

WORKING PAPER

**INTER-INDUSTRY AND
U.S. R&D SPILLOVERS,
CANADIAN INDUSTRIAL
PRODUCTION AND
PRODUCTIVITY GROWTH**

*Working Paper Number 19
February 1998*



Industry Canada

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CANADIAN INDUSTRIAL
PRODUCTION AND
PRODUCTIVITY GROWTH**

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EXECUTIVE SUMMARY

R&D investment generates new products that can be produced relatively more efficiently. Consequently, R&D activities affect living standards. A major reason for the policy focus surrounding R&D activities is that there is a public good aspect to R&D capital accumulation. The benefits of R&D effort cannot be completely appropriated by R&D performers. This means that the benefits of R&D investment spill over to other producers. In particular, there are R&D spillovers that relate to the transmission of knowledge between industries and nations. Indeed, a country's stock of knowledge depends on its own R&D investment as well as the R&D investment conducted in other nations. Thus international spillovers associated with R&D investment imply that national living standards are interdependent.

The purpose of this study is to investigate the extent to which inter-industry and intra-industry R&D spillovers exist from U.S. to Canadian industries, and to determine the production cost, factor intensity (that is, input per unit of output) and productivity growth effects associated with these spillovers. Specifically, we want to investigate how inter-industry and intra-industry spillovers from the United States affect production structures of Canadian manufacturing industries. For example, we address the question of how U.S. spillovers affect labour intensities. We also consider the effects on production efficiency from U.S. spillovers. Efficiency relates to production cost and productivity growth. Productivity growth stresses the temporal impact of R&D spillovers on efficiency, while production cost focuses on the spillover impacts at a given time.

This study is an extension of a 1994 paper by the author (the main parts of which have been published as Bernstein 1996 and 1997), which considers domestic inter-industry spillovers in conjunction with U.S. intra-industry spillovers. The present study examines the effects of spillovers on average variable cost, input-output ratios or factor intensities of labour, intermediate inputs, physical and R&D capital, and productivity growth rates for 11 Canadian industries over the period from 1966 to 1991. The industries examined are chemical products, electrical products, food and beverage, fabricated metals, non-electrical machinery, non-metallic minerals, paper and allied products, petroleum products, primary metals, rubber and plastics, and transportation equipment.

The following conclusions are reached:

- The nature of U.S. spillovers was tested. A question arises as to whether or not U.S. inter-industry and intra-industry spillovers generate effects on the production processes of Canadian manufacturing industries. In eight of the industries examined, there are no significant international/inter-industry spillovers. In these eight industries, international spillovers are intra-industry. In three industries (namely food and beverage, fabricated metals, and rubber and plastics), international spillovers are both intra-industry and inter-industry. This conclusion is not surprising. International links would tend to be stronger within an industry rather than across industries. In addition, since domestic inter-industry spillovers are influenced by U.S. spillovers in the corresponding industry, U.S. inter-industry spillovers are indirectly related through Canadian spillovers. (Note that data in the analysis are defined at the two-digit Standard Industrial Classification. The data relate to Canadian industries and not to individual firms. Thus it is not possible to consider domestic intra-industry spillovers. By necessity, domestic intra-industry spillovers, if they exist, are assumed to be internalized within the industry data.) In two of the three remaining industries (food and beverage, and rubber and plastics), inter-industry spillovers are continental. In other words, in these two industries the source of inter-industry spillovers is defined by the combination of Canadian and U.S. R&D capital stocks. In the food and beverage industry and the rubber and plastics industry, the U.S. inter-industry spillover

- generates effects on factor intensities, production cost and productivity growth that are different from the effects associated with the U.S. intra-industry spillover. In the last industry, fabricated metals, international spillovers are both intra-industry and inter-industry. In this industry, the international spillover is defined by a combination of U.S. intra-industry and inter-industry R&D capital stocks.
- Domestic R&D spillovers cause average variable cost to decrease in seven industries, namely, electrical products, food and beverage, fabricated metals, non-metallic minerals, petroleum products, rubber and plastics, and transportation equipment. The decrease ranges from 0.02 percent for fabricated metals to 0.33 percent for rubber and plastics. The largest cost decreases associated with the inter-industry spillover occur for rubber and plastics. It should be recalled that in this industry inter-industry spillovers are continental, that is both Canadian and U.S. In all cases, cost decreases are highly inelastic.
 - There is a complementary relationship between R&D capital intensity and domestic R&D capital stock in eight industries. In other words, the domestic spillover causes R&D intensity to move in the same direction as the domestic spillover. The eight industries are food and beverage, fabricated metals, non-electrical machinery, non-metallic minerals, paper and allied products, petroleum products, primary metals, and rubber and plastics. A 1.0 percent increase in the domestic spillover increases R&D intensity from a low of 0.01 percent for food and beverage to a high of 0.99 percent for rubber and plastics. With respect to the physical capital, labour and intermediate input intensities, domestic spillovers usually cause these factor intensities to decline. These results, taken together, imply that the majority of Canadian manufacturing industries are becoming more knowledge-intensive. The increase in knowledge intensity arises for two reasons. First, knowledge diffuses among Canadian industries through inter-industry spillovers. Second, in response to these spillovers, industries increase their own R&D intensities.
 - Intra-industry spillovers from the United States exert greater influence on Canadian industries than do domestic inter-industry spillovers. In the cases of the food and beverage industry and the rubber and plastics industry, inter-industry spillovers are continental; consequently, combined U.S. intra-industry and inter-industry spillovers generate greater cost reductions than Canadian inter-industry spillovers. For fabricated metals, international spillovers are both intra- and inter-industry, and these spillovers cause greater cost reductions than domestic inter-industry spillovers. International spillovers from the United States cause variable cost reductions in all industries. A 1.0 percent increase in the U.S. spillover reduces average variable cost from a low of about 0.02 percent in food and beverage to a high of about 0.78 percent in petroleum products. Therefore, at any one time the efficiency gains associated with U.S. spillovers outweigh the efficiency gains from Canadian spillovers.
 - There is generally a complementary relationship between Canadian R&D intensity and intra-industry spillovers from the United States. In two industries (food and beverage, and petroleum products), foreign intra-industry spillovers and domestic R&D intensity are substitutes for each other. In the nine cases where they are complements, the increase in R&D intensity ranges from 0.17 percent for chemical products to about 1.0 percent for transportation equipment, representing a 1.0 percent increase in the foreign spillover. In addition, U.S. spillovers increase physical capital intensities and reduce non-capital input intensities of Canadian manufacturing industries. Therefore, U.S. spillovers cause Canadian manufacturing production to become more intensive with respect to physical capital and knowledge, and less intensive with respect to labour and intermediate input.

- For seven of the manufacturing industries examined, U.S. intra-industry R&D spillovers are the major reason for productivity gains. The percentage contributions range from around 58 percent in transportation equipment to 100 percent in petroleum products. Spillovers are also the main contributor to total factor productivity (TFP) growth for fabricated metals and for rubber and plastics. In the former case, the spillover is the combined Canadian and U.S. inter-industry spillover. In the latter case, the spillover is the combined intra- and inter-industry spillover from the United States. In two industries (chemical products, and food and beverage), output growth, through scale, dominates the elements of TFP. However, even in these industries, the U.S. spillover contributes to productivity gains. Over time, therefore, production efficiency is relatively more affected by U.S. spillovers than by spillovers from Canadian industries.

1. INTRODUCTION

R&D investment generates new products that can be produced relatively more efficiently. Consequently, R&D activities affect living standards. A major reason for the policy focus surrounding R&D activities is that there is a public good aspect to R&D capital accumulation. The benefits of R&D effort cannot be completely appropriated by R&D performers. This means that the benefits of R&D investment spill over to other producers. In particular, there are R&D spillovers that relate to the transmission of knowledge between industries and nations. Indeed, a country's stock of knowledge depends on its own R&D investment as well as the R&D investment conducted in other nations. Thus international spillovers associated with R&D investment imply that national living standards are interdependent.

The purpose of this study is to investigate the extent to which inter-industry and intra-industry R&D spillovers exist from U.S. to Canadian industries, and to determine the production cost, factor intensity (that is, input per unit of output) and productivity growth effects associated with these spillovers. Specifically, we want to investigate how inter-industry and intra-industry spillovers from the United States affect production structures of Canadian manufacturing industries. For example, we address the question of how U.S. spillovers affect labour intensities. We also consider the effects on production efficiency from U.S. spillovers. Efficiency relates to production cost and productivity growth. Productivity growth stresses the temporal impact of R&D spillovers on efficiency, while production cost focuses on the spillover impacts at a given time.

This study is an extension of a 1994 paper by the author (the main parts of which have been published as Bernstein 1996 and 1997), which considers domestic, inter-industry spillovers in conjunction with U.S. intra-industry spillovers. The present study examines the effects of spillovers on average variable cost, input-output ratios or factor intensities of labour, intermediate inputs, physical and R&D capital, and productivity growth rates for 11 Canadian industries over the period from 1966 to 1991. The 11 industries under consideration are chemical products, electrical products, food and beverage, fabricated metals, non-electrical machinery, non-metallic minerals, paper and allied products, petroleum products, primary metals, rubber and plastics, and transportation equipment.

In this study, spillover sources are defined in three different ways. First are domestic (or intra-national) inter-industry spillovers. For example, the domestic inter-industry spillover for the Canadian chemical products industry is the sum of the R&D capital stocks of the Canadian non-chemical products manufacturing industries in this study. The second type of spillover is foreign (or international) and intra-industry from the United States. For example, for the Canadian chemical products industry, the international, intra-industry spillover from the United States is the R&D capital of the U.S. chemical products industry. The third source of spillover is international and inter-industry. This means that the international inter-industry spillover from the United States is the sum of the R&D capital stocks of U.S. manufacturing industries other than chemical products. Spillovers are measured as the sum of R&D capital stocks. R&D capital is the accumulation of undepreciated and deflated R&D expenditures.

The report is organized into four sections and three appendixes. The section on spillover elasticities describes the results of the econometric models used to estimate the effects of R&D spillovers on average variable cost and factor intensities in the Canadian manufacturing industries. The section on productivity growth describes the measurement and decomposition of productivity growth for each of the industries. Following these sections is the conclusion. Appendix 1 sets out the theoretical model. Appendix 2 describes the estimation model, and Appendix 3 discusses the data and estimation results.

2. SPILLOVER ELASTICITIES

This section discusses the effects of domestic and foreign spillovers on average variable cost of production as well as on the structure of production. Production structure refers to factor intensities (that is, input-output ratios). The model and discussion of the data are presented in the appendixes.

Spillovers are measured as the sum of deflated, undepreciated R&D expenditures (or, in other words, the sum of the R&D capital stocks). The domestic or intra-national spillover facing any one industry is the sum of the R&D capital stocks of the domestic industries other than the particular industry under consideration. For example, the intra-national spillover for the chemical products industry is the sum of the R&D capital stocks of all Canadian manufacturing industries excluding the chemical products industry. Since the unit of analysis is industry data (not firm-level data) defined at the two-digit Standard Industrial Classification, there cannot be domestic intra-industry spillovers. These spillovers, if they exist, are assumed by necessity to be internalized within the industry data.

There are two types of international spillovers from the United States to Canada. One spillover is intra-industry and the other is inter-industry. For example, for the Canadian chemical products industry, one spillover is the R&D capital stock of the U.S. chemical products industry. This spillover is international and intra-industry. The second international spillover from the United States is measured as the sum of the R&D capital stocks of all non-chemical manufacturing industries in the United States. This spillover is international and inter-industry.

The effects of spillovers on production cost and factor intensities are estimated for 11 Canadian manufacturing industries: chemical products, electrical products, food and beverage, fabricated metals, non-electrical machinery, non-metallic minerals, paper and allied products, petroleum products, primary metals, rubber and plastics, and transportation equipment. The model, described in the appendixes, is estimated separately for each of the industries over the period from 1966 to 1991. For each, the model was estimated in three ways. First, the U.S. inter-industry spillover was combined with the domestic (or intra-national) inter-industry spillover. Thus we have the equation $S_{1t} = S_{1t}^d + \theta_1 S_{1t}^i$, where S_{1t} is the inter-industry spillover, S_{1t}^d is the intra-national or domestic inter-industry spillover, S_{1t}^i is the international inter-industry spillover and the parameter θ_1 reflects the international contribution to the inter-industry spillover. Second, the U.S. inter-industry spillover was combined with the U.S. intra-industry spillover. Thus we have the equation $S_{2t} = S_{2t}^w + \theta_2 S_{2t}^i$, where S_{2t} is the international spillover, S_{2t}^w is the intra-industry (or within) international spillover and S_{2t}^i is the international inter-industry spillover (note that the variables S_{1t}^i and S_{2t}^i are identical). The parameter θ_2 is to be estimated and represents the inter-industry contribution to the international spillover.

In the third estimation, both international spillover parameters were constrained to equal zero. This is the case where international spillovers are intra-industry. The model was not estimated for the case where international spillovers are only inter-industry because from Bernstein (1994) we know that international intra-industry spillovers exist.

As seen from the results presented in Table A-1, in eight of the industries examined there are no significant international inter-industry spillovers. In other words, the parameters $\theta_1 = \theta_2 = 0$. In these eight industries, international spillovers are intra-industry, and intra-national spillovers are inter-industry. In the remaining three industries (namely, food and beverage, fabricated metals, and rubber and plastics), international spillovers are both intra-industry and inter-industry.

Different results were obtained for the food and beverage, fabricated metals, and rubber and plastics industries. In two of these three (namely, the food and beverage and the rubber and plastics industries), inter-industry spillovers are continental. In other words $\theta_1 > 0$, and $\theta_2 = 0$. Thus inter-industry spillovers are independent of the country of origin. Canadian and U.S. inter-industry spillovers generate the same effects on the production processes of the food and beverage and the rubber and plastics industries. Here spillovers are distinguished as inter-industry (both intra-national and international) and intra-industry (which are international). In the fabricated metals industry, international spillovers are both intra-industry and inter-industry, while domestic spillovers are inter-industry. It should be recalled that, in the other eight industries, spillovers are intra-national/inter-industry and international/intra-industry. A last implication of these results is that in all 11 industries there are two spillover sources.

The spillover effects on production cost and factor intensities for the preferred models are presented in Tables 1 and 2. These tables show the sample mean and standard deviations (in parentheses) of the yearly spillover elasticities.

First, the spillover effects on average variable cost are considered. The direct effect reflects the percentage change in average variable cost when physical and R&D capital are fixed. This result is shown in the second column of Tables 1 and 2. The average variable cost effect (shown in the first column) includes the spillover effects transmitted through capital intensity changes.

According to Table 1, a 1 percent increase in R&D spillover from domestic sources causes average variable cost to decrease in seven industries, namely, electrical products, food and beverage, fabricated metals, non-metallic minerals, petroleum products, rubber and plastics, and transportation equipment. The decrease ranges from 0.02 percent for fabricated metals to 0.33 percent for rubber and plastics. The largest cost decreases associated with the inter-industry spillover occur for rubber and plastics. In this industry, inter-industry spillovers are continental, that is, both Canadian and U.S. In all cases, cost decreases are highly inelastic.

For R&D capital intensity (shown in the last column in the tables), there is a complementary relationship between it and domestic R&D capital stock in eight industries. In other words, the domestic spillover causes R&D intensity to move in the same direction as the spillover. The eight industries where R&D capital intensity increases are food and beverage, fabricated metals, non-electrical machinery, non-metallic minerals, paper and allied products, petroleum products, primary metals, and rubber and plastics. The range of movement is from 0.01 percent for food and beverage to 0.99 percent for rubber and plastics. It should be noted that these two industries framing the elasticity range capture inter-industry spillover elasticities at the continental level. This result implies that there is no relationship between the magnitude of continental inter-industry spillover elasticities with respect to R&D intensity and domestic inter-industry elasticities.

With respect to physical capital, there exists a substitutable relationship between physical capital intensities and the domestic inter-industry R&D spillover in six industries: chemical products, food and beverage, fabricated metals, paper and allied products, petroleum products, and transportation equipment. The decreases range from 0.01 percent for chemical products to 0.25 percent for paper and allied products. It is instructive to note that, with respect to the continental inter-industry elasticities, in one case (food and beverage) physical capital intensity declines while in the other (rubber and plastics) physical capital intensity rises. In all cases the elasticities are highly inelastic (in other words, small).

Table 1
Domestic Inter-Industry Spillover Elasticities

Industry	Average Variable Cost	Direct Average Variable Cost	Labour Intensity	Inter-mediate Input Intensity	Physical Capital Intensity	R&D Capital Intensity
<i>Chemical Products</i>	0.051 (0.017)	0.048 (0.013)	0.046 (0.020)	0.053 (0.016)	-0.008 (0.003)	-0.133 (0.040)
<i>Electrical Products</i>	-0.034 (0.030)	-0.033 (0.029)	-0.034 (0.032)	-0.035 (0.028)	0.057 (0.019)	-0.191 (0.088)
<i>*Food and Beverages</i>	-0.047 (0.024)	-0.034 (0.018)	-0.043 (0.025)	-0.049 (0.023)	-0.071 (0.025)	0.013 (0.007)
<i>Fabricated Metals</i>	-0.020 (0.009)	-0.011 (0.005)	-0.018 (0.012)	-0.021 (0.008)	-0.034 (0.014)	0.120 (0.047)
<i>Non-Electrical Machinery</i>	0.097 (0.023)	0.093 (0.025)	0.095 (0.023)	0.099 (0.025)	0.141 (0.066)	0.152 (0.036)
<i>Non-Metallic Minerals</i>	-0.061 (0.011)	-0.049 (0.010)	-0.057 (0.011)	-0.063 (0.011)	0.045 (0.010)	0.060 (0.011)
<i>Paper and Allied Products</i>	0.063 (0.046)	0.037 (0.025)	0.065 (0.054)	0.061 (0.042)	-0.250 (0.038)	0.0327 (0.071)
<i>Petroleum Products</i>	-0.029 (0.019)	-0.012 (0.009)	-0.025 (0.024)	-0.031 (0.017)	-0.131 (0.072)	0.108 (0.017)
<i>Primary Metals</i>	0.070 (0.030)	-0.060 (0.023)	0.066 (0.034)	0.073 (0.027)	0.553 (0.283)	0.986 (0.121)
<i>*Rubber and Plastics</i>	-0.329 (0.210)	-0.165 (0.108)	-0.282 (0.177)	-0.334 (0.214)	0.120 (0.037)	0.266 (0.054)
<i>Transportation Equipment</i>	-0.097 (0.025)	-0.080 (0.021)	-0.074 (0.029)	-0.109 (0.023)	-0.119 (0.070)	-0.658 (0.081)

* An asterisk signifies that the inter-industry spillover is both Canadian and U.S.

Non-capital input intensities (labour and intermediate input intensities) always move in the same direction as changes in inter-industry spillover. Non-capital input intensities are substitutable for the domestic R&D spillover in seven industries: electrical products, food and beverage, fabricated metals, non-metallic minerals, petroleum products, rubber and plastics, and transportation equipment. The decrease in labour and intermediate input intensities ranges from around 0.02 percent for fabricated metals to 0.30 percent for rubber and plastics.

Table 2
U.S. Intra-Industry Spillover Elasticities

Industry	Average Variable Cost	Direct Average Variable Cost	Labour Intensity	Inter-mediate Input Intensity	Physical Capital Intensity	R&D Capital Intensity
<i>Chemical Products</i>	-0.147 (0.055)	-0.144 (0.054)	-0.132 (0.062)	-0.153 (0.051)	0.042 (0.011)	0.166 (0.030)
<i>Electrical Products</i>	-0.395 (0.127)	-0.370 (0.121)	-0.369 (0.141)	-0.415 (0.119)	0.320 (0.037)	0.443 (0.075)
<i>Food and Beverages</i>	-0.018 (0.010)	-0.014 (0.009)	-0.017 (0.010)	-0.019 (0.010)	-0.053 (0.019)	-0.402 (0.221)
<i>*Fabricated Metals</i>	-0.089 (0.029)	-0.050 (0.017)	-0.077 (0.040)	-0.095 (0.024)	0.029 (0.007)	0.340 (0.075)
<i>Non-Electrical Machinery</i>	-0.393 (0.238)	-0.392 (0.238)	-0.381 (0.230)	-0.402 (0.245)	0.021 (0.005)	0.606 (0.020)
<i>Non-Metallic Minerals</i>	-0.119 (0.085)	-0.101 (0.077)	-0.123 (0.092)	-0.116 (0.080)	0.279 (0.092)	0.386 (0.107)
<i>Paper and Allied Products</i>	-0.302 (0.156)	-0.178 (0.081)	-0.308 (0.188)	-0.299 (0.141)	0.286 (0.172)	0.387 (0.041)
<i>Petroleum Products</i>	-0.775 (0.390)	-0.336 (0.185)	-0.651 (0.509)	-0.869 (0.322)	1.116 (0.578)	-0.698 (0.253)
<i>Primary Metals</i>	-0.160 (0.054)	-0.150 (0.014)	-0.179 (0.048)	-0.154 (0.031)	0.602 (0.307)	0.315 (0.050)
<i>Rubber and Plastics</i>	-0.557 (0.230)	-0.281 (0.121)	-0.478 (0.184)	-0.566 (0.235)	0.205 (0.188)	0.444 (0.045)
<i>Transportation Equipment</i>	-0.398 (0.023)	-0.301 (0.024)	-0.292 (0.031)	-0.454 (0.045)	0.792 (0.368)	0.997 (0.023)

* An asterisk signifies that the spillover is both intra-industry and inter-industry.

Taken together, these results on the domestic inter-industry spillover elasticities imply that the majority of Canadian manufacturing industries are becoming more knowledge-intensive. The increase in knowledge intensity arises for two reasons. First, knowledge diffuses among Canadian industries through inter-industry spillovers. Second, in response to these spillovers, industries increase their own R&D intensities.

Table 2 presents the results on foreign or international R&D spillovers from the United States. It should be recalled that, in all cases except for fabricated metals, international spillovers are intra-industry. With respect to average variable cost, intra-industry spillovers from the United States exert greater influence on Canadian industries than do domestic inter-industry spillovers. In

the cases of the food and beverage and the rubber and plastics industries, inter-industry spillovers are continental; consequently, combined U.S. intra-industry and inter-industry spillovers (that is, the effects shown in Tables 1 and 2 together) generate greater cost reductions than Canadian inter-industry spillovers. For fabricated metals, international spillovers are both intra- and inter-industry, and these spillovers cause greater cost reductions than domestic inter-industry spillovers. International spillovers from the United States cause variable cost reductions in all industries. Table 2 shows that intra-industry spillovers from the United States reduce cost from a low of about 0.02 percent in food and beverage to a high of about 0.78 percent in petroleum products.

In nine industries there is a complementary relationship between domestic R&D intensity and intra-industry spillovers from the United States. In the food and beverage and the petroleum products industries alone, foreign intra-industry spillovers and domestic R&D intensity are substitutes for each other. In the nine cases of complements, the increase in R&D intensity ranges from 0.17 percent for chemical products to about 1.0 percent for transportation equipment.

With respect to physical capital intensity, intra-industry spillovers from the United States generate increases in 10 industries. Only in the food and beverage industry does the spillover reduce physical capital intensity. The elasticities range from a low of 0.02 percent for non-electrical machinery to about 1.12 percent for petroleum products.

Lastly, the non-capital input intensities move in the same direction in response to intra-industry spillovers from the United States, and this direction is always downward. Thus international/intra-industry spillovers reduce non-capital input intensities. The range of elasticities is from a low of about 0.02 percent for food and beverage to a high of about 0.65 percent for labour and 0.87 percent for intermediate inputs in the petroleum products industry. Moreover, as indicated by the Table 1 results for food and beverage and for rubber and plastics, and the Table 2 results for fabricated metals (results encompassing inter-industry spillovers from the United States), in this study all U.S. spillovers reduce non-capital intensities.

The general conclusion to emerge is that U.S. spillovers reduce cost, and these reductions exceed the effects from domestic spillovers. This result means that, at a given time, the efficiency gains from spillovers originating in the United States dominate the efficiency gains from domestic spillovers. In addition, U.S. spillovers increase capital intensities and reduce non-capital input intensities of Canadian manufacturing industries. In response to growing spillovers from the United States, therefore, production structures become relatively more intensive with respect to physical and R&D capital, and relatively less intensive with respect to labour and intermediate input.

3. PRODUCTIVITY GROWTH

In this section, total factor productivity (TFP) growth rates are measured and decomposed for the 11 Canadian manufacturing industries examined. In particular, the focus is on determining the contribution of R&D spillovers to TFP growth rates. The previous section of this paper includes a discussion of the efficiency effects at a given time associated with spillovers. TFP growth relates to the temporal efficiency effects.

There are two components to the decomposition of TFP growth. The first effect is due to returns to scale, and the second is the spillover effect. The latter represents the effect of changes in the rate of technological change on TFP growth. The spillover effects are divided according to their sources. For eight of the industries examined, one source is the domestic inter-industry spillover and the other is the U.S. intra-industry spillover. For the food and beverage and the rubber and plastics industries, the two sources are the continental inter-industry spillover and the U.S. intra-industry spillover. In fabricated metals, the two sources are domestic inter-industry spillovers and U.S. intra-/inter-industry spillovers.

The first column of Table 3 shows the average annual TFP growth rates over the period from 1966 to 1991. The remaining columns show the decomposition of TFP growth rates. Rather than being derived from the model, the growth rates are based on the actual data over the period. The productivity growth decomposition is, however, derived from the model. Hence there will be a difference between the sum of the elements comprising the decomposition and TFP growth rates. This difference is captured by the residual element in Table 3. In general, this table shows that all industries except food and beverage achieved productivity gains, with the electrical products industry registering the highest productivity growth rate of 1.8 percent.

For the chemical products industry, with a productivity growth rate of 0.8 percent, the greatest contributor to productivity gains is the scale element. In other words, output growth, through increasing returns to scale, generates positive growth in total factor productivity. Since domestic spillovers are cost-increasing, they contribute to productivity losses. Conversely, U.S. intra-industry spillovers are cost-reducing and hence cause productivity gains. It is interesting to notice that the negative influence of domestic spillovers and the positive effect of international spillovers tend to offset each other in the chemical products industry.

The high productivity growth rate for the electrical products industry arises from the U.S. intra-industry spillover. Although domestic spillovers and output growth through increasing returns to scale contribute to productivity growth, their influence is swamped by the foreign spillover. Indeed, the international spillover accounts for 84 percent of the productivity growth rate.

On average, food and beverage suffered productivity losses over the period. However, these losses are not attributable to R&D spillovers. Inter-industry spillovers (Canadian and U.S. combined) accounted for productivity gains of 0.016 percent, while U.S. intra-industry spillovers generated productivity growth of 0.014 percent. The major factor leading to productivity losses is the decline in output growth.

Productivity growth averaged 0.42 percent for fabricated metals. As for electrical products, the main contributor to the gains in productivity is the spillover from the United States. In this case, the international spillover represents intra-industry and inter-industry effects. The foreign intra-/inter-industry spillover accounts for 88 percent of the productivity gains in this industry. The same conclusion can be drawn for most of the remaining industries shown in Table 3. The foreign intra-/inter-industry spillover accounts for 72 percent of the productivity gains in the case of non-

Table 3
Decomposition of Average Annual Total Factor Productivity (TFP) Growth Rates, 1966–91
 (percent)

Industry	TFP Growth Rate	Scale	Domestic Inter-Industry Spillovers	Intra-Industry Spillovers from the United States	Residual
<i>Chemical Products</i>	0.810	0.722	-0.398	0.371	0.115
<i>Electrical Products</i>	1.814	0.189	0.271	1.525	-0.171
<i>Food and Beverages</i>	-0.884	-0.501	0.016*	0.014	-0.385
<i>Fabricated Metals</i>	0.419	0.088	0.006	0.369**	-0.044
<i>Non-Electrical Machinery</i>	1.108	0.014	-0.052	0.804	0.342
<i>Non-Metallic Minerals</i>	0.402	0.038	0.086	0.395	-0.117
<i>Paper and Allied Products</i>	0.107	0.004	-0.022	0.083	0.042
<i>Petroleum Products</i>	0.399	0.026	0.003	0.405	-0.035
<i>Primary Metals</i>	0.293	0.055	-0.033	0.212	0.059
<i>Rubber and Plastics</i>	0.714	0.266	0.608*	0.102	-0.262
<i>Transportation Equipment</i>	0.361	0.097	0.044	0.208	0.012

* A single asterisk signifies that domestic spillover includes U.S. inter-industry spillover.

** A double asterisk signifies that U.S. intra-industry spillover includes U.S. inter-industry spillover.

electrical machinery, 98 percent in the case of non-metallic minerals, 78 percent in the case of paper and allied products, 100 percent in the case of petroleum products, 72 percent in the case of primary metals, and 58 percent in the case of transportation equipment. The exception is rubber and plastics: in this instance, the major element that contributes to productivity growth is the inter-industry spillover. This spillover, it will be recalled, is continental, containing both Canadian and U.S. spillovers. The continental inter-industry spillover accounts for 85 percent of productivity gains, while the U.S. intra-industry spillover accounts for only 14 percent of the growth.

Thus the general conclusion of this section is that for seven of the manufacturing industries examined, U.S. intra-industry R&D spillovers are the major reason for productivity gains. Spillovers are also the main contributor to TFP growth for fabricated metals and for rubber and plastics. In the former case the spillover is the combined Canadian and U.S. inter-industry spillover. In the latter case the spillover is the combined intra-/inter-industry spillover from the United States. Only in the chemical products and the food and beverage industries, output growth, through scale, dominates the elements of TFP. However, even in these industries, the U.S. spillover contributes to productivity gains.

4. CONCLUSION

In this study the effects on production cost, factor intensities and productivity growth of domestic inter-industry and U.S. intra- and inter-industry spillovers are estimated. Eleven Canadian manufacturing industries are analyzed over the period from 1966 to 1991. The industries are chemical products, electrical products, food and beverage, fabricated metals, non-electrical machinery, non-metallic mineral products, paper and allied products, petroleum products, primary metals, rubber and plastics, and transportation equipment.

In this study the nature of U.S. spillovers was tested. In particular, an objective was to determine whether inter-industry and intra-industry spillovers generate independent effects on the production processes of Canadian manufacturing industries. In eight of the industries examined, there are no significant international/inter-industry spillovers. In these eight industries, international spillovers are intra-industry. In three industries (namely, food and beverage, fabricated metals, and rubber and plastics), international spillovers are both intra-industry and inter-industry. This conclusion is not surprising. International links would tend to be stronger within an industry rather than across industries. In addition, as domestic inter-industry spillovers are influenced by U.S. spillovers in the corresponding industry, U.S. inter-industry spillovers are indirectly related through Canadian spillovers.

In food and beverage and in rubber and plastics, inter-industry spillovers are continental. Inter-industry spillovers are independent of the country of origin. In the fabricated metals industry, international spillovers are both intra-industry and inter-industry.

Concerning the effects of spillovers on production cost and factor intensities, the general conclusion is that U.S. spillovers reduce cost and that these reductions exceed the effects from domestic spillovers. This result means that, at a given time, the efficiency gains from spillovers originating in the United States dominate the efficiency gains from domestic spillovers. In addition, U.S. spillovers increase capital intensities and reduce non-capital input intensities of Canadian manufacturing industries. Therefore, production structures become relatively more intensive with respect to physical and R&D capital, and relatively less intensive with respect to labour and intermediate input in response to growing spillovers from the United States.

TFP growth rates are measured and decomposed for the 11 Canadian manufacturing industries examined. TFP growth relates to the temporal efficiency effects. The conclusion is that for seven of the manufacturing industries examined, U.S. intra-industry R&D spillovers are the major reason for productivity gains. The percentage contributions range from around 58 percent in the case of transportation equipment to 100 percent in the case of petroleum products. Spillovers are also the main contributor to TFP growth for the fabricated metals and the rubber and plastics industries. In the former case the spillover is the combined Canadian and U.S. inter-industry spillover. In the latter case the spillover is the combined intra-/inter-industry spillover from the United States. Only in the chemical products and the food and beverage industries, output growth, through scale, dominates the elements of TFP. However, even in these industries the U.S. spillover contributes to productivity gains.

APPENDIX 1 THEORETICAL MODEL

In this model producers use labour, intermediate inputs, physical and R&D capital, as well as R&D spillovers and other production efficiency effects to produce output. Producers minimize cost subject to a production function given by the following equation:

$$(1) \quad y_t = F(v_t, K_t, S_{t-1}, t),$$

where y is output, v is the vector of labour and intermediate input demands, K is the vector of physical and R&D capital demands, and S is the vector of R&D spillovers.

Next, in the equation $S_{1t} = S_{1t}^d + \theta_1 S_{1t}^i$, where S_{1t} is the interindustry spillover, S_{1t}^d is the intra-national or domestic inter-industry spillover, S_{1t}^i is the international inter-industry spillover, and the parameter θ_1 (which is to be estimated) reflects the international contribution to the inter-industry spillover. International spillovers are defined in a similar fashion in the equation $S_{2t} = S_{2t}^w + \theta_2 S_{2t}^i$, where S_{2t} is the international spillover, S_{2t}^w is the intra-industry (or within) international spillover and S_{2t}^i is the international inter-industry spillover (note that the variables S_{1t}^i and S_{2t}^i are identical). The parameter θ_2 is to be estimated and represents the inter-industry contribution to the international spillover. Lagged R&D capital stocks are used as the spillovers because borrowed knowledge emanates from the undepreciated and existing stocks of R&D capital. Next, t represents production efficiency effects that do not arise from R&D spillovers. F is the production function, which has the usual properties.

The problem of minimizing cost subject to the production function can be handled in two stages. In the first stage, given output and capital inputs, the costs of labour and intermediate inputs are minimized. Thus,

$$(2) \quad \min_v w_t^T v_t$$

subject to the production function [equation (1)]. Now w is the vector of exogenous labour and intermediate input prices. If we substitute the solution to equation 2 into non-capital cost or variable factor cost (that is, $w^T v$) we get the following equation:

$$(3) \quad c_t^v = C^v(w_t, y_t, K_t, S_{t-1}, t),$$

where c^v is variable cost and C^v is the variable cost function. By applying Shephard's Lemma (that is, $\partial c^v / \partial w_i = v_i$), the demands for the variable factors can be retrieved from the variable cost function. Thus,

$$(4) \quad v_t = \nabla_w C^v(w_t, y_t, K_t, S_{t-1}, t).$$

The variable factor demands depend on the variable factor prices, output, the capital inputs, R&D spillovers and exogenous efficiency effects.

To determine demands for capital inputs, we proceed to the second stage of the problem. With the variable cost function, total cost is minimized. Thus,

$$(5) \quad \min_K C^v(w_t, y_t, K_t, S_{t-1}, t) + \omega_t^T K_t$$

where ω is the vector of capital input prices (or, in other words, capital rental rates). The solution to equation 5 is given by the following:

$$(6) \quad \nabla C_k^v(w_t, y_t, K_t, S_{t-1}, t) + \omega = 0.$$

The solution to equation 6 points out that capital demands depend on non-capital input prices, R&D spillovers, exogenous efficiency effects and capital input prices. Equation sets 4 and 6 describe the theoretical model that is to be estimated.

describ

APPENDIX 2 ESTIMATION MODEL

To estimate the theoretical model, we specify a variable cost function, or more precisely an average variable cost function, as follows:

$$(7) \quad \begin{aligned} c_i^v / y_i = & \left(\sum_{i=1}^2 \beta_i w_{it} + 0.5 \sum_{i=1}^2 \sum_{j=1}^2 \beta_{ij} w_{it} w_{jt} W_t^{-1} + \sum_{i=1}^2 \sum_{j=1}^2 \phi_{ij} w_{it} S_{jt-1} \right. \\ & \left. + \sum_{i=1}^2 \phi_i w_{it} t \right) y_i^{\eta-1} + \left[\sum_{i=1}^2 \alpha_i k_{it} + 0.5 \sum_{i=1}^2 \sum_{j=1}^2 \alpha_{ij} k_{it} k_{jt} / y_i^{\eta-1} \right. \\ & \left. + \sum_{i=1}^2 \sum_{j=1}^2 \psi_{ij} k_{it} S_{jt-1} + \sum_{i=1}^2 \psi_i k_{it} t \right] W_t \end{aligned}$$

Here the parameters to be estimated are given by $\beta_i, \beta_{ij}, \phi_{ij}, \phi_i, \alpha_i, \alpha_{ij}, \psi_{ij}, \psi_i, i, j = 1, 2$, and η is the inverse of the degree of returns to scale. It should be recalled that there are also the U.S. inter-industry spillover parameters θ_1 and θ_2 to be estimated. The non-capital factor prices are denoted as w_i ; $i = 1$ is the labour price; and $i = 2$ is the price of intermediate inputs. In addition, capital intensities are $k_i = K_i/y$ where K_i is the capital input, $i = 1$ is physical capital, $i = 2$ is R&D capital, y is output and t is the time trend. $W = \sum_{i=1}^2 a_i w_i$, where a_i ($i = 1, 2$) are fixed coefficients. W can be defined as a Laspeyres index of non-capital input prices.

Using the average variable cost function (7) and cost minimization conditions, non-capital input demands are given by the following equation:

$$(8) \quad \begin{aligned} v_i = & \left(\beta_i + \sum_{j=1}^2 \beta_{ij} w_{jt} W_t^{-1} - 0.5 \sum_{j=1}^2 \sum_{h=1}^2 \beta_{hj} w_{ht} w_{jt} W_t^{-2} a_i + \sum_{j=1}^2 \phi_{ij} S_{jt-1} \right. \\ & \left. + \phi_i t \right) y_i^{\eta-1} + \left[\sum_{j=1}^2 \alpha_j k_{jt} + 0.5 \sum_{h=1}^2 \sum_{j=1}^2 \alpha_{hj} k_{ht} k_{jt} / y_i^{\eta-1} \right. \\ & \left. + \sum_{h=1}^2 \sum_{j=1}^2 \psi_{hj} k_{ht} S_{jt-1} + \sum_{h=1}^2 \psi_h k_{ht} t \right] a_i, \quad i = 1, 2 \end{aligned}$$

non-capital input intensities are $v_i = v_i / y$, $i = 1, 2$, v_1 is labour input and v_2 is intermediate

Based on the average variable cost function and cost minimization, the demands for the physical and R&D capital inputs are as follows:

$$(9) \quad k_{it} = \left(\alpha_{ij} A_{it} - \alpha_{ij} A_{jt} \right) / \lambda, \quad i \neq j, \quad i, j = 1, 2$$

$A_{it} = \left(-\alpha_i - \sum_{j=1}^2 \psi_{ij} S_{jt-1} - \psi_i t - \omega_i W_t^{-1} \right) y_i^{\eta-1}$, $i = 1, 2$, and $\lambda = (\alpha_{11} \alpha_{22} - \alpha_{12}^2)$, ω_i is the price of the i th capital input. It should be recalled that $k_i = K_i/y$ are the capital intensities, with k_1 the physical capital intensity and $i = 2$ the R&D capital intensity. Equation sets 8 and 9 define the model that is to be estimated.

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The estimation results are presented in Appendix 3. The model is estimated for each of the 11 industries. We imposed the restriction that the variable cost function must be concave in the non-capital input prices. Thus we set $\beta_{11} = -b^2_{11}$. From the tables in Appendix 3, we see that correlation coefficients between the actual and fitted values of the endogenous variables are quite high. The model appears to fit the data well.

Spillover Elasticities

The effects of spillovers on average variable cost and the factor intensities can be determined by differentiating equations 7, 8 and 9 with respect to S_j and S_2 . First, in terms of the capital intensities, (that is, equation set 9), we have the following:

$$ek_c S_j = S_j y^{\eta-1} (\alpha_{12} \psi_{dj} - \alpha_{dd} \psi_{cj}) / \lambda k_c \quad j = 1, 2, \quad c \neq d, \quad c, d = 1, 2$$

where $ek_c S_j$ is the j th spillover elasticity of the c th capital intensity.

Second, for the non-capital input demands (that is, equation set 8), we have the following:

$$\begin{aligned} e v_i S_h = & [[\phi_{ih} y^{\eta-1} / \alpha_i + (\psi_{hh} k_h + \psi_{gh} k_g)] + (ek_1 S_h)(k_1 / S_h) \\ & (\alpha_1 + \sum_{j=1}^2 \alpha_{1j} k_j y^{\eta-1} + \sum_{j=1}^2 \psi_{1j} S_j + \psi_1 t) + (ek_2 S_h)(k_2 / S_h) \\ & (\alpha_2 + \sum_{j=1}^2 \alpha_{2j} k_j y^{\eta-1} + \sum_{j=1}^2 \psi_{2j} S_j + \psi_2 t)] a_i S_h / v_i, \quad i = 1, 2 \quad g \neq h, \quad g, h = 1, 2 \end{aligned}$$

where $e v_i S_h$ is the h th spillover elasticity of the i th non-capital input demand.

The last set of elasticities shows the effects of the spillovers on average variable cost:

$$\begin{aligned} ec_y^v S_h = & [[(\phi_{1h} w_1 + \phi_{2h} w_2) y^{\eta-1} / W + \psi_{hh} k_h + \psi_{gh} k_g] \\ & + (ek_1 S_h)(k_1 / S_h) (\alpha_1 + \sum_{j=1}^2 \alpha_{1j} k_j y^{\eta-1} + \sum_{j=1}^2 \psi_{1j} S_j + \psi_1 t) \\ & + (ek_2 S_h)(k_2 / S_h) (\alpha_2 + \sum_{j=1}^2 \alpha_{2j} k_j y^{\eta-1} + \sum_{j=1}^2 \psi_{2j} S_j \\ & + \psi_2 t)] W S_h / (c^v / y), \quad g \neq h, \quad g, h = 1, 2 \end{aligned}$$

where $ec_y^v S_h$ is the h th spillover elasticity of average variable cost.

Productivity Growth

TFP growth can be measured as follows:

$$TFPG(t,s) = (y_t - y_s)/y_m - s_{vm}^T (v_t - v_s)/v_m - s_{km}^T (K_t - K_s)/K_m,$$

where the subscript t represents the current period, s represents the past period, the subscript m designates the mean value of a variable (e.g., $y_m = (y_t + y_s)/2$), and s_v is the vector of non-capital cost shares for non-capital inputs, defined as $s_{im} = (w_{im} v_{im}) / ((c/y)_m y_m)$ where c is the sum of variable and capital costs. The mean values of the cost shares of the capital inputs are defined in a similar fashion.

TFP growth rates may be decomposed by using the estimated variable cost function. The difference in cost between time periods is expressed as follows:

$$\begin{aligned} c_t^v - c_s^v = & 0.5 \left[\sum_{i=1}^n (v_{it} + v_{is})(w_{it} + w_{is}) \right. \\ & + \left((\partial c^v / \partial y)_t + (\partial c^v / \partial y)_s \right) (y_t - y_s) \\ & + \sum_{k=1}^m \left((\partial c^v / \partial K_k)_t + (\partial c^v / \partial K_k)_s \right) (K_{kt} - K_{ks}) \\ & + \sum_{j=1}^o \left((\partial c^v / \partial S_j)_t + (\partial c^v / \partial S_j)_s \right) (S_{jt} - S_{js}) \\ & \left. + \left((\partial c^v / \partial t)_t + (\partial c^v / \partial t)_s \right) (t - s) \right] \end{aligned}$$

Cost differences are attributable to the variable factor prices, output quantity, capital stocks, R&D spillovers and time trend. In addition, by definition of variable cost, the change over two periods is given by $c_t^v - c_s^v = \sum_{i=1}^n (w_{is} (v_{it} - v_{is}) + v_{it} (w_{it} - w_{is}))$. Using the result with the two previous equations yields the following:

$$\begin{aligned} TFPG(t,s) = & ((y_t - y_s)/y_m) \left[1 - (\partial c^v / \partial y)_m (y/c)_m \right] \\ & - \sum_{j=1}^o (\partial c^v / \partial S_j)_m (S_{jm}/y_m) (y/c)_m (S_{jt} - S_{js})/S_{jm} \\ & - (\partial c^v / \partial t)_m (t - s) (y/c)_m / y_m \end{aligned}$$

The decomposition of TFP growth, as shown by the right side of the equation, consists of three elements. The first element is the scale effect. If there are constant returns to scale in long-run equilibrium, the term inside the square brackets is zero. The second element relates to the R&D spillover effects, of which there are two. The third element is the one associated with the time trend.

APPENDIX 3 DATA AND ESTIMATION RESULTS

The sample period for the estimation models is from 1966 to 1991. The data were obtained from a number of Statistics Canada catalogues and the CANSIM data base of Statistics Canada. The variables used in the estimation of the model are defined as follows. The quantity of output is measured in millions of 1986 dollars. The price of output is a price index obtained by dividing current dollar gross output by 1986 dollar gross output, with 1986 = 1.00. The quantity of labour is labour compensation in millions of 1986 dollars. The price of labour compensation is indexed to 1.00 in 1986. The quantity of intermediate inputs is obtained by netting value added from gross output, and its price is obtained in the same manner as the price of output, with 1986 = 1.00. Both physical and R&D capital stocks are measured in millions of 1986 dollars.

In order to form R&D capital stocks, R&D expenditures were deflated by their price indexes to form R&D investment. The benchmark stock was calculated as R&D investment in the initial period deflated by the depreciation rate for R&D capital (assumed to be 10 per cent), plus the average growth rate for physical capital. With the initial R&D capital stock we developed a time series by using the perpetual inventory formula.

Moreover, to avoid double counting we subtracted the relevant labour, intermediate input, and physical-capital R&D expenditure components from these inputs. For example, we subtracted the wages and salaries of scientists and engineers from labour costs. The spillover variables are based on one-year lagged R&D capital stocks.

The rental rates are obtained as follows. The rental rate of physical capital is before-tax and is defined as:

$$\omega_k = q_k (r + \delta) (1 - itc_k - u_c z) / (1 - u_c)$$

where q_k is the acquisition price of capital, r is the interest rate on long-term government bonds, δ_k is the physical capital depreciation rate, itc_k is the investment tax credit rate, u_c is the corporate income tax rate and z is the present value of capital cost allowances.

allowances is calculated using the declining balance method, distinguished by whether the half-year rule is in effect. For buildings and engineering construction, the present value of capital cost allowances, outside the half-year rule is as follows:

The present value of capital cost allowances is calculated using the declining balance method. The sum is calculated under two regimes: with and without the half-year rule. In addition, capital cost allowances are calculated for buildings and engineering construction and for machinery and equipment. The present value of capital cost allowances, z_b , is the discounted sum of capital cost allowances, z_b .

$$z_b = cca_b (1 - itc_b) / (r + cca_b)$$

where subscript b refers to building and engineering construction. The present value of capital cost allowances is as follows:

where cca_b is capital cost allowances and itc_b is the investment tax credit rate for buildings and engineering construction. Inside the half-year rule the present value of capital cost allowances is as follows:

$$z_b = cca_b (1 - itc_b) / (r + cca_b)$$

$$z_b = cca_b (1 - itc_b) / 2 + (1 - cca_b) / (r + cca_b)$$

The present value of cost allowances for machinery and equipment, z_m , outside the half-year rule is as follows:

$$z_m = \sum_{t=0}^T cca_m (1 - itc_m) / (1 + r)^t$$

where t represents time, T represents number of years and the subscript m stands for machinery and equipment. Inside the half-year rule the discounted sum is:

$$z_m = \sum_{t=0}^{T-1} cca_m (1 - itc_m) / (1 + r)^t + (cca_m (1 - itc_m) (1 + 1 / (1 + r)^T)) / 2$$

The aggregate z is an index of z_b and z_m , where the weights are the shares of the acquisition values of the capital stocks.

The before-tax rental rate on R&D capital is defined as:

$$\omega_r = q_r (r + \delta_r) ((1 - u_c) (1 - itc_r) - u_c d) / (1 - u_c)$$

where q_r is the R&D investment price (see Bernstein 1992), $\delta_r = 0.1$ is the R&D capital depreciation rate, itc_r is the R&D investment tax credit, and d is the present value of incremental R&D investment allowance.

The present value of incremental investment allowance at time $t = 0$ is:

$$d = iia_r \left(1 - \sum_{t=1}^3 1 / (3(1 + r)^t) \right)$$

where iia_r is the incremental investment allowance rate. If current R&D investment expenditures exceed an average of R&D expenditures in the past three years, then a tax reduction is allowed on the R&D expenditures in period t at the rate iia_r .

The parsimonious specification of the model was always selected. Thus the parameters associated with the time trend (ϕ_i, ψ_i) and the spillover parameters interacting with the variable factor prices (ϕ_{ij}) are here set to zero (see equation 7).

Table A-1
International Spillovers

Industry	International Spillover	
	Intra-/Inter-industry*	Intra-industry
Chemical Products	465.6774	464.955)

Table A-2
Estimation Results

	Chemical Products		Electrical Products		Food and Beverages		Fabricated Metals	
<i>Parameters</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>
β_1	0.490	0.219	0.501	0.157	0.233	0.017	0.508	0.164
β_2	0.047	0.002	0.197	0.005	0.076	0.002	0.211	0.080
β_{11}	0.289	0.010	0.440	0.020	0.327	0.017	0.611	0.249
ϕ_1	-17.436	6.060	-2.147	1.012				
ϕ_2	11.357	5.766	-3.268	1.617	-0.545	0.044	-1.082	0.427
α_{11}	164.166	48.482	24.266	7.766	0.781	0.102	1.407	0.707
α_{22}	1 531.62	499.110	303.272	95.056	3.745	0.562	11.946	4.113
ψ_{11}			-0.00005	0.00003				
ψ_{12}	-0.00005	0.00001	-0.0001	0.00007	-0.000003	0.000001	-0.000003	0.000001
ψ_{21}					-0.000001	0.0000001	0.00001	0.000001
ψ_{22}	-0.0003	0.00009	-0.0003	0.00002	0.00001	0.000003	-0.00003	0.00002
α_1	1.024	0.589	0.645	0.074	0.456	0.011	1.065	0.771
α_2	0.045	0.009						
θ_1					0.831	0.366		
θ_2							0.977	0.210

Correlation Coefficient of Actual and Fitted Values				
<i>Labour Intensity</i>	0.813	0.970	0.841	0.894
<i>Inter. Input Intensity</i>	0.835	0.772	0.817	0.887
<i>Physical Capital Intensity</i>	0.909	0.882	0.813	0.821
<i>R&D Capital Intensity</i>	0.985	0.926	0.719	0.736

Table A-2 (cont'd)

<i>Parameters</i>	Non-Electrical Machinery		Non-Metallic Minerals		Paper and Allied Products		Petroleum Products	
	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>
β_1	0.668	0.114	0.370	0.013	21.764	6.116	25.930	5.909
β_2	0.079	0.009	0.111	0.024	5.506	2.118	4.810	1.773
β_{11}	0.264	0.040	0.375	0.017	4.290	0.485	3.924	0.520
ϕ_1			-0.965	0.243			-1.734	1.484
ϕ_2	13.251	5.008	-0.897	0.336	0.738	0.192	-0.258	0.076
α_{11}	100.204	39.537	8.555	2.181	0.078	0.032	0.234	0.112
α_{22}	7 080.69	1 167.38	21.319	10.668	0.667	0.236	0.025	0.016
ψ_{11}					0.0002	0.00009		
ψ_{12}	0.002	0.0006	-0.00005	0.00002	0.00005	0.00001	-0.00003	0.00001
ψ_{21}	-0.016	0.006						
ψ_{22}	-0.059	0.008	-0.00009	0.00004	-0.00005	0.00002	-0.00004	0.00001
α_1	0.846	0.150	0.478	0.016	40.656	11.300	36.868	8.269
α_2	0.048	0.016	0.244	0.009	12.341	4.887	7.615	3.330

Correlation Coefficient of Actual and Fitted Values				
<i>Labour Intensity</i>	0.875	0.866	0.959	0.817
<i>Inter. Input Intensity</i>	0.878	0.837	0.884	0.962
<i>Physical Capital Intensity</i>	0.789	0.751	0.906	0.831
<i>R&D Capital Intensity</i>	0.886	0.862	0.920	0.959

Table A-2 (cont'd)

<i>Parameters</i>	Primary Metals		Rubber and Plastics		Transportation Equipment	
	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>Estimate</i>	<i>Standard Error</i>
β_1	12.578	4.240	0.278	0.115	0.298	0.027
β_2	7.461	3.811	0.036	0.009	0.111	0.036
β_{11}	3.121	0.449	0.139	0.049	0.453	0.022
ϕ_1						
ϕ_2	-0.042	0.010	4.642	1.623	-1.786	0.487
α_{11}	0.020	0.007	11.672	3.189	3.070	1.054
α_{22}	0.199	0.073	23.526	10.325	31.679	13.360
ψ_{11}	0.000 1	0.00003				
ψ_{12}	-0.0003	0.00007	-0.0003	0.00005	0.0001	0.00004
ψ_{21}						
ψ_{22}	-0.0001	0.00002	0.00003	0.00005	-0.0002	0.00008
α_1	16.393	5.429	2.454	1.005	0.687	0.067
α_2	0.045	0.017				
θ_1			0.859	0.247		
θ_2						

Correlation Coefficient of Actual and Fitted Values			
<i>Labour Intensity</i>	0.863	0.868	0.820
<i>Inter. Input Intensity</i>	0.859	0.772	0.962
<i>Physical Capital Intensity</i>	0.829	0.809	0.817
<i>R&D Capital Intensity</i>	0.980	0.904	0.861

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