. industries was between 0.83 and 0.91, depending on how the industry results are aggregated. The average over the next decade rose to between 0.98 and 1.04 and from 1925-90 the Canadian firms in my sample never had a lower level of T.F.P. than the U.S. firms, on average.[31] After 1925 the average T.F.P. (using Canadian VA weights) of the Canadian firms never dropped below 103% of the U.S. firms' T.F.P.. In aggregate there is virtually no evidence of Canadian manufacturing technical inefficiency amongst the firms in my sample. If one breaks these aggregate results down by industry, not surprisingly some Canadian industries fare better than others. The results, disaggregated by industry, are presented in Table 2.5.

After 1920 the Canadian steel firms did fairly well relative to their U.S. counterparts. Only during the years immediately after WWII and the early 1980s did the ratio of Canadian to U.S. firms' T.F.P. drop below 0.90.

Cotton textile firms in Canada do appear to have been consistently less efficient than the U.S. firms. This result is not surprising given the effort Canadian cotton textile producers exerted to maintain their tariff protection and the Canadian firms' consistently poor performance in international markets.

[31] After 1925 the Canadian firms are never less technically efficient than the U.S. firms, on average, if Canadian VA weights are used to aggregate the industry results. If U.S. VA weights are used the Canadian firms are less efficient, on average, in only five years (1926, 1946, 1988, 1989 and 1990).

Table 2.5: Canadian Relative to American T.F.P. By Industry

	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	Mean
Steel	0.74	0.98	1.19	0.88	1.03	0.99	0.92	0.95	0.96
Cotton	0.90	0.87	0.92	0.85	0.64	0.72	0.82		0.82
Silk	1.10	0.95	0.81	0.81	1.15	1.36	1.44	1.51	1.14
Cement	0.80	0.71	0.94	1.00	1.09	1.15	1.27	1.08	1.01
Sugar	0.95	1.14	1.33	1.12	1.15	1.52	1.01		1.21
Oil		1.20	0.90	0.83	0.91	0.84	1.08	0.90	0.95
Paper		1.30	1.83	1.47	1.39	1.25	1.22	1.22	1.39
Wine			1.77	1.22	1.34	1.64	1.62		1.53
Spirits			0.72	0.90	0.81	0.87	1.19	2.30	1.15

More surprising is the performance of the silk and synthetic fibre textile firms during the post-WWII era. The Canadian firms have consistently exhibited greater T.F.P. than the U.S. firms in the sample after 1950. The dramatic improvement in Canadian silk and synthetic fibre textile producers' relative T.F.P. performance coincides very closely with the movement of both Canadian and American firms into synthetic fibres and out of silk. Another interesting feature of the Canadian industry is that the Canadian firms' output was dominated by production for the Canadian auto industry. The signing of the Auto Pact in 1965 solidified this source of demand for the Canadian firms. It is unlikely that these events were unrelated to the Canadian silk and synthetic fibre textile mills' T.F.P. success after WWII.

In cement we see a very interesting pattern of relative T.F.P. performance. Prior to the mid-1950s the Canadian market was dominated by one large producer, Canada Cement. During this period the U.S. firms' T.F.P. was significantly greater than Canada Cement's T.F.P.. However, as more firms entered the Canadian market the trend was reversed and from the 1950s until the end of the sample period Canada's cement producers were more technically efficient than the U.S. firms in my sample, despite the fact that Canada Cement continued to be the largest single Canadian producer. Increased competition may have played a role in the improvement in the Canadian industry's relative T.F.P. performance. Cement is the only industry in the sample for which the Canadian firms were, on average, larger than the American firms in the sample.

Like cement, Canadian sugar refining was dominated by few large firms. The U.S. sugar refineries in my sample were, on average, quite a bit larger than the Canadian firms, but these U.S. refineries appear to have focused on regional markets. Whether the competitive pressures within the Canadian national market explain the Canadian firms consistently better T.F.P. performance, relative to the U.S. firms, remains an interesting hypothesis.

The issue of size may also play a role in determining the underlying reasons for Canadian oil refineries poor T.F.P. performance. In this industry the U.S. refineries in my sample were, on average, substantially larger than the Canadian refineries and they appear to have been more technically efficient. This generalization does not hold during the 1970s. The U.S. oil refineries in my sample suffered a decline in their T.F.P. during this decade and the Canadian firms caught up and briefly surpassed them.

Given the excellent export performance of Canadian paper mills it is not unexpected to find that the Canadian firms consistently, and quite dramatically, out performed the American firms.

Finally turning to the two alcoholic beverage industries, we see that the relative T.F.P. measures are volatile for both industries. Part of the explanation for this is poor coverage of the U.S. industries, particularly the wine industry. The Canadian distilleries were initially less productive than the U.S. distilleries in my sample. This gap narrows significantly, particularly immediately after WWII, and by the late 1960s the Canadian firms were at least as technically efficient as the U.S. firms. At the very end of the 1980s the Canadian distilleries became significantly more productive than the remaining U.S. distillery in the sample. In the wine industry it appears that the Canadian firms in the sample were significantly more efficient that the U.S. wineries through the entire period. At least part of this T.F.P. gap favouring the Canadian firms may have been due to the greater degree of market power they likely enjoyed as a result of government regulations controlling the sale of wine in Canada. Another potential explanation is unmeasured quality differences amongst the inputs employed and output produced.

In general, it appears that Canadian paper mills, sugar refineries and wineries were consistently more technically efficient than their American counterparts. After 1950 the Canadian cement and synthetic fibre textile firms became more efficient than the U.S. firms. Canadian steel mills, oil refineries and distilleries were certainly not substantially less efficient than the U.S. companies in the same industry. Only Canadian cotton textile mills have been poor performers in terms of relative T.F.P. levels. The mean Canadian relative to American T.F.P. ratio for the firms in my sample from 1907-1990 was between 1.034 and 1.137, depending on the method of aggregating the industry level figures. To those familiar with the traditional claims of Canadian technical inefficiency the results presented here must be surprising. To conclude that these T.F.P. results are not just seventy-eight case studies, but they have more general implications for the entire Canadian manufacturing sector, I must demonstrate that the figures are not merely a function of methodological or firm selection.

2.5 The Representativeness of the Sample

If the results I have presented in the preceding section are not dependent on my choice of methodology or firm selection, then they should be consistent with the more general, in a cross sectional sense, existing relative T.F.P. figures in the literature. The relative T.F.P. figures in the existing literature rely on aggregate data and cover very few years. Green and Baldwin (1987) report that the median relative T.F.P. ratio out of 51 manufacturing industries in 1929 was between 0.89 and 0.96, depending on capital proxy and output measure. In 1929 my median industry had a relative T.F.P. ratio of 0.97. Baldwin and Gorecki (1986) find that the median relative T.F.P. ratio amongst the industries covered by my sample in 1970 was between 0.63 and 1.01 and in 1979 between 0.73 and 1.20, depending on aggregation technique and input elasticity estimation. My median industry relative T.F.P. ratio was 1.04 in 1970 and 1.22 in 1979. Bernstein, Denny, Fuss, Nakamura and Waverman (1992) claim that the median relative T.F.P. ratio of the industries I have been able to cover was 0.987 in 1964-66, 0.979 in 1974-76 and 1.030 in 1983-85. During these periods my median relative T.F.P. figure was 0.977, 0.973 and 1.127, respectively. My T.F.P. results are consistent with the existing figures in the literature, even though these existing figures rely on a broader cross section of firms, aggregate data and distinct methodologies.

I may have included industries in my sample which were not typical of Canadian manufacturing in general because they have traditionally been efficient relative to their American counterparts. This concern stems from the labour productivity evidence in the existing literature which indicates that, as a whole, the Canadian manufacturing sector has had low productivity relative to the U.S. manufacturing sector. To test the representativeness of the nine industries covered in my sample I have calculated Canadian relative to American value added per worker from aggregate data sources for my nine industries at decennial intervals. Value added figures were adjusted for differences in input and output prices between Canada and the U.S. and the number of workers were adjusted for differences in average hours worked per week in total manufacturing in Canada and the U.S.. The value added figures have been adjusted for differences in input and output prices in the following manner:

If:

$$PQ = w_L L + w_K K + w_M M$$

And:

$$VA = PQ - w_M M = w_L L + w_K K$$

Then:

$$\frac{VA_{cda}}{VA_{us}} = \frac{P_{cda}Q_{cda} - w_M^{cda} M_{cda}}{P_{us}Q_{us} - w_M^{us} M_{us}} \tag{2.7}$$

Adjusting for output and input price differences yields:

Table 2.6: Ratio Canadian : American Aggregate Value Added Per Worker

Industry	1919	1929	1939	1950	1960	1970	1980	1990
Steel	0.84	0.75	0.83	0.68	0.74	0.73	0.70	0.60
Cotton	0.94	0.80	0.85	0.40	0.35	0.60		
Silk	1.00	0.65	1.00	0.74	1.06	1.16	0.87	
Cement	0.78	1.12	1.59	1.85	1.96	1.23	1.02	
Sugar	0.42	0.92	1.51	0.76	1.06	0.62		
Oil		0.90	0.80	0.70	0.93	0.88	1.12	0.91
Paper		1.05	0.73	1.25	1.08	0.84	1.59	
Wine			1.03	1.15	0.93	1.53		
Spirits			1.33	1.71	0.51	0.74	0.72	0.72
Cdn VAW	0.83	0.90	0.86	1.04	0.97	0.84	1.17	0.69
US VAW	0.87	0.83	0.86	0.89	0.86	0.81	1.10	0.66

$$\frac{VA_{cda}}{VA_{us}} = \frac{P_{cda}Q_{cda} - w_M^{cda}M_{cda}}{P_{us} * (P_{cda}/P_{us})Q_{us} - w_M^{us} * (w_M^{cda}/w_M^{us})M_{us}} \tag{2.8}$$

Therefore:

$$\frac{VA_{cda}}{VA_{us}} = \frac{P_{cda}Q_{cda} - w_M^{cda}M_{cda}}{P_{cda}Q_{us} - w_M^{cda}M_{us}} \tag{2.9}$$

Table 2.6 indicates that Green and Baldwin's (1992; Pg. 20) claim that, "...the use of partial productivity measures in international productivity comparisons may lead to very misleading results...", is true over a long time period when comparing the Canadian and American industries covered by my sample of firms. Like the broadly based labour productivity evidence in the literature, Canadian value added per worker relative to American value added per worker was substantially and consistently less than one in almost all of the industries represented in my sample. Cement is the only industry which was an exception to this generalization. My nine industries appear to conform to the poor labour productivity performance identified in the literature. Therefore, by the criteria of relative labour productivity they were not atypical industries.

I can now address the issue of whether the firms within the industries were atypical. In other words, I must attempt to determine whether the criteria for firm selection has

Table 2.7: Ratio Canadian : American Firm Level Value Added Per Worker

Industry	1919	1929	1939	1950	1960	1970	1980	1990	Mean
Steel	0.77	1.00	0.79	0.74	0.73	0.77	0.78	1.32	0.90
Cotton		0.98	0.83	0.65	0.81	0.84			0.83
Silk		0.97	0.81	0.64	0.81	0.85	1.00		0.85
Cement		0.67			0.76	0.97	1.14		0.90
Sugar				0.72	0.80	0.94			0.81
Oil		0.86	0.75	0.70	0.92	0.89	0.87	1.07	0.85
Paper		0.91	0.80	0.79	0.96	0.92	1.02		0.93
Wine			0.78	0.76	0.89	0.81			0.80
Spirits			0.78	0.68	0.81	0.83	0.89	1.09	0.84
Cdn VAW	0.77	0.92	0.80	0.75	0.88	0.87	0.94	1.22	0.92
US VAW	0.77	0.94	0.79	0.73	0.84	0.85	0.92	1.22	0.91

picked out only the most efficient Canadian firms within each industry. The firm level data sources used to compile the appropriate figures used in the calculation of relative T.F.P. ratios contain information from balance sheets and income accounts. This means that information such as revenue or number of employees is not plentiful. To calculate value added per worker for the Canadian and American firms in my sample I needed one piece of information in addition to that used to calculate T.F.P. ratios; number of employees. For the T.F.P. evidence I have approximately 5500 firm-year observations. For the relative value added per worker evidence cited below I have slightly more than 3300 firm-year observations. The decline in firm-year observations is particularly pronounced in the cement and sugar refining industries.

To calculate value added per worker at the firm level the number of employees for each firm was multiplied by the average hourly wage rate for the industry and the average hours worked per week for total manufacturing. This figure was then added to the total return to capital paid by the firm per week and the sum divided by the number of employees adjusted for differences in hours worked between Canada and the U.S.. The firm level results were aggregated up to the industry level using the same procedure which was used to aggregate the firm level T.F.P. results, then the relative value added per worker ratios between the Canadian and American industries represented in my sample were generated.

As we can see from Table 2.7 the ratios of Canadian to American value added per worker for my sample of firms were substantially and consistently less than one. We may reject the hypothesis that the mean ratio of value added per worker between the Canadian and American industries was greater than or equal to one with 95% confidence for all nine industries and both aggregating schemes. For six of the nine industries we can reject the null that the mean ratios were greater than or equal to 0.90 with 95% confidence. Only paper, cement and steel have average relative value added per worker ratios greater than 0.90. For the remaining six industries, the Canadian firms' value added per worker figures were over 15% lower than the American firms', on average.

The labour productivity evidence from my sample suggests two conclusions. The first is that the firms in my sample and the industries they represent were not atypical, if we judge them by their labour productivity performance. The second is that the Canadian firms do seem to have been traditionally less productive in their use of the labour input. To reconcile the labour productivity and T.F.P. performances of these firms we need to consider evidence on the partial factor productivities of the other inputs employed by the firms in my sample.

2.6 Reconciliation of T.F.P. and Labour Productivity Results

Lempriere and Rao (1992: Pg. 5) argue that, "...when the focus is on an establishment, firm or industry level, the appropriate concept of output is gross output, not net output, because the intermediate inputs... play an important role in the production process." This is particularly true for the industries covered by my sample. Therefore, I have calculated labour, capital and intermediate input productivities using gross output, rather than value added, as the numerator. As mentioned above, revenue figures are not plentiful at the firm level. Revenue figures are required to calculate gross output. Hence, the partial factor productivity gross output measures generated for my sample of firms could not be based on as many firm-year observations as the value added per worker or T.F.P. figures presented above. My partial factor productivity gross output measures are based on approximately 2750 firm-year observations. Again, cement and sugar refining industries suffer the greatest decline in observations.

Each firm's gross output was measured as its net sales (total revenue less sales and excise taxes) deflated by an index of its output prices. Output per worker was derived by dividing each firm's gross output by the number of workers, adjusted for differences in hours worked between Canada and the U.S.. Output per unit of capital was derived by dividing each firm's gross output by a real measure of its capital input, which is generated using information on fixed assets and annual investment from the firm's balance sheets and income accounts. (See the data appendix at the end of this chapter.) Output per unit of intermediate input was derived by dividing each firm's gross output by an index of real intermediate input. The index of real intermediate input was calculated by subtracting each firm's value added figures from its revenue figures to get the total cost of intermediate input in each year. This cost figure was then deflated by an index of intermediate input prices to get a real measure of the intermediate input used by each firm in each year. As with the T.F.P. results the firm level partial factor results have been aggregated up to the industry level, then the Canadian relative to the American industry ratios were generated. I would also like to highlight the fact that the partial factor productivity measures using gross output in the numerator are quite volatile. As I aggregate across time or across industries this volatility diminishes. The general trends rather then the specific annual results are more revealing of the underlying economic forces at work.

The relative output per worker figures for the industries represented in my sample are presented in Table 2.8. These figures are substantially more volatile than the relative value added per worker figures derived from the firm level data, but on average the story remains the same. For both aggregating schemes and five of the nine industries represented Canadian labour productivity was lower than American labour productivity. For all industries except cement and marginally oil refining, the mean ratio of Canadian to American labour productivity was lower than the mean ratio of Canadian to American T.F.P.. (Compare

Table 2.8: Ratio Canadian : American Firm Level Output Per Worker

	1919	1929	1939	1950	1960	1970	1980	1990	Mean
Steel	0.53	0.66	0.83	0.96	1.14	1.25	0.82	0.42	0.87
Cotton		0.07	0.71		0.65	0.77			0.73
Silk		0.21	0.07		0.52	0.65	0.40		0.45
Cement					1.46	2.56	1.62		1.42
Sugar						0.86			0.62
Oil		1.61	0.99	1.03	1.21	0.95	1.08	0.63	1.00
Paper		0.69	1.39	1.04	1.24	0.94	1.11		1.26
Wine				1.60	1.58	1.04			1.17
Spirits					0.08	0.45	0.62	0.35	0.44
Cdn VAW	0.53	0.3	1.14	1.03	1.10	1.02	0.96	0.46	0.99
US VAW	0.53	0.97	0.99	1.01	1.06	1.08	0.98	0.49	0.94

the results presented in Table 2.8 and Table 2.5.)

The mean ratio of Canadian to American gross output per unit of capital was substantially greater than one for five of the nine industries in my sample and for both aggregating schemes. These results are illustrated in Table 2.9. The relatively high Canadian capital productivities suggest one possible reason why some of the Canadian industries' T.F.P. ratios were not substantially and consistently lower than the American industries' T.F.P. ratios, even though their labour productivity ratios often were substantially and consistently lower. Some of the Canadian industries had very high capital productivity ratios, relative to the U.S. firms which compensated for their low labour productivity ratios.

For all of the industries represented in my sample of firms intermediate inputs accounted for the largest share of total cost. Intermediate inputs' cost share was often greater than labour and capital's shares combined. Hence, we expect the productivity of intermediate inputs to play a large role in determining T.F.P.. From Table 2.10 we can see that, like the labour productivity results, the results for intermediate input productivity were mixed. Some Canadian industries had gross output per unit of intermediate input which was substantially greater than the U.S. industries'. However, other Canadian industries and for both aggregating schemes the Canadian to American intermediate input productivity ratios were slightly less than one.

Table 2.9: Ratio Canadian : American Firm Level Output Per Unit of Capital

	1919	1929	1939	1950	1960	1970	1980	1990	Mean
Steel	0.73	0.91	1.13	1.23	1.02	1.19	0.98	1.03	1.04
Cotton		0.71	0.64		0.38	0.68			0.68
Silk		0.04	0.02		0.21	0.23	0.34		0.29
Cement					1.20	1.15	1.08		1.13
Sugar						0.48			0.65
Oil		3.51	1.33	1.79	1.59	1.94	2.89	0.93	1.90
Paper		2.26	5.08	0.97	2.66	2.5	3.09		2.99
Wine				0.86	0.85	1.76			1.24
Spirits						0.52	0.15		0.22
Cdn VAW	0.73	1.90	3.47	1.11	1.90	1.69	2.02	1.00	1.85
US VAW	0.73	1.41	2.29	1.24	1.47	1.66	2.11	0.99	1.57

Table 2.10: Ratio Canadian : American Firm Level Output Per Unit of Intermediate Input

	1919	1929	1939	1950	1960	1970	1980	1990	Mean
Steel	0.67	1.20	1.14	0.78	0.74	0.66	0.59	0.82	0.89
Cotton		1.06	0.86		0.76	0.81			0.79
Silk					1.41	2.32	2.42		1.81
Cement					1.16	0.64	0.81		0.84
Sugar					1.13	1.36			1.20
Oil		0.79	0.89	0.76	0.85	0.86	0.97	0.88	0.84
Paper		1.21	1.37	0.89	0.96	0.60	1.04		0.91
Wine				0.98	1.22	0.71			1.03
Spirits					1.09	0.96	1.48	1.87	1.34
Cdn VAW	0.67	1.16	1.23	0.86	0.94	0.81	1.04	1.01	0.96
US VAW	0.67	1.09	1.18	0.82	0.88	0.74	0.96	0.90	0.91

In general these partial factor productivity results suggest that the Canadian firms in my sample had slightly lower labour and intermediate input productivities and substantially higher capital productivity, on average, relative to the U.S. firms in my sample. Since T.F.P. can be calculated as a weighted average of partial factor productivities[32], I can use these partials to calculate an alternate measure of relative T.F.P. between the Canadian and American industries in my sample. A Tornqvist index of partials, using industry average Canadian and American cost share weights, measures relative T.F.P. if firms' production technology can be characterized by a constant returns to scale translog production function with a Hicks neutral productivity parameter.[33]

$$\frac{A^1}{A^0} = \left(\frac{(Q/L)^1}{(Q/L)^0}\right)^{0.5(sl^1+sl^0)} \left(\frac{(Q/M)^1}{(Q/M)^0}\right)^{0.5(sm^1+sm^0)} \left(\frac{(Q/K)^1}{(Q/K)^0}\right)^{0.5(sk^1+sk^0)} \qquad (2.10)$$

Where:

Q =Physical Output

A =Hicks Neutral Productivity Parameter

L =Labour Input

K =Capital Input

M =Intermediate Input (Materials, Fuel, Services)

$si^t = \frac{w_i^t * i^t}{C^t(\ldots)}$

This exercise can act as a test of my assumption, required to implement the translog cost function method, that firms were price takers in input and output markets. I have compared the industry level translog cost function T.F.P. results (TFP1) to the T.F.P. results generated by calculating a Tornqvist index of partial factor productivities (TFP2). Table 2.11 indicates that the cost function method and weighted average of the partials method generate results which are qualitatively consistent. The mean ratios of Canadian

[32] Allen, 1983, Pg. 97.

[33] See Diewert, 1976, Pg. 116-17.

Table 2.11: Mean Ratio Canadian : American T.F.P. and Partials

	TFP1	Std Dev	Q/L	Q/K	Q/M	TFP2	Std Dev
Steel	0.96	0.15	0.87	1.04	0.89	0.88	0.15
Cotton	0.79	0.14	0.73	0.68	0.79	0.74	0.12
Silk	1.15	0.28	0.45	0.29	1.81	1.16	0.13
Cement	1.04	0.27	1.42	1.13	0.84	1.03	0.18
Sugar	1.21	0.25	0.62	0.65	1.20	1.04	0.32
Oil	0.95	0.16	1.00	1.90	0.84	0.98	0.12
Paper	1.39	0.26	1.26	2.99	0.91	1.11	0.27
Wine	1.53	0.39	1.17	1.24	1.03	1.06	0.24
Spirits	1.15	0.61	0.44	0.22	1.34	0.72	0.08
Cdn VAW	1.14	0.18	0.99	1.85	0.96	1.01	0.19
US VAW	1.04	0.13	0.94	1.57	0.91	0.96	0.14

to American industry level T.F.P. lie on the same side of one in every industry, except for distilleries, for both calculation methods and generally the mean ratios are of very similar magnitudes.[34] This is in spite of the fact that the TFP2 results are based on physical inputs and outputs, rather than input and output prices, and they use only slightly over half of the firm year observations employed in the TFP1 measure.

The T.F.P. ratios for distilleries and wineries appear substantially higher for the translog cost function method than for the Tornqvist index of partial factor productivities. Given the fact that the Canadian firms in my sample representing these two industries likely had more market power than their American counterparts and there may have been significant unmeasured quality differences between the Canadian and American industries' inputs and outputs this result may not be surprising. Because these two industries are tiny relative to some of the others in the sample, any bias in their T.F.P. results will not substantially alter the general conclusions regarding the T.F.P. performance of my entire sample. [35]

[34]The simple correlation coefficient between the two T.F.P. series lies between 0.771 and 0.780 (depending on aggregation technique).

[35]An appendix to this chapter contains a graphical presentation of these partial and total factor productivity results.

2.7 Conclusion

The widely accepted view in the empirical literature on Canadian manufacturers' performance is that Canadian firms have traditionally been substantially less efficient, in a technical sense, than American firms. This belief is based primarily on evidence which indicates that Canadian manufacturing firms have been too small, too diversified and operate with a lower level of labour productivity than their U.S. counterparts. Existing evidence which has been presented in the literature suggests that if one measures technical efficiency by comparing T.F.P. levels, rather than labour productivity levels, then the evidence of Canadian inefficiency is not strong.

Using data compiled from a sample of thirty-nine Canadian and thirty-nine American manufacturing firms, which span most of the twentieth century, I have calculated Canadian relative to American T.F.P. ratios for nine industries. I can find little evidence of Canadian technical inefficiency. It appears that after 1925 the Canadian firms in my sample were at least as technically efficient as the U.S. firms, on average, and in some industries they tended to be substantially more efficient. Only Canadian cotton textile mills suffered from consistently lower T.F.P. than the U.S. firms in the same industry.

My T.F.P. results are consistent with the fragmentary T.F.P. figures available in the literature. Evidence on value added per worker indicates that both the industries included in my sample and the firms within these industries were fairly typical, in terms of labour productivity performance. In particular, the Canadian industries covered by my sample of firms had value added per worker figures which were consistently and often significantly below those for the U.S. industries covered.

This chapter also contains gross output partial factor productivity figures for labour, capital and intermediate inputs. These results help to reconcile the T.F.P. and labour productivity evidence. On average, the Canadian firms had slightly lower labour and intermediate input productivities, but these were often offset by capital productivity which tended to be higher than the U.S. firms' capital productivity.

In the next chapter I use counterfactual experiments to disaggregate the variation between the Canadian and American firms' partial factor productivities into variation due to input price differences, scale differences, biases in the technology employed and neutral technological differences. These results not only identify the sources of the cross country variation in partials, but they also provide evidence of flexibility in the employment of inputs and adaptive use of technology by the Canadian firms in my sample.

Data Appendix

Some of the data sources are common to all firms in all industries. The income paid to capital figures used to calculate w_K for each firm are net sales less cost of sales and selling and administrative expenses. Net sales are gross sales less all sales and excise taxes. The cost of sales includes all labour costs, including pensions and payroll taxes, all materials, fuel and some service costs. Selling and administrative expenses include the remaining service costs, including the value of executive remuneration's. The income paid to capital figure, therefore, represents the entire cost of capital to the firm, including retained earnings, dividend payments, interest on debt, depreciation and all corporate income and profit taxes.

Capital stocks are calculated by taking the initial value of the firms' gross fixed assets and expressing this figure in 1910 dollars (so all firms' capital stocks are in consistent units), then annually adding net investment, in 1910 dollars, to this seed value. Gross fixed assets include all land, buildings and equipment, at historic cost. Net investment is measured as gross investment less depreciation. The annual change in gross fixed assets plus retired capital is used as a measure of gross investment. The calculation of depreciation is slightly more involved. It is assumed that the initial seed value for each firm is dominated by land and plant, which depreciates slowly. This seed value is assumed to have a 100 year service life and straight line depreciation. Additions to the capital stock (ie. gross investment) are assumed to be dominated by machinery and equipment, which depreciates at a rapid rate. Gross investment is assumed to have a 20 year service life and straight line depreciation. After the service life is complete the capital is assumed to have been retired from the gross fixed assets of the firm. Sensitivity analysis indicates that, as long as service lives are assumed to be the same in the Canadian and American firms, changes in the assumed lives of capital have little impact on the relative T.F.P. results discussed in this chapter.

To deflate initial gross fixed assets and net investment a price index for capital was used. For the Canadian firms this index was industry specific after 1926. The Canadian indexes come from *Fixed Capital Flows and Stocks* (StatsCan catalogue No. 13-568) and the earlier publication, *Fixed Capital Flows and Stocks: Methodology.* For the U.S. a more general price index for capital equipment is used for all industries. This U.S. price index comes from *The Statistical History of the U.S.* (Series E7, E84 and E86) and *U.S. Statistical Abstracts* (various years). The U.S. nominal surplus and nominal prices were converted into Canadian dollars using the official exchange rate from *Canadian Historical Statistics* (Series J562) and *The Bank of Canada Review* (various years). U.S. capital stocks were converted into Canadian dollars using the OECD gross fixed capital formation implicit purchasing power parity measure between Canada and the U.S. for 1970. This can be found in the OECD Statistics Directorate's *National Accounts: Main Aggregates, Vol. 1 (1996)* (Pages 30 and 154).

The prices used were industry specific and their construction is described in point form below. Where nominal prices had to be weighted to match the price indexes used average Canadian shares in revenue or materials cost were used for both Canadian and American prices. Therefore, all purchasing power parity measures use Canadian average weights. The shares in the cost function methodology used in this paper were derived using both aggregate and firm level data. From aggregate industry data sources shares for materials and fuel cost and labour cost were calculated. Where available the sum of surplus over the sum of net sales was then calculated for all the firms in each industry. These figures represented sk^t for the firms in the sample. The shares for materials and fuel cost and labour cost were then used with the firm specific sk^t figures to calculate sm^t and sl^t. Under a constant returns to scale assumption we can write; $sk^t + sm^t + sl^t = 1$. A ten year average was then used for each of these shares. The method for calculating shares was the same for all industries in both Canada and the U.S..

To aggregate up to the industry level each firms' growth rate is weighted by their share of the surplus generated by all firms in the sample, in each industry. Surplus is used to weight firms because it is available for all firms in all years. To aggregate the industries up to the manufacturing sector level the value added generated by all of the industries in the sample is gathered from aggregate sources listed below, then divided by the value added generated by each individual industry to get industry shares in value added. The value added weights are then multiplied by the industry T.F.P. growth rates and relative levels to get weighted average T.F.P. growth rates and relative T.F.P. levels for all nine of the industries covered by the sample. Value added weights are calculated using Canadian and U.S. data. The median industries' relative T.F.P. levels have also been calculated and these are offered as an alternative to the value added aggregation schemes.

In the interests of brevity the description of price data and data used to construct each industries' share parameters and weights are listed in point form. Any further questions regarding data sources may be referred to the author.

- Unless otherwise stated all U.S. aggregate data for the calculation of shares and prices comes from *U.S. Census of Manufacturers: Industry Reports.*

- Unless otherwise stated all U.S. hourly wage rates come from *Employment, Earnings and Hours* and *U.S. Statistical History*, (USSH), series D802.

- Another important source of data for the American industries was *U.S. Statistical Abstracts*, (USSA), for various years.

- Unless otherwise stated all Canadian wage rates come from StatsCan catalogue No. 72-002 (continued 72-202) and *Canadian Historical Statistics,* 2nd Ed., (CHS), Chapter E.

- Unless otherwise stated all Canadian price indexes and nominal prices come from *Prices and Price Indexes* (continued 62-002 and 62-011).

- Another important source of data for the Canadian industries was *The Canada Year Book*, (CYB), for various years.

- Steel Mills

- Cdn Aggregate Data-CHS (R343-59), 41-D-40, 41-250.

- Cdn Output Price Index-Rolling Mill Products.

- Cdn Nominal Output Price-Heavy Structural Shapes, Steel Rails and Wire Rod/Rebar.

- Cdn Materials Price Index and Nominal Price-Iron Ore, Steel Scrap and Coke (American Iron and Steel Institute; *Annual Statistical Report*).

- U.S. Output Price Index and Nominal Price-Heavy Structural Shapes, Steel Rails and Wire Rod/Rebar (American Iron and Steel Institute; *Annual Statistical Report*).

- U.S. Materials Price Index and Nominal Price-Iron Ore, Steel Scrap and Coke (American Iron and Steel Institute; *Annual Statistical Report* and U.S. Bureau of Mines; *Materials Survey*).

* Cotton Textile Mills

  - Cdn Aggregate Data-CHS (R243-45), 34-205.

  - Cdn Output Price Index-Cotton Mill Products.

  - Cdn Nominal Output Price-Cotton Sheeting, Cotton Gingham and Cotton Thread.

  - Cdn Materials Price Index and Nominal Price-Raw Cotton.

  - U.S. Output Price Index-Cotton Goods (Bureau of Labor Statistics; *Handbook of Labor Statistics*).

  - U.S. Nominal Output Price-Cotton Sheeting, Cotton Gingham and Cotton Thread (USSA).

  - U.S. Materials Price Index and Nominal Price-Raw Cotton (USSA and USSH series E126).

* Silk and Synthetic Textile Mills

- Cdn Aggregate Data-CHS (R243-45), 34-208.

- Cdn Output Price Index-Silk Fabric and Synthetic Fibre Fabric.

- Cdn Nominal Output Price-Flat Silk Crepe, Rayon Fabric.

- Cdn Materials Price Index and Nominal Price-Raw Silk and Synthetic Fibres and Tow.

- U.S. Output Price Index-Silk Fabric and Man Made Fibres Fabric (Bureau of Labor Statistics; *Handbook of Labor Statistics*).

- U.S. Nominal Output Price-Narrow Silk Fabric and Nylon Fabric (USSA).

- U.S. Materials Price Index and Nominal Price-Raw Silk and Man Made Fibres (USSA).

• Cement Manufacturers

  - Cdn Aggregate Data-44-204.

  - Cdn Output Price Index and Nominal Price-Portland Cement.

  - Cdn Materials Price Index and Nominal Price-Limestone and Fuel Oil No. 2 (26-217 and 26-225).

  - U.S. Output Price Index and Nominal Price-Portland Cement (Bureau of Mines; *Minerals Year Book*).

  - U.S. Materials Price Index and Nominal Price-Limestone and Fuel Oil No. 2 (USSA and Bureau of Mines; *Minerals Year Book*).

• Sugar Refineries

  - Cdn Aggregate Data-32-222.

  - Cdn Output Price Index and Nominal Price-Granulated White Sugar.

- Cdn Materials Price Index and Nominal Price-Raw Sugar in N.Y. in Cdn Dollars.

- U.S. Output Price Index and Nominal Price-Granulated Sugar (USSA).

- U.S. Materials Price Index and Nominal Price-Raw Sugar in N.Y. (USSA and International Sugar Council; *Sugar Year Book*).

- Oil Refineries

  - Cdn Aggregate Data-45-205.

  - Cdn Output Price Index and Nominal Price-Gasoline in Toronto and Fuel Oil No. 2.

  - Cdn Materials Price Index and Nominal Price-Domestic Crude Oil (CHS; series N180-81, CYB, *Energy Statistics Handbook*).

  - U.S. Output Price Index and Nominal Price-Gasoline and Fuel Oil No. 2 (USSA).

  - U.S. Materials Price Index and Nominal Price-Crude Oil (Bureau of Mines; *Minerals Year Book*).

- Paper Mills

  - Cdn Aggregate Data-36-204.

  - Cdn Output Price Index and Nominal Price-Newsprint, Kraft Paper and Fine Paper (36-204).

  - Cdn Materials Price Index and Nominal Price-Paper Grade Sulphite Woodpulp (36-204).

  - U.S. Output Price Index-Paper/All Grades (USSH series L209).

  - U.S. Nominal Output Price-Newsprint, Wrapping Paper and Fine Book Paper (USSA and *U.S. Census of Manufacturers; Industry Reports*).

- U.S. Materials Price Index and Nominal Price-Woodpulp (USSA and USSH series L208).

- Wineries
  - Cdn Aggregate Data-32-207.
  - Cdn Output Price Index-Winery Products.
  - Cdn Nominal Output Price-Export Price of Canadian Wine (CYB).
  - Cdn Materials Price Index and Nominal Price-Grapes (CANSIM No. 1399 and No. 5598) and Granulated White Sugar.
  - U.S. Output Price Index-Winery Products (Bureau of Labour Statistics; *Producer Price Indexes*).
  - U.S. Nominal Output Price-Import Price; Wines (USSA).
  - U.S. Materials Price Index and Nominal Price-Grapes (USSA and Bureau of Labor Statistics; *Producer Price Indexes*) and Granulated Sugar (USSA).

- Distilleries
  - Cdn Aggregate Data-32-206.
  - Cdn Output Price Index-Whisky, Distillery Products.
  - Cdn Nominal Output Price-Whisky (CYB).
  - Cdn Materials Price Index and Nominal Price-Mixed Grains (CANSIM No. 3550).
  - U.S. Output Price Index-Distillery Products (USSA).
  - U.S. Nominal Output Price-Whiskey (USSA).

- U.S. Materials Price Index and Nominal Price-Grains (USSA and Bureau of Labor Statistics; *Producer Price Indexes*).

Graphical Appendix

Figure 2.1: TFP Levels-Steel Mills

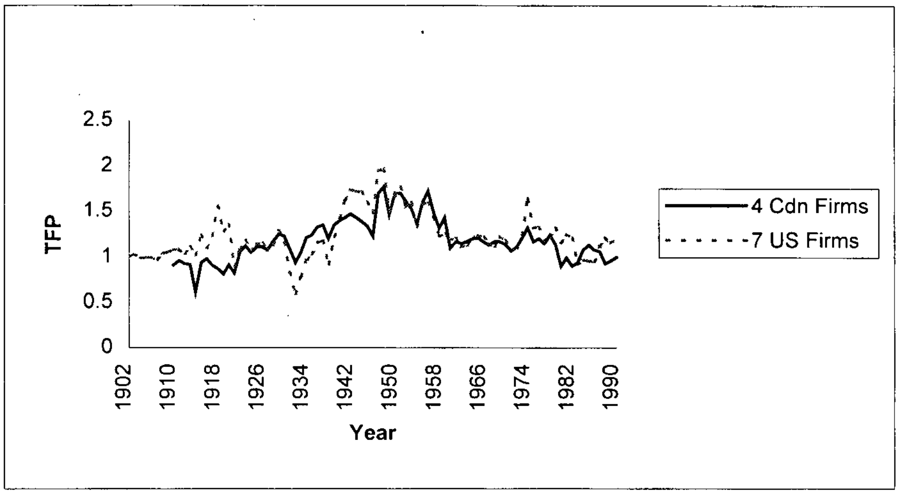


Figure 2.2: Relative Productivity-Steel Mills

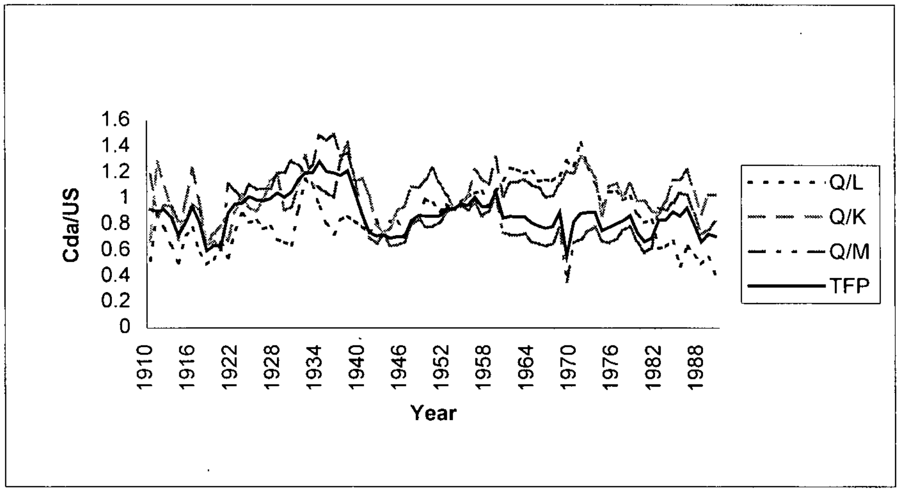


Figure 2.3: TFP Levels-Cotton Mills

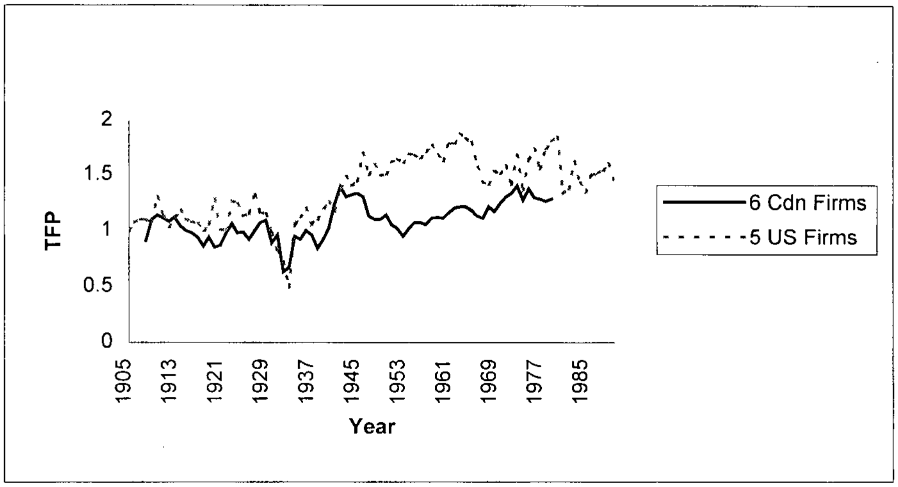


Figure 2.4: Relative Productivity-Cotton Mills

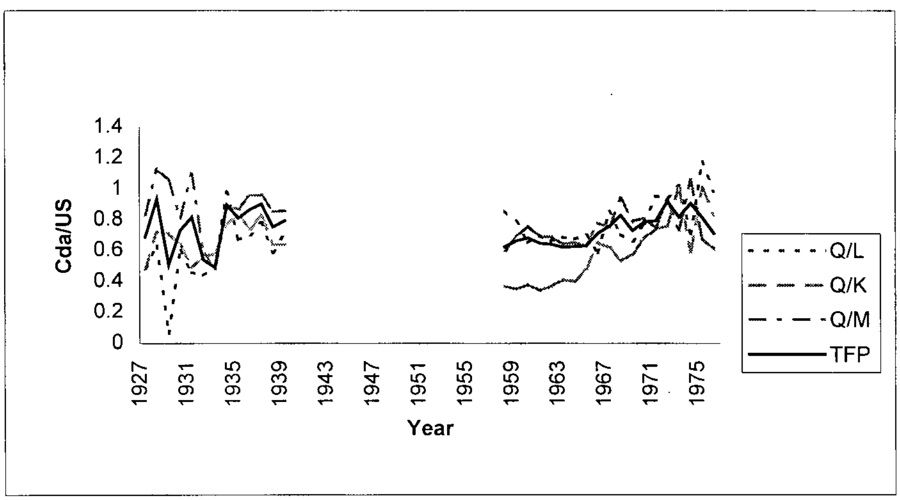


Figure 2.5: TFP Levels-Silk and Synthetic Fibre Mills

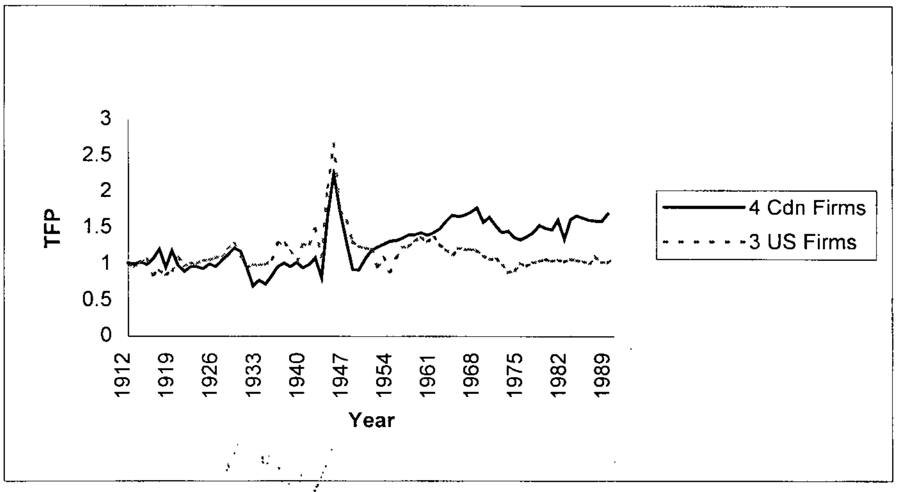


Figure 2.6: Relative Productivity-Silk and Synthetic Fibre Mills

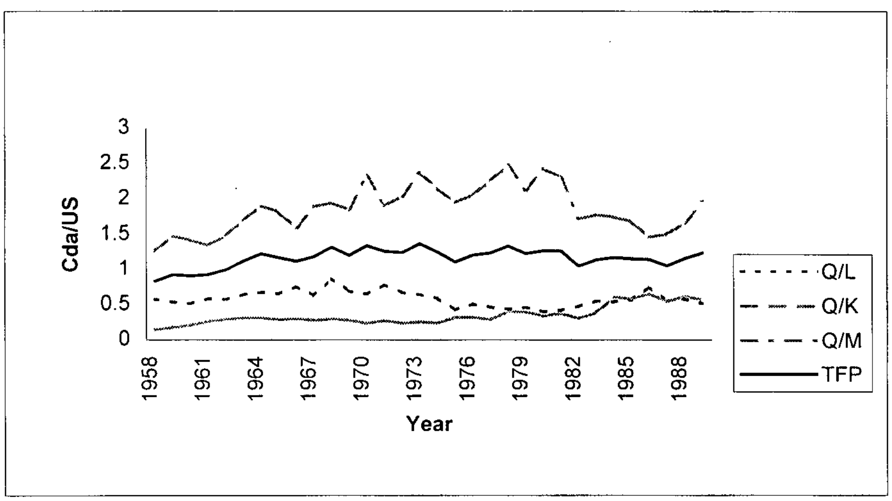


Figure 2.7: TFP Levels-Cement Manufacturers

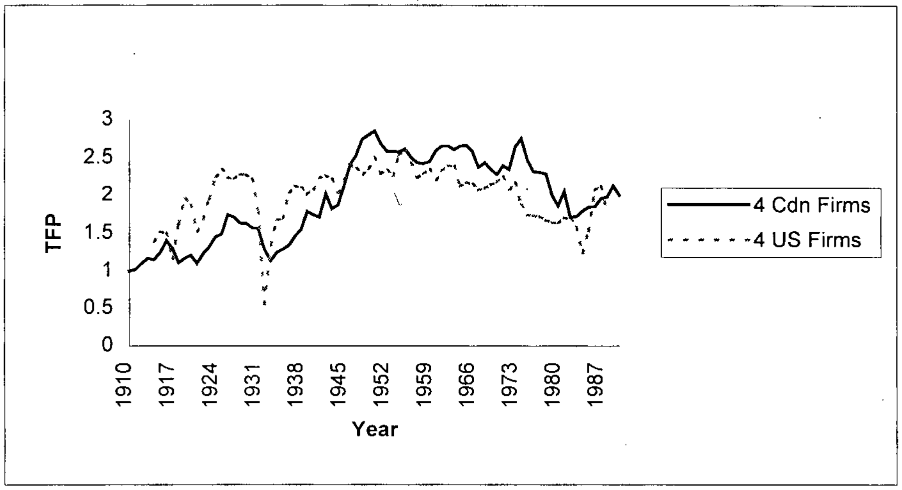


Figure 2.8: Relative Productivity-Cement Manufacturers

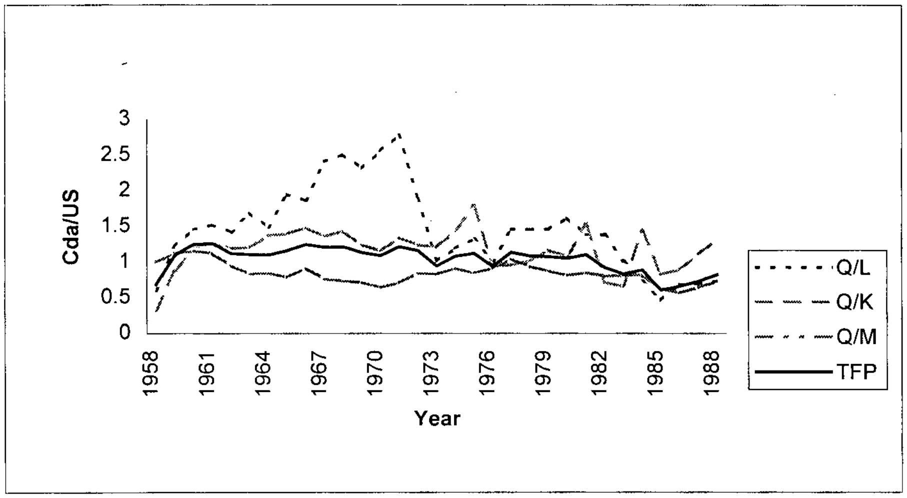


Figure 2.9: TFP Levels-Sugar Refineries

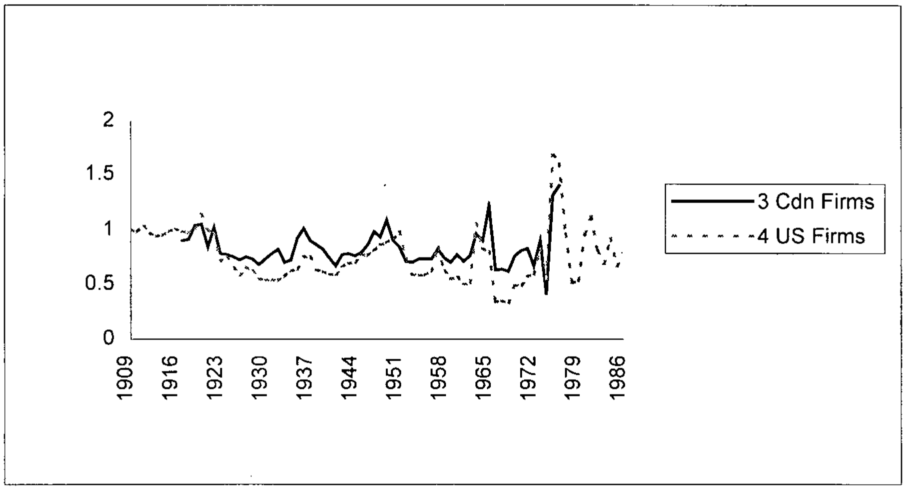


Figure 2.10: Relative Productivity-Sugar Refineries

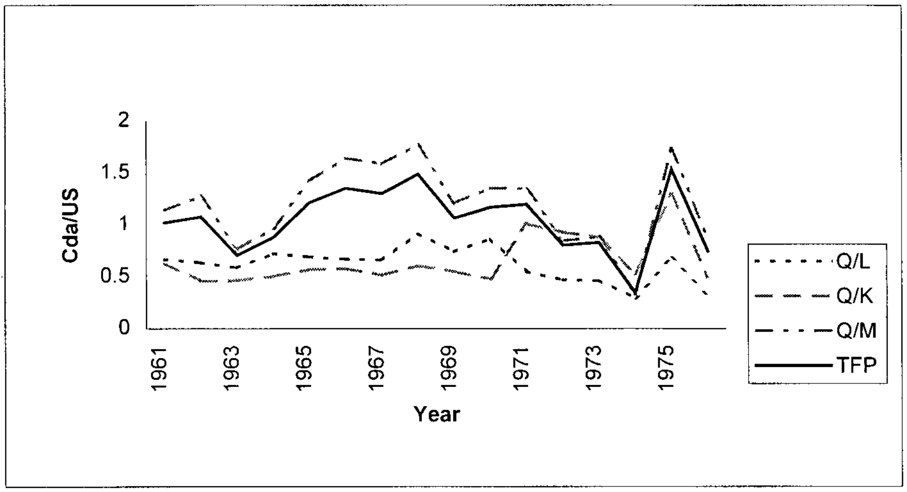


Figure 2.11: TFP Levels-Oil Refineries

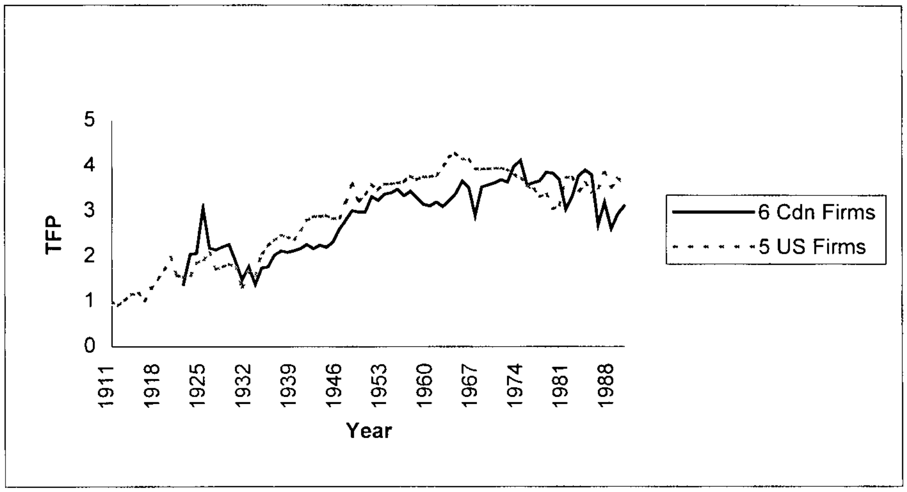


Figure 2.12: Relative Productivity-Oil Refineries

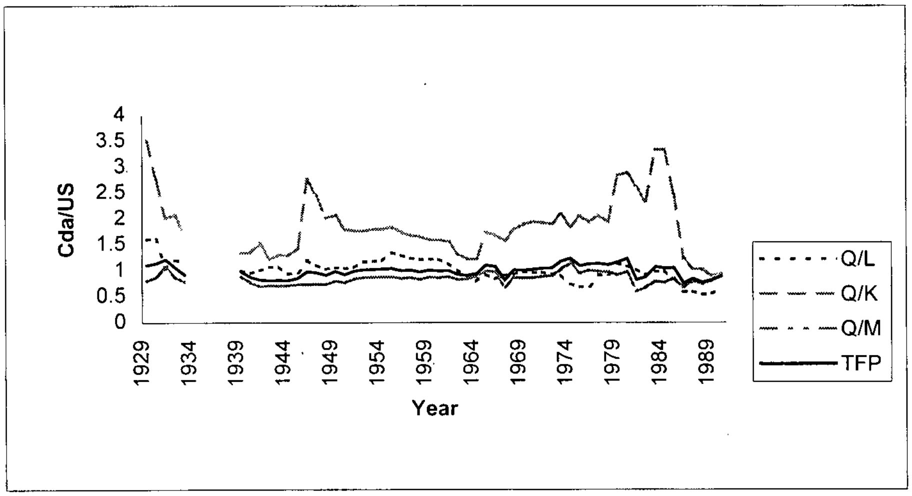


Figure 2.13: TFP Levels-Paper Mills

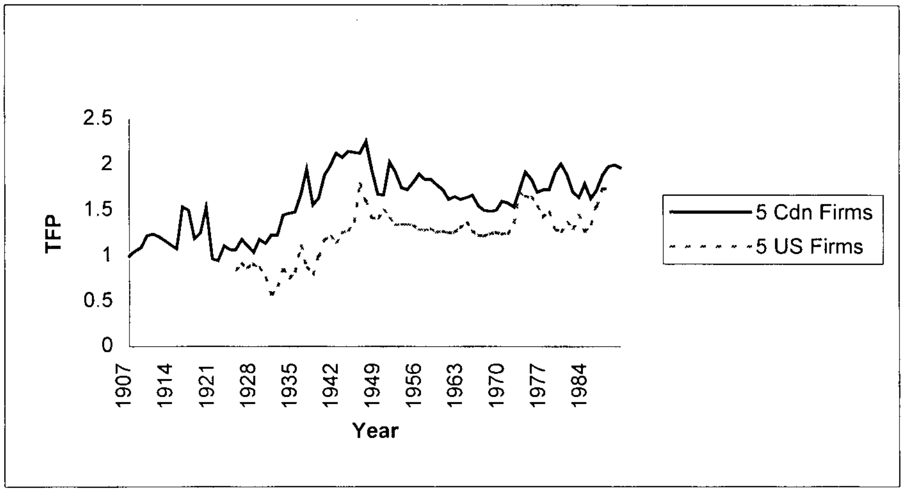


Figure 2.14: Relative Productivity-Paper Mills

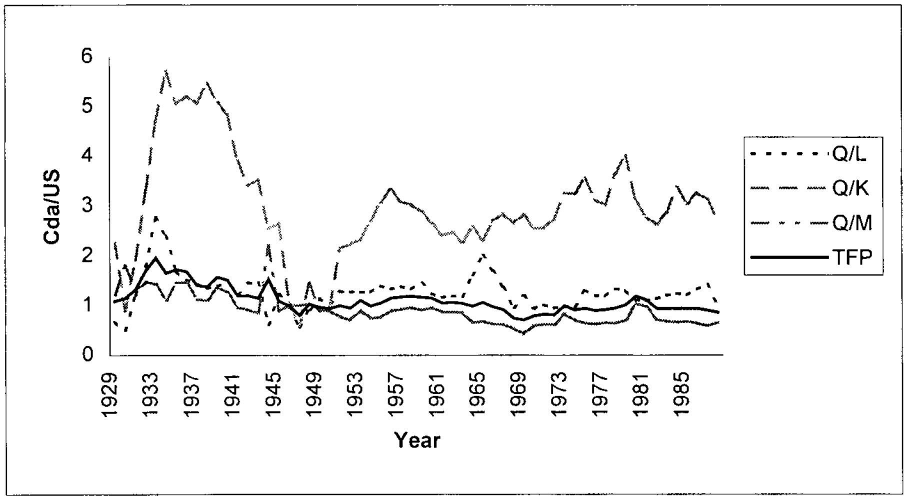


Figure 2.15: TFP Levels-Wineries

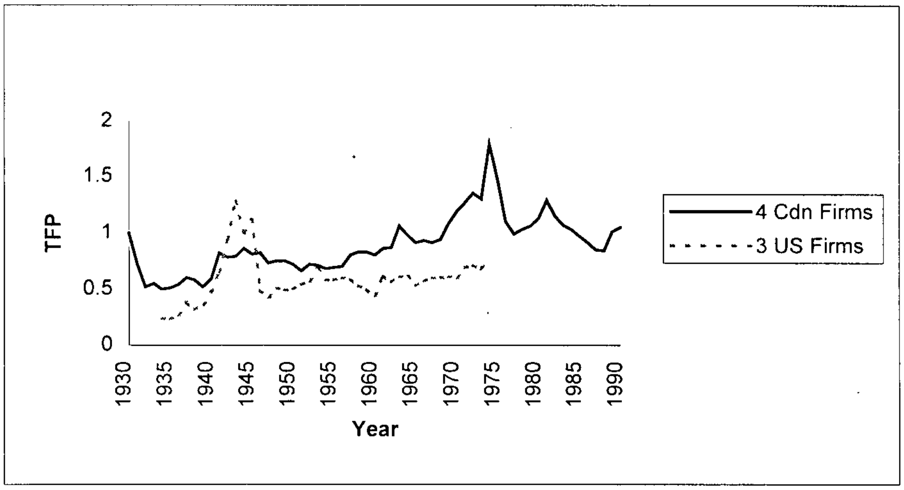


Figure 2.16: Relative Productivity-Wineries

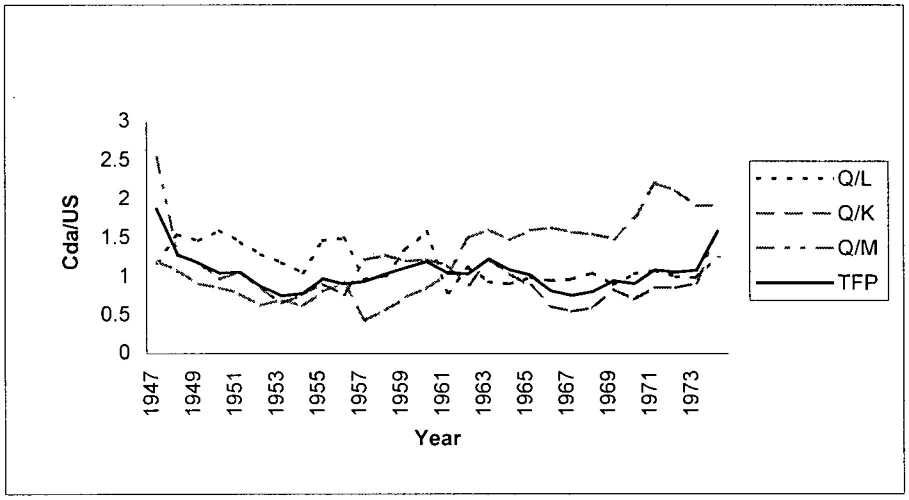


Figure 2.17: TFP Levels-Distilleries

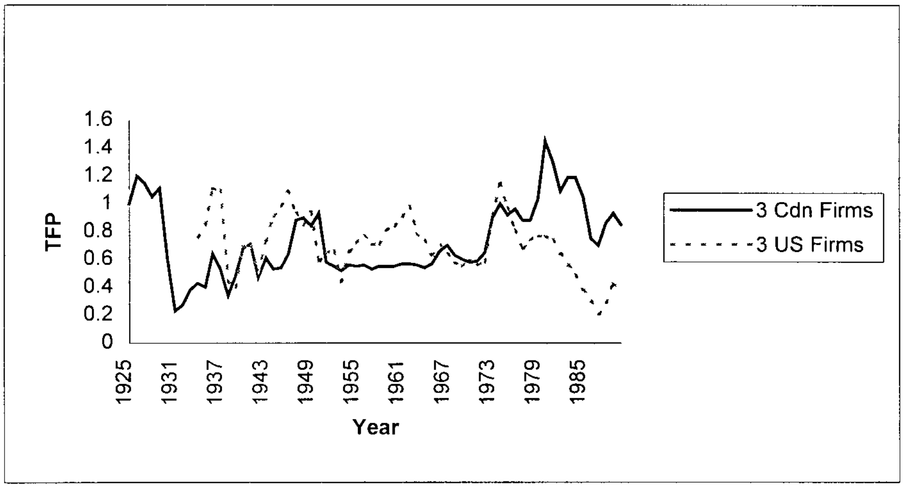
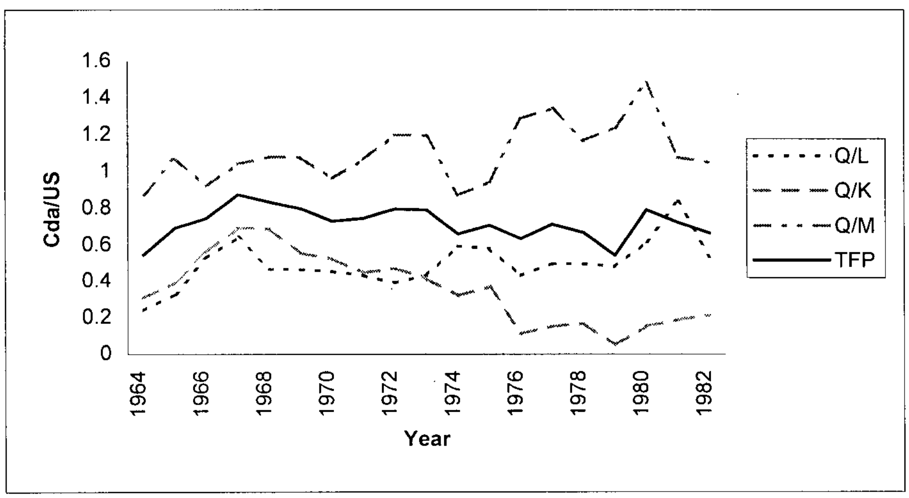


Figure 2.18: Relative Productivity-Distilleries



Chapter 3
Disaggregation of the Cross Country Variation In Partial Factor Productivities

In Chapter 2 I compared the technical efficiency of the entire production processes of the thirty-nine Canadian and thirty-nine American firms in my sample by calculating relative T.F.P. ratios. I found that, on average, there was virtually no difference between the Canadian and the American firms' technical efficiency after 1925. This evidence does not support claims of Canadian technical inefficiency made in the literature on scale, labour productivity and in the debate between Economic Nationalists and Continentalists. I also measured relative partial factor productivities in Chapter 2. The results indicate that the Canadian firms' T.F.P. levels were roughly equal to the American firms' T.F.P. levels because, while the Canadian firms' labour and intermediate input productivities were slightly lower than the Americans', their capital productivity tended to be higher. On average, these variations in the firms' partials offset one another such that overall T.F.P. was approximately equal.

In this Chapter I seek to explain the cross country variation in the partials presented in Chapter 2. Using data from my sample of thirty-nine Canadian and thirty-nine American manufacturing firms I have estimated the parameters of systems of input demand functions derived from generalized Leontief cost functions for the nine Canadian and nine American industries represented. Using these parameter estimates I have calculated predicted values for Canadian and American labour, capital and intermediate input productivities for each industry. The cross country differences in these predicted partial factor productivities have then been attributed to cross country differences in input prices, scale, neutral technology and differences due to domestically unique biases in technology. In other words, the variation in partial factor productivities due to different input prices, different firm sizes, different positions of the industries' cost functions and different shapes of the industries' cost functions have been identified. The explanations for the cross country variation in partials suggest that the Canadian manufacturers in my sample who experienced disadvantages due to scale and neutral technological differences overcame these problems by employing input combinations and technology which was unique and consistent with cost minimizing responses to domestic input market conditions.

On average, Canadian labour and intermediate input productivities have been lower than American, while Canadian capital productivity has been higher for the firms in my sample. These partial factor productivity differences reflect lower Canadian labour and intermediate input prices and higher capital costs. The input price differences have resulted in Canadian firms choosing different points on their isoquants and adopting, developing and adapting their technology to reflect the uniquely Canadian input market conditions. The total effect is such that the Canadian firms used the inputs which were relatively inexpensive liberally and the inputs which were relatively more expensive conservatively. These results indicate that the Canadian manufacturing firms in my sample were responding to domestic input market conditions in at least two ways. The Canadian firms were choosing input combinations which were consistent with cost minimizing behaviour and, as Peter Wylie (1989) has suggested was true for the 1900-1929 period, they were adopting, developing and adapting their technology in a manner consistent with theories of induced innovation throughout most of the twentieth century.[1] This behaviour is inconsistent with much of the anecdotal evidence quoted in the literature on the performance of Canadian entrepreneurs in the manufacturing sector.

In Section 2 I have briefly summarized some of the literature on Canadian entrepreneurial performance. Section 3 describes the derivation of the regression equations and the estimation techniques I have used. In the fourth section I briefly summarize the characteristics of the Canadian and American industries' production technologies implied by my econometric

[1]Theories of induced innovation suggest that firms will seek to adopt and adapt technology such that they can save on relatively expensive inputs and use relatively cheaper inputs. See Hicks, 1968, Pg. 124, Habakkuk, 1962, Pg. 43 or Binswanger, 1974, Pg. 957.

results. The fifth section includes an explanation of how I identified the components of the partial factor productivity differences between the Canadian and American manufacturers in my sample and the results from this disaggregation exercise are discussed. In the final section I suggest some conclusions which follow from the evidence presented in this chapter and I suggest some areas which remain to be studied. The appendix presents the econometric results in detail.

3.2 Entrepreneurial Performance: The Literature

> "...Canadian capitalists have never been a wholly reliable lot ... (they) do leave something to be desired."[2]

> "Canada provides a dramatic illustration of the stultification of an indigenous entrepreneurial class..."[3]

> "Reliance on borrowed foreign technology,..., does not by itself preclude the evolution of a more independent technological base... What is required is a commitment from industry to assimilate, adapt, and innovate on the base of the technology it initially borrowed... We discover no zeal for this endeavor on the part of the great majority of Canadian manufacturers."[4]

Canadian Economic Nationalists and Continentalists have accepted the view that domestic manufacturers have traditionally been technically inefficient and this has lowered Canadian income per capita. Canada's poor labour productivity performance relative to the U.S. is the most common evidence of technical inefficiency cited. The quotes which open this section indicate that in addition to being technically inefficient many Nationalist writers[5] also felt that Canada's manufacturers have been unresponsive to domestic

[2] Watkins, in Forward to Levitt, 1970, Pg. x.
[3] Levitt, 1970, Pg. 58.
[4] Williams, 1994, Pg. 119.
[5] See Wallace Clement, 1977, Pg. 293 in addition to the sources in footnotes 2, 3 and 4.

input market conditions and unwilling or unable to adapt their technology to the economic environments they face. These are commonly cited symptoms of entrepreneurial failure.[6]

The ability of Canadian manufacturers to survive in the face of international competition, if they were forced to do so with the removal of their tariff protection, was one of the key points of contention within the Nationalist-Continentalist debate. However, it is not only those arguing about the costs and benefits of free trade who have argued that poor performance amongst Canadian entrepreneurs is common.

Business historians often identify Canadian entrepreneurs' perceived failings. Michael Bliss (1987; Pg. 565), while discussing the failure of Massey-Harris-Ferguson, states that, "... the Massey failure reflected bad management practices writ large. Other gigantic Canadian corporations suffered from similar, if milder illnesses." Arguing that the Canadian business class was generally myopic and slow to react to changes in domestic and international markets during the 1920s and 1930s Bliss (1987: Pg. 385) claims that, "... prudent businessmen built enough reserves during good years to be able to hold on through depression. Many were not prudent..." To illustrate his point he uses examples from Canadian sugar refineries, meat packers and forest products producers. We can also find similar failure themes in work by Marchildon (1996; Pg. 152) and even the classic Canadian firm history on the Steel Company of Canada by Kilbourn (1960; Pg. 131). The vast majority of evidence indicating Canadian entrepreneurial failure in both business histories and Nationalist-Continentalist writings is anecdotal. This anecdotal evidence often chronicles examples of slow adoption of new techniques, inaction in the face of changes in input market conditions and generally conservative business practices.[7]

In response to the anecdotal evidence indicating Canadian entrepreneurial failure there are a number of studies which indicate that slow adoption of new technology or inactivity in the face of changing economic environments may be economically rational behaviour.

[6]The classic entrepreneurial failure references deal with the performance of British entrepreneurs during the last half of the nineteenth century. For example, see Habakkuk, 1962, Pg. 215-16 or Aldcroft, 1964, Pg. 114, or Elbaum and Lazonick, 1986, Ch. 1.

[7]See Williams, 1994, Pg. 25, for a summary of the Canadian entrepreneurial failure hypothesis and the existing evidence.

Much of this literature is based on the work of Paul David (1975) in which he argues that the adoption of new techniques or technology is dependent on the existence of certain conditions in firms input and output markets. In the absence of those conditions inactivity or slow adoption may be optimal. Some Canadian examples illustrating this point can be found in the slow mechanization of Salmon canning on the west coast[8], the rate of adoption of mechanized reaping in Ontario[9], or the continued construction of wooden hulled ships in Canada in the face of increasing competition from metal hulled steam ships built in Britain.[10] These Canadian examples of rational slow adoption of new techniques suggest that the anecdotal evidence most often presented in support of Canadian entrepreneurial weakness and inflexibility may be misleading.

Continentalists have never subscribed to the view that Canadian entrepreneurs have been inherently weak and incompetent. While arguing in favour of freer trade between Canada and the U.S. Wonnacott and Wonnacott (1982; Pg. 422-24) state that Canadians need not fear a truncated management structure or a loss of control over economic variables, at a micro or macro level. Saunders (1982) summarizes the Continentalist's claims that Canadian producers have the ability to compete in a world free of government protection. Any evidence of entrepreneurial failure, the Continentalist writers claimed, was due to a lack of competition in the Canadian economic environment. Contintentalists felt that the tariff protection enjoyed by Canadian manufacturers allowed some examples of incompetence to go unpunished by competitive market forces.

Empirical evidence of Canadian firms' flexibility, responsiveness and willingness to adopt and adapt new technology, even though they received effective tariff protection, is accumulating. In a 1989 article Wylie measured the ability of Canadian manufacturers to adapt imported technology to specifically Canadian input prices by looking at changes in input shares in response to changing input price ratios in Canada and the U.S. from 1900-29. Wylie (1989; Pg. 589) writes, "... in early twentieth century Canadian manufacturing

[8] Newell, 1988.
[9] Pomfret, 1976.
[10] Harley, 1973.

there was a measurable element of indigenous technological adaptation... which confirms the Continentalist view..." This suggests that Canadian entrepreneurs were successfully adapting imported technology to domestic market conditions as early as 1929. Evidence of the type Wylie presented indicates the willingness of Canadian manufacturers to adjust to new economic environments.

3.3 Methodology

The T.F.P. results discussed in Chapter 2 were derived using data drawn from a sample of thirty-nine Canadian and thirty-nine American manufacturing firms. In this chapter the econometric results are based on data drawn from the same sample of firms. These firms represent nine industries; steel mills (four Canadian and seven American firms), cotton textile mills (six Canadian and five American firms), silk and synthetic fibre textile mills (four Canadian and three American firms), cement manufacturers (four Canadian and four American firms), sugar refineries (three Canadian and four American firms), paper mills (five Canadian and five American firms), oil refineries (six Canadian and five American firms), wineries (four Canadian and three American firms) and distilleries (three Canadian and three American firms). Firms were included in the sample if data was available in corporate annual reports or annual industrial manuals for twenty years or more, if the firms generated at least 85% of their revenue from goods produced in either Canada or the U.S., if they generated at least 85% of their revenue from the sale of products which are considered the output of the industry in which it has been grouped and if their outputs and choices of inputs could be closely matched to other firms within their industry in both Canada and the U.S.. Industry coverage varies widely between industries, years and countries. For example, both Canadian and American coverage of the steel industry is virtually complete, while Canadian and American distilleries cover only 20 - 25% of the total value added generated in the industry. The unbalanced panel covers the years 1907-1990 for the Canadian firms and 1902-1990 for the U.S. firms. Firm level data has been used because the Canadian and American manufacturers could be closely matched and long time series of annual data which was comparable between Canada and the U.S. and across time was available.[11]

In Chapter 2 partial factor productivity ratios were calculated for the Canadian and American firms in my sample. In an effort to determine why these partials varied between countries and industries and, if input price differences are responsible, to determine how input prices influenced the partials, I have estimated input demand functions derived from generalized Leontief cost functions for the eighteen Canadian and American industries in my sample.

The input demand functions derived from the generalized Leontief cost function specification are linear in input prices, the dependent variables from these functions describe inverse partial factor productivities and there is a substantial body of empirical literature which employs the generalized Leontief specification. The generalized Leontief functional form is flexible in the sense that it is a second order approximation of any arbitrary cost function.[12]

The translog cost function specification employed in the derivation of the T.F.P. results presented in Chapter 2 is also flexible, yields input demand functions which are linear in input prices, the dependent variables from these functions can be easily transformed into partial factor productivities by multiplying them by a ratio of output to input prices and there is an extensive related empirical literature which relies on the translog specification. I have chosen to employ the generalized Leontief specification in this chapter for three reasons. First, the generalized Leontief specification has been employed by Cain and Paterson (1986) to address, in part, exactly the issues I seek to address in this chapter. These issues include, but are not restricted to, the existence and impact of scale effects and biased technical change on manufacturing industries partial and total factor productivities. Second, the use of inverse partial factor productivities as dependent variables and relative input prices, output levels and a time trend as independent variables implies that,

[11]Further details on firm selection criteria and sample characteristics are available in Chapter 2, Section 3.

[12]For a detailed discussion of the properties of the generalized Leontief cost function see Diewert, 1971.

without additional transformation, the econometric results provide me with a clear and direct measure of the impact of input prices, scale and biased technical change on partial and total factor productivities. Finally, the fact that the results presented in this chapter are consistent with and supportive of the T.F.P. results in Chapter 2, even though a different methodology has been employed, different data used and a different underlying cost function specification assumed, indicates the robustness of both sets of results to altering the methodology, data and specification assumptions.

Diewert (1971) proposed a constant returns to scale generalized Leontief cost function. With three inputs, labour (L), capital (K) and intermediate input (M) and a productivity parameter (A) this specification can be written:

$$C = Q\left(\sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}(w_i w_j)^{0.5} + A\sum_{i=1}^{n}\alpha_i w_i\right) \tag{3.1}$$
$$i, j = L, K, M$$
$$d_{ij} = d_{ji}$$

Where:

C = Total Cost

Q = Physical Quantity of Output

w_i = Exogenous Price of Input i

Diewert and Wales (1987) sought to relax the assumptions associated with the Diewert (1971) specification. They estimated the parameters and discussed the characteristics of a generalized Leontief cost function with the linear homogeneity in output constraint relaxed. This general specification takes the form:

$$\begin{aligned} C \;=\; & Q\sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}(w_i w_j)^{0.5} + AQ\sum_{i=1}^{n}\alpha_i w_i + Q^2\sum_{i=1}^{n}\beta_i w_i \\ & + \sum_{i=1}^{n} d_i w_i + A\sum_{i=1}^{n}\gamma_i w_i + A^2 Q\sum_{i=1}^{n}\delta_i w_i \end{aligned} \tag{3.2}$$

$$i, j = L, K, M$$
$$d_{ij} = d_{ji}$$

I have chosen to employ a more general modified version of the Diewert (1971) specification described by (3.1) which does not require the estimation of all the parameters included in the Diewert and Wales (1987) specification described by (3.2). Parks (1971) first suggested a non-homothetic in output version of the generalized Leontief cost function. Parks' adaptation allows for the estimation of scale effects, in addition to bias technical change effects and the impact of relative input prices on inverse partial factor productivities. This form facilitates the estimation of all the influences I am interested in, without the need to estimate the additional parameters proposed by Diewert and Wales (1987). The Parks adaptation of the Diewert constant returns to scale Leontief cost function has been employed in empirical work which addresses issues closely related to those I wish to investigate. Woodland (1975) used aggregate data on Canadian industrial sectors for the years 1946-1969 to estimate input demand functions derived from the Parks specification of the generalized Leontief cost function. Cain and Paterson (1986) used aggregate data from the *U.S. Census of Manufacturing* for the years 1850-1919 to estimate input demand functions derived from the Parks' specification. The Parks specification takes the form:

$$C = Q\left(\sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}(w_i w_j)^{0.5} + A\sum_{i=1}^{n}\alpha_i w_i + Q\sum_{i=1}^{n}\beta_i w_i\right) \tag{3.3}$$
$$i, j = L, K, M$$
$$d_{ij} = d_{ji}$$

Other empirical work using generalized Leontief cost functions has emphasized the need to include scale effects in input demand functions and has argued that there is evidence that in some specific situations the Diewert, Diewert and Wales and Parks specifications should be modified to reflect the existence of short run fixed factors in manufacturers' production technologies. Denny, Fuss and Waverman (1981) used data from American manufacturing industries for the years 1949-1971 and Canadian manufacturing industries for the years 1961-1975 to estimate the parameters of input demand functions, with a fixed capital constraint in the short run, while investigating the effects of the oil shocks on substitution possibilities in these two sectors. Park and Kwon (1995) use a similar methodology to investigate the possibility of output growth without productivity growth in Korean manufacturing industries for the years 1966-1989.

Applying Sheppard's Lemma to the functional form (3.3) I can derive input demand equations:

$$i = Q\left(\sum_{j=1}^{n} d_{ij}\left(\frac{w_j}{w_i}\right)^{0.5} + \alpha_i A + \beta_i Q\right)$$
$$i, j = L, K, M$$
$$d_{ij} = d_{ji}$$

If an additive disturbance term is included, symmetry is imposed and it is assumed that the productivity parameter can be characterized by a time trend, then I have three input demand equations which are linear in input prices, output and productivity:

$$\frac{L_t}{Q_t} = d_{LL} + d_{LK}\left(\frac{w_{Kt}}{w_{Lt}}\right)^{0.5} + d_{LM}\left(\frac{w_{Mt}}{w_{Lt}}\right)^{0.5} + \alpha_L t + \beta_L Q_t + e_{Lt} \tag{3.4}$$
$$\frac{K_t}{Q_t} = d_{KK} + d_{LK}\left(\frac{w_{Lt}}{w_{Kt}}\right)^{0.5} + d_{KM}\left(\frac{w_{Mt}}{w_{Kt}}\right)^{0.5} + \alpha_K t + \beta_K Q_t + e_{Kt} \tag{3.5}$$
$$\frac{M_t}{Q_t} = d_{MM} + d_{LM}\left(\frac{w_{Lt}}{w_{Mt}}\right)^{0.5} + d_{KM}\left(\frac{w_{Kt}}{w_{Mt}}\right)^{0.5} + \alpha_M t + \beta_M Q_t + e_{Mt} \tag{3.6}$$

The $d_{ij}(i{\neq}j)$ parameters from the input demand functions reflect factor substitution between inputs i and j. If $d_{ij} > 0$ this implies that i and j are substitutes in production. If $d_{ij} < 0$ this implies that i and j are complements in production. The α_i parameters from (3.4), (3.5) and (3.6) indicate biases in technical change. If $\alpha_i > 0$ then technical change is input i using. If $\alpha_i < 0$ then technical change is input i saving. The β_i parameters from the input demand functions indicate the impact of output levels on the productivity of factor i. If $\beta_i > 0$ then there are decreasing returns to scale in the use of input i. If $\beta_i < 0$ then there are increasing returns to scale in the use of input i.[13]

Alternatives to (3.4), (3.5) and (3.6) which included t^2 and Q^2 terms have been estimated. Results from these estimations have not been reported because the inclusion of the additional independent variables does not improve the fit of the regression equations[14] and in a number of cases the inclusion of additional independent variables altered the parameter estimates such that the conditions required for the estimated cost functions to be concave in input prices were violated.[15]

The preferred specifications of the three input demand equations have been estimated for all eighteen industries covered in my sample. The inverse of the predicted dependent variables describe partial factor productivities. To fully characterize the entire cost function, which duality implies is equivalent to fully characterizing the production technology employed, I need not estimate the cost function for each industry along with the input demand functions. One implication of this full characterization within the input demand functions is that all neutral and biased technological change is captured in the input demand equations. Therefore, biased elements of technical change can be identified from the parameter estimates alone, but any neutral technological change cannot be directly measured.

Every cost function must demonstrate certain properties to satisfy the theoretical definition of a cost function. These properties imply that every cost function must be homogeneous of degree one in input prices and continuous in input prices. By construction the generalized Leontief cost function described by (3.3) satisfies these conditions. However, cost functions must also be non-decreasing in input prices ($\frac{dC_t}{dw_{it}} \geq 0, \forall i, t$) and concave in

[13]Decreasing returns to scale in the use of input i implies that the elasticity of demand for input i with respect to output is greater than one. Increasing returns to scale in the use of input i implies that the elasticity of demand for input i with respect to output is less than one.

[14]Fit was measured by system R^2 values and parameter significance.

[15]The violation of the concavity condition with the inclusion of t^2 and Q^2 terms occurred for U.S. paper mills, U.S. cement manufacturers and U.S. wineries.

input prices (Hessian must be negative semi-definite). Meeting these conditions is dependent on the parameter estimates from (3.4), (3.5) and (3.6). A sufficient condition for these properties to be met is for all $d_{ij}(i \neq j)$ parameters to be greater than or equal to zero and at least one to be strictly positive. However, this implies that there are no complementarities between inputs. This is a strong assumption which I have refused to impose during estimation.[16] Therefore, for each industry the parameter estimates have been used to check that the non-decreasing in input prices and concavity properties required of a cost function are satisfied at the observed prices. These properties hold for all eighteen industries at the mean of the data. Failure rates for these conditions and the number of observations on which the estimations are based are reported in Table 3.1. All years for which the properties did not hold were discarded in generating the results presented in Section 4 and 5 of this chapter.

Diewert and Wales, Parks, Woodland and Cain and Paterson all discuss the need to check the cost function properties. Diewert and Wales (1987; Table 1) report a failure rate of 1.000. Parks (1971; Pg. 156) reports that the concavity property is violated for, "...most years and at the mean of the data". He ignores this problem because the parameter estimate responsible for the failure is not statistically significant. Woodland (1975; Pg. 177) reports failure rates of 1.000 in some of his industries, but due to the significance of some of the parameter estimates responsible he also chooses to ignore the problem. Cain and Paterson (1986; Pg. 164) list the sufficient conditions required for a well behaved cost function, but it is unclear if the existence of these conditions was checked and, if they were checked, what the failure rates were.

I have estimated equations (3.4), (3.5) and (3.6) for each industry as a system of seemingly unrelated regressions.[17] There are two reasons for running these equations as a system. First, I must impose cross-equation symmetry restrictions on the parameters. Sec-

[16] Woodland, 1975, Pg. 173, argues that the implied constraint on Canadian technology is too restrictive to be imposed by the researcher.

[17] The econometric techniques used were drawn primarily from Berndt, 1991, Pg. 460-65 and Cain and Paterson, 1986.

Table 3.1: Cost Function Properties

	N	Failure Rate
Steel: Cda	80	0.000
US	79	0.000
Cotton: Cda	32	0.000
US	64	0.000
Silk: Cda	32	0.000
US	65	0.182
Cement: Cda	33	0.147
US	52	0.483
Sugar: Cda	16	0.000
US	49	0.320
Oil: Cda	57	0.035
US	66	0.179
Paper: Cda	62	0.000
US	53	0.415
Wine: Cda	44	0.000
US	33	0.405
Spirits: Cda	19	0.000
US	53	0.000

ond, because we would expect the error terms from these equations to be correlated across the equations I can improve the efficiency of my estimates by exploiting this information. I have estimated the input demand functions using an iterative Zellnor seemingly unrelated estimator technique (I.Z.E.F.). This technique estimates each equation separately by ordinary least squares to get an error covariance matrix. This error covariance matrix is then used when the three equations are simultaneously estimated using generalized least squares. This procedure is repeated until the estimated parameters converge. I.Z.E.F. is more efficient than equation by equation ordinary least squares because it exploits the information implied by the cross equation correlation of the disturbance terms. I.Z.E.F. is equivalent to maximum likelihood estimation.

There is some evidence of autocorrelation amongst the errors in equations (3.4), (3.5) and (3.6). This autocorrelation implies inefficient but consistent parameter estimates. Correcting for first order autocorrelation following the procedure suggested by Berndt and

Savin (1975; Pg. 950) does not change any of the qualitative results discussed in Section 4. However, the resulting quantitative changes in the parameter estimates for some of the industries represented in my sample lead to the violation of the concavity conditions required for a well behaved cost function. These violations were particularly prevalent in U.S. paper mills and U.S. wineries. To avoid discarding these industries, and because the uncorrected parameter estimates are consistent, I have chosen to use the estimates from the I.Z.E.F. regressions which have not been corrected for autocorrelation in the derivation of the results discussed in Sections 4 and 5 of this chapter.[18] Therefore, the additive disturbance terms included in (3.4), (3.5) and (3.6) are assumed to be independently and identically distributed with a non-singular, non-diagonal covariance matrix.[19]

The estimation results from these systems are presented in the econometric appendix at the end of this chapter. Because some of the industries have very few observations (see Table 3.1) and I have estimated twelve parameters in all systems the econometric results must be interpreted cautiously. In many cases the parameter estimates are not statistically significant. Alternative specifications of the system often have a quantitative, although not qualitative, effect on the estimates. However, given the data available and the generally high correlation coefficients between the observed and predicted dependent variables (see Table 3.2), I believe my estimated parameters and results generated with these parameters will be fairly resilient to the future addition of more observations within my existing nine industries and the addition of firms in other manufacturing industries.

3.4 Canadian and American Manufacturers' Production Technologies

With the parameter estimates from equations (3.4), (3.5) and (3.6) I have calculated predicted values for labour, capital and intermediate input productivities for both the Canadian and American industries represented in my sample. The ratios of predicted to observed

[18]Cain and Paterson, 1986, make no mention of the possible existence of autocorrelation and apparently do not correct for it.

[19]Berndt, 1991, Pg. 463.

partial factor productivities are generally quite close to one, and the correlation coefficient between the predicted and observed dependent variables tend, with a few exceptions, to be quite high. The few cases in which fit appears weak are coincident with those industries for which there are relatively few observations. (See Table 3.2.) Detailed information on the statistical significance of the parameter estimates is available in the Econometric Appendix which follows this chapter.

The estimated input demand systems fully characterize the cost functions for the eighteen industries represented in my sample of firms. This implies that they also fully characterize the underlying production technology employed by these industries. Therefore, I can describe some of the key elements of these underlying production technologies using the estimated parameters from the input demand systems.

Wald tests have been performed to evaluate the hypotheses discussed in this section. A Wald test measures "loss of fit" due to the imposition of the constraints implied by the null hypothesis. Wald statistics are Chi-Square distributed, with degrees of freedom equal to the number of free parameters in the unconstrained model. Unless otherwise stated there are three degrees of freedom for each Wald statistic reported for the tests in this chapter.

I test for the presence of returns to scale by testing the joint hypothesis that the dependent variables in equation (3.4), (3.5) and (3.6), the inverse of the partial factor productivities, are not influenced by the level of output. More formally, I have tested the joint hypothesis that $\hat{\beta}_L = 0$, $\hat{\beta}_K = 0$ and $\hat{\beta}_M = 0$, for each industry represented by my sample of firms. (See Table 3.3.) In Table 3.3 an (*) denotes rejection of the null with 95% confidence and (**) denotes rejection with 90% confidence.

For seven of the nine U.S. industries in my sample I can reject the hypothesis that they were employing constant returns to scale technology with at least 95% confidence. For U.S. oil refineries I can reject this hypothesis with 90% confidence. However, for U.S. cotton mills I cannot reject the constant returns to scale hypothesis with any standard level of confidence. Another interesting feature of the scale results for the U.S. industries in my sample is that not all employed technology which reflected increasing returns. In fact, four

Table 3.2: Mean Ratio Observed : Predicted (Correlation Coefficient)

	Q/L (R)	Q/K (R)	Q/M (R)
Steel: Cda	0.925	1.041	1.016
	(0.893)	(0.720)	(0.918)
US	1.068	1.042	1.079
	(0.935)	(0.678)	(0.610)
Cotton: Cda	0.882	1.009	1.014
	(0.820)	(0.816)	(0.857)
US	1.051	0.870	1.010
	(0.678)	(0.629)	(0.834)
Silk: Cda	0.960	0.991	1.007
	(0.947)	(0.949)	(0.807)
US	1.146	1.138	1.037
	(0.805)	(0.765)	(0.923)
Cement: Cda	1.170	0.968	0.993
	(0.744)	(0.805)	(0.972)
US	1.292	1.068	1.246
	(0.701)	(0.830)	(0.650)
Sugar: Cda	1.038	1.001	1.066
	(0.602)	(0.865)	(0.841)
US	1.086	1.084	1.068
	(0.791)	(0.619)	(0.681)
Oil: Cda	0.883	1.016	1.024
	(0.768)	(0.739)	(0.739)
US	1.019	1.196	1.076
	(0.753)	(0.720)	(0.711)
Paper: Cda	1.015	1.035	1.024
	(0.862)	(0.664)	(0.820)
US	0.999	0.990	0.968
	(0.957)	(0.614)	(0.746)
Wine: Cda	0.978	1.000	1.025
	(0.700)	(0.955)	(0.912)
US	1.170	1.016	1.129
	(0.879)	(0.812)	(0.628)
Spirits: Cda	0.959	1.041	1.004
	(0.931)	(0.910)	(0.974)
US	0.856	1.109	1.018
	(0.648)	(0.722)	(0.881)

Table 3.3: Null: Constant Returns to Scale

	W_3
Steel: Cda	10.638*
US	92.382*
Cotton: Cda	22.509*
US	1.586
Silk: Cda	41.290*
US	8.435*
Cement: Cda	5.033
US	28.384*
Sugar: Cda	66.168*
US	55.660*
Oil: Cda	41.227*
US	6.651**
Paper: Cda	40.802*
US	48.058*
Wine: Cda	28.385*
US	109.973*
Spirits: Cda	30.367*
US	82.508*

of the nine U.S. industries' technologies had decreasing returns to scale in the use of the labour input ($\hat{\beta}_L > 0$), four of the nine also had decreasing returns to scale in the use of the capital input ($\hat{\beta}_K > 0$) and five of the nine U.S. industries had decreasing returns to scale in the use of the intermediate inputs ($\hat{\beta}_M > 0$). (See Table 3.4.) In Table 3.4 an (*) denotes statistical significance at the 95% level and an (**) denotes statistical significance at the 90% level. These results are not radically different from those reported by Cain and Paterson (1986; Table 4) for nineteen U.S. manufacturing industries for the years 1850-1919.[20] Empirical work on returns to scale in U.S. manufacturing during the antebellum industrialization period conforms to Cain and Paterson's view that U.S. manufacturing firms' technologies were not characterized by constant returns to scale, but this does not imply that they were necessarily characterized by increasing returns to scale.[21]

For eight of the nine Canadian industries in my sample I can reject the constant returns

[20]O'Brien, 1988, offers evidence which supports Cain and Paterson's (1986) scale results. He claims that during the last years of the nineteenth century returns to scale in U.S. manufacturing firms were not

Table 3.4: Estimated Returns to Scale

		$\hat{\beta}_L$	$\hat{\beta}_K$	$\hat{\beta}_M$
Steel:	Cda	0.034	-0.002	0.0005*
	US	-0.009*	-0.002*	-0.00003*
Cotton:	Cda	$-0.4 * 10^{-6}$	$0.4 * 10^{-7*}$	$-0.2 * 10^{-6*}$
	US	$0.6 * 10^{-7}$	$-0.3 * 10^{-9}$	$0.2 * 10^{-8}$
Silk:	Cda	$-0.8 * 10^{-6}$	$-0.3 * 10^{-6*}$	$0.5 * 10^{-5}$
	US	$-0.2 * 10^{-6}$	$-0.7 * 10^{-8}$	$-0.4 * 10^{-7*}$
Cement:	Cda	-0.00005*	-0.00003*	$-0.5 * 10^{-6}$
	US	-0.0001	$0.4 * 10^{-5}$	0.00003
Sugar:	Cda	$-0.1 * 10^{-6}$	$-0.6 * 10^{-7*}$	$-0.6 * 10^{-5*}$
	US	$-0.2 * 10^{-8}$	$-0.4 * 10^{-8*}$	$0.7 * 10^{-8}$
Oil:	Cda	$-0.2 * 10^{-7*}$	$-0.5 * 10^{-8*}$	$-0.4 * 10^{-8*}$
	US	$0.1 * 10^{-7*}$	$0.2 * 10^{-8}$	$0.4 * 10^{-9}$
Paper:	Cda	-0.184**	0.045*	-0.00009
	US	0.031**	0.002	0.0002*
Wine:	Cda	0.001*	$0.4 * 10^{-5}$	0.002**
	US	0.002	0.0006*	-0.005*
Spirits:	Cda	-0.002*	0.0003	0.0006*
	US	-0.00006	$-0.3 * 10^{-5}$	-0.0001*

to scale hypothesis with 95% confidence. For Canadian cement manufacturers I cannot reject the constant returns to scale with any standard level of confidence. (See Table 3.3.)

The Canadian industries are only slightly less likely to have been employing technology characterized by decreasing returns to scale then the U.S. industries in my sample. Two of the nine industries appear to have employed technology with decreasing returns to scale in the use of the labour input ($\hat{\beta}_L > 0$), four of the nine had decreasing returns to scale in the use of the capital input ($\hat{\beta}_K > 0$) and four of the nine had decreasing returns to scale in the use of the intermediate inputs ($\hat{\beta}_M > 0$). (See Table 3.4.) In addition to Eastman and Stykolt's seminal work on scale in the Canadian manufacturing sector, Woodland (1975; Appendix B) found increasing returns to scale for all inputs for aggregate Canadian manufacturing for the years 1946-1969. Woodland estimated input demand systems derived

sufficient to encourage firm mergers.

[21]See Atack, 1977, or Sokoloff, 1984.

from Leontief cost functions, but he used value added as output measures, divided capital into structures and equipment, relied on aggregate sectoral level data and only covered a subset of the years my results cover. Baldwin and Gorecki (1986; Table 4.3) also found evidence of increasing returns to scale in seventeen of nineteen Canadian manufacturing industries during the years 1946-1977. Baldwin and Gorecki generated their scale figures by estimating translog production functions, with aggregate industry level data on a subset of the years my sample covers. The difference in my scale results and those in the existing literature may be due to methodological differences, the level of aggregation or the period covered.

Using my parameter estimates I can also test for the existence of technical changes in the eighteen industries my sample of firms represent. If there had been no technical change in an industry, then I would not be able to reject the joint hypothesis that $\hat{\alpha}_L = 0$, $\hat{\alpha}_K = 0$ and $\hat{\alpha}_M = 0$ for that industry. For all eighteen industries in my sample I can reject the no technical change hypothesis with at least 95% confidence. (See Table 3.5.) In Table 3.5 an (*) denotes rejection of the null with 95% confidence and (**) denotes rejection with 90% confidence.

For seven of the nine Canadian industries and all nine of the American industries the technical changes were labour saving ($\hat{\alpha}_L < 0$). For eight of the nine Canadian and all nine of the U.S. industries the technical changes were also capital saving ($\hat{\alpha}_K < 0$). For eight of the nine Canadian industries and six of the nine U.S. industries the technical changes were intermediate inputs saving ($\hat{\alpha}_M < 0$). (See Table 3.6.) In Table 3.6 an (*) denotes statistical significance at the 95% level and an (**) denotes statistical significance at the 90% level. Given the long time period covered by my sample, the substantial T.F.P. growth experienced by most of the industries represented[22] and the fact that from the econometric estimates alone we cannot distinguish between biased and neutral technical changes it is not surprising that for six of the nine Canadian industries and six of the nine U.S. industries technical change has saved on the use of all three inputs.

[22]See the graphical appendix at the end of Chapter 2.

Table 3.5: Null: No Technical Change

	W_3
Steel: Cda	76.180*
US	1055.318*
Cotton: Cda	95.253*
US	119.200*
Silk: Cda	43.826*
US	150.073*
Cement: Cda	163.474*
US	38.878*
Sugar: Cda	39.269*
US	42.584*
Oil: Cda	121.762*
US	94.940*
Paper: Cda	122.452*
US	263.574*
Wine: Cda	170.544*
US	23.495*
Spirits: Cda	120.800*
US	10.169*

Turning to joint factor substitution possibilities, I can reject the hypothesis of no joint factor substitution with at least 95% confidence for all nine Canadian industries and eight of the nine American industries. For U.S. cement manufacturers I can reject the no joint factor substitution hypothesis with only slightly over 80% confidence. (See Table 3.7.) An (*) denotes rejection of the null with 95% confidence and (**) denotes rejection with 90% confidence in Table 3.7. To evaluate this hypothesis I have tested the null that $\widehat{d_{LK}} = 0$, $\widehat{d_{LM}} = 0$ and $\widehat{d_{KM}} = 0$ for each of the eighteen industries represented in my sample. The results from my Wald tests of this null are consistent with the existing literature on substitution possibilities amongst inputs in U.S. manufacturing industries during the late nineteenth and early twentieth centuries.[23]

For all nine Canadian and five of the nine American industries covered by my sample

[23]See Schmitz, 1981, Table 2, 3 and 4 and Cain and Paterson, 1986, Pg. 157. The existence of joint factor substitution possibilities is not tested for explicitly, but can be inferred to exist for Canadian manufacturing industries during the period 1962-1975 from Denny, Fuss and Waverman, 1981, Table 11.3.

Table 3.6: Estimated Technical Change

	$\hat{\alpha_L}$	$\hat{\alpha_K}$	$\hat{\alpha_M}$
Steel: Cda	−9.789*	−0.549*	−0.041*
US	−5.204*	−0.340*	−0.006
Cotton: Cda	−0.037*	−0.002*	−0.003
US	−0.019*	−0.0007*	−0.004*
Silk: Cda	−0.038*	−0.0004	−0.004
US	−0.095*	−0.001*	−0.007*
Cement: Cda	0.076	−0.006	0.038*
US	−0.325*	−0.021*	0.004
Sugar: Cda	0.003*	−0.00007	−0.006
US	−0.0007*	−0.00008**	−0.017*
Oil: Cda	−0.003*	0.0004*	−0.0002
US	−0.013*	−0.002*	−0.0005*
Paper: Cda	−6.551*	−1.050*	−0.023*
US	−11.212*	−1.197*	−0.025*
Wine: Cda	−0.295*	−0.015*	−1.026*
US	−0.952*	−0.152*	0.357
Spirits: Cda	−0.122	−0.076	−0.282*
US	−0.073*	−0.0009	0.023

of firms labour and capital were substitutes in production ($\widehat{d_{LK}} > 0$). For all eighteen industries labour and intermediate inputs were substitutes in production ($\widehat{d_{LM}} > 0$) and for seven of the nine Canadian and six of the nine American industries capital and intermediate inputs were substitutes in production ($\widehat{d_{KM}} > 0$). (See Table 3.8.) In Table 3.8 an (*) denotes statistical significance at the 95% level and an (**) denotes statistical significance at the 90% level.

To further investigate factor substitution possibilities I have calculated cross price input demand elasticities for the eighteen industries represented in my sample of firms. The cross price input demand elasticity between input i and j reflects the percentage change in the quantity of input i demanded when the price of input j increases by one percent. These elasticities have been calculated by inserting the estimated parameters, predicted dependent variables and independent variables from the input demand systems (3.4), (3.5) and (3.6) into equation (3.7).

Table 3.7: Null: No Joint Factor Substitution

	W_3
Steel: Cda	274.937*
US	44.937*
Cotton: Cda	49.584*
US	116.701*
Silk: Cda	76.376*
US	195.981*
Cement: Cda	41.679*
US	4.673
Sugar: Cda	263.017*
US	285.303*
Oil: Cda	76.695*
US	249.244*
Paper: Cda	192.250*
US	117.687*
Wine: Cda	155.012*
US	22.612*
Spirits: Cda	236.752*
US	55.665*

$$\widehat{\epsilon_{ij}^t} = \frac{1}{2}\left(\frac{\widehat{d_{ij}}(w_j^t/w_i^t)^{0.5}}{\widehat{i^t/Q^t}}\right) \qquad (3.7)$$

$$i, j = L, K, M$$

$$i \neq j$$

I have evaluated all 108 (54 Canadian and 54 American) cross price input demand elasticities at the mean of the data. 90 of these elasticities (50 Canadian and 40 American) indicate that the inputs were substitutes in production for one another at the mean of the data ($\widehat{\epsilon_{ij}} > 0$). Only two of the calculated cross price input demand elasticities (Canadian paper mills $\widehat{\epsilon_{ML}}$ and U.S. paper mills $\widehat{\epsilon_{ML}}$) were elastic at the mean of the data ($\widehat{|\epsilon_{ij}|} > 1$). (See Table 3.9.) These results are consistent with earlier empirical work which indicates that, for both Canadian and U.S. manufacturing industries, cross price input demand elasticities have tended to lie between zero and one (in absolute value).[24]

[24] See Schmitz, 1981, Pg. 270 and Diewert and Wales, 1987, Table 2 for U.S. estimates, or Denny, Fuss

Table 3.8: Estimated Factor Substitution Possibilities

	$\hat{d}_{LK}$	$\hat{d}_{LM}$	$\hat{d}_{KM}$
Steel: Cda	24.241*	16.041*	−2.072*
US	6.396**	5.674*	0.324
Cotton: Cda	0.025**	0.304*	0.024
US	0.011*	0.189*	−0.012**
Silk: Cda	0.009*	0.198*	0.00002
US	0.0007	0.293*	0.015*
Cement: Cda	0.568*	1.590*	−0.734*
US	−0.154	0.532*	0.340
Sugar: Cda	0.006*	0.283*	0.017*
US	−0.006*	0.323*	0.024*
Oil: Cda	0.013*	0.021*	0.010*
US	−0.007*	0.016**	0.036*
Paper: Cda	14.686*	18.244*	0.143
US	47.549*	17.957*	−4.701*
Wine: Cda	0.259*	8.226*	0.024
US	−0.398	2.563	3.524*
Spirits: Cda	0.909	4.202*	0.075
US	0.060	3.867*	−0.013

The estimation of input demand systems derived from generalized Leontief cost functions has allowed me to describe some of the characteristics of the underlying production technologies employed by the industries represented by my sample of firms. In general I have found that both the Canadian and American industries in my sample employed technology which was not constant returns to scale, experienced technical change and had joint factor substitution possibilities. In six of the nine Canadian industries covered the technology employed had decreasing returns to scale for at least one input. The same was true for six of the nine U.S. industries covered. In seven of the nine Canadian industries technical change saved on all three inputs. This was true for six of the nine American industries. Finally, for seven of the nine Canadian industries, but only two of the nine American industries, all three inputs were substitutes for one another. Aside from some features of the scale results the technological characteristics of the nine Canadian and nine

and Waverman, 1981, Table 11.3 for Canadian estimates.

Table 3.9: Cross Price Input Demand Elasticities - Evaluated at the Mean of the Data

	ϵ_{LK} (Std Dev)	ϵ_{LM} (Std Dev)	ϵ_{KL} (Std Dev)	ϵ_{KM} (Std Dev)	ϵ_{ML} (Std Dev)	ϵ_{MK} (Std Dev)
Steel: Cda	0.018 (0.010)	0.074 (0.029)	0.523 (0.123)	-0.139 (0.020)	0.740 (0.074)	-0.046 (0.014)
US	0.004 (0.002)	0.029 (0.010)	0.166 (0.057)	0.025 (0.004)	0.301 (0.047)	0.007 (0.002)
Cotton: Cda	0.010 (0.009)	0.088 (0.057)	0.398 (0.193)	0.174 (0.053)	0.630 (0.101)	0.032 (0.005)
US	0.006 (0.003)	0.071 (0.025)	0.543 (0.544)	-0.236 (0.167)	0.579 (0.094)	-0.020 (0.008)
Silk: Cda	0.004 (0.003)	0.091 (0.030)	0.203 (0.060)	0.000 (0.000)	0.538 (0.049)	0.000 (0.000)
US	0.000 (0.000)	0.071 (0.060)	0.015 (0.016)	0.212 (0.085)	0.974 (0.188)	0.042 (0.011)
Cement: Cda	0.046 (0.010)	0.133 (0.022)	0.650 (0.267)	-0.395 (0.147)	0.520 (0.067)	-0.111 (0.030)
US	-0.003 (0.022)	0.014 (0.121)	-0.065 (0.071)	0.119 (0.077)	0.217 (0.029)	0.078 (0.027)
Sugar: Cda	0.025 (0.008)	0.249 (0.054)	0.246 (0.046)	0.089 (0.023)	0.601 (0.108)	0.022 (0.004)
US	-0.019 (0.008)	0.404 (0.065)	-0.321 (0.189)	0.335 (0.106)	0.556 (0.087)	0.027 (0.010)
Oil: Cda	0.045 (0.080)	0.132 (0.301)	0.317 (0.152)	0.274 (0.081)	0.217 (0.068)	0.064 (0.014)
US	-0.015 (0.011)	0.067 (0.052)	-0.100 (0.041)	0.532 (0.181)	0.168 (0.053)	0.198 (0.033)
Paper: Cda	0.013 (0.004)	0.196 (0.063)	0.396 (0.222)	0.025 (0.009)	1.312 (0.198)	0.006 (0.003)
US	0.037 (0.012)	0.239 (0.071)	0.645 (0.140)	-0.476 (0.099)	1.330 (0.280)	-0.152 (0.051)
Wine: Cda	0.021 (0.007)	0.147 (0.050)	0.366 (0.147)	0.005 (0.001)	0.920 (0.230)	0.002 (0.000)
US	-0.010 (0.013)	0.023 (0.019)	-0.296 (0.227)	0.682 (0.419)	0.210 (0.075)	0.209 (0.080)
Spirits: Cda	0.063 (0.004)	0.262 (0.063)	0.764 (0.222)	0.039 (0.009)	0.895 (0.198)	0.011 (0.003)
US	0.010 (0.013)	0.498 (0.335)	0.103 (0.031)	-0.017 (0.004)	0.655 (0.131)	-0.002 (0.001)

American industries represented in my sample of firms are consistent with those reported in more general, in a cross sectional sense, empirical literature. I now turn to a discussion of how these domestically unique characteristics of the underlying production technologies, in addition to domestically unique input market conditions, led to cross country variation in partial factor productivities.

3.5 Cross Country Disaggregation

The central focus of this section is a comparison of Canadian relative to American productivity. Therefore, it is important that the predicted ratios of Canadian to American partial factor productivities do not differ dramatically from the observed ratios. From Table 3.10 we see that the predicted relative partials are generally very close to the observed relative partials. In Table 3.10 I have also reported the mean relative T.F.P. ratio for each industry as reported in Chapter 2 (TFP1). These average T.F.P. ratios measure the overall technical efficiency of the Canadian relative to American manufacturers in my sample of firms. They are based on the assumption that the cost function, which is dual to the firms' technology, is characterized by a constant returns to scale translog specification and they are calculated using data from approximately 5500 firm-year observations on input and output prices and input cost shares.

A Tornqvist index of partial factor productivities is an alternative measure of T.F.P. based on the assumption that firms' technology is characterized by a constant returns to scale translog production function.[25] In column five of Table 3.10 I have included a Tornqvist index of Canadian relative to American *observed* mean partial factor productivities (TFP2$'$).[26] This index reflects the mean Canadian relative to American T.F.P. for each industry in my sample based on different assumptions about the underlying technology, different data (physical quantities of inputs and outputs, rather than input and output prices) and covering only a subset of the firm year observations on which the TFP1 ratios

[25] Allen, 1983, Pg. 97.

[26] The TFP2$'$ figures in column 5 of Table 3.10 differ slightly from the TFP2 figures in column 6 of Table 2.11 in Chapter 2 because TFP2$'$ reports the ratio of means, rather than the mean ratio.

Table 3.10: Mean Ratio Canadian : American TFP and Partials

	TFP1	Q/L	Q/K	Q/M	$TFP2'$	$\widehat{Q/L}$	$\widehat{Q/K}$	$\widehat{Q/M}$	TFP3
Steel	0.959	0.811	1.029	0.857	0.875	0.922	1.029	0.914	0.933
Cotton	0.821	0.622	0.570	0.784	0.718	0.882	0.580	0.765	0.772
Silk	1.137	0.591	0.267	1.786	1.305	0.543	0.259	1.789	1.294
Cement	1.011	0.848	1.025	0.728	0.833	1.022	1.406	0.682	0.939
Sugar	1.209	0.408	0.483	1.361	1.251	0.399	0.540	1.313	1.212
Oil	0.946	0.960	1.738	0.846	1.031	1.143	1.923	0.896	1.116
Paper	1.394	1.219	2.925	0.723	1.185	1.185	2.887	0.687	1.148
Wine	1.527	1.038	1.103	0.881	0.941	1.286	0.781	1.035	1.039
Spirits	1.153	0.505	0.347	1.096	0.938	0.355	0.316	1.082	0.903

are based.[27] In column nine of Table 3.10 I have included a Tornqvist index of Canadian relative to American *predicted* partial factor productivities (TFP3) derived from the estimation of equations (3.4), (3.5) and (3.6).

Given the differences in their derivation these three alternative industry level T.F.P. ratios are remarkably similar. While the T.F.P. ratios implied by the observed ($TFP2'$) and predicted (TFP3) partial factor productivity ratios do tend to be slightly lower than the more comprehensive price based (TFP1) ratio, the pattern of performance is very similar and the conclusion that there is a lack of evidence in favour of consistent and substantial Canadian inefficiency, continues to hold for all three measures.

Focusing on the ratio of Canadian relative to American predicted partials (columns 6, 7, 8 in Table 3.10) it appears that the general trend is for the Canadian industries to have lower labour (five of nine industries) and intermediate input (five of nine industries) productivities, but higher capital productivity (four of nine industries). The most intuitive reason we would expect Canadian industries to have different partial factor productivities than their American counterparts is because of differences in Canadian and American input prices. For example, if Canadian firms were demonstrating cost minimizing behaviour we would expect them to use more labour, and hence have lower labour productivity, than U.S. firms if Canadian labour costs were lower, *ceteris paribus.*

[27] Physical quantity data can be calculated for approximately 2750 firm year observations.

Table 3.11: Mean Ratio Canadian : American Input Prices (Cdn$)

	w_L	w_K	w_M
Steel	0.840	1.291	0.957
Cotton	0.875	0.990	0.987
Silk	0.906	0.658	2.982
Cement	0.980	1.178	0.790
Sugar	0.839	1.543	1.000
Oil	0.875	1.476	0.933
Paper	0.942	2.040	0.664
Wine	0.827	1.161	0.657
Spirits	0.920	0.415	0.880

3.5.1 Variation Due to Input Price Differences

To study the direct impact of input price differences on Canadian relative to American partial factor productivities we must isolate variation in the partials due to differences in input prices from variation due to differences in scale and technology. I have used the estimated parameters from the input demand equations (3.4), (3.5) and (3.6) which describe the U.S. industries' cost functions, and hence the underlying U.S. technology, with U.S. output figures and Canadian input prices to calculate counterfactual predicted Canadian partials. This counterfactual experiment isolates the differences in the Canadian and American predicted partials due directly to input price differences. Intuitively, I assume that the Canadian firms and American firms share an isoquant. I then determine what input combinations the Canadian firms would have chosen given that the slopes of the isocost functions they faced differed from the slopes of the American firms' isocost functions. This uniquely Canadian choice of input combination leads to a uniquely Canadian set of partials which differ from the American partials only because of input price differences.

Not surprisingly if the Canadian and American firms in my sample shared the same technology and output levels, and hence the same isoquant, the Canadian firms would employ those inputs which were cheaper relatively liberally and those inputs which were more expensive relatively conservatively. When Canadian labour was cheaper, relative to capital and intermediate inputs, Canadian firms would have used more labour than the

American firms and Canadian labour productivity would have been lower. This situation describes Canadian steel mills, cotton textile mills, silk and synthetic fibre textile mills and sugar refineries. However, it is not necessarily the case that lower Canadian labour costs should always lead to lower Canadian labour productivity. In Canadian distilleries, for example, the cost of labour was lower than in the U.S., on average, but the cost of labour relative to capital and intermediate inputs was higher. Therefore, if the Canadian and American distilleries in my sample had shared an isoquant, the Canadian distilleries would have chosen to use labour more conservatively, and hence had higher labour productivity, than the U.S. distilleries, even though the cost of labour to the Canadian distilleries was lower, on average. A dissection of the direct effect of input prices on each industries' partials is possible, but in every case the nation's industry which faced the higher input price, relative to the other inputs, used that input more conservatively and the nation's industry which faced the lower input price, relative to the other inputs, used that input more liberally. (See Table 3.14.)

3.5.2 Variation Due to Scale

In Chapter 2, Section 2 I briefly reviewed the existing literature on the impact of scale on Canadian manufacturers. The theme of most of this literature is that the small size of the tariff protected Canadian market facilitated profitable production in too many firms of inefficiently small size, producing product lines which were too diversified. If a firm is employing a production process which exhibits increasing returns to scale for some or all of its inputs, then expanding its output level or lengthening its production run by increasing the size of the market in which it can compete will result in higher productivity for those inputs for which there are increasing returns.

By conducting a counterfactual experiment similar to that described in the subsection above, except isolating the influence of domestically unique levels of output rather than domestically unique input prices, I can study the effects of scale on Canadian relative to American partial factor productivities. Once again I have used the estimated parameters

Table 3.12: Mean Ratio Canadian : American Output Levels

	Q_{cda}/Q_{us}
Steel	0.087
Cotton	0.662
Silk	0.061
Cement	1.826
Sugar	0.521
Oil	0.412
Paper	0.376
Wine	0.534
Spirits	0.097

from equations (3.4), (3.5) and (3.6) which describe the U.S. industries cost functions. However, for the scale counterfactual I use U.S. input prices and Canadian levels of output. Therefore, to calculate the set of counterfactual partials for this experiment I have assumed that the Canadian and American firms have the same technology and face the same input prices. The only remaining differences in their partials must be due to domestically unique levels of output.

All the Canadian industries represented in my sample had lower average output levels than their American counterparts, except for cement manufacturers. Each firm's output levels have been calculated by deflating net sales by an index of their nominal output prices. The firm level output measures were aggregated up to the industry level by weighting each firm's output by its share of the total variable profit generated by all the firms in that industry.[28] Table 3.12 reports the annual average Canadian relative to American industry average output levels for the years for which both are available.

Because the Canadian industries in my sample, aside from cement manufacturers, had lower output levels than the U.S. industries we would expect the counterfactual Canadian partials to be higher than the American if that input experienced decreasing returns to scale and lower than the American if that input experienced increasing returns to scale. This is exactly what we observe. (See Table 3.14.) In general the effects of scale were quite

[28] See the data appendix at the end of Chapter 2 for more details.

small. The presence of decreasing returns to scale in a number of the U.S. industries in my sample implied that the counterfactual Canadian partials were actually higher than the American predicted partials due to the effects of lower Canadian output levels. Six of the nine U.S. industries in my sample were using technology which, on average, experienced decreasing returns to output. Therefore, decreasing returns to scale, coupled with lower Canadian output levels, actually improved Canadian partial factor productivity and total factor productivity in five of the nine industries studied.[29] This result is in contrast to the majority of the literature on Canadian, but not American, returns to scale.[30] A more detailed study of the influence of scale on Canadian manufacturers partial and total factor productivities remains a topic for further research.

3.5.3 Variation Due to Technology

Measuring the impact of input price differences on relative partial factor productivities, imposing common technology and output levels on the Canadian and American firms measures only the direct effect of input price differences. Wylie (1989), Woolf (1984) and Cain and Paterson (1981 and 1986) have argued that there is strong empirical evidence in favour of input price induced biased technical change in both Canadian and American manufacturing industries. Woolf estimated input cost shares, derived from translog production functions, in an attempt to identify biases in technical change in U.S. manufacturing industries from 1900-1929. Cain and Paterson employ similar methods based on translog cost functions (1981) and generalized Leontief cost functions (1986), rather than production functions, for U.S. manufacturing industries from 1850-1919. Wylie uses Woolf's parameter estimates, but Canadian input cost shares and input prices, to calculate Canadian technological change biases. Wylie's reliance on U.S. parameter estimates implicitly assumed that Canadian manufacturers employed, with adaptations, U.S. technology and suffered no ill effects from scale, unbiased technical differences or measured

[29] Canadian cement manufacturers partial and total factor productivities were lowered due to the effects of decreasing returns amongst the inputs in the U.S. technology.

[30] See Section 4 of this chapter.

input quality differences.

Woolf, Cain and Paterson and Wylie all suggest that there is significant biased technical change in both U.S. and Canadian manufacturing industries and that the biases were a response to changes in input prices over time and differences in input prices between Canada and the U.S.. Proponents of induced biased technical change argue that we should expect technical innovations to save on those inputs which are becoming relatively more expensive and use those inputs which are becoming relatively cheaper.[31] As Wylie argues (1989; Pg. 577), if Canadian firms were adapting U.S. technology to domestic input market conditions, then we expect Canadian technology to have been saving, relative to U.S. technology, those inputs which were relatively more expensive in Canada, such as capital and coal, and using those inputs which were relatively cheaper in Canada, such as labour and electricity. If we find evidence of this adaptation then we have evidence that input price differences were having an indirect effect on relative partial factor productivities through biased technical innovation. That suggests that Canadian manufacturers were not only moving along a given isoquant, but actually altering the shape of their isoquants, in response to domestic input market conditions.

Differences in partial factor productivities between Canadian and American manufacturing firms could have been the result of technological differences only if the Canadian and American firms were using different technology. The parameter estimates from the input demand equations (3.4), (3.5), (3.6) often appear quite different for the Canadian and American industries. A simple Wald test of the hypothesis that the Canadian and American industries represented in my sample had the same cost function parameters confirms that for all nine industries we may reject the common technology hypothesis with at least 95% confidence. The Wald statistics from the tests of the common cost function null have twelve degrees of freedom. (See Table 3.13.) In Table 3.13 an (*) denotes rejection of the null with 95% confidence.

[31] This induced technical change argument was first articulated by Hicks, 1968. It has been further refined in work by Binswanger, 1974 and Salter, 1966.

Table 3.13: Null: Common Cost Functions

	W_{12}
Steel	844.280*
Cotton	975.911*
Silk	1612.585*
Cement	6496.593*
Sugar	346.274*
Oil	2411.012*
Paper	1706.629*
Wine	75413.982*
Spirits	6819.520*

To determine the impact technological differences had on Canadian relative to American partials we must isolate the technological differences from differences due directly to domestically unique input prices and output levels. I have used the estimated parameters from the Canadian industries input demand equations (3.4), (3.5) and (3.6) with U.S. input prices and output levels to calculate counterfactual predicted Canadian partial factor productivities. Intuitively, I am assuming that the Canadian and American firms in my sample faced identical conditions in their input markets and had identical output levels, but produced subject to their own domestically unique technology. Therefore, in this counterfactual scenario the Canadian and American firms share isocost functions and output levels, but choose input combinations, which imply partial factor productivities, subject to their own technology.

The counterfactual predicted Canadian partials, relative to the predicted U.S. partials indicate the variation due to domestically unique technology. However, unlike Woolf (1984), Cain and Paterson (1981) and Wylie (1989) my counterfactuals are not input cost shares, but partial factor productivities. Therefore, they capture not only differences due to biased technology, but also differences due to unbiased or neutral technology. I can separate the effects of biased technological differences from neutral technological differences by using a measure of the T.F.P. variation which remains after controlling for input price and output level variation to reflect neutral technological differences. The remaining T.F.P. differences, after controlling for input price and output level differences, may be due to factors such as measurement error, input quality variation and unbiased technological differences. I can calculate a measure of the remaining T.F.P. differences with a Tornqvist index of the common input prices and scale, but domestically unique technology counterfactual partial factor productivities.

With this disaggregation technique I am attempting to attribute the total technological difference between the Canadian and American partials to differences due to different positions of their isoquants, after controlling for scale (ie. differences due to neutral technological variation) and differences due to different shapes of their isoquants (ie. differences due to biased technology). The predicted Canadian partials from the common input price and common scale counterfactual relative to the predicted U.S. partials represent the partial factor productivity variation due to technological differences. A Tornqvist index of these counterfactual Canadian predicted partials relative to the U.S. predicted partials reflects the T.F.P. gap between the Canadian and American industries which remains after imposing common input prices and output levels. By definition this gap measures neutral technological differences between the two nation's industries. Scaling the total technological difference by the neutral technological difference leaves only the effects of biased technology (ie. only the effects of the different shapes of the firms' isoquants, controlling for different isocost functions and different positions of the isoquants). In other words, I give the Canadian firms U.S. input prices and output levels and I shift the Canadian cost functions so they are at the same position or level as the U.S. cost functions. The remaining differences in the Canadian and American partials must be due to biased technology which is domestically unique. Having identified the variation in the Canadian and American industries' partials due directly to input prices, scale and biases in their technology, the remaining variation must be due to neutral technological differences.

The Tornqvist index of the counterfactual Canadian predicted partials relative to the U.S. predicted partials indicates that, after controlling for input price and output level differences, five of the nine Canadian industries in my sample experienced higher partial and total factor productivities relative to the American industries in my sample due to neutral technological differences. However, Canadian steel mills, cotton textile mills, cement manufacturers and oil refineries had lower productivity than their American counterparts because of neutral technological differences. Canadian cotton textile mills were the only firms for which this neutral technological gap was pronounced. (See Table 3.14.)

My results support Wylie's (1989; Pg. 589) claim that Canadian firms were actively adopting, developing or adapting technology which reflected the unique input market conditions they faced. In seven of my nine industries the Canadian firms were employing technology which, on average, was relatively labour saving when Canadian labour was relatively more expensive and relatively labour using when Canadian labour was relatively cheaper. The same is true in five of nine industries with respect to capital and six of nine industries with respect to intermediate input. In other words, in eighteen of twenty-seven cases the Canadian firms were employing technology which, on average, saved expensive inputs and used cheap inputs, relative to their U.S. counterparts. (See Table 3.14.)

The econometric results and counterfactual experiments reported here indicate that the variations in partials were due to different input prices, output levels, neutral technological differences and different biases in technology. Which of these influences dominated varied broadly over time and across industries. We can say that even after controlling for technological differences and scale differences the Canadian firms used their relatively cheaper inputs relatively liberally and this led to lower partial factor productivity for these inputs. It is also apparent that the Canadian firms were employing technology which was using relatively cheaper inputs and saving relatively more expensive inputs compared to the technology the U.S. firms were using. This evidence is consistent with cost minimizing behaviour and rational selection and adaptation of technology. It is not consistent with the view that Canadian manufacturers have traditionally been inflexible and myopic in their responses to domestic input market conditions. We can also say that those Canadian industries in my sample which suffered due to scale or neutral technological differences compensated for those shortcomings by choosing input combinations and adapting, adopt-

Table 3.14: Mean Ratio Canadian : American Predicted and Counterfactual Partials

	Total	Input Prices	Scale	Biased A	Neutral A
Steel: Q/L	0.922	0.984	0.898	1.145	0.895
Q/K	1.029	1.375	0.856	0.879	0.920
Q/M	0.914	1.021	0.992	0.991	0.910
TFP	0.933	1.068	0.956	1.000	0.909
Cotton: Q/L	0.882	0.997	1.077	1.335	0.473
Q/K	0.580	0.903	0.953	1.196	0.528
Q/M	0.765	1.199	1.063	0.830	0.673
TFP	0.772	1.113	1.053	1.000	0.606
Silk: Q/L	0.543	0.795	0.960	0.514	1.274
Q/K	0.259	0.380	0.985	0.583	1.311
Q/M	1.789	1.047	0.792	1.272	1.678
TFP	1.294	0.904	0.857	1.000	1.533
Cement: Q/L	1.022	1.675	1.073	0.324	0.950
Q/K	1.406	1.470	0.984	1.126	0.827
Q/M	0.682	0.871	0.700	1.313	0.798
TFP	0.939	1.238	0.875	1.000	0.856
Sugar: Q/L	0.399	0.979	0.983	0.272	1.165
Q/K	0.540	1.735	0.662	0.089	1.054
Q/M	1.313	0.334	1.196	1.112	1.672
TFP	1.212	0.456	1.151	1.000	1.604
Oil: Q/L	1.143	1.464	1.182	0.541	0.957
Q/K	1.923	0.536	1.947	1.565	0.875
Q/M	0.896	0.925	1.157	0.885	0.929
TFP	1.116	0.880	1.316	1.000	0.920
Paper: Q/L	1.185	1.518	1.187	0.479	1.001
Q/K	2.887	0.840	1.132	2.910	1.005
Q/M	0.687	0.973	1.020	0.692	1.001
TFP	1.148	1.072	1.075	1.000	1.002
Wine: Q/L	1.286	1.013	1.118	0.825	1.330
Q/K	0.781	0.614	1.007	0.829	1.331
Q/M	1.035	0.528	0.993	1.082	1.432
TFP	1.039	0.624	1.016	1.000	1.400
Spirits: Q/L	0.355	1.101	0.927	0.317	1.010
Q/K	0.316	0.861	0.835	0.602	1.018
Q/M	1.082	0.926	0.942	1.178	1.035
TFP	0.903	0.944	0.929	1.000	1.030

ing and developing technology which took advantage of the input market environment they faced.

3.6 Conclusion

In this chapter I have attempted to explain what role input prices, scale and technology played in the observed cross country variation in Canadian and American partial factor productivities. I suggested that Canadian and American partials differed due to scale and neutral technological differences and because domestically unique input prices promoted the use of domestically unique input combinations and technology. The relatively low Canadian labour and intermediate input prices and relatively high Canadian capital prices led to the use of relatively more labour and intermediate input and less capital by the Canadian firms in my sample and the use of relatively labour and intermediate input using and capital saving technology.

Having identified an important role played by input price variation in the determination of Canadian relative to American productivity levels, we are left with the question of why Canadian and American input prices differed. With respect to the price of labour, Canadian immigration policy has traditionally been far more open than American and Canadian immigration has traditionally been balanced between rural and urban destinations, particularly after WWI.[32] This is in contrast to the restricted U.S. immigration policies, particularly with respect to migrants destined for urban centres. The inflow of urban migrants into Canada may have kept Canadian manufacturing wages below U.S. wages.

Intermediate inputs are dominated by raw materials. It is not surprising, given Canada's natural endowments, that Canadian raw materials were generally less expensive than American, particularly for the industries included in my sample.

Wylie (1989; Pg. 576) claims that Canadian capital costs were higher than American due to the tariff. If this were the case we would expect the purchase price of Canadian

[32]See Green and Green, 1993.

capital goods to be higher than the American purchase price. A 1970 exchange rate and purchasing power parity measure with an index of the purchase prices of capital for total manufacturing in Canada and the U.S. indicates that the average purchase price for capital faced by Canadian manufacturers has been over 20% higher than the average American purchase price for capital between the years 1910-1990.

In addition to higher purchase prices Canadian capital costs may have been higher than American because Canadian manufacturers' capital needs have traditionally been satisfied by foreign lenders.[33] As Canadian manufacturers looked further afield for investors they may have had to pay an increasing risk premium to compensate for more expensive information collection and monitoring costs borne by the foreign lenders.[34] Therefore, the reliance on foreign investment and the need to pay this risk premium may explain at least part of the higher Canadian capital costs. Real riskless interest rates in Canada have traditionally been slightly lower than American real riskless interest rates. If we measure relative real interest rates as the average annual returns on government bonds deflated by a wholesale price index, then the Canadian real riskless interest rates have averaged 9.2% lower than American real riskless interest rates for the years 1910-1990. Risk premia vary across time, industries and even firms. Therefore, establishing the risk premia Canadian firms must pay in addition to the real riskless interest rate would not be straight forward. Additional research effort is required to address this issue. However, for the Canadian risk premia to be responsible for the higher Canadian capital costs it would have to be at least 9.2% greater than the risk premia paid by the U.S. manufacturers to overcome the lower real riskless interest rate in Canada.

The final component of capital cost which may be responsible for the higher capital costs in Canada is the depreciation rate. If Canadian depreciation rates were higher than American depreciation rates, then the user cost of capital in Canada would be higher, *ceteris paribus*. Depreciation rates are time, industry and firm dependent. This implies

[33]See Safarian, 1966, or Norrie and Owram, 1991, Pg. 446-51.

[34]For a discussion of the impact of international borders on trade, information and capital flows see McCallum, 1995, Pg. 617, or Helliwell and McCallum, 1995, Pg. 46.

that getting an accurate measure of depreciation rates is not a simple matter and it requires more serious consideration. However, by comparing the share of new investment devoted to structures, relative to equipment at decennial intervals in Canadian and American total manufacturing I can investigate one of the determinants of depreciation rates. The average share of new investment expenditures spent on structures in Canadian total manufacturing has been 28.5% higher than in U.S. total manufacturing, between the years 1925-1985. Since structures depreciate at a much slower rate than equipment, this indicates that new investment in Canadian manufacturing likely has probably depreciated at a slower rate than in U.S. manufacturing. This assumes that Canadian and American structures depreciate at the same rate and Canadian and American equipment depreciates at the same rate. Tests of these assumptions require further empirical research.

It appears that high Canadian purchase prices for capital goods were more likely to have been responsible for high Canadian capital costs, rather than higher real interest rates or higher depreciation rates. However, I am not confident in rejecting any of the potential sources of cross country variation in capital costs based on the evidence discussed here.

The results presented in this chapter indicate that, on average, the Canadian manufacturers in my sample were responding to domestic input prices in a manner which is consistent with cost minimization and input price induced innovation. However, because of the nature of the econometric evidence I have not been able to indicate the relative responsiveness of the Canadian firms nor have I been able to comment on the responsiveness of the Canadian firms to changes in their input prices which are idiosyncratic to Canada. These issues are addressed in Chapter 4.

Econometric Appendix

A system of three input demand equations has been estimated for the eighteen industries represented in my sample of firms. As mentioned in the text these equations take the form:

$$\frac{L_t}{Q_t} = d_{LL} + d_{LK}\left(\frac{w_{Kt}}{w_{Lt}}\right)^{0.5} + d_{LM}\left(\frac{w_{Mt}}{w_{Lt}}\right)^{0.5} + \alpha_L t + \beta_L Q + e_1 \tag{3.4}$$

$$\frac{K_t}{Q_t} = d_{KK} + d_{LK}\left(\frac{w_{Lt}}{w_{Kt}}\right)^{0.5} + d_{KM}\left(\frac{w_{Mt}}{w_{Kt}}\right)^{0.5} + \alpha_K t + \beta_K Q + e_2 \tag{3.5}$$

$$\frac{M_t}{Q_t} = d_{MM} + d_{LM}\left(\frac{w_{Lt}}{w_{Mt}}\right)^{0.5} + d_{KM}\left(\frac{w_{Kt}}{w_{Mt}}\right)^{0.5} + \alpha_M t + \beta_M Q + e_3 \tag{3.6}$$

The input demand equations have not been corrected for autocorrelation. The correlation coefficients between the predicted and observed dependent variable are listed in Table 3.2 in the text. The number of observations on which the estimates are based are listed in Table 3.1 in the text. In the tables which follow an (*) denotes statistical significance at the 95% level and an (**) denotes statistical significance at the 90% level.

The $\widehat{dum}_{cda}$ parameter has been included for Canadian distilleries to account for an apparent discontinuity in the capital productivity series from 1976-82 for this industry. During this period data is available for only one small Canadian distillery.

Positive $d_{ij}(i{\neq}j)$ parameter estimates indicate substitutes in the production process. Negative $d_{ij}(i{\neq}j)$ parameter estimates indicate complements in the production process. Positive α_i parameter estimates indicate falling partial factor productivity of input i, on average, over time. This implies input i using technical change. Negative α_i parameter estimates indicate rising partial factor productivity of input i, on average, over time. This implies input i saving technical change. Positive β_i parameter estimates indicate falling partial factor productivity of input i, on average, as output increases. This implies decreasing returns to scale in the use of input i. Negative β_i parameter estimates indicate rising partial factor productivity of input i, on average, as output increases. This implies increasing returns to scale in the use of input i.

Table 3.15: Steel Mills

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	19414*	2458.90	10633*	425.38
$\hat{d}_{LK}$	24.241*	3.59	6.396**	3.46
$\hat{d}_{LM}$	16.041*	1.28	5.674*	2.74
$\hat{\alpha}_L$	−9.789*	1.28	−5.204*	0.22
$\hat{\beta}_L$	0.034	0.03	−0.009*	0.001
$\hat{d}_{KK}$	1091.100*	376.70	725.000*	203.05
$\hat{d}_{KM}$	−2.072**	1.12	0.324	0.99
$\hat{\alpha}_K$	−0.549*	0.20	−0.340*	0.11
$\hat{\beta}_K$	−0.002	0.004	−0.002*	0.0003
$\hat{d}_{MM}$	79.088*	13.67	13.504	19.96
$\hat{\alpha}_M$	−0.041*	0.007	−0.006	0.01
$\hat{\beta}_M$	0.0005*	0.0002	−0.00003	0.00003

Table 3.16: Cotton Textile Mills

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	73.718*	11.81	37.290*	5.34
$\hat{d}_{LK}$	0.025**	0.02	0.011*	0.004
$\hat{d}_{LM}$	0.304*	0.06	0.189*	0.02
$\hat{\alpha}_L$	−0.037*	0.006	−0.019*	0.003
$\hat{\beta}_L$	$-0.372 * 10^{-6}$	$0.30 * 10^{-6}$	$0.606 * 10^{-7}$	$0.80 * 10^{-7}$
$\hat{d}_{KK}$	4.283*	0.81	1.376*	0.25
$\hat{d}_{KM}$	0.024	0.03	−0.012**	0.007
$\hat{\alpha}_K$	−0.002*	0.0004	−0.0007*	0.0001
$\hat{\beta}_K$	$0.414 * 10^{-7}$*	$0.15 * 10^{-7}$	$-0.305 * 10^{-9}$	$0.29 * 10^{-8}$
$\hat{d}_{MM}$	5.353	3.80	8.295*	1.31
$\hat{\alpha}_M$	−0.003	0.002	−0.004*	0.0007
$\hat{\beta}_M$	$-0.192 * 10^{-6}$*	$0.72 * 10^{-7}$	$0.239 * 10^{-8}$	$0.14 * 10^{-7}$

Table 3.17: Silk And Synthetic Fibre Mills

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	76.264*	13.41	187.940*	19.934
$\hat{d}_{LK}$	0.009*	0.003	0.0007	0.008
$\hat{d}_{LM}$	0.198*	0.07	0.293*	0.02
$\hat{\alpha}_L$	-0.038*	0.007	-0.095*	0.01
$\hat{\beta}_L$	$-0.806 * 10^{-6}$	$0.20 * 10^{-5}$	$-0.182 * 10-6$*	0.001
$\hat{d}_{KK}$	0.746	0.54	2.043*	0.59
$\hat{d}_{KM}$	0.00002	0.004	0.015*	0.004
$\hat{\alpha}_K$	-0.0004	0.0003	-0.001*	0.0003
$\hat{\beta}_K$	$-0.280 * 10^{-6*}$	$0.65 * 10^{-7}$	$-0.685 * 10^{-8}$	$0.10 * 10^{-7}$
$\hat{d}_{MM}$	8.080	5.33	13.814*	2.33
$\hat{\alpha}_M$	-0.004	0.003	-0.007*	0.001
$\hat{\beta}_M$	$0.534 * 10^{-6}$	$0.34 * 10^{-6}$	$-0.376 * 10^{-7*}$	$0.17 * 10^{-7}$

Table 3.18: Cement Manufacturers

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	-146.010	100.64	-647.980*	200.99
$\hat{d}_{LK}$	0.568*	0.19	-0.154	0.15
$\hat{d}_{LM}$	1.590*	0.26	0.532	0.41
$\hat{\alpha}_L$	0.076	0.05	-0.325*	0.10
$\hat{\beta}_L$	-0.00005*	0.00002	-0.0001	0.0001
$\hat{d}_{KK}$	13.016	53.28	43.429*	13.34
$\hat{d}_{KM}$	-0.734*	0.20	0.340	0.27
$\hat{\alpha}_K$	-0.006	0.03	-0.021*	0.007
$\hat{\beta}_K$	-0.00003*	0.00001	$0.391 * 10^{-5}$	$0.75 * 10^{-5}$
$\hat{d}_{MM}$	-74.897*	13.16	-6.567	23.95
$\hat{\alpha}_M$	0.038*	0.007	0.004	0.01
$\hat{\beta}_M$	$-.478 * 10^{-6}$	$0.42 * 10^{-5}$	0.00003	0.00002

Table 3.19: Sugar Refineries

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	-5.397^*	1.95	1.391^*	0.23
$\hat{d}_{LK}$	0.006^*	0.002	-0.006^*	0.001
$\hat{d}_{LM}$	0.283^*	0.02	0.323^*	0.02
$\hat{\alpha}_L$	0.003^*	0.0007	-0.0007^*	0.0001
$\hat{\beta}_L$	$-0.105 * 10^{-6}$	$0.69 * 10^{-7}$	$-0.169 * 10^{-8*}$	$0.19 * 10^{-8}$
$\hat{d}_{KK}$	0.183	0.27	0.176^*	0.08
$\hat{d}_{KM}$	0.017^*	0.01	0.024^*	0.007
$\hat{\alpha}_K$	-0.00007	0.0001	-0.00008^{**}	0.00004
$\hat{\beta}_K$	$-0.568 * 10^{-7*}$	$0.78 * 10^{-8}$	$-0.385 * 10^{-8*}$	$0.60 * 10^{-9}$
$\hat{d}_{MM}$	14.481	45.89	32.760^*	7.78
$\hat{\alpha}_M$	-0.006	0.02	-0.017^*	0.004
$\hat{\beta}_M$	$-0.574 * 10^{-5*}$	$0.16 * 10^{-5}$	$0.712 * 10^{-8}$	$0.62 * 10^{-7}$

Table 3.20: Oil Refineries

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	6.021^*	1.17	26.145^*	3.55
$\hat{d}_{LK}$	0.013^*	0.004	-0.007^*	0.005
$\hat{d}_{LM}$	0.021^*	0.005	0.016^{**}	0.008
$\hat{\alpha}_L$	-0.003^*	0.0006	-0.013^*	0.002
$\hat{\beta}_L$	$-0.177 * 10^{-7*}$	$0.41 * 10^{-8}$	$0.106 * 10^{-7*}$	$0.50 * 10^{-8}$
$\hat{d}_{KK}$	-0.664^*	0.21	3.214^*	0.79
$\hat{d}_{KM}$	0.010^{**}	0.003	0.036^*	0.003
$\hat{\alpha}_K$	0.0004^*	0.0001	-0.002^*	0.0004
$\hat{\beta}_K$	$-0.504 * 10^{-8*}$	$0.79 * 10^{-9}$	$0.147 * 10^{-8}$	$0.11 * 10^{-8}$
$\hat{d}_{MM}$	0.327	0.21	1.069^*	0.36
$\hat{\alpha}_M$	-0.0002	0.0001	-0.0005^*	0.0002
$\hat{\beta}_M$	$-0.351 * 10^{-8*}$	$0.79 * 10^{-9}$	$0.422 * 10^{-9}$	$0.53 * 10^{-9}$

Table 3.21: Paper Mills

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	13141*	2652.30	22227*	2054.60
$\hat{d}_{LK}$	14.686*	6.49	47.549*	12.67
$\hat{d}_{LM}$	18.244*	1.39	17.957*	1.66
$\hat{\alpha}_L$	−6.551*	1.36	−11.212*	1.05
$\hat{\beta}_L$	−0.184**	0.11	0.031**	0.02
$\hat{d}_{KK}$	2054.00*	393.30	2419.400*	831.28
$\hat{d}_{KM}$	0.143	0.77	−4.701*	1.26
$\hat{\alpha}_K$	−1.050*	0.20	−1.197*	0.43
$\hat{\beta}_K$	0.045*	0.01	0.002	0.006
$\hat{d}_{MM}$	44.281*	13.67	47.280*	5.95
$\hat{\alpha}_M$	−0.023*	0.003	−0.025*	0.003
$\hat{\beta}_M$	−0.00009	0.0001	0.0002*	0.00004

Table 3.22: Wineries

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	582.000*	58.39	1868.200*	458.13
$\hat{d}_{LK}$	0.259*	0.06	−0.398	0.44
$\hat{d}_{LM}$	8.226*	0.77	2.563	5.66
$\hat{\alpha}_L$	−0.295*	0.03	−0.952*	0.24
$\hat{\beta}_L$	0.001*	0.0002	0.002	0.001
$\hat{d}_{KK}$	29.325*	3.20	295.460*	88.18
$\hat{d}_{KM}$	0.023	0.24	3.524*	1.27
$\hat{\alpha}_K$	−0.015*	0.002	−0.152*	0.05
$\hat{\beta}_K$	$0.379 * 10^{-5}$	0.00001	0.0006*	0.0002
$\hat{d}_{MM}$	1993.700*	253.27	−688.360	857.58
$\hat{\alpha}_M$	−1.026*	0.13	0.357	0.45
$\hat{\beta}_M$	0.002**	0.0009	−0.005*	0.002

Table 3.23: Distilleries

	Cdn Estimate	Std Err	US Estimate	Std Err
$\hat{d}_{LL}$	247.400	167.35	145.16*	50.69
$\hat{d}_{LK}$	0.909	1.07	0.06	0.08
$\hat{d}_{LM}$	4.202*	0.39	3.867*	0.53
$\hat{\alpha}_L$	−0.122	0.09	−0.073*	0.03
$\hat{\beta}_L$	−0.002*	0.0006	−0.00006	0.00004
$\hat{d}_{KK}$	149.050	298.20	2.061	4.68
$\hat{d}_{KM}$	0.075	0.28	−0.013	0.09
$\hat{\alpha}_K$	−0.076	0.15	−0.0009	0.002
$\hat{\beta}_K$	0.0003	0.0007	$-0.256 * 10^{-5}$	$0.24 * 10^{-5}$
$\hat{dum}_{cda}$	1.959*	0.90		
$\hat{d}_{MM}$	551.270*	50.38	−43.795	31.722
$\hat{\alpha}_M$	−0.282*	0.03	0.023	0.02
$\hat{\beta}_M$	0.0006*	0.0002	−0.0001*	0.00001

Chapter 4
The Responsiveness of Canadian Manufacturers

If Canadian manufacturers have traditionally been unresponsive to domestic input market conditions, as many Economic Nationalist writers and Canadian business historians claim, then we would not expect to find evidence that they were making decisions about the technology and input combinations they employed in a cost minimizing manner. Therefore, we would not expect them to employ technology which used their relatively more expensive inputs conservatively and their relatively cheap inputs liberally. However, in Chapter 3 I present evidence from my sample of seventy-eight Canadian and American manufacturing firms which indicates that, on average, the nine Canadian industries represented did use technology with these input employment characteristics. The evidence in Chapter 3 also demonstrates that the Canadian firms in my sample were employing input combinations which reflected the input prices they faced, controlling for technological and scale differences between the Canadian and American industries. In particular, the Canadian firms input price responses reinforced the relative input saving and using technological biases.

The results in Chapter 3 do not support claims of weak entrepreneurial performance amongst Canadian manufacturers. These results are based on econometric estimation of input demand functions which describe partial factor productivities. The estimated parameters describe the average changes in the Canadian and American partials over time.

In this chapter I present additional evidence which supports the view that the Canadian firms in my sample were altering the intensity of input use in response to changes in their input markets in a manner consistent with cost minimization. I also argue that the Canadian firms were not only responding to continental input price movements, but they reacted to changes in their input markets which were idiosyncratic to Canada. In particular, the Canadian firms in my sample appear to have been increasing the use of inputs which were becoming relatively cheaper, and decreasing the use of inputs which were becoming relatively more expensive. This suggests that the Canadian manufacturers in my sample were responding in an economically rational manner to changes in their input prices by substituting amongst inputs along a given isoquant. These results add robustness to, and confidence in, the econometric work discussed in Chapter 3.

In an effort to establish relative responsiveness to input market conditions I have used the estimated parameters and predicted dependent variables from the input demand equations described in Chapter 3 to derive the Canadian and American industries' own price input demand elasticities. The Canadian industries' own price input demand elasticities are comparable to, and often greater than, the U.S. industries' own price input demand elasticities. This implies that the Canadian firms in my sample tended to be at least as responsive to their input market conditions as the American firms. This relative responsiveness is not consistent with poor entrepreneurial performance.

In Section 2 I present evidence reflecting Canadian responsiveness to domestic input price changes. The next section reports on the derivation of the own price input demand elasticities for the Canadian and American industries represented in my sample. The final section provides a brief summary and some concluding remarks.

4.2 Responsiveness To Changes in Domestic Input Market Conditions

The partial factor productivity figures from my sample of firms have unique characteristics across industries and between Canada and the U.S.. In Chapter 3 I argue that the cross country variation can be attributed to input price differences, scale differences, technological biases and the level of neutral technological efficiency. I claimed that on average the Canadian partials reflected conditions in the Canadian input markets. In this section I present additional evidence that the Canadian firms in my sample responded to changes in their input market conditions.

Table 4.1: Mean Ratio Canadian : American Partials

	Q/L	Std Dev	Q/K	Std Dev	Q/M	Std Dev
Steel	0.87	0.23	1.04	0.17	0.89	0.23
Cotton	0.73	0.21	0.68	0.18	0.79	0.16
Silk	0.45	0.24	0.29	0.18	1.81	0.36
Cement	1.42	0.61	1.13	0.30	0.84	0.15
Sugar	0.62	0.17	0.65	0.24	1.20	0.40
Oil	1.00	0.22	1.90	0.63	0.84	0.11
Paper	1.26	0.37	2.99	1.10	0.91	0.33
Wine	1.17	0.24	1.24	0.51	1.03	0.39
Spirits	0.44	0.20	0.22	0.20	1.34	0.45
Cdn VAW	0.99	0.29	1.85	0.86	0.96	0.20
US VAW	0.94	0.21	1.57	0.53	0.91	0.17

Table 4.2: Mean Ratio Canadian : American Factor Combinations

	K/L	Std Dev	M/L	Std Dev
Steel	0.80	0.18	1.07	0.50
Cotton	1.34	0.37	0.88	0.30
Silk	2.14	1.39	0.33	0.21
Cement	1.58	0.90	1.79	0.90
Sugar	0.97	0.48	0.55	0.15
Oil	0.63	0.16	1.21	0.30
Paper	0.42	0.23	1.56	0.58
Wine	1.07	0.53	1.24	0.38
Spirits	1.84	0.99	0.37	0.17
Cdn VAW	0.75	0.16	1.16	0.43
US VAW	0.79	0.19	1.14	0.38

Table 4.3: Mean Ratio Canadian : American Input Prices (Cdn$)

	WL	Std Dev	WK	Std Dev	WM	Std Dev
Steel	0.84	0.17	1.29	0.56	0.96	0.18
Cotton	0.85	0.15	1.32	2.72	0.93	0.14
Silk	0.86	0.15	0.79	1.58	1.97	0.92
Cement	0.85	0.18	1.23	1.56	0.87	0.09
Sugar	0.80	0.11	2.22	1.49	1.00	0.00
Oil	0.88	0.11	1.43	0.60	0.97	0.16
Paper	0.94	0.12	2.01	1.18	0.68	0.14
Wine	0.82	0.08	1.25	1.24	0.60	0.16
Spirits	0.88	0.11	0.58	0.48	0.82	0.11
Cdn VAW	0.89	0.11	1.57	0.70	0.89	0.07
US VAW	0.89	0.10	1.42	0.66	0.92	0.11

Casual observation reveals that, on average, the differing partial factor productivities, input combinations and input prices between the Canadian and American firms and industries in my sample appear consistent with sound economic decision making on behalf of Canadian producers. Faced with changing input prices the Canadian producers in my sample appear to have altered their input combinations, which resulted in different partial productivity measures, but overall equivalent technical efficiency relative to the American producers.

Using evidence on Canadian input price ratios and input combinations I can test the hypothesis that Canadian producers responded to changing domestic market conditions. We would expect cost minimizing producers to use inputs which were becoming relatively more expensive conservatively and inputs which were becoming relatively cheaper liberally.

Comparing the Canadian and American industries in my sample we see that, on average, the Canadian industries had lower labour costs and lower labour productivity, higher capital costs and higher capital productivity and lower intermediate input costs and lower intermediate input productivity. This is the type of evidence we would predict if Canadian producers were reacting to Canadian input prices in a cost minimizing manner. A more refined test of Canadian producers' responses to changes in input prices can be performed using a simple ordinary least squares (O.L.S.) regression of the input ratios of each

Canadian industry in my sample on a constant, a time trend and relative input prices.

For example, the average real capital input divided by the average number of employee hours per week (k/l) for Canadian steel mills has been regressed on a constant (Const), a year variable representing the years 1910-90 (Yrs) and the average hourly wage divided by the average ex post return per unit of capital (wl/wk). The Yrs variable has been included in these regressions to control for any time trend in the input ratios due to technological changes. As we would predict in the presence of cost minimizing behaviour, the parameter estimate on the relative input price ratio is positive and statistically significant at the 95% level. Therefore, Canadian steel producers have traditionally increased their capital to labour ratio when faced with increased labour relative to capital costs. A similar result holds for all nine Canadian industries in my sample. The positive parameter estimates on the relative labour to capital price ratios are statistically significant at the 95% level for eight of the nine industries.[1] (See Equation 4.1.[2] An (*) denotes statistical significance at the 95% level. An (**) denotes statistical significance at the 90% level.)

A similar series of regressions was run using average hourly wage rates relative to an index of average intermediate input prices (wl/wm), in place of the labour to capital price ratio and an index of average real intermediate inputs to average employee hours per week (m/l), in place of the capital to labour ratio. Again I find that the parameter estimates on the labour to intermediate input price ratios are positive for all nine industries and statistically significant at the 95% for eight of the nine industries.[3] (See Equation 4.2. An (*) denotes statistical significance at the 95% level. An (**) denotes statistical significance at the 90% level.)

Equations 4.1 and 4.2 represent a reduced form of the Canadian industries' relative input demand equations. The results indicate that Canadian producers have responded

[1] For Canadian silk and synthetic fibre textile mills the parameter estimate on wl/wk is positive and statistically significant at the 90% level.

[2] A Cochrane-Orcutt iterative estimation technique has been used to account for first order autocorrelation in equations 4.1, 4.2, 4.3b and 4.4b.

[3] For Canadian distilleries the parameter estimate on wl/wm is positive and statistically significant at the 90% level.

Equation 4.1: $k/l = Const + \beta Yrs + \gamma wl/wk + \epsilon$

	Const (t stat)	β (t stat)	γ (t stat)	R^2
Steel	-3.873^* (-4.63)	0.0021^* (4.79)	0.0021^* (2.66)	0.951
Cotton	-0.412 (-1.44)	0.0002 (1.59)	0.0043^* (3.09)	0.682
Silk	2.220^{**} (1.74)	-0.0011^{**} (-1.69)	0.0011^{**} (1.93)	0.821
Cement	14.706^* (3.06)	-0.0074^* (-3.02)	0.0683^* (7.60)	0.877
Sugar	2.485 (0.27)	-0.0013 (-0.27)	0.0836^* (2.98)	0.532
Oil	-21.979^* (-4.33)	0.0114^* (4.40)	0.0266^* (3.37)	0.977
Paper	-1.027 (-0.88)	0.0006 (0.95)	0.0130^* (3.57)	0.597
Wine	-1.014 (-1.03)	0.0006 (1.12)	0.0081^* (2.37)	0.827
Spirits	1.263 (0.89)	-0.0006 (-0.81)	0.0262^* (7.49)	0.793

Equation 4.2: $m/l = Const + \beta Yrs + \gamma wl/wm + \epsilon$

	Const (t stat)	β (t stat)	γ (t stat)	R^2
Steel	-0.0450^* (-2.69)	0.0002^* (2.71)	0.0858^* (5.56)	0.974
Cotton	-16.699^* (-4.13)	0.0102^* (4.09)	0.0883^* (4.27)	0.926
Silk	-17.911 (-1.51)	0.0091 (1.51)	0.1311^* (2.29)	0.952
Cement	48.552 (1.38)	-0.0252 (-1.40)	0.5658^* (3.25)	0.588
Sugar	1037.8^{**} (1.93)	-0.5250^{**} (-1.92)	0.4000^* (8.80)	0.874
Oil	-6.471 (-1.50)	0.0034 (1.55)	0.3096^* (10.05)	0.961
Paper	-0.0119 (-0.32)	0.00001 (0.30)	0.2006^* (6.63)	0.913
Wine	4.871 (0.07)	-0.0024 (-0.06)	0.1522^* (5.17)	0.825
Spirits	-36.059^* (-2.03)	0.0185^* (2.04)	0.1045^{**} (1.68)	0.723

to changes in relative input prices by altering the intensity of their input usage in a manner consistent with cost minimization. However, these results do not really address the heart of the Nationalist criticism of Canadian manufacturers' entrepreneurial performance. The real concern for Nationalists is that Canadian manufacturers have not consistently responded to changes in their input markets which are idiosyncratic to Canada. Therefore, the observation that Canadian firms were responding to changes in input price ratios may reflect their reactions to changes in the continental market not the Canadian market because Canadian and American input price ratios in the same industries are closely correlated.

To investigate the reactions of the Canadian producers in my sample to exclusively domestic price movements I have used a simple O.L.S. regression to separate Canadian input price ratios into their orthogonal components. This method identifies the idiosyncratic movements in Canadian input price ratios. In a series of first stage regressions the Canadian industries' labour to capital price ratios have been regressed on a constant and the American industries' labour to capital price ratios. The errors from this regression represent changes in the Canadian input price ratio which are not accounted for by changes in the U.S. input price ratio. In second stage regressions each Canadian industry's capital to labour ratio (k/l) has been regressed on the errors from the first stage regression (e1), a constant (Const) and a time trend (Yrs). All nine of the estimated parameters on e1 are positive, five are statistically significant at the 95% level and two more are statistically significant at the 90% level. (See Equation 4.3a and 4.3b. An (*) denotes statistical significance at the 95% level. An (**) denotes statistical significance at the 90% level.)

Performing a similar series of regressions using labour and intermediate input price ratios (wl/wm) in the first stage regressions and then the intermediate input to labour ratios (m/l) for the Canadian industries, the errors (e2) from the first stage regressions, a constant (Const) and a time trend (Yrs) in the second stage regressions, I find that all of the parameter estimates on e2 are positive and five are statistically significant at the 95% level, while one more is statistically significant at the 90% level. (See Equation 4.4a and

Equation 4.3a: $(wl/wk)_{cda} = Const + \alpha(wl/wk)_{us} + e1$
Equation 4.3b: $(k/l)_{cda} = Const + \beta Yrs + \gamma e1 + \epsilon$

	Const (t stat)	β (t stat)	γ (t stat)	R^2
Steel	−4.055* (-3.94)	0.0022* (4.08)	0.0009 (0.58)	0.938
Cotton	-0.348 (-1.15)	0.0002 (1.33)	0.0050* (3.18)	0.686
Silk	2.203** (1.75)	-0.0011 (-1.69)	0.0010** (1.84)	0.820
Cement	15.177* (3.69)	−0.0075* (-3.57)	0.0608* (8.69)	0.892
Sugar	0.8426 (0.09)	-0.0031 (-0.65)	0.0726* (2.53)	0.500
Oil	39.168* (2.24)	−0.0211* (-2.27)	0.0113** (1.75)	0.979
Paper	-1.233 (-1.11)	0.0007 (1.22)	0.0080* (2.34)	0.540
Wine	-2.116 (-1.03)	0.0011 (1.09)	0.0054 (1.36)	0.800
Spirits	-0.046 (-0.04)	0.0001 (0.16)	0.0259* (3.03)	0.600

Equation 4.4a: $(wl/wm)_{cda} = Const + \alpha(wl/wm)_{us} + e2$
Equation 4.4b: $(m/l)_{cda} = Const + \beta Yrs + \gamma e2 + \epsilon$

	Const (t stat)	β (t stat)	γ (t stat)	R^2
Steel	-0.882* (-4.35)	0.0005* (4.42)	0.0707* (3.40)	0.969
Cotton	-36.789* (-11.26)	0.0192* (11.45)	0.0515** (1.73)	0.896
Silk	-37.991* (-7.23)	0.0194* (7.30)	0.1282* (2.03)	0.948
Cement	-43.357 (-0.74)	0.0225 (0.76)	0.1887 (0.77)	0.732
Sugar	6099.3* (2.86)	-3.0851* (-2.85)	2.4330* (2.48)	0.546
Oil	-13.666* (-3.60)	0.0072* (3.71)	0.1376* (2.08)	0.899
Paper	-0.209* (-4.06)	0.0001* (4.14)	0.0187 (0.48)	0.857
Wine	-243.87* (-5.63)	0.1269* (5.75)	0.1764* (4.47)	0.781
Spirits	-56.813* (-4.30)	0.0291* (4.35)	0.1366 (0.93)	0.704

4.4b. An (*) denotes statistical significance at the 95% level. An (**) denotes statistical significance at the 90% level.)

Equations 4.3b and 4.4b represent reduced form relative input demand equations, in which only the idiosyncratic component of relative input prices are included. The results indicate that the Canadian firms in the nine industries in my sample appear to have been responding in a cost minimizing way to changes in relative input prices which were idiosyncratic to Canadian input markets. In other words, when Canadian producers faced changes in domestic relative input prices, which were not explained by changes in U.S. relative input prices, they responded by altering their input intensities such that the increasingly expensive inputs were used more conservatively, in relative terms.

4.3 Relative Responsiveness

Not only were the Canadian producers responding to changes in relative input prices as economic theory would predict, but they were often more responsive than the American producers in the same industry. To measure relative responsiveness to changing input prices I have used the estimated parameters from the input demand equations, (3.4), (3.5) and (3.6), described in Chapter 3, to derive own price input demand elasticities for labour, capital and intermediate inputs for the eighteen industries covered in my sample.

Own price input demand elasticity measures the percentage change in input quantity demanded for a one percent increase in the input's own price. In general own price input demand elasticity can be defined as:

$$\epsilon_{ii} = \frac{di/dw_i}{w_i/i}$$

Where:

$i = L, K, M$

w_i =Exogenous Price of Input i

Q =Physical Quantity of Output

For a generalized Leontief cost function we can write own price elasticity as[4]:

$$\widehat{\epsilon_{ii}^{t}} = -\frac{1}{2}\left(\sum_{j=1 j\neq i}^{n} \frac{\widehat{d_{ij}}(w_j^t/w_i^t)^{0.5}}{\widehat{i^t/Q^t}}\right)$$

These elasticity calculations use estimated parameters and predicted dependent variables from (3.4), (3.5), (3.6), as well as observed exogenous relative input prices. This implies that these elasticities have both variances and covariances. However, the distributions of these elasticities are unknown. Therefore, no statistical tests to determine the relative magnitude of the Canadian and American elasticities can be performed.

In Table 4.4 I present the own price input demand elasticities, evaluated at the mean of the data, and their standard deviations. The own price input demand elasticities are

[4]See Berndt, 1991, Pg. 464.

Table 4.4: Own Price Input Elasticities - Evaluated at the Mean of the Data

	ϵ_{LL} (Std Dev)	ϵ_{KK} (Std Dev)	ϵ_{MM} (Std Dev)
Steel: Cda	-0.092 (0.038)	-0.342 (0.129)	-0.694 (0.066)
US	-0.033 (0.012)	-0.191 (0.060)	-0.308 (0.047)
Cotton: Cda	-0.099 (0.065)	-0.571 (0.245)	-0.662 (0.104)
US	-0.077 (0.027)	-0.307 (0.381)	-0.559 (0.094)
Silk: Cda	-0.094 (0.033)	-0.203 (0.060)	-0.538 (0.049)
US	-0.071 (0.061)	-0.227 (0.099)	-1.016 (0.194)
Cement: Cda	-0.179 (0.031)	-0.255 (0.123)	-0.409 (0.045)
US	-0.011 (0.100)	-0.054 (0.018)	-0.295 (0.050)
Sugar: Cda	-0.273 (0.059)	-0.334 (0.055)	-0.623 (0.112)
US	-0.385 (0.061)	-0.014 (0.113)	-0.583 (0.093)
Oil: Cda	-0.177 (0.380)	-0.590 (0.229)	-0.280 (0.081)
US	-0.052 (0.040)	-0.432 (0.145)	-0.366 (0.081)
Paper: Cda	-0.209 (0.066)	-0.422 (0.230)	-1.317 (0.199)
US	-0.276 (0.082)	-0.169 (0.075)	-1.178 (0.242)
Wine: Cda	-0.168 (0.057)	-0.371 (0.148)	-0.922 (0.230)
US	-0.013 (0.007)	-0.386 (0.194)	-0.419 (0.148)
Spirits: Cda	-0.324 (0.156)	-0.803 (0.341)	-0.906 (0.234)
US	-0.508 (0.348)	-0.087 (0.030)	-0.653 (0.131)

a measure of the responsiveness of the Canadian and American producers in my sample to input price changes. All nine Canadian industries were more responsive to input price changes than their U.S. counterparts, at the mean of the data, for at least one of their inputs. These elasticities reflect relative responsiveness to input price changes on behalf of the Canadian firms in my sample, not myopia and inflexibility.

The Canadian firms in my sample appear to have been responding to input price changes in a cost minimizing fashion, and they do not appear to have been systematically less responsive than the U.S. firms in my sample. Economic Nationalists have argued that Canadian manufacturers have needed tariff protection and government support because without this support their tendency to be slow to adapt and adopt new techniques and unresponsive to changes in their domestic markets would prove devastating for the Canadian economy. The evidence from my sample of firms suggests that the competitive pressures within the relatively small protected Canadian market have been sufficient to encourage responsiveness, flexibility and adaptability.

4.4 Conclusion

Evidence from my sample of seventy-eight Canadian and American manufacturing firms indicates that Canadian producers have traditionally been both technically efficient and responsive to domestic input market conditions. When we measure the productivity of the entire production process simultaneously I find no evidence of substantial and consistent technical inefficiency amongst my Canadian firms, relative to their American counterparts, on average, after 1925. I also find that the Canadian firms in my sample had slightly lower labour and intermediate input productivities, but significantly higher capital productivity, on average. These differences in partial factor productivities reflected differences in input prices, scale and technology. In this chapter I have presented evidence which suggests that my Canadian firms were responding in a manner which economic theory predicts to changes in their relative input price ratios, even if these changes were idiosyncratic to Canada. I have also argued that the Canadian firms were not substantially and consistently less responsive than their U.S. counterparts to changes in their input prices. This evidence leads me to claim that there is little empirical support for any conclusions which imply substantial and consistent Canadian manufacturing technical inefficiency or poor entrepreneurial performance characterized by a lack of responsiveness to domestic input market conditions by the Canadian manufacturers in my sample of firms.

Chapter 5

Conclusion

Modern economic growth theory promotes the idea that the performance of a nation's manufacturing sector is a key determinant of its ability to generate income per capita. In Canada there is a substantial body of theoretical and empirical literature which attempts to explain why Canadian income per capita has traditionally been lower than American income per capita. Either directly or indirectly much of this literature seeks to link the structure of Canadian tariffs to the performance of the Canadian manufacturing sector, hence to Canadian income per capita. The notion that the Canadian tariff structure was responsible for poorly performing manufacturers, who in turn were responsible for low Canadian income per capita, laid the theoretical and empirical foundations for a policy debate in Canada between Economic Nationalists and Continentalists.

Since 1984 Canada's trade and industrial policies have come to reflect the main elements of the Continentalist platform; hemispheric free trade zones, fewer restrictions on foreign investment in Canada and a general retreat by the Federal Government from the Canadian business environment. During the 1960s, 1970s and early 1980s Continentalist writers claimed that just such a shift in government policy would result in the rationalization of the Canadian manufacturing sector. It was argued that the increased competitive pressures would lead to a Darwinian "survival of the fittest" economic environment in Canada. There are two implicit assumptions in this argument. The first is that prior to 1984 Canadian manufacturers had not been performing up to some international (ie. American) standard. The second is that once forced into a competitive environment Canadian firms would prove themselves capable.

Economic Nationalists opposed the Continentalist platform, not because they felt that Canadian firms were performing well before 1984, so rationalization was not necessary, but because, in addition to political and social concerns, they felt that Canadian entrepreneurs would not prove themselves capable if they were exposed to unfettered foreign competition.

At the heart of the Nationalist-Continentalist debate was a search for an explanation of, and remedy for, traditionally low Canadian income per capita relative to the U.S.. If we are to judge the success or failure of the Continentalist platform since its adoption in 1984, in terms of Canadian manufacturing firms' performance and the effect the performance of these firms has had on Canadian income per capita, then we must firmly establish their traditional performance record. In particular, we must determine whether Canadian manufacturing firms entered the post-1984 environment from a position of relative weakness or relative strength compared to Canada's main trading partner, the U.S..

Both Nationalists and Continentalists believed that Canadian manufacturers had traditionally been inefficient relative to U.S. manufacturers, in a technical sense. Technical efficiency measures a production units ability to convert inputs into outputs. The belief in Canadian technical inefficiency was based on relative labour productivity evidence. Nationalists, but not Continentalists, also believed that Canadian manufacturers were unresponsive, myopic and weak, in spite of the tariff protection they have received. The evidence in favour of entrepreneurial failure amongst Canada's manufacturers is primarily anecdotal.

In this thesis I have attempted to quantify the performance of a sample of Canadian manufacturing firms, relative to a matching sample of U.S. firms. I have presented evidence which indicates that for my sample of firms, on average, after 1925, there is no evidence of consistent and substantial Canadian technical inefficiency. I have measured technical inefficiency as Canadian relative to American industry level T.F.P.. I have also presented evidence suggesting that, on average, the Canadian firms in my sample do not display the characteristics one might expect of firms which are led by inflexible, myopic and unresponsive entrepreneurs. I have argued that the Canadian firms in my sample appear to have employed input combinations and technology which used their relatively expensive inputs conservatively and their relatively inexpensive inputs liberally. The Canadian firms in my sample also appear to have been, on average, at least as responsive to changes in their input prices as the American firms in my sample. These characteristics of the Canadian firms in my sample do not support arguments in favour of an entrepreneurial failure hypothesis.

Any assessment of the efficacy of the Continentalist platform should not be based on the assumption that Canadian manufacturers have traditionally been technically inefficient and inflexible, myopic and unresponsive, if the results from my sample of firms are representative. However, if Canadian manufacturers have not traditionally been relatively inefficient, nor suffered from a lack of competent leadership, then we must look elsewhere for explanations of Canada's relatively low income per capita. Alternative explanations may flow from the study of issues such as exogenous differences in input endowments, endogenous input quality differences, or perhaps more attention should be paid to non-manufacturing sectors of the Canadian and American economies, which have traditionally been responsible for 70-75% of the total income generated.

If we are convinced of the importance of manufacturing sectors in determining income per capita, then my firm level evidence does suggest an additional alternative explanation to be considered. For the nine industries in my sample, from 1907-1990, the average ratio of real wages between Canada and the U.S. was 0.84, while the average ratio of real ex post returns per unit of capital was 1.13. This implies that Canadian returns to labour were lower than American, while Canadian returns to capital were higher. Because Canadian manufacturing capital was largely foreign owned it is possible that, had the returns to capital in Canada not been flowing out of the country, then Canadian overall income per capita may have been slightly higher. A rough "back of the envelop" calculation suggests that the average ratio of Canadian to American real G.N.P. per capita could have been slightly over 10% higher (ie. 0.81 rather than 0.73) if the high Canadian returns to capital had stayed in Canada instead of flowing to the U.S.. Of course there may be positive externalities associated with foreign investment which offset this outflow of capital income, but the overall impact of foreign ownership in Canada, in light of the empirical evidence presented in this thesis, remains a intriguing topic for future research.

Bibliography

[1] Aldcroft, D., "The Entrepreneur and the British Economy, 1870-1914", *Economic History Review,* 1964, Vol. 17, Pg. 113-34.

[2] Allen, R.C.,"The Efficiency and Distribution Consequences of 18^{th} Century Enclosures", *Economic Journal,* 1982, Vol. 92, Pg. 937-53.

[3] Allen, R.C., "Recent Developments in Production, Cost and Index Number Theory, With An Application to International Differences in the Cost and Efficiency of International Steelmaking in 1907-09", *Productivity in the Economies of Europe,* P. Fremdling, P. O'Brein (eds.), Klett-Cotta, Stuttgart, Ger., 1983.

[4] Allen, R.C., "Entrepreneurship, Total Factor Productivity and Economic Efficiency", *Favorites of Fortune,* P. Higonnet, D. Landes, H. Rosovsky (eds.), Harvard University Press, Cambridge, U.S., 1991.

[5] Atack, J., "Returns to Scale in Antebellum U.S. Manufacturing", *Explorations in Economic History,* 1977, Vol. 14, Pg. 337-59.

[6] Baldwin, J., P. Gorecki, *The Role of Scale in Canada/US Productivity Differences in the Manufacturing Sector, 1970-79, Research Study Volume 6, Macdonald Commission,* U of T Press, Toronto, Can., 1986.

[7] Berndt, E., *the Practice of Econometrics: Classic and Contemporary,* Addison-Wesley, Don Mills, Can., 1991.

[8] Berndt, E., N. Savin, "Estimation and Hypothesis Testing in Singular Equation Systems With Autoregressive Disturbances", *Econometrica,* 1975, Vol. 43, Pg.

937-57.

[9] Bernstein, J., M. Denny, M. Fuss, S. Nakamura, L. Waverman, "Productivity in Manufacturing Industries, Canada, Japan and the US, 1953-86: Was the "Productivity Slowdown" Reversed?" *Canadian Journal of Economics,* 1992, Vol. 25, Pg. 584-603.

[10] Binswanger, H., "A Microeconomic Approach to Induced Innovation", *Economic Journal,* 1974, Vol. 84, Pg. 940-56.

[11] Binswanger, H., V. Ruttan, *Induced Innovation,* John Hopkins University Press, Baltimore, U.S., 1978.

[12] Bliss, Michael, *Northern Enterprise: Five Centuries of Canadian Business,* McClelland and Stewart, Toronto, Can., 1987.

[13] Cain, L., D. Paterson, "Factor Biases and Technical Change in Manufacturing: The American System, 1850-1919", *Journal of Economic History,* 1981, Vol. 41, Pg. 341-60.

[14] Cain, L., D. Paterson, "Biased Technological Change, Scale and Factor Substitution in American Industry, 1850-1919", *Journal of Economic History,* 1986, Vol. 46, Pg. 153-64.

[15] Caves, D., L. Christensen, "The Relative Efficiency of Public and Private Firms in a Competitive Environment: The Case of Canadian Railroads", *Journal of Political Economy,* 1980, Vol. 88, Pg. 958-76.

[16] Caves, D., Michael Porter, Michael Spence, John Scott, *Competition in the Open Economy: A Model Applied to Canada,* Harvard University Press, Cambridge, US, 1980.

[17] Clement, W., *Continental Corporate Power: Economic Elite Linkages Between Canada and the U.S.,* McClelland and Stewart, Toronto, Can., 1977.

[18] Dales, J., *The Protective Tariff in Canada's Development,* University of Toronto Press, Toronto, Can., 1966.

[19] Daly, D., B. Keys, E Spence, *Scale and Specialization in Canadian Manufacturing,* Economic Council of Canada, Ottawa, Can., 1968.

[20] David, P., *Technical Choice, Innovation and Economic Growth,* Cambridge University Press, New York, U.S., 1975.

[21] Denny, M., M. Fuss, J. May, "Intertemporal Changes in Regional Productivity in Canadian Manufacturing", *Canadian Journal of Economics,* 1981, Vol. 14, Pg. 390-408.

[22] Denny, M., M. Fuss, L. Waverman, "Substitution Possibilities For Energy: Evidence From U.S. and Canadian Manufacturing Industries", *Modeling and Measuring Natural Resource Substitution,* E. Berndt, B. Field (eds.), M.I.T. Press, Cambridge, U.S., 1981.

[23] Denny, M., J. May, "Post-War Productivity in Canadian Manufacturing", *Canadian Journal of Economics,* 1978, Vol. 11, Pg. 29-41.

[24] Diewert, E., "An Application of the Sheppard Duality Theorem: A Generalized Linear Production Function", *Journal of Political Economy,* 1971, Vol. 79, Pg. 482-507.

[25] Diewert, E., "Exact and Superlative Index Numbers", *Journal of Econometrics,* 1976, Vol. 4, Pg. 115-45.

[26] Diewert, E., T. Wales, "Flexible Functional Forms and Global Curvature Conditions", *Econometrica,* 1987, Vol. 55, Pg. 43-68.

[27] Easterbrook, W., Hugh Aitken, *Canadian Economic History,* Macmillan Co., Toronto, Can., 1956.

[28] Eastman, H., S. Stykolt, *The Tariff and Competition in Canada,* Macmillan Co., Toronto, Can., 1967.

[29] Elbaum, B., W. Lazonick, *The Decline of the British Economy,* Clarendon Press, N.Y., U.S., 1986.

[30] Firestone, O., *Canada's Economic Development; 1867-1953,* Bowes and Bowes, London, UK, 1958.

[31] Frank, J., *Assessing Trends in Canada's Competitive Position: The Case of Canada and the United States,* The Conference Board of Canada, Ottawa, Can., 1977.

[32] Fullerton, D., H. Hampson, *Canadian Secondary Manufacturing,* Royal Commission on Canada's Economic Prospects (Gordon Commission), Ottawa, Can., 1957.

[33] Gorecki, P., *Economies of Scale and Efficient Plant Size in Canadian Manufacturing Industries,* Consumer and Corporate Affairs, Ottawa, Can., 1976.

[34] Green, A., J. Baldwin, *Productivity Differentials Between the Canadian and American Manufacturing Sectors as of 1929: A Reexamination,* Paper Prepared for Bellagio Conference (March 1986), 1987.

[35] Green, A., D. Green, "Balanced Growth and the Geographical Distribution of European Immigrant Arrivals to Canada, 1900-1912", *Explorations in Economic History,* 1993, Vol. 30, Pg. 31-59.

[36] Green, A., M. Urquhart, "New Estimates of Output Growth in Canada", *Perspectives on Canadian Economic History,* D. McCalla (ed.), Copp, Clark, Pitman, Toronto, Can., 1987.

[37] Habakkuk, H.J., *American and British Technology in the* 19^{th} *Century,* Cambridge University Press, New York, U.S., 1962.

[38] Harley, C.K., "The Persistence of Old Techniques: The Case of North American Wooden Ship Building", *Journal of Economic History,* 1973, Vol. 33, Pg. 372-98.

[39] Helliwell, J., J. McCallum, "National Borders Still Matter For Trade", *Policy Options,* 1995, Pg. 44-48.

[40] Hicks, J., *The Theory of Wages,* Macmillan, Toronto, Can., 1932, (Reprinted 1968).

[41] Hood, W., A. Scott, *Output, Labour and Capital in the Canadian Economy,* Royal Commission on Canada's Economic Prospects, Ottawa, Can., 1957.

[42] Kilbourn, W., *The Elements Combined: A History of the Steel Company of Canada,* Clark, Irwin and Co. Ltd., Toronto, Can., 1960.

[43] Lempriere, T., P. Rao, *A Comparison of the Total Factor Productivity and Total Cost Performance of Canadian and US Industries; Working Paper No. 45,* Economic Council of Canada, Ottawa, Can., 1992.

[44] Levitt, K., *Silent Surrender: The Multinational Corporation in Canada,* Macmillan Co., Toronto, Can., 1970.

[45] Lumsden, I. (ed.), *Close the 49th Parallel; The Americanization of Canada,* University of Toronto Press, Toronto, Can., 1970.

[46] Lucus, R., "Why Does Capital Not Flow From Rich to Poor Countries?", *American Economic Review,* 1990, Vol. 80, Pg. 92-96.

[47] Marchildon, G., *Profits and Politics: Beaverbrook and the Guilded Age of Canadian Finance,* University of Toronto Press, Toronto, Can., 1996.

[48] Marr, W., D. Paterson, *Canada: An Economic History,* Macmillan Co., Toronto, Can., 1980.

[49] McCallum, J., "National Borders Matter: Canada-U.S. Regional Trade Patterns", *American Economic Review,* 1995, Vol. 85, Pg. 615-23.

[50] McCloskey, D., L. Sandberg, "From Damnation to Redemption: Judgements on the Late Victorian Entrepreneur", *Explorations in Economic History,* 1971, Vol. 8, Pg.

89-108.

[51] Nadiri, N., "Some Approaches to the Theory and Measurement of Total Factor Productivity; A Survey", *Journal of Economic Literature,* 1970, Vol. 8, Pg. 1137-77.

[52] Newell, D., "The Rationality of Mechanization in the Pacific Salmon Canning Industry Before the Second World War", *Business History Review,* 1988, Vol. 62, Pg. 626-55.

[53] Norrie, K., Douglas Owram, *A History of the Canadian Economy,* Harcourt Brace and Co., Toronto, Can., 1996.

[54] O'Brien, A., "Factory Size, Economies of Scale and the Great Merger Wave of 1898-1902", *Journal of Economic History,* 1988, Vol. 48, Pg. 639-49.

[55] Park, S., J. Kwon, "Rapid Economic Growth With Increasing Returns to Scale and Little or No Productivity Growth", *Review of Economics and Statistics,* 1995, Vol. 77, Pg. 332-51.

[56] Parks, R.W., "Price Responsiveness of Factor Utilization in Swedish Manufacturing: 1870-1950", *Review of Economics and Statistics,* 1971, Vol. 53, Pg. 129-39.

[57] Pomfret, R., "Mechanization of Reaping in 19^{th} Century Ontario", *Journal of Economic History,* 1976, Vol. 36, Pg. 399-415.

[58] Romer, P., "Increasing Returns and Long-Run Growth", *Journal of Political Economy,* 1986, Vol. 94, Pg. 1002-37.

[59] Safarian, A., *Foreign Ownership of Canadian Industry,* McGraw-Hill Co., Toronto, Can., 1966.

[60] Salter, W., *Productivity and Technical Change,* Cambridge University Press, Cambridge, U.S., 1966.

[61] Saunders, R., "Continentalism and Economic Nationalism in the Manufacturing Sector: Seeking Middle Ground", *Canadian Public Policy,* 1982, Vol. 8, Supplement, Pg. 463-79.

[62] Schmitz, M., "The Elasticity of Substitution in 19^{th} Century Manufacturing", *Explorations in Economic History,* 1981, Vol. 18, Pg. 290-303.

[63] Sokoloff, K., "Was the Transition From the Artisanal Shop to the Non-Mechanized Factory Associated With Gains in Efficiency?", *Explorations in Economic History,* 1984, Vol. 21, Pg. 351-82.

[64] Solow, R., "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics,* 1957, Vol. 39, Pg. 312-20.

[65] Stykolt, S., *Efficiency in the Open Economy,* Oxford University Press, Toronto, Can., 1969.

[66] West, E., *Canada-United States Price and Productivity Differences in Manufacturing Industries, 1963,* Economic Council of Canada, Ottawa, Can., 1971.

[67] Williams, G., *Not For Export,* McClelland and Stewart Ltd., Toronto, Can., 1994.

[68] Wonnacott, P., R. Wonnacott, "Free Trade Between the US and Canada: Fifteen Years Later", *Canadian Public Policy,* 1982, Vol. 8, Supplement, Pg. 412- 27.

[69] Woodland, A., "Substitution of Structures, Equipment and Labour in Canadian Production", *International Economic Review,* 1975, Vol. 16, Pg. 171-87.

[70] Woolf, A., "Electricity, Productivity and Labour Saving: American Manufacturing, 1900-1929," *Explorations in Economic History,* 1984, Vol. 21, Pg. 176- 91.

[71] Wylie, P., "Technological Adaptation in Canadian Manufacturing, 1900-29", *Journal of Economic History,* 1989, Vol. 49, Pg. 569-91.