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PUBLIC INFRASTRUCTURE, INPUT EFFICIENCY AND PRODUCTIVITY
GROWTH: AN APPLIED ANALYSIS

by

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A Thesis Submitted to the Faculty of Graduate Studies and Research
in Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

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Ottawa, Ontario

April 2004

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ABSTRACT

The objectives of the thesis are: (1) to specify and test for input efficiency effects and to quantify these for the Canadian food processing industry; (2) to determine whether the provision of public infrastructure has affected cost and input choice in the industry and, if significant, to determine the magnitude of this effect; and (3) to measure and decompose total factor productivity growth (TFPG) for this industry - efficiency and public infrastructure effects are part of the decomposition.

The approach involves estimation of an input demand system – using data for 1963 to 1997 – that allows for input efficiency and public infrastructure effects. Each demand equation includes the stock of public infrastructure as an explanatory variable so that the effect of public infrastructure on the cost-minimizing level of each input can be both tested for and measured. User costs are estimated as part of the model and these are measured in after-tax terms. Estimated parameters from the demand system are then used to decompose TFPG into its components.

The estimation results show that input efficiency effects in the Canadian food processing industry have been important for all inputs, but largest for capital. Public infrastructure growth has lowered the cost of production in the Canadian food processing industry since the early 1980's. Growth in public infrastructure

has led to increased use of capital and decreased use of labour by food processors. Observed TFPG in the Canadian food processing industry has been cyclical and has trended downwards between the 1960's and the 1990's. The efficiency component of observed TFPG has also been cyclical, with an average close to zero between 1964 and 1996. Increased public infrastructure provision has had a positive effect on TFPG.

ACKNOWLEDGEMENTS

I thank Professor Jeffrey Bernstein, my thesis advisor, for his direction and persistence in helping me undertake and complete this thesis. By challenging me, he has helped me develop a much broader range of skills than I had at the outset, and has ensured that I learned more than just the things that I thought were important.

Also, I thank the other members of my thesis committee – Professors Keir Armstrong and Kathleen Day – and the Ph.D. supervisor, Professor Zhiqi Chen, who helped me develop the thesis during two workshops and in discussions before and after these meetings, and who tested my understanding of a range of issues related to my thesis during the Examination. The questions posed to me by the External Examiner, Professor Michael Denny (University of Toronto), and the Internal Examiner, Professor Roland Thomas (Sprott School of Business), challenged my intuition and led me to clarify several aspects of my thesis; I thank them, too, for their contributions.

The Government of Canada provided financial support for my studies, and my colleagues at the Department of Agriculture gave me encouragement and moral support along the way. I am very grateful for this assistance.

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CHAPTER 1

INTRODUCTION

Infrastructure capital investments made by all levels of government in Canada provide a range of services to both individuals and businesses. Federal, provincial and municipal government investments in public infrastructure currently account for about twelve per cent of all non-residential capital investment in Canada. As Figure 1.1 shows, capital investments made by these three levels of government was exceeded by only two sectors of the economy over the past decade – the mining, oil and gas extraction sector and the manufacturing sector.

Given the substantial amounts that the various levels of government spend when building public infrastructure – together, these expenditures exceeded seventeen billion dollars in 2002 – it is surprising that so little is known about the effect that these investments have on the economic performance of the private sector. One way to measure this economic importance is in terms of the effect of public infrastructure on cost of production and total factor productivity growth for any sector, subsector, or group of firms in the Canadian economy.

Public infrastructure capital can be viewed as an input to the production process in that changes in the level of this input will lead to changes in production techniques, cost of production and output. Since the level of infrastructure is set by government policy, private enterprises will make their production decisions subject to the level of public infrastructure they observe.

Figure 1.1 Share of Non-Residential Capital Investment in the Canadian Economy:
Top Three Sectors, 1993-2002

SOURCE: Statistics Canada, CANSIM II, Table 031-0002
NOTE: government is referred to in the table as Public Administration

Figure 1.2 Share of Shipments in Canadian Manufacturing Sector,
Top Three Producers, 1993-2001

SOURCE: Statistics Canada, CANSIM II, Table 301-0003

In other words, the level of public infrastructure typically affects the production decisions of these enterprises. This dissertation seeks to measure the effect of public infrastructure provision on the input use, cost of production and total factor productivity growth of food processors in Canada.

The food processing industry is one of the most important manufacturing subsectors in Canada.¹ As illustrated in Figure 1.2, the value of total shipments by food processors has been exceeded only by makers of transportation equipment during the past decade. Over the same period, the number of employees working for food processors has exceeded that in any other subsector in manufacturing, with an average share of twelve per cent of all employment in manufacturing (see Figure 1.3).

The food processing industry is therefore a useful case for an analysis of the effect of public infrastructure on private business. As noted earlier, there is little information on the economic importance of public infrastructure in Canada, and so this study will provide new results, albeit for one segment of the manufacturing sector of the Canadian economy. While the analysis breaks little in the way of new ground in terms of theoretical or empirical methods, it does make a contribution to the existing

¹The Canadian food processing industry can be defined in terms of several classifications. Within the North American Industry Classification System (NAICS) it is subsector 311000. Within the 1980 Standard Industrial Classification (1980 SIC) it is group 10 of Division E. In terms of Statistics Canada's KLEMS database (see [2],[1]), it is industry 8 at the 'M' level of aggregation. (The acronym 'KLEMS' comes from the fact that the data are for capital (K), labour (L), energy (E), materials (M) and services (S).inputs.)

Figure 1.3 Share of Employment in Canadian Manufacturing Sector,
Top Three Employers, 1993-2002

SOURCE: Statistics Canada, CANSIM II, Table 281-0024

body of knowledge by applying the various theoretical and measurement tools to a specific case that has not been tested, namely the effect of public infrastructure on input choices, total cost and total factor productivity growth of Canadian food processors

The two theoretical chapters that follow provide a modelling framework for the analysis of the effects of public infrastructure on production in the food processing subsector. Chapter 2 introduces the notion of efficiency-adjusted inputs within an intertemporal framework that minimizes current and expected future acquisition costs, subject to a production function that incorporates public infrastructure and knowledge spillovers. The optimization conditions from this problem lead to the specification for user costs of efficiency-adjusted inputs. Further, elasticities for input demand functions are developed; these elasticities enable measurement of the effects of infrastructure on factor requirements and production cost.

The second theoretical chapter (Chapter 3) extends the results in Chapter 2 by introducing corporate income taxes and local taxes into the analysis. A comprehensive set of tax instruments is incorporated into input acquisition and hiring prices. The intertemporal cost-minimization problem is then re-defined in terms of these after-tax prices, allowing the derivation of after-tax user costs for efficiency-adjusted inputs. These user costs then become the input prices in the cost function that can be used to obtain specifications of the demand functions for efficiency-adjusted inputs. These demand functions are used to estimate the response of food processors to changes in the total stock of public infrastructure.

The data needed to estimate the input demand equations are described in Chapter 4. The database has three parts: (i) raw data; (ii) derived data; and

(iii) the estimation database. The raw data consist of time series needed to construct the after-tax user costs for efficiency-adjusted inputs and time series needed to construct the observed input quantities, public infrastructure and knowledge spillovers. The raw data underlying the after-tax user costs include tax time series for corporate income tax rates, capital cost allowances, investment tax credits, local property taxes and local business taxes. The raw series are then used to compute aggregates or to make other derivations that put the various raw series in a form that is usable in the estimation framework. These derived data are then combined with the relevant raw data series to create an annual time-series estimation database that covers the years 1963-1996.

The empirical version of the model is developed in Chapter 5, where the functional form, econometric specification and econometric results are presented. Estimates of the efficiency parameters, elasticities of demand for efficiency-adjusted inputs and elasticities with respect to input prices, output, public infrastructure and spillovers are also presented here.

The relationship between the cost function specified in Chapter 3 and total factor productivity growth (TFPG) is derived in Chapter 6, which also provides a link between the estimated elasticities from Chapter 5 and the decomposition of TFPG into scale, public infrastructure and spillover components. In this way, the importance of public infrastructure as a determinant of TFPG is quantified. The last chapter provides a conclusion that summarizes the results from each of Chapters 2-6, and discusses the overall outcome of the analysis.

CHAPTER 2

BASIC THEORETICAL MODEL

2.1 INTRODUCTION

Efficiency gains in production arise when new inputs generate an improvement in technical efficiency that is not fully offset by costs of adjustment. The framework outlined here largely follows that developed in [7], where efficiency gains are captured using input-specific parameters, while taking the interaction of all inputs into account. In so doing, this approach does not restrict the set of inputs that are subject to changes in technical efficiency.

2.2 THE PRODUCTION FUNCTION AND INPUT EFFICIENCY

Suppose a production function F in year t can be written in the following manner:¹

$$y_t = F(z_{1t}, z_{2t}, \dots, z_{Nt}, G_t, S_t, t), \quad (2.1)$$

where: y_t is the quantity of output produced in year t ; z_{it} is the efficiency-adjusted quantity of input i used in year t ; G_t is a $1 \times L$ vector of public infrastructure stocks in place in year t (with each element representing one of L types of public infrastructure); and S_t is a $1 \times M$ vector of knowledge spillovers in year t .² The

¹The production function $F : \mathbb{R}_+^{N+L+M+1} \rightarrow \mathbb{R}_+$ is assumed to be continuous, increasing and quasi-concave in input quantities.

²Each element of the vector S_t might be the R&D capital for an industry other than the one under consideration (see, for example, [5, pp. 316-317]).

variable t , in addition to indexing the year of observation, also captures exogenous disembodied technical change.

Net investment in input i involves two components. The first component, x_{it} , represents the quantity of gross investment in the i^{th} input observed in year t , while the second component, $\delta_i v_{it-1}$, represents replacement investment – the amount needed to just replace the amount of old input that depreciates between the previous and the current year. The coefficient, δ_i , is the geometric decay rate for the i^{th} input, with $0 \leq \delta_i \leq 1$ and v_{it-1} is the observed stock of input i in year $t - 1$. When $\delta_i = 1$, the i^{th} input is non-durable and when $0 \leq \delta_i < 1$, the i^{th} input is durable. Net investment, then, is $x_{it} - \delta_i v_{it-1}$, and the observed stock of input i in year t is provided by:

$$v_{it} = v_{it-1} + (x_{it} - \delta_i v_{it-1}) \quad , \quad i = 1, 2, \dots, N . \quad (2.2)$$

(See Appendix A for details on the underlying relationship between the current stock and an infinite stream of past investments.)

In this analysis, the approach to input efficiency allows for the possibility that the marginal product of new inputs may be higher or lower than that of old inputs. Any change in input levels (i.e. over and above replacements) will involve the introduction of new inputs to the production process. While the technical efficiency of new inputs may exceed that of old ones, adjustment costs can offset positive efficiency effects. Efficiency adjustment is accommodated by the following equation:

$$z_{it} = v_{it-1} + h_i(x_{it} - \delta_i v_{it-1}) \quad , \quad i = 1, 2, \dots, N , \quad (2.3)$$

where: h_i is the efficiency adjustment parameter for input i . Notice that the difference between v_{it} – as defined by (2.2) – and z_{it} – as defined by (2.3) – is in the treatment of net investment, which is weighted here by h_i .³

The value of h_i can lie in one of three possible ranges, each with different implications for efficiency effects:

- (i) $h_i > 1$. In this case, the marginal product of net additions of input i in the current year exceeds that of existing units of the input (i.e. those that comprise the quantity used in the previous year); more specifically, the higher technical efficiency of net additions outweighs the adjustment costs of introducing these net input additions to the production process.
- (ii) $0 < h_i < 1$. In this case, the marginal product of net additions of input i in the current year is lower than that of existing units of the input; even if the technical efficiency of a net addition of the input is higher than that of existing units, it is insufficient to offset costs of adjustment.
- (iii) $h_i = 1$. This is the case where the marginal product of net additions of input i in the current year is the same as that of existing units; this equivalence

³Efficiency-adjusted inputs could also be defined in this model by making an adjustment to gross additions instead of net additions, i.e. by using the equation

$$z_{it} = h_i x_{it} + (1 - \delta_i) v_{it-1}$$

(where x_{it} is gross additions) instead of equation (2.3). For capital, data are available for x_{it} – this is investment. But for other inputs, equivalent ‘investment’ data are rarely available. Labour data, for example, are usually reported at the industry level as total employment, i.e. only v_{it} and v_{it-1} are observed. Thus, there is a good practical reason to use net additions rather than gross additions. It is likely, moreover, that even if data were available for the gross adjustment model that it would yield similar results to the net adjustment model. The two methods, when applied in an adjustment cost context has led to results for capital that are “substantially the same” [33, p. 1072].

may be due to the increased technical efficiency of net additions being just offset by costs of adjustment.⁴

Note that h_i is strictly positive – a negative value for h_i would mean that a marginal increase in net investment would lead to a marginally lower efficiency-adjusted level for that input, and thereby a marginally lower amount of output.

2.3 COST MINIMIZATION

2.3.1 OPTIMIZATION

Suppose that optimal levels of efficiency-adjusted inputs are determined by minimizing the expected present value of an infinite future stream of input requirements subject to:

- (i) a technology constraint – expression (2.1);
- (ii) an accumulation relationship for each input – expression (2.2); and
- (iii) a relationship between the efficiency-adjusted and observed quantity – expression (2.3), i.e.

⁴Efficiency adjustments apply just as well to non-durable inputs (where $\delta_i = 1$), i.e. the marginal product of replacements in a workforce (up to the amount needed to keep the workforce at its existing level) will differ from the marginal product of labour that is added to the workforce. This might come about because, for example, the added labour is allocated to new machinery purchased to accomodate the expansion in employment.

$$\min_{\{x_{1t+\tau}, \dots, x_{Nt+\tau}\}_{\tau=0}^{\infty}} E_t \left\{ \sum_{\tau=0}^{\infty} (1 + \rho_{t+\tau})^{-\tau} \left(\sum_{i=1}^N q_{it+\tau} x_{it+\tau} \right) \right\}, \quad (2.4)$$

subject to: (i) $y_{t+\tau} = F(z_{1t+\tau}, z_{2t+\tau}, \dots, z_{Nt+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) \quad \forall t, \tau$;

(ii) $v_{it+\tau} = x_{it+\tau} + (1 - \delta_i)v_{it+\tau-1} \quad \forall t, \tau, i = 1, 2, \dots, N$; and

(iii) $z_{it+\tau} = h_i(x_{it+\tau} - \delta_i v_{it+\tau-1}) + v_{it+\tau-1} \quad \forall t, \tau, i = 1, 2, \dots, N$,

where: E_t denotes an expectation based on information available in year t ; $\rho_{t+\tau}$ is the discount rate in year $t + \tau$; and $q_{it+\tau}$ is the acquisition or hiring price for the i^{th} input for year $t + \tau$.⁵ Producers form expectations of the acquisition and hiring prices; assume, as is customary, that there are static expectations regarding the discount rate, i.e. assume that $E_t(\rho_{t+\tau}) = \rho_t \quad \forall \tau$.⁶

Next, rearrange constraint (ii) to isolate $x_{it+\tau}$ and substitute this expression for $x_{it+\tau}$ in the objective function and constraint (iii); then substitute the revised constraint (iii) into constraint (i) to replace each z_i . With these changes, the Lagrangian for the revised optimization problem – which now solves for the optimal levels of $v_{1t+\tau}, v_{2t+\tau}, \dots, v_{Nt+\tau} \forall \tau$ – is:

⁵The intertemporal constrained minimization problem (2.4) is assumed to be the optimization framework used by processors to derive a production plan – that is, the cost-minimizing level of inputs for the current year and each year in the future (i.e. for $t, t + 1, \dots$) that will be used to produce the amount of output that has been specified for each of these years (i.e. $y_t, y_{t+1}, \dots$). This production plan, which is based on information available to processors in year t , will be optimal until $t + 1$, when new information comes along. At that time, processors will want to solve for a new production plan, this being now for years $t + 1, t + 2, \dots$. As a result, there will actually be ‘ τ ’ plans formed for any year $t + \tau$, the first being formed in year t , the next in another in year $t + 1$, etc. Since plans made in year t for any future year will always be dominated by (i.e. be more costly than) plans made after t for that same future year (unless no new information develops) the only part of the production plan formed in year t that is of interest is the set of inputs $\{x_{1t+0}, \dots, x_{Nt+0}\}$.

⁶Chapter 3, Appendix C, provides detail regarding the discount rate and its relationship to the weighted-average cost of capital arising from the financial decisions made by processors.

$$\mathcal{L} = \sum_{\tau=0}^{\infty} (1 + \rho_t)^{-\tau} \left[\sum_{i=1}^N q_{it+\tau}^e (v_{it+\tau} - (1 - \delta_i)v_{it+\tau-1}) + \lambda_{t+\tau} \left(y_{t+\tau} - F \left(\begin{matrix} \cdot \\ t + \tau \end{matrix} \right) \right) \right], \quad (2.5)$$

where: $q_{it+\tau}^e = E_t(q_{it+\tau})$; $q_{it}^e = q_{it}$; $\lambda_{t+\tau}$ is the Lagrangian multiplier in year $t + \tau$; and $F \left(\begin{matrix} \cdot \\ t + \tau \end{matrix} \right)$ denotes:

$$F \left(h_1(v_{1t+\tau} - \mu_1 v_{1t+\tau-1}), \dots, h_N(v_{Nt+\tau} - \mu_N v_{Nt+\tau-1}), G_{t+\tau}, S_{t+\tau}, t + \tau \right)$$

where $\mu_i = 1 - 1/h_i \forall i$.

The first-order condition for each input i in year $t + \tau$ is:

$$\begin{aligned} (1 + \rho_t)^{-\tau} q_{it+\tau}^e - (1 + \rho_t)^{-\tau} \lambda_{t+\tau} (\partial F \left(\begin{matrix} \cdot \\ t + \tau \end{matrix} \right) / \partial z_{it+\tau}) h_i \\ - (1 + \rho_t)^{-(\tau+1)} q_{it+\tau+1}^e (1 - \delta_i) \\ - (1 + \rho_t)^{-(\tau+1)} \lambda_{t+\tau+1} (\partial F \left(\begin{matrix} \cdot \\ t + \tau + 1 \end{matrix} \right) / \partial z_{it+\tau+1}) (-h_i \mu_i) = 0, \\ \tau = 1, 2 \dots; i = 1, 2 \dots N. \end{aligned} \quad (2.6)$$

Let

$$w_{it+\tau}^e = q_{it+\tau}^e - d_i a_t q_{it+\tau+1}^e, \quad \tau = 1, 2 \dots; i = 1, 2 \dots N, \quad (2.7)$$

where: $d_i = (1 - \delta_i)$ and $a_t = 1/(1 + \rho_t)$. Multiply (2.6) by $(1 + \rho_t)^\tau$, substitute (2.7) into the resulting expression and rearrange to get:

$$\begin{aligned}
h_i \lambda_{t+\tau} \partial F \left(\begin{array}{c} \cdot \\ t + \tau \end{array} \right) / \partial z_{it+\tau} &= w_{it+\tau}^e \\
&+ a_t \mu_i \left[h_i \lambda_{t+\tau+1} \partial F \left(\begin{array}{c} \cdot \\ t + \tau + 1 \end{array} \right) / \partial z_{it+\tau+1} \right] , \\
\tau &= 1, 2, \dots ; i = 1, 2, \dots, N.
\end{aligned} \tag{2.6'}$$

Successive substitutions on the right-hand side of (2.6') generate, for each year up to $T_M > t$:⁷

$$\begin{aligned}
h_i \lambda_{t+\tau} \partial F \left(\begin{array}{c} \cdot \\ t + \tau \end{array} \right) / \partial z_{it+\tau} &= w_{it+\tau}^e + \sum_{v=1}^{T_M-1} (a_t \mu_i)^v w_{it+\tau+v}^e \\
&+ (a_t \mu_i)^{T_M} \left[h_i \lambda_{t+\tau+T_M} \partial F \left(\begin{array}{c} \cdot \\ t + \tau + T_M \end{array} \right) / \partial z_{it+\tau+T_M} \right] , \\
\tau &= 0, 1, 2, \dots ; i = 1, 2, \dots, N.
\end{aligned} \tag{2.8}$$

Provided that, for each τ and for each input i , the term

$$h_i \lambda_{t+\tau+T_M} \partial F \left(\begin{array}{c} \cdot \\ t + \tau + T_M \end{array} \right) / \partial z_{it+\tau+T_M}$$

is finite $\forall T_M$ – this is ensured by quasi-concavity of F – and, providing that $|a_t \mu_i| < 1$,⁸ the following limit condition (the transversality condition) exists:

⁷Use (2.6') to derive an expression for $h_i \lambda_{t+\tau+1} \partial F \left(\begin{array}{c} \cdot \\ t+\tau+1 \end{array} \right) / \partial z_{it+\tau+1}$ in terms of $w_{it+\tau+1}^e$ and $h_i \lambda_{t+\tau+2} \partial F \left(\begin{array}{c} \cdot \\ t+\tau+2 \end{array} \right) / \partial z_{it+\tau+2}$. Then substitute this into (2.6') and expand. Next use (2.6') to derive an expression for $h_i \lambda_{t+\tau+2} \partial F \left(\begin{array}{c} \cdot \\ t+\tau+2 \end{array} \right) / \partial z_{it+\tau+2}$ in terms of $w_{it+\tau+2}^e$ and $h_i \lambda_{t+\tau+3} \partial F \left(\begin{array}{c} \cdot \\ t+\tau+3 \end{array} \right) / \partial z_{it+\tau+3}$ and so-on.

⁸Note that to ensure that the marginal product is non-negative in all years, it must be that $h_i > 0 \forall i$ – see (2.8). Also, since negative real rates of return are ruled out, $a_t > 0$. These preliminaries lead to a pair of cases for $|a_t \mu_i|$:

$$\lim_{T_M \rightarrow \infty} (a_t \mu_i)^{T_M} \left[h_i \lambda_{t+\tau+T_M} \partial F \left(\frac{\cdot}{t+\tau+T_M} \right) / \partial z_{it+\tau+T_M} \right] = 0.$$

Then, in the limit (2.8) reduces to:

$$\lambda_{t+\tau} \partial F \left(\frac{\cdot}{t+\tau} \right) / \partial z_{it+\tau} = (1/h_i) \left(w_{it+\tau}^e + \sum_{v=1}^{\infty} (a_t \mu_i)^v w_{it+\tau+v}^e \right) , \quad (2.9)$$

$$\tau = 0, 1, 2, \dots ; i = 1, 2, \dots, N.$$

This equation shows that the value of the marginal product at the cost-minimizing level of the efficiency-adjusted input i – the left-hand side of (2.9) – equals the discounted expected marginal cost of holding the input at that level in perpetuity – the right-hand side of (2.9).

The right-hand side of (2.9) is referred to as the user cost of efficiency-adjusted input i ; in particular, this user cost in year $t + \tau$ is denoted by the variable:

$$\omega_{it+\tau} = (1/h_i) \left(w_{it+\tau}^e + \sum_{v=1}^{\infty} (a_t \mu_i)^v w_{it+\tau+v}^e \right) , \quad (2.9')$$

$$\tau = 0, 1, 2, \dots ; i = 1, 2, \dots, N.$$

(a) When $\mu_i \geq 0$ ($h_i \geq 1$), the condition $a_t \mu_i < 1$ requires that

$$h_i > -1/\rho_t ,$$

which is always met since ρ_t is always > 0 .

(b) When $\mu_i < 0$ ($0 < h_i < 1$) the condition $a_t \mu_i > -1$ requires that

$$h_i > 1/(2 + \rho_t) .$$

As a result, the only restriction on h_i is that it exceed $1/(2 + \rho_t)$. For a discount rate of 3%, this means that h_i must be greater than 0.49 $\forall i$.

The derivations to this point are useful in the sense that they define the user cost of each input in terms of expected acquisition prices, the efficiency parameter and the decay rate for that input. These user costs affect factor requirements – a straightforward way to see this is with the cost function. To derive the cost function, consider the following minimization problem for processors in year t

$$\min_{z_{1t}, z_{2t}, \dots, z_{Nt}} \left\{ \sum_{i=1}^N \omega_{it} z_{it} \mid y_t = F(z_{1t}, z_{2t}, \dots, z_{Nt}, G_t, S_t, t) \right\}. \quad (2.10)$$

The Lagrangian for (2.10) is

$$\mathcal{L}_z = \sum_{i=1}^N \omega_{it} z_{it} - \lambda_{zt} [y_t - F(z_{1t}, z_{2t}, \dots, z_{Nt}, G_t, S_t, t)]$$

with first-order conditions

$$\omega_{it} = \lambda_{zt} \partial F \left(\cdot \right) / \partial z_{it} \quad , \quad i = 1, 2, \dots, N. \quad (2.11)$$

Substitute for ω_{it} in (2.11) using (2.9') and rearrange to get:

$$\lambda_{zt} \partial F \left(\cdot \right) / \partial z_{it} = (1/h_i) \left(w_{it+\tau}^e + \sum_{v=1}^{\infty} (a_t \mu_i)^v w_{it+\tau+v}^e \right). \quad (2.11')$$

Since $\lambda_{zt} = \lambda_t$ – compare (2.9) and (2.11') – the two problems give the same first-order conditions and therefore the same level of optimal demands for each efficiency-adjusted input. Since a cost function can be used to represent all relevant aspects of the production technology, the analysis that follows will use this function to derive all of the information needed.

A cost function is defined for all $\omega_{it+\tau}, y_{t+\tau}, G_{t+\tau}, S_{t+\tau}$ and $t + \tau$ as⁹

⁹Note that, given the properties of the production function F assumed earlier, the cost function $C : \mathbb{R}_+^{N+L+M+2} \rightarrow \mathbb{R}_+$ will fulfill several properties required for duality between F and C [15, Theorem 1, p. 553; p.537]. The cost function can then be used to completely describe the production technology.

$$\begin{aligned}
C(\omega_{1t+\tau}, \omega_{2t+\tau}, \dots, \omega_{Nt+\tau}, y_{t+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) \equiv \\
\min_{z_{1t+\tau}, z_{2t+\tau}, \dots, z_{Nt+\tau}} \left\{ \sum_{i=1}^N \omega_{it+\tau} z_{it+\tau} \mid \right. \\
\left. F(z_{1t+\tau}, z_{2t+\tau}, \dots, z_{Nt+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) \geq y_{t+\tau} \right\} \quad , \quad \tau = 0, 1, 2, \dots
\end{aligned} \tag{2.12}$$

Application of Shephard's Lemma [15, p. 555] to (2.12) gives the optimal efficiency-adjusted demand functions:

$$\begin{aligned}
z_{it+\tau}^* &= Z_i(\omega_{1t+\tau}, \dots, \omega_{Nt+\tau}, y_{t+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) \\
&= \partial C(\omega_{1t+\tau}, \omega_{2t+\tau}, \dots, \omega_{Nt+\tau}, y_{t+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) / \partial \omega_{it+\tau} \\
&\quad \tau = 0, 1, 2, \dots; i = 1, 2, \dots, N.
\end{aligned} \tag{2.13}$$

Note that, while (2.13) allows a derivation of the optimal efficiency-adjusted input levels planned by producers in year t for years $t, t + 1, t + 2, t + 3, \dots$, as previously noted, the only levels of interest are those planned for year t . Thus, the only set of input demand functions germane to this analysis is that where $\tau = 0$ in (2.13), i.e.

$$\begin{aligned}
z_{it}^* &= Z_i(\omega_{1t}, \dots, \omega_{Nt}, y_t, G_t, S_t, t) \\
&= \partial C(\omega_{1t}, \omega_{2t}, \dots, \omega_{Nt}, y_t, G_t, S_t, t) / \partial \omega_{it} \quad , \quad i = 1, 2, \dots, N.
\end{aligned} \tag{2.13'}$$

Although z_{it}^* is unobservable, it is possible to relate this to v_{it} . Assuming that the efficiency-adjusted levels are cost-minimizing (i.e. $z_{it} = z_{it}^* \forall i, t$), combine constraints (ii) and (iii) as in (2.5), and use (2.13') to obtain:

$$v_{it} = (1/h_i) Z_i \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) + \mu_i v_{it-1} \quad , \quad i = 1, 2, \dots, N. \quad (2.14)$$

where: $Z_i \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right)$ is the demand function defined by (2.13'). This expresses the current level of observed input i as a weighted average of the optimal level of efficiency-adjusted input – captured by the function $Z_i \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right)$ – and the observed input quantity from the previous year.

2.3.2 PRICE EXPECTATIONS AND USER COSTS FOR EFFICIENCY-ADJUSTED INPUTS

Price expectations play an important role in the optimization framework outlined above; this subsection provides details regarding the data generating process used to define the expected acquisition or hiring prices $q_{it+\tau}^e$ and the implications for user costs. Producers are assumed to know this data generating process and to use it when forming expectations about future acquisition or hiring prices of inputs.

Suppose that processors make expectations of the acquisition or hiring prices based on a first-order autoregressive process, which at time t ($\tau = 0$) is specified as:

$$q_{it+1}^e = \phi_i + \theta_i q_{it} \quad , \quad i = 1, 2, \dots, N, \quad (2.15)$$

where: q_{it+1}^e denotes $E_t(q_{it+1})$, and ϕ_i, θ_i are parameters that are known to the processors, but are unknown to the analyst and therefore must be measured in

the estimation stage. The expected realized error is zero;

$$E_t(e_{it+1}) = E_t(q_{it+1} - q_{it+1}^e) = 0 .$$

To determine the expected acquisition price in year $t + \tau$, note that

$$q_{it+2}^e = \phi_i + \theta_i q_{it+1}^e$$

where q_{it+2}^e denotes $E_t(q_{it+2})$, and substitute this into (2.15). Make substitutions in this manner successively for each year forward to obtain the following expression for the expected (in year t) acquisition or hiring price for year $t + \tau$:

$$q_{it+\tau}^e = \phi_i(1 - \theta_i^\tau)/(1 - \theta_i) + \theta_i^\tau q_{it} \quad (2.16)$$

$$\tau = 1, 2, \dots; i = 1, 2, \dots, N ,$$

where $q_{it+\tau}^e$ denotes $E_t(q_{it+\tau})$ – as is clear from this expression, it is necessary that $\theta_i \neq 1$ for each input i ; however, no other condition needs to be placed on either the sign or magnitude of ϕ_i or θ_i .¹⁰

¹⁰The successive substitutions with (2.15) lead to the following expression:

$$q_{it+\tau}^e = \phi_i \sum_{v=0}^{\tau-1} \theta_i^v + \theta_i^\tau q_{it} . \quad (i)$$

Since the sum $\sum_{v=0}^{\tau-1} \theta_i^v$ has the solution $(1 - \theta_i^\tau)/(1 - \theta_i)$ when $\theta_i \neq 1 \forall i$ [12, p. 26], (i) can be expressed as (2.16) in this case. Note that no restriction on θ_i at all is needed if $\phi_i = 0$ in the expectations process (2.15), since in this case, the process takes the simpler form

$$q_{it+1}^e = \theta_i q_{it} , \quad i = 1, 2, \dots, N . \quad (ii)$$

Successive substitutions with (ii) mean that (i) and (2.16) simplify to

$$q_{it+\tau}^e = \theta_i^\tau q_{it} . \quad (iii)$$

Use of (2.7) and (2.16) allows a substitution for $w_{it+\tau+v}^e$ in (2.9') to give:

$$\begin{aligned} \omega_{it+\tau} = (1/h_i) & \left\{ [\phi_i/(1-\theta_i)] [(1-\theta_i^\tau) - d_i a_t (1-\theta_i^{\tau+1})] \right. \\ & + [\phi_i/(1-\theta_i)] \sum_{v=1}^{\infty} (a_t \mu_i)^v [(1-\theta_i^{\tau+v}) - d_i a_t (1-\theta_i^{\tau+v+1})] \\ & \left. + [\theta_i^\tau - d_i a_t \theta_i^{\tau+1}] q_{it} + \sum_{v=1}^{\infty} (a_t \mu_i)^v [\theta_i^{\tau+v} - d_i a_t \theta_i^{\tau+v+1}] q_{it} \right\} , \\ & \tau = 0, 1, 2, \dots ; \quad i = 1, 2, \dots, N . \end{aligned} \quad (2.17)$$

Collection of terms in (2.17) leads to:

$$\begin{aligned} \omega_{it+\tau} = (1/h_i) & \left\{ [\phi_i/(1-\theta_i)] [(1-d_i a_t) - \theta_i^\tau (1-d_i a_t \theta_i)] \right. \\ & + (1-d_i a_t) \sum_{v=0}^{\infty} (a_t \mu_i)^v - \theta_i^\tau (1-d_i a_t \theta_i) \sum_{v=1}^{\infty} (a_t \mu_i \theta_i)^v \\ & \left. + [\theta_i^\tau (1-d_i a_t \theta_i)] \left[1 + \sum_{v=1}^{\infty} (a_t \mu_i \theta_i)^v \right] q_{it} \right\} , \\ & \tau = 0, 1, 2, \dots ; \quad i = 1, 2, \dots, N . \end{aligned} \quad (2.18)$$

Equation (2.18) contains two geometric series:

(a) $\sum_{v=1}^{\infty} (a_t \mu_i)^v$, which has the solution $a_t \mu_i / (1 - a_t \mu_i)$ – providing $|a_t \mu_i| < 1 \forall i$;

and

(b) $\sum_{v=1}^{\infty} (a_t \mu_i \theta_i)^v$, which has the solution $a_t \mu_i \theta_i / (1 - a_t \mu_i \theta_i)$ – providing $|a_t \mu_i \theta_i| < 1 \forall i$.¹¹

¹¹Solution (a) is ensured when $|a \mu_i| < 1$, the necessary condition for which, as noted earlier, is that $h_i > 1/(2 + \rho)$. On the other hand, for solution (b), only sufficient

With solutions (a) and (b), (2.18) simplifies to:

$$\omega_{it+\tau} = (1/h_i)[\phi_i/(1-\theta_i)] \{ (1-d_i a_t)/(1-a_t \mu_i) - \theta_i^\tau (1-d_i a_t \theta_i)/(1-a_t \mu_i \theta_i) \} \quad (2.18')$$

$$+ (1/h_i) [\theta_i^\tau (1-d_i a_t \theta_i)/(1-a_t \mu_i \theta_i)] q_{it}$$

$$\tau = 0, 1, 2, \dots; i = 1, 2, \dots, N.$$

Since, for estimation purposes, the only year of interest is year t (i.e. for $\tau = 0$), the user cost for efficiency-adjusted inputs can be further simplified and expressed in more compact notation as:¹²

$$\omega_{it} = \Theta_{0it} + \Theta_{1it} q_{it}, \quad i = 1, 2, \dots, N, \quad (2.19)$$

where:

$$\Theta_{0it} = (1/h_i)[\phi_i/(1-\theta_i)] \{ (1-d_i a_t)/(1-a_t \mu_i) - (1-d_i a_t \theta_i)/(1-a_t \mu_i \theta_i) \}$$

and

$$\Theta_{1it} = (1/h_i) (1-d_i a_t \theta_i)/(1-a_t \mu_i \theta_i).$$

Notice that Θ_{0it} and Θ_{1it} are not fixed parameters, but vary over time due to that fact that the discount rate used to determine the minimum expected acquisition and hiring cost of the production plan also varies over time.

conditions on the components of the product $a_t \mu_i \theta_i$ can be established, namely (i) that $h_i > 1/(2 + \rho)$ and (ii) that $|\theta_i| < 1$.

Note that the geometric series $\sum_{t=0}^{\infty} m^t$, where $m \in \mathbb{R}$, has the solution $1/(1-m)$ if $|m| < 1$ [12, p. 52, Theorem 2]. The solution to the same series with the first element ($m^0 = 1$) removed, i.e. $\sum_{t=1}^{\infty} m^t$ is therefore $[1/(1-m)] - 1 = m/(1-m)$.

¹²Note that, in the case of expectations where $\phi_i = 0 \forall i$, $\Theta_{0it} = 0 \forall i$ and $\forall t$, and (2.19) reduces to $\omega_{it} = \Theta_{1it} q_{it}$.

Unlike traditional user costs, ω_{it} as defined by equation (2.19) cannot be evaluated prior to estimation since values for the parameters μ_i, ϕ_i and θ_i cannot be observed. This aspect of the model is addressed in the estimation chapter.

2.4 ELASTICITIES

2.4.1 INTRODUCTION

Elasticities of input demand and production cost with respect to input prices, output quantity, infrastructure stocks, knowledge spillovers and disembodied technical change are important elements when analyzing the effects of changes in market conditions and government policies on producers.

This section presents the elasticities of efficiency-adjusted and observed input demands for each input i with respect to:

- own and cross user costs of efficiency-adjusted inputs (ω_i, ω_j) , and acquisition or hiring prices (q_i, q_j) ;
- output quantity (y) ;
- infrastructure capital (G) ;
- knowledge spillovers (S) ; and
- disembodied technical change (t) .

2.4.2 PRICE ELASTICITIES OF DEMAND FOR EFFICIENCY-ADJUSTED INPUTS

ELASTICITIES WITH RESPECT TO USER COSTS

The elasticity of demand for efficiency-adjusted input i with respect to the user cost of this input, ω_{it} , evaluated in year t , is:

$$\epsilon_{iit}^{z\omega} = \left[\partial Z_i \left(\cdot \right) / \partial \omega_{it} \right] (\omega_{it}/z_{it}^*) , \quad i = 1, 2, \dots, N. \quad (2.20a)$$

where: $Z_i \left(\cdot \right)$ is the demand function defined by (2.13') and z_{it}^* is the value of this function (i.e. the optimal demand) in year t .

Similarly, the elasticity of demand for efficiency-adjusted input i with respect to the user cost of input j , ω_{jt} ($j \neq i$), and evaluated in year t , is:

$$\epsilon_{ijt}^{z\omega} = \left[\partial Z_i \left(\cdot \right) / \partial \omega_{jt} \right] (\omega_{jt}/z_{it}^*) , \quad i, j = 1, 2, \dots, N ; j \neq i. \quad (2.20b)$$

ELASTICITIES WITH RESPECT TO ACQUISITION OR HIRING PRICES

To determine the elasticity of demand for efficiency-adjusted input i with respect to the acquisition or hiring price for that input, q_{it} , note that by (2.19), $\partial \omega_{it} / \partial q_{it} = \Theta_{1it}$. This result allows a definition of this elasticity in year t , as:

$$\begin{aligned} \epsilon_{iit}^{zq} &= \left[\partial Z_i \left(\cdot \right) / \partial \omega_{it} \right] (\partial \omega_{it} / \partial q_{it}) (q_{it}/z_{it}^*) \\ &= \epsilon_{iit}^{z\omega} (q_{it}/\omega_{it}) \Theta_{1it} , \quad i = 1, 2, \dots, N. \end{aligned} \quad (2.21a)$$

Using the same reasoning, the elasticity of demand for efficiency-adjusted input i with respect to the acquisition or hiring of input j , q_{jt} ($j \neq i$), in year t , is:

$$\epsilon_{ijt}^{zq} = \epsilon_{ijt}^{z\omega} (q_{jt}/\omega_{jt}) \Theta_{1jt} , \quad i, j = 1, 2, \dots, N ; j \neq i. \quad (2.21b)$$

2.4.3 SHORT-RUN PRICE ELASTICITIES OF DEMAND FOR OBSERVED INPUTS

Since (2.14) is in fact a first-order difference equation, v_{it} is not necessarily in a stationary state. Therefore, elasticity derivations need to distinguish between levels of v_i in the short run, where $v_{it} \neq v_{it-1}$, and the level v_i in the long run; in the latter case, v_i is in a stationary state, i.e. $v_{it} = v_{it-1} = V_i$ (where V_i is the long-run level of v_i).¹³

SHORT-RUN PRICE ELASTICITIES OF OBSERVED INPUTS WITH RESPECT TO USER COSTS OF EFFICIENCY-ADJUSTED INPUTS

The short-run elasticity of observed demand for input i with respect to the user cost of this input, ω_{it} , is, using (2.14) and (2.20a):

$$\begin{aligned}\epsilon_{iit}^{v\omega} &= (1/h_i) \left[\partial Z_i \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial \omega_{it} \right] (\omega_{it}/v_{it}) \\ &= \epsilon_{iit}^{z\omega} [z_{it}^*/(h_i v_{it})], \quad i = 1, 2, \dots, N.\end{aligned}\tag{2.22a}$$

Similarly, the short-run elasticity of observed demand for input i with respect to the user cost of input j , ω_{jt} , now using (2.14) and (2.20b), is:

$$\begin{aligned}\epsilon_{ijt}^{v\omega} &= (1/h_i) \left[\partial Z_i \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial \omega_{jt} \right] (\omega_{jt}/v_{it}) \\ &= \epsilon_{ijt}^{z\omega} [z_{it}^*/(h_i v_{it})], \quad i = 1, 2, \dots, N.\end{aligned}\tag{2.22b}$$

¹³This analysis does not look at the reasons why a stationary state might come about for v_i . There are many different possible ingredients that could lead to such a stationary state, among them: stationary states for all input acquisition prices that come about from long-run equilibria in factor markets; the same constant rate of growth for all acquisition prices; and changes in non-price variables that fully offset price changes in their effects on observed input demands.

SHORT-RUN PRICE ELASTICITIES OF OBSERVED INPUTS WITH RESPECT TO ACQUISITION OR HIRING COSTS

As established earlier, the link between elasticities with respect to efficiency-adjusted user costs and those to acquisition or hiring prices is through (2.19), and the result that $\partial\omega_{it}/\partial q_{it} = \Theta_{1it}$. Accordingly, the short-run elasticity of observed input demand to acquisition or hiring prices – using (2.14) and (2.19) – is

$$\begin{aligned}\epsilon_{iit}^{vq} &= (1/h_i) \left[\partial Z_i \left(\cdot \right) / \partial \omega_{it} \right] (\partial \omega_{it} / \partial q_{it}) (q_{it} / v_{it}) \\ &= \epsilon_{iit}^{v\omega} (q_{it} / \omega_{it}) \Theta_{1it} \quad , \quad i = 1, 2, \dots, N,\end{aligned}\tag{2.23a}$$

and the cross-price elasticity is:

$$\begin{aligned}\epsilon_{ijt}^{vq} &= (1/h_i) \left[\partial Z_i \left(\cdot \right) / \partial \omega_{jt} \right] (\partial \omega_{jt} / \partial q_{jt}) (q_{jt} / v_{it}) \\ &= \epsilon_{iit}^{v\omega} (q_{jt} / \omega_{jt}) \Theta_{1jt} \quad , \quad i = 1, 2, \dots, N.\end{aligned}\tag{2.23}$$

2.4.4 LONG-RUN PRICE ELASTICITIES OF DEMAND FOR OBSERVED INPUTS

Up to this point, the derivations for observed demands have captured short-run effects. In the long run, the level of input i is V_i , and so (2.14) reduces to:

$$V_i = (1/h_i) Z_i(\cdot) + \mu_i V_i \quad , \quad i = 1, 2, \dots, N,\tag{2.14s}$$

where $Z_i(\cdot)$ is the demand function for efficiency-adjusted input.

Expression (2.14s) simplifies to:

$$V_i = Z_i(\cdot) \quad , \quad i = 1, 2, \dots, N,\tag{2.14s'}$$

i.e., the long-run value of input i is merely that for the efficiency-adjusted input in the year where a stationary state is reached, and so the long-run elasticities of observed input demand are the same as those for efficiency-adjusted inputs. One way to interpret this result is that adjustment for efficiency effects is only necessary in the short run, since in the long run, observed inputs will be the same as efficiency-adjusted ones. In the transition to the long run, then, the marginal product of net input additions and the marginal product of existing inputs must converge, so that in the long run the two marginal products are the same.

2.4.5 ELASTICITIES OF EFFICIENCY-ADJUSTED INPUT DEMAND TO NON-PRICE VARIABLES

The following derivations are with respect to (2.13'). In particular, the elasticity of demand for efficiency-adjusted input i with respect to output quantity is defined as:

$$\epsilon_{it}^{zy} = \left[\partial Z_i \left(\frac{\cdot}{t} \right) / \partial y_t \right] (y_t / z_{it}^*) \quad , \quad i = 1, 2, \dots, N. \quad (2.24)$$

Since there are L types of infrastructure, each input will have L elasticities with respect to infrastructure. The elasticity of efficiency-adjusted input i with respect to a change in the stock of the k^{th} type of infrastructure is:

$$\epsilon_{it}^{zGk} = \left[\partial Z_i \left(\frac{\cdot}{t} \right) / \partial G_{kt} \right] (G_{kt} / z_{it}^*) \quad , \quad k = 1, 2, \dots, L ; \quad i = 1, 2, \dots, N. \quad (2.25)$$

Similarly, since there are M sources of knowledge spillovers, each input will have M elasticities with respect to spillovers. The elasticity of efficiency-adjusted input i with respect to a change in the r^{th} spillover is:

$$\epsilon_{it}^{zS_r} = \left[\partial Z_i \left(\cdot \right) / \partial S_{rt} \right] (S_{rt}/z_{it}^*) \quad , \quad r = 1, 2, \dots, M ; \quad i = 1, 2, \dots, N. \quad (2.26)$$

The elasticity of efficiency-adjusted input i with respect to disembodied technical change is:

$$\epsilon_{it}^{zt} = \left[\partial Z_i \left(\cdot \right) / \partial t \right] (1/z_{it}^*) \quad , \quad i = 1, 2, \dots, N. \quad (2.27)$$

2.4.6 ELASTICITIES OF OBSERVED INPUT DEMAND TO NON-PRICE VARIABLES

The following derivations are with respect to (2.14). The elasticity of observed input demand i to a change in output is:

$$\begin{aligned} \epsilon_{iyt}^{vy} &= (1/h_i) \left[\partial Z_i \left(\cdot \right) / \partial y_t \right] (y_t/v_{it}) \\ &= \epsilon_{it}^{zy} [z_{it}^*/(h_i v_{it})] \quad , \quad i = 1, 2, \dots, N. \end{aligned} \quad (2.28)$$

Analogously, the elasticity of observed input demand i to a change in the stock of the k^{th} type of infrastructure is:

$$\begin{aligned} \epsilon_{it}^{vGk} &= (1/h_i) \left[\partial Z_i \left(\cdot \right) / \partial G_{kt} \right] (G_{kt}/v_{it}) \\ &= \epsilon_{it}^{zGk} [z_{it}^*/(h_i v_{it})] \quad , \quad k = 1, 2, \dots, L ; \quad i = 1, 2, \dots, N. \end{aligned} \quad (2.29)$$

Likewise, the elasticity of observed demand for input i with respect to a change in the r^{th} spillover is:

$$\begin{aligned}
\epsilon_{it}^{vS_r} &= (1/h_i) \left[\partial Z_i \left(\cdot \right) / \partial S_{rt} \right] (S_{rt}/v_{it}) \\
&= \epsilon_{it}^{zS_r} [z_{it}^*/(h_i v_{it})] \quad , \quad r = 1, 2, \dots, M ; \quad i = 1, 2, \dots, N.
\end{aligned} \tag{2.30}$$

Finally, the elasticity of observed demand for input i to technical change is defined as:

$$\begin{aligned}
\epsilon_{it}^{vt} &= (1/h_i) \left[\partial Z_i \left(\cdot \right) / \partial t \right] (1/v_{it}) \\
&= \epsilon_{it}^{zt} [z_{it}^*/(h_i v_{it})] \quad , \quad i = 1, 2, \dots, N.
\end{aligned} \tag{2.31}$$

2.4.7 ELASTICITIES OF COST WITH RESPECT TO NON-PRICE VARIABLES

From (2.12) the cost of optimal efficiency-adjusted inputs in year t is¹⁴

$$c_t^* = \sum_{i=1}^N \omega_{it} z_{it}^* = C \left(\cdot \right)_t ,$$

where $C \left(\cdot \right)_t = C(\omega_{1t}, \omega_{2t}, \dots, \omega_{Nt}, y_t, G_t, S_t, t)$. Given this definition, the elasticity of cost with respect to output is

$$\epsilon_t^{cy} = \left[\partial C \left(\cdot \right)_t / \partial y_t \right] (y_t/c_t^*) = \sum_{i=1}^N c_{it}^* \epsilon_{it}^{zy} , \tag{2.32}$$

¹⁴Note that the elasticity of cost with respect to prices is already captured, since by Shephard's lemma, $\partial C \left(\cdot \right)_t / \partial \omega_{it} = z_{it}^*$ – see (2.13').

Also, note that since $c_t^* = \sum_{i=1}^N \omega_{it} z_{it}^*$,

$$\partial C \left(\cdot \right)_t / \partial y_t = \sum_{i=1}^N \omega_{it} \partial Z_i \left(\cdot \right)_t / \partial y_t .$$

In other words, the elasticity of cost with respect to any non-price variable (in this case y_t) can be expressed a multiplicative transformation of the efficiency-adjusted input demand functions.

where: $c_{it}^* = \omega_{it} z_{it}^* / c_t^*$, i.e. the cost elasticity can be expressed as a expenditure share-weighted average of the elasticities of demand for efficiency-adjusted inputs with respect to output.¹⁵

The elasticity of cost with respect to a change in the stock of the k^{th} type of infrastructure is

$$\epsilon_t^{cGk} = \left[\partial C \left(\cdot \right) / \partial G_{kt} \right] (G_{kt} / c_t^*) = \sum_{i=1}^N c_{it}^* \epsilon_{it}^{zGk} \quad (2.33)$$

, $k = 1, 2, \dots, L$,

while the elasticity of cost with respect to a change in the magnitude of the r^{th} knowledge spillover is

$$\epsilon_t^{cSr} = \left[\partial C \left(\cdot \right) / \partial S_{rt} \right] (S_{rt} / c_t^*) = \sum_{i=1}^N c_{it}^* \epsilon_{it}^{zSr} \quad , \quad r = 1, 2, \dots, M \quad , \quad (2.34)$$

and the elasticity of cost to disembodied technical change is:

$$\epsilon_t^{ct} = \left[\partial C \left(\cdot \right) / \partial t \right] (1 / c_t^*) = \sum_{i=1}^N c_{it}^* \epsilon_{it}^{zt} \quad . \quad (2.35)$$

¹⁵The fact that the cost elasticity can be derived from the input elasticities is important when the cost function is not actually estimated (i.e. when only the input demand equations are estimated). The same is true for the other cost elasticity derivations that follow.

CHAPTER 3

THEORETICAL MODEL: WITH TAXES

3.1 INTRODUCTION

Canadian corporations face a variety of taxes that are levied on them by federal, provincial and local governments. This analysis incorporates some of the more important of these taxes into the basic theoretical model, thereby allowing the measurement of after-tax user costs of efficiency-adjusted inputs.

The next section provides a description of various elements of the corporate tax setting such as net income for income tax purposes, the various corporate income tax rates, corporate income tax credits and local taxes. The third section provides mathematical specifications for the corporate tax elements. After-tax acquisition and hiring prices are derived using these specifications, and are used in the development of the cost-minimizing production plan in the fourth section. Here, the basic model is extended to include the effects of taxes, so that results from optimization – the user costs for efficiency-adjusted inputs and the optimal demands for those inputs – are after-tax levels. The fifth section shows how after-tax user costs for efficiency-adjusted inputs are specified when the cost minimization framework from Chapter 2 is modified to incorporate the effects of taxes.

3.2 THE CORPORATE TAX SETTING

Canadian corporate income taxes are based on a definition of net income – called net income for income tax purposes – that is derived from the income statement that firms prepare for their own operations, the main component of which is the value of production (total revenue) less reported total expenses (the sum of sales and operating expenses).¹ Two adjustments are made to the firm’s income statement when deriving net income for income tax purposes: (i) any provision made by the firm for income tax on its statement (usually an expense) is added back into revenue; and (ii) the depreciation expense in the firm’s income statement is removed and replaced with capital cost allowances (CCAs) set by income tax legislation. Of the two adjustments, (ii) is the most important one from an analytical standpoint.²

¹The income statement prepared by corporations – referred to in federal corporate tax Schedule 1 as ‘Net Income (Loss) after Taxes and Extraordinary Items per Financial Statements’ – includes several types of revenue and expense items not considered in this analysis. Omission of these items does not affect the analysis in any material way. See *Guide to the General Index of Financial Information (GIFI) for Corporations*, RC4088(E) Rev .01, Canada Customs and Revenue Agency.

For this analysis, the relevant total expense items are:

- cost of sales and operating expense items that are expenditures on non-capital inputs (labour, energy, materials and services)
- amortization of tangible assets (depreciation expense)
- interest and bank charges (interest expense)
- business taxes and property taxes.

²There are several other additions and deductions from the firm’s income statement that are made in order to obtain net income for income tax purposes, but these are not germane to the analysis at hand and their omission should not affect the outcome of the analysis in a material way. For a recent example of these adjustments, see Schedule 1 (T2SCH1) – entitled ‘Net Income (loss) for Income Tax Purposes’ – that is attached to

The CCA for an asset represents the rate of depletion of that asset assumed for income tax purposes. CCA rates are defined for a wide variety of capital assets and several different methods are used to define the CCA rates (declining balance, straight line, accelerated – see [9, pp. 125-126] for details). The principle underlying all CCA rates is that, whatever method is chosen, the corporation can deduct up to the allowable amount when calculating its net income for income tax purposes.

Income tax payable to federal and provincial governments is equal to taxes levied on taxable income – which, in this analysis, is the same as net income for income tax purposes³ – at rates set by these levels of government, less applicable credits from these taxes. The tax and credit rates are:⁴

- **Base amount of federal corporate income tax.** This amount is equal to the basic federal income tax rate times taxable income.
- **Corporate surtax.** In some years, the base corporate income tax has been supplemented by a surtax. The corporate surtax rate is applied to the full amount of the base tax or some proportion of it.
- **Federal tax abatement.** By agreement with the provinces, the federal government allows a tax abatement. This deduction from the base amount of federal corporate income tax is equal to the abatement rate times taxable

the T2 Corporation Income Tax Return; both forms are available from Canada Customs and Revenue Agency at www.ccra-adrc.gc.ca

³Taxable income is equal to net income for income tax purposes, less several deductions and one addition (see T2 Corporation Income Tax Return). None of these adjustments are relevant to this analysis.

⁴Only the rates and credits germane to this analysis are considered here. A variety of other deductions and adjustments are specified in the tax regulations; these other elements are ignored here, in part because many of them do not apply to food processors.

income). The provinces then apply their own corporate income tax rates to taxable income.

- **Manufacturing and processing profits credit.** This deduction from the base amount of federal corporate income tax is available to corporations that derive at least 10% of their gross revenue from manufacturing or processing activities in Canada. If corporations get less than 100% of their revenue from manufacturing or processing activities, a formula allows for the corporation to receive credit for that portion of revenue attributable to these activities [27, pp. 219-220; 320-323]. For purposes of this analysis, the producers are assumed to get 100% of their revenue from manufacturing or processing activities, and so the credit is applied to all taxable income at the full rate.
- **Investment tax credit.** This tax credit has given, for certain years, a deduction against the base amount of federal corporate income tax. It is calculated as a proportion of the cost of the qualifying asset. Since it directly reduces the tax bill of the corporation, “a 5 per cent investment credit is necessarily worth much more to any [corporation]... than a 5 per cent capital cost allowance would be” [27, p. 222]. Note that a claim for the investment tax credit will generally reduce the un-depreciated amount that would otherwise be available for CCA deductions by the amount of credit originally claimed [27, p. 222].

Federal corporate income tax payable is calculated as the base amount of federal corporate income tax plus the corporate surtax, less the federal tax abatement, the manufacturing and processing profits deduction and the investment tax credit.

- **Provincial corporate income tax.** The provinces apply their own corporate income tax rates to taxable income and provide a variety of tax credits. For purposes of this analysis, provincial tax credits are ignored. Provincial corporate income tax payable is therefore calculated as the provincial corporate tax rate times taxable income.

Corporate income tax payable is federal corporate income tax payable plus provincial corporate income tax payable.

The only other taxes levied on corporations that are included in this analysis are local taxes, namely:

- **Property tax.** Application of this tax to land and buildings owned by corporations varies considerably, both within and across provinces. The tax payable depends on the rate of tax and the tax base, the latter of which is the “taxable assessed value of a specific property” [9, p. 217].
- **Business tax.** This tax is applied by local governments to occupants of commercial buildings; if the owners happen to also be the occupants, they will pay both a property tax and a business tax. On the other hand, if the occupants do not own the property, they will only pay the business tax (although the property tax will presumably be incorporated into the rent they pay). The manner in which the business tax is levied also varies considerably across jurisdictions; the tax base ranges from square footage occupied to rental value. In particular, the assessed value of the property occupied represents one base for the business tax that is fairly common [9, p. 243].

Thus corporate tax payable is equal to the corporate income tax payable plus the corporate local tax payable.

3.3 MODELLING TAX ELEMENTS

Total revenue less non-capital input cost is defined as:⁵

$$\mathcal{T}_t^B = p_t y_t - \sum_{i \in \mathbb{N}_b} q_{it} x_{it} . \quad (3.1)$$

The CCA in year t for asset type $j \in \mathbb{N}_c$ is calculated as:

$$\mathfrak{X}_{jt}^x = \gamma_{jt} \sum_{\iota=0}^{\infty} (1 - \gamma_{j-\iota})^{\iota} \mathfrak{C}_{jt-\iota}^x \quad (3.2)$$

where: $\mathfrak{C}_{jt-\iota}^x = q_{jt-\iota} x_{jt-\iota} (1 - \psi_{t-\iota}^I)$, $\iota = 0, 1, 2, \dots$ is the acquisition cost of asset type j less any investment tax credit claimed against that cost; $\gamma_{j-\iota}$ is the CCA rate for asset type j in year $t - \iota$ ($\iota = 0, 1, 2, \dots$); and $\psi_{t-\iota}^I$ is the rate of the investment tax credit for asset type j in year $t - \iota$ ($\iota = 0, 1, 2, \dots$). (Note that the rate of investment tax credit is the same for all capital types.)⁶

Interest paid on debt is the product of a nominal interest rate and debt, i.e.

$$\mathfrak{X}_t^{\mathfrak{B}} = r_t \mathfrak{B}_{t-1} , \quad (3.3)$$

⁵In the analysis that follows, it is helpful to divide the indicators for inputs into several sets. If producers use a total of N inputs, $\mathbb{N}_a = \{1, 2, \dots, N\}$ can be defined as the set of all input indicators. Define $\mathbb{N}_c$ as the set of capital input indicators and $\mathbb{N}_b$ as the set of non-capital input indicators, so $\mathbb{N}_a = \mathbb{N}_b \cup \mathbb{N}_c$. Define $\mathbb{N}_d$ as the set of property capital input indicators, and let $\mathbb{N}_e$ be the set of remaining (or other) capital input indicators. Then $\mathbb{N}_c = \mathbb{N}_d \cup \mathbb{N}_e$.

⁶See Appendix B for details regarding the derivation of (3.2).

where: r_t is the nominal rate of interest paid by producers in year t to debt (loans, bonds, mortgages, etc.) and $\mathfrak{B}_{t-1}$ is the nominal value of debt carried over to year t from $t - 1$.

To determine the amount of local taxes payable, it is first necessary to specify the way in which property capital is valued in the model, since these taxes are assumed to be based on the current value of the property (i.e. the current value is the tax base). For a property purchased in year $t - \iota$, with real quantity $x_{it-\iota}$, the current value will be that quantity times some price.⁷ Suppose that the current value of the property is equal to the purchase price times a geometrically declining factor, i.e. $q_{kt}^{U t-\iota} = q_{kt-\iota}(1 - \delta_k)^\iota$, where $0 < \delta_k < 1$ is the physical decay rate for property type k . Then the value of the property in year t is

$$V_{kt}^{t-\iota} = q_{kt}^{U t-\iota} x_{it-\iota} , \quad (3.4)$$

and, since it is assumed that all properties can be valued in this manner, the value of all properties of type k purchased up to and including year t is

$$V_{kt} = \sum_{\iota=0}^{\infty} V_{kt}^{t-\iota} = \sum_{\iota=0}^{\infty} [q_{kt-\iota}(1 - \delta_k)^\iota x_{it-\iota}] . \quad (3.5)$$

Given the value of property as defined above, local taxes payable (the sum of property and business taxes payable) is specified as:

$$\mathfrak{M}_t^L = (\kappa_t^{LL} + \kappa_t^{LB}) \sum_{k \in \mathbb{N}_d} V_{kt} \quad (3.6)$$

⁷For example, the real quantity could be a new, 20,000 square foot production facility. From a property valuation point of view, the area in year t is the same as that in $t - \iota$ (i.e. it is the same 20,000 sq. ft. of real estate), the difference is only in the value of that property.

where κ_t^{LL} is the average property tax rate; and κ_t^{LB} is the average business tax rate.

Taxable income in year t is $\mathcal{J}_t^B$ less CCAs, interest cost and local taxes. This is specified, with the CCAs now summed over all asset types, as

$$\mathcal{J}_t^T = \mathcal{J}_t^B - \left[\sum_{j \in \mathbb{N}_c} \mathfrak{x}_{jt}^x \right] - \mathfrak{x}_t^{\mathfrak{B}} - \mathfrak{w}_t^L . \quad (3.7)$$

(Note that $\mathcal{J}_t^T$ is also net income for income tax purposes – as pointed out earlier, for purposes of this analysis, the two measures of income are the same.)

The elements of the federal corporate income tax, with mathematical specifications of these elements, are:

- federal corporate income tax

$$\mathfrak{W}_t^{FC} = \kappa_t^{FC} \mathcal{J}_t^T , \quad (3.8a)$$

where κ_t^{FC} is the basic federal corporate income tax rate;

- the corporate surtax, which is applied to $\mathfrak{W}_t^{FC}$, i.e.

$$\mathfrak{W}_t^{FS} = \kappa_t^{FS} \mathfrak{W}_t^{FC} , \quad (3.8b)$$

where κ_t^{FS} is the federal corporate surtax rate;

- federal tax abatement

$$\mathfrak{W}_t^{FP} = \kappa_t^{FP} \mathcal{J}_t^T , \quad (3.8c)$$

where κ_t^{FP} is the abatement rate;

- the manufacturing and processing profits tax credit

$$\mathfrak{W}_t^{FM} = \psi_t^M \mathcal{J}_t^T , \quad (3.8d)$$

where ψ_t^M is the manufacturing and processing profits tax credit rate; and

- the investment tax credit

$$\mathfrak{W}_t^{FI} = \sum_{j \in \mathbb{N}_c} \psi_t^I q_{jt} x_{jt} \quad (3.8e)$$

where ψ_t^I is the investment tax credit rate in year t .

Federal corporate income tax payable is thus

$$\mathfrak{W}_t^F = \mathfrak{W}_t^{FC} + \mathfrak{W}_t^{FS} - \mathfrak{W}_t^{FP} - \mathfrak{W}_t^{FM} - \mathfrak{W}_t^{FI} . \quad (3.9)$$

Provincial corporate income tax payable is specified as

$$\mathfrak{W}_t^P = \kappa_t^{PC} \mathfrak{J}_t^T , \quad (3.10)$$

where: κ_t^{PC} is the provincial corporate income tax rate.

Total corporate income tax payable is the sum of federal and provincial corporate income taxes, i.e.

$$\mathfrak{W}_t^C = \mathfrak{W}_t^F + \mathfrak{W}_t^P \quad (3.11)$$

3.4 MINIMIZATION OF AFTER-TAX INPUT ACQUISITION AND HIRING COST

With specifications for all the tax elements given above, it is possible to derive the after-tax acquisition and hiring prices. These are divided by input class, i.e. by property capital input, other capital input and non-capital input. Details regarding the derivation of these prices can be found in Appendix C.

The after-tax acquisition price for property capital is:

$$\begin{aligned}
 Q_{kt+\tau} &= \left(1 + \Xi_{kt+\tau}^2 - \sum_{\iota'=1}^{\infty} a_t^{-\iota'} \Xi_{kt+\tau+\iota'}^{4Ft+\tau}\right) q_{kt+\tau} \\
 &\quad + \sum_{\iota'=1}^{\infty} a_t^{-\iota'} \left[\Xi_{t+\tau+\iota'}^3 q_{kt+\tau} (1 - \delta_k)^{\iota'} \right] , \\
 k &\in \mathbb{N}_d ; \quad \tau = 0, 1, 2, \dots ;
 \end{aligned} \tag{3.12}$$

where

$$\begin{aligned}
 \Xi_{kt+\tau}^2 &= \Xi_{t+\tau}^3 - \Xi_{t+\tau}^1 \gamma_{kt} (1 - \psi_{t+\tau}^I) - \psi_{t+\tau}^I ; \\
 \Xi_{t+\tau}^3 &= (1 - \Xi_{t+\tau}^1) (\kappa_{t+\tau}^{LL} + \kappa_{t+\tau}^{LB}) ; \\
 \Xi_{t+\tau}^1 &= \kappa_{t+\tau}^{FC} (1 + \kappa_{t+\tau}^{FS}) - \kappa_{t+\tau}^{FP} - \psi_{t+\tau}^M + \kappa_{t+\tau}^{PC} ; \\
 \Xi_{kt+\tau+\iota'}^{4Ft+\tau} &= \Xi_{t+\tau+\iota'}^1 \gamma_{kt+\tau+\iota'} (1 - \gamma_{kt+\tau+\iota'})^{\iota'} (1 - \psi_{t+\tau}^I) ; \text{ and} \\
 \Xi_{t+\tau+\iota'}^3 &= (1 - \Xi_{t+\tau+\iota'}^1) (\kappa_{t+\tau+\iota'}^{LL} + \kappa_{t+\tau+\iota'}^{LB}) .
 \end{aligned}$$

The variable $\Xi_{kt+\tau}^2$ gives the combined tax effect in year $t + \tau$ of a property investment made in that year, i.e.: local taxes; the the tax-reducing effect from the capital cost allowance on the investment; and the investment tax credit on the investment. The variable $\Xi_{t+\tau}^3$ is the local tax rate in year $t + \tau$ after the corporate tax effect of deducting this expense when determining net income for income tax purposes; similarly, $\Xi_{t+\tau+\iota'}^3$ is the same rate for year $t + \tau + \iota'$. The variable $\Xi_{t+\tau}^1$ is the combined federal and provincial corporate income tax rate, comprised of the rates in components (3.8a)-(3.8e) and (3.10). Finally, the variable $\Xi_{kt+\tau+\iota'}^{4Ft+\tau}$ is the present value (in $t + \tau$) of the tax reduction effect of all future CCA deductions arising from an investment made in $t + \tau$ – note that only the investment tax credit rate for $t + \tau$ is used in constructing this variable, since future CCAs are determined on the original purchase price (book value) less the investment tax credit claimed for the investment at in $t + \tau$.

The after-tax acquisition for other capital is:

$$\begin{aligned}
 Q_{rt+\tau} = & \left[1 - \psi_{t+\tau}^I - \Xi_{rt+\tau}^4 \right. \\
 & \left. - \sum_{\iota'=1}^{\infty} a_t^{-\iota'} \Xi_{rt+\tau+\iota'}^{4Ft+\tau} \right] q_{rt+\tau} \quad , \\
 & r \in \mathbb{N}_e ; \quad \tau = 0, 1, 2, \dots \quad ,
 \end{aligned} \tag{3.13}$$

where $\Xi_{rt+\tau}^4$ and $\Xi_{rt+\tau+\iota'}^{4Ft+\tau}$ are defined in the same way as these variables for property capital, and the after-tax acquisition for non-capital inputs is:

$$Q_{it+\tau} = (1 - \Xi_{t+\tau}^1) q_{it+\tau} \quad , \quad i \in \mathbb{N}_b ; \quad \tau = 0, 1, 2, \dots \quad . \tag{3.14}$$

In the context of a tax environment, the production problem involves the minimization of after-tax input acquisition and hiring cost of inputs for an exogenous production plan, subject to constraints (i)-(iii) as defined in the basic model – see Chapter 2, expression (2.4).⁸ The optimization problem is written as:

$$\min_{\{x_{1t+\tau}, \dots, x_{Nt+\tau}\}_{\tau=0}^{\infty}} E_t \left\{ \sum_{\tau=0}^{\infty} a_t^{\tau} \left(\sum_{u=1}^N Q_{ut+\tau} x_{ut+\tau} \right) \right\} \quad , \tag{3.15}$$

subject to: (i) $y_{t+\tau} = F(z_{1t+\tau}, z_{2t+\tau}, \dots, z_{Nt+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) \quad \forall t, \tau$;

(ii) $v_{ut+\tau} = x_{ut+\tau} + (1 - \delta_u) v_{ut+\tau-1} \quad \forall t, \tau, \quad u = 1, 2, \dots, N$; and

(iii) $z_{ut} = h_u(x_{ut} - \delta_u v_{ut-1}) + v_{ut-1} \quad \forall t, \tau, \quad u = 1, 2, \dots, N$,

Rearrange constraints (ii) to give $x_{ut+\tau} = v_{ut+\tau} - (1 - \delta_u) v_{ut+\tau-1}$, $u = 1, 2, \dots, N$ and substitute for each $x_{1t+\tau}, x_{2t+\tau}, \dots, x_{Nt+\tau}$ in the objective function and in constraint (iii). Then, substitute the revised constraints (iii) into constraint (i) to

⁸Note that for the capital inputs in this minimization problem, only the current and future after-tax costs of an acquisition are taken into account. See Appendix C for details.

replace $z_{1t+\tau}, z_{2t+\tau}, \dots, z_{Nt+\tau}$. The revised optimization problem – which is now expressed solely in terms of observed input quantities $v_1, v_2 \dots v_N$ – has the following Lagrangian associated with it:

$$\mathcal{L} = \sum_{\tau=0}^{\infty} a_t^{\tau} \left[\sum_{u=1}^N Q_{ut+\tau}^e (v_{ut+\tau} - (1 - \delta_u) v_{ut+\tau-1}) + \lambda_{t+\tau} \left(y_{t+\tau} - F \left(\begin{matrix} \cdot \\ t + \tau \end{matrix} \right) \right) \right] . \quad (3.16)$$

The first-order condition for each input u in year $t + \tau$ is:

$$\begin{aligned} (1 + \rho_t)^{-\tau} Q_{ut+\tau}^e - (1 + \rho)^{-\tau} \lambda_{t+\tau} (\partial F \left(\begin{matrix} \cdot \\ t + \tau \end{matrix} \right) / \partial z_{ut+\tau}) h_u \\ - (1 + \rho)^{-(\tau+1)} Q_{ut+\tau+1}^e (1 - \delta_u) \\ - (1 + \rho_t)^{-(\tau+1)} \lambda_{t+\tau+1} (\partial F \left(\begin{matrix} \cdot \\ t + \tau + 1 \end{matrix} \right) / \partial z_{ut+\tau+1}) (-h_u \mu_u) = 0 , \\ \tau = 1, 2 \dots ; u = 1, 2 \dots N. \end{aligned} \quad (3.17)$$

Recall that $F \left(\begin{matrix} \cdot \\ t+\tau \end{matrix} \right)$ denotes:

$$F \left(h_1(v_{1t+\tau} - \mu_1 v_{1t+\tau-1}), \dots, h_N(v_{Nt+\tau} - \mu_N v_{Nt+\tau-1}), G_{t+\tau}, S_{t+\tau}, t + \tau \right),$$

so that

$$\partial F \left(\begin{matrix} \cdot \\ t + \tau \end{matrix} \right) / \partial v_{ut+\tau} = \left[\partial F \left(\begin{matrix} \cdot \\ t + \tau \end{matrix} \right) / \partial z_{ut+\tau} \right] h_u$$

and

$$\partial F \left(\begin{matrix} \cdot \\ t + \tau + 1 \end{matrix} \right) / \partial v_{ut+\tau} = - \left[\partial F \left(\begin{matrix} \cdot \\ t + \tau + 1 \end{matrix} \right) / \partial z_{ut+\tau} \right] h_u \mu_u.$$

Let:

$$W_{ut+\tau}^e = Q_{ut+\tau}^e - d_u a_t Q_{ut+\tau+1}^e , \tau = 1, 2 \dots ; u = 1, 2 \dots N. \quad (3.18)$$

Then multiplication of (3.17) by $a_t^{-\tau}$, substitution of (3.18) into the thus revised version and rearrangement of the resulting expression leads to:

$$h_u \lambda_{t+\tau} \partial F \left(\begin{array}{c} \cdot \\ t + \tau \end{array} \right) / \partial z_{ut+\tau} = W_{ut+\tau}^e + a_t \mu_u \left[h_u \lambda_{t+\tau+1} \partial F \left(\begin{array}{c} \cdot \\ t + \tau + 1 \end{array} \right) / \partial z_{ut+\tau+1} \right] , \quad (3.17')$$

$$\tau = 1, 2 \dots ; u = 1, 2 \dots N.$$

Successive substitutions on the right-hand side of (3.17') generate, for the year $T_M > t$:

$$h_u \lambda_{t+\tau} \partial F \left(\begin{array}{c} \cdot \\ t + \tau \end{array} \right) / \partial z_{ut+\tau} = W_{ut+\tau}^e + \sum_{v=1}^{T_M-1} (a_t \mu_u)^v W_{ut+\tau+v}^e + (a_t \mu_u)^{T_M} \left[h_u \lambda_{t+\tau+T_M} \partial F \left(\begin{array}{c} \cdot \\ t + \tau + T_M \end{array} \right) / \partial z_{ut+\tau+T_M} \right] , \quad (3.17'')$$

$$\tau = 0, 1, 2, \dots ; u = 1, 2, \dots, N.$$

Providing, for each τ and for each input u , that the term

$$h_u \lambda_{t+\tau+T_M} \partial F \left(\begin{array}{c} \cdot \\ t + \tau + T_M \end{array} \right) / \partial z_{ut+\tau+T_M}$$

is finite $\forall T_M$ and, providing that $|a_t \mu_u| < 1$, the following limit exists:

$$\lim_{T_M \rightarrow \infty} (a_t \mu_u)^{T_M} \left[h_u \lambda_{t+\tau+T_M} \partial F \left(\begin{array}{c} \cdot \\ t + \tau + T_M \end{array} \right) / \partial z_{ut+\tau+T_M} \right] = 0.$$

Then, in the limit, (3.17'') reduces to:

$$\lambda_{t+\tau} \partial F \left(\frac{\cdot}{t+\tau} \right) / \partial z_{ut+\tau} = (1/h_u) \left(W_{ut+\tau}^e + \sum_{v=1}^{\infty} (a_t \mu_u)^v W_{ut+\tau+v}^e \right) , \quad (3.19)$$

$$\tau = 0, 1, 2, \dots ; u = 1, 2, \dots, N.$$

This equation shows that the value of the marginal product at the after-tax cost-minimizing level of the efficiency-adjusted input u – the left-hand side of (3.19) – equals the discounted expected marginal after-tax cost of holding the input at that level in perpetuity – the right-hand side of (3.19). The after-tax user cost of efficiency-adjusted input u in year $t + \tau$, denoted by $\omega_{ut+\tau}^A$, is thus defined as follows:

$$\omega_{ut+\tau}^A = (1/h_u) \left(W_{ut+\tau}^e + \sum_{v=1}^{\infty} (a_t \mu_u)^v W_{ut+\tau+v}^e \right) , \quad (3.20)$$

$$\tau = 0, 1, 2, \dots ; u = 1, 2, \dots, N.$$

As with the theoretical model in Chapter 2, the cost-minimization problem developed above can be re-cast by letting the minimum after-tax cost of production in year $t + \tau$ be represented by the cost function:

$$C^A(\omega_{1t+\tau}^A, \omega_{2t+\tau}^A, \dots, \omega_{Nt+\tau}^A, y_{t+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) \equiv \min_{z_{1t+\tau}, z_{2t+\tau}, \dots, z_{Nt+\tau}} \left\{ \sum_{u=1}^N \omega_{ut+\tau}^A z_{ut+\tau} \right. \\ \left. | F(z_{1t+\tau}, z_{2t+\tau}, \dots, z_{Nt+\tau}, G_{t+\tau}, S_{t+\tau}, t + \tau) = y_{t+\tau} \right\} , \quad \tau = 0, 1, 2, \dots \quad (3.21)$$

Applying Shephard's Lemma to (3.21), the optimal efficiency-adjusted input levels for year t are:

$$\begin{aligned} z_{ut}^{A*} &= Z_u^A(\omega_{1t}^A, \dots, \omega_{Nt}^A, y_t, G_t, S_t, t) \\ &= \partial C^A(\omega_{1t}^A, \omega_{2t}^A, \dots, \omega_{Nt}^A, y_t, G_t, S_t, t) / \partial \omega_{ut}^A, u = 1, 2, \dots, N. \end{aligned} \quad (3.22)$$

Since z_{ut}^{A*} is not observable, the following equation is used to measure the efficiency-adjusted input (this is the after-tax version of (2.14) in Chapter 2):

$$v_{ut} = (1/h_u) Z_u^A \left(\cdot \right)_t + \mu_u v_{ut-1}, \quad u = 1, 2, \dots, N. \quad (3.23)$$

where $Z_u^A \left(\cdot \right)_t$ is the demand function defined by (3.23).

3.5 AFTER-TAX USER COSTS FOR EFFICIENCY-ADJUSTED INPUTS

To develop an empirically usable version of the user cost equation (3.20), the form for expected after-tax acquisition and hiring prices $Q_{ut+\tau}^e$ in (3.18) must first be determined. Since there are three classes of inputs (property capital, other capital and non-capital inputs) there are also three sets of expected after-tax acquisition and hiring prices, based on (3.12), (3.13) and (3.14). Each set of prices requires assumptions about the expectations that processors have regarding: (i) future tax, credit and allowance rates; and (ii) future non-tax elements of the after-tax prices.

With respect to (i) above, producers are assumed to have static expectations regarding tax instruments. More generally, the requirement is that tax instruments and other stochastic elements of the after-tax acquisition and hiring prices

be independent random variables. This assumption appears to be reasonable, since tax, credit and allowance rates change only periodically. For (ii) above, expectations regarding non-tax elements are dealt with using the process (2.15).

With these preliminaries established, it is now possible to address expectations of the after-tax acquisition or hiring prices. For property capital, the expectation of (3.12) gives:

$$\begin{aligned}
 E_t(Q_{kt+\tau}) &= \left(1 + \Xi_{kt}^2 - \Xi_t^1 \gamma_{kt} (1 - \psi_t^I) \sum_{\iota'=1}^{\infty} a_t^{-\iota'} (1 - \gamma_{kt})^{\iota'}\right) q_{kt+\tau}^e \quad (3.12e) \\
 &\quad + \Xi_t^3 \sum_{\iota'=1}^{\infty} a_t^{-\iota'} \left[q_{kt+\tau}^e (1 - \delta_k)^{\iota'} \right] , \\
 &\quad k \in \mathbb{N}_d ; \quad \tau = 0, 1, 2, \dots .
 \end{aligned}$$

By combining terms and using solutions for the two geometric series in (3.12e), it is possible to get the more compact expression:

$$Q_{kt+\tau}^e = \Lambda_{kt} q_{kt+\tau}^e , \quad k \in \mathbb{N}_d ; \quad \tau = 0, 1, 2, \dots , \quad (3.12e')$$

where $\Lambda_{kt} = \{1 - \psi_t^I - (1 + \rho_t) [\Xi_{kt}^4 / (\rho_t + \gamma_{kt}) - \Xi_t^3 / (\rho_t + \delta_k)]\}$

For other capital, the expectation of (3.13) is

$$\begin{aligned}
 E_t(Q_{rt+\tau}) &= \left(1 - \psi_t^I - \Xi_{rt}^4 \right. \quad (3.13e) \\
 &\quad \left. - \Xi_t^1 \gamma_{rt} (1 - \psi_t^I) \sum_{\iota'=1}^{\infty} a_t^{-\iota'} (1 - \gamma_{rt})^{\iota'}\right) q_{rt+\tau}^e , \\
 &\quad r \in \mathbb{N}_e ; \quad \tau = 0, 1, 2, \dots
 \end{aligned}$$

Use the solution to the geometric series in (3.13e) and combine terms to get

$$Q_{rt+\tau}^e = \Lambda_{rt} q_{rt+\tau}^e, \quad r \in \mathbb{N}_e; \tau = 0, 1, 2, \dots, \quad (3.13e')$$

where $\Lambda_{rt} = \{1 - \psi_t^I - \Xi_{rt}^4 (1 + \rho_t) / (\rho_t + \gamma_{rt})\}$.

For non-capital inputs, the expected after-tax acquisition price equation is simply

$$Q_{it+\tau}^e = \Lambda_{it} q_{it+\tau}^e, \quad i \in \mathbb{N}_b; \tau = 0, 1, 2, \dots, \quad (3.14e)$$

where $\Lambda_{it} = 1 - \Xi_t^1$.

The multiplicative relationship between the tax elements – captured by Λ_{ikt} , Λ_{rt} , and Λ_{it} – and the expected acquisition/hiring prices – q_{kt}^e , q_{rt}^e , and q_{it}^e respectively – means that the results from Chapter 2 for the derived user costs of efficiency-adjusted inputs can just be adapted for the after-tax case. In particular, the user cost equation (2.19) is modified to accommodate taxes, so that for the after-tax user cost of efficiency-adjusted inputs in year t is

$$\omega_{ut}^A = \Theta_{0ut}^A + \Theta_{1ut}^A q_{ut} \quad , \quad u = 1, 2, \dots, N \quad , \quad (3.24)$$

where

$$\begin{aligned} \Theta_{0ut}^A = \Lambda_{ut} (1/h_u) [\phi_u / (1 - \theta_u)] \Big\{ & [(1 - a_t d_u) / (1 - a_t \mu_u) \\ & - (1 - a_t d_u \theta_u) / (1 - a_t \mu_u \theta_u)] \Big\} ; \end{aligned}$$

$$\Theta_{1ut}^A = \Lambda_{ut} (1/h_u) (1 - d_u a_t \theta_u) / (1 - a_t \mu_u \theta_u)$$

and the specification for Λ_{ut} depends on whether u is: a property capital input (in which case $\Lambda_{ut} = \Lambda_{kt}$ since $u \in \mathbb{N}_d$); an other capital input (here, $\Lambda_{ut} = \Lambda_{rt}$, since $u \in \mathbb{N}_e$); or a non-capital input (where $\Lambda_{ut} = \Lambda_{it}$, since $u \in \mathbb{N}_b$).

A final aspect of the theoretical model with taxes is the elasticity derivations. Here, the formulas are the same as in Chapter 2, except that the relevant functions and variables are appended with the superscript 'A'.

CHAPTER 4

DATA

4.1 INTRODUCTION

Several types of data are needed for estimation of the model developed in Chapter 3. In the next section, the raw database is described – this database is comprised of time series and other data in the form that they are obtained from statistical agencies and other sources. In the third section, data used to measure some of the variables in the model are derived by aggregating and/or transforming the various series in the raw database. In the final section, the raw and derived data series are combined to create an estimation database, i.e. one that can be read directly by the econometric program used to estimate the model.

4.2 RAW DATABASE

4.2.1 INTRODUCTION

Raw data collection is based on the variables in the theoretical model with taxes. In particular, since the estimated equation for each input has the form:¹

$$v_{ut} = (1/h_u) Z_u^A(\omega_{1t}^A, \dots, \omega_{Nt}^A, y_t, G_t, S_t, t) + \mu_u v_{ut-1}$$

¹This expression is just (3.23). It is repeated here for convenient cross-reference.

it follows that to estimate the model, time series data are needed for the following variables:²

variable	variable description
v_u	observed quantity of input u , $u = 1, 2, \dots, N$
y	output quantity
G	vector of k infrastructure stocks , $k = 1, 2, \dots, L$
S	vector of r knowledge spillovers, $r = 1, 2, \dots, M$
t	trend

as well as time series for each of the components of $\omega_{1t}^A, \omega_{2t}^A, \dots, \omega_{Nt}^A$ – see below.

To make the raw data collection task manageable, it is important from the outset to limit the number of inputs (N), the number of types of infrastructure stock (L) and the number of sources of spillovers (M); in the derivation of variables and/or as part of the specification of the empirical model, each of these limits may subsequently be reduced from its initial value. Initial values for the limits are: $N = 21$ (17 types of capital;³ labour; energy; materials; and services);

²After-tax user costs for efficiency-adjusted inputs (ω_u^A , $u = 1, 2, \dots, N$) are not observable and so are not included in either the raw or derived databases. Instead, all of the data components needed to derive these as part of the estimation process are developed here.

³The capital types (asset groups) in the raw database are:

Property Capital	code	Other Capital	code
Industrial Buildings	4001	Computers, Etc.	6002
Commercial Buildings	4002	Tractors/Field Equipment	6011
Other Non-Residential Buildings	4004	Autos/Parts	6201
Transportation Structures	5002	Trucks/Part	6203
Waterworks Structures	5003	Oth Transport Equipment	4001
Sewage Structures	5004	Processing Equipment	7002
Oil and Gas Structures	5007	Communications Equipment	7003
Other Structures	5009	Furniture	7004
		Other Machinery and Equipment	7005

$L = 17$ (17 types of infrastructure capital) ; and $M = 3$ (knowledge spillovers from other manufacturing in Canada, the Canadian federal government and from food processors in the United States). The starting year for the time series is 1963 – this is the first year for which all of the raw data are available; the end year is 1997 – this is the last year for which all of the series are available.⁴

4.2.2 RAW DATA FOR AFTER-TAX USER COSTS OF EFFICIENCY-ADJUSTED INPUTS

While after-tax user costs for efficiency-adjusted inputs cannot be computed prior to estimation (since the parameters h_u are not known), recall from Chapter 3, expression (3.24), that

$$\omega_{ut}^A = \Theta_{0ut}^A + \Theta_{1ut}^A q_{ut} \quad , \quad u = 1, 2, \dots, N \quad ,$$

where the data component of both Θ_{0ut}^A and Θ_{1ut}^A is Λ_{ut} . Thus, to estimate ω_{1t}^A , $\omega_{2t}^A, \dots, \omega_{Nt}^A$, each tax component Λ_{ut} ($u = 1, 2, \dots, N$) must be known.

Also recall from the definitions accompanying (3.12e'), (3.13e') and (3.14e) that the tax components in these equations are specified as follows:

⁴Data for most series are available up to at least 2000 – where this is the case, the most recent information collected is included in the raw database. Similarly, some series begin in 1960 or 1961 – these earlier observations are also included in the database; some are actually used when constructing derived data, or where lagged variables are needed. The main limiting factor in the length of the data series is the information from the KLEMS database [26], namely the expenditure and price data for labour, energy, materials and services – all these data series end in 1997.

input type	specification of tax component
property capital	$\Lambda_{kt} = 1 - \psi_t^I - \Xi_{kt}^4 (1 + \rho_t) / (\rho_t + \gamma_{kt})$ $+ \Xi_t^3 (1 + \rho_t) / (\rho_t + \delta_k) \quad , k \in N_d$
other capital	$\Lambda_{rt} = 1 - \psi_t^I - \Xi_{rt}^4 (1 + \rho_t) / (\rho_t + \gamma_{rt}) \quad , r \in \mathbb{N}_e$
non-capital	$\Lambda_{it} = (1 - \Xi_t^1) \quad , i \in \mathbb{N}_b$

The data elements of the after-tax user costs for efficiency-adjusted inputs are thus

variable notation	variable description	sub- element of:
q_{ut}	acquisition/hiring price	—
κ_t^{FC}	basic federal corporate income tax rate	Ξ_t^1
κ_t^{FS}	federal corporate surtax rate	Ξ_t^1
κ_t^{FP}	federal tax abatement rate	Ξ_t^1
ψ_t^M	manuf.&processing profits tax credit rate	Ξ_t^1
κ_t^{PC}	provincial corporate income tax rate	Ξ_t^1
γ_{jt}	capital cost allowance rate	Ξ_{jt}^4
ψ_t^I	investment tax credit rate	Ξ_{jt}^4
κ_t^{LL}	average property tax rate	Ξ_t^3
κ_t^{LB}	average business tax rate	Ξ_t^3
δ_j	decay rate	—
ρ_t	discount rate	—

Acquisition prices for each of the 17 capital asset types are defined as investment deflators and are obtained from the Investment and Capital Stock Division at Statistics Canada. These data are presented in Table 1aR (for property cap-

ital) and Table 1bR (for other capital).⁵ The subgroups of assets that comprise each asset group are listed in Table 1cR.

Hiring prices for labour and acquisition prices for energy, materials (an aggregate of intermediate and purchased inputs) and purchased services are taken from the Statistics Canada KLEMS database – see [1],[26] – and are presented in Table 2R.

Federal corporate income tax data excepting capital cost allowance rates – i.e. for the rates κ_t^{FC} , κ_t^{FS} , κ_t^{FP} , ψ_t^M and ψ_t^I – are presented in Table 3R. Corporate income tax rates for the ten provinces (used to compute κ_t^{PC} in the next section) are also given in Table 3R. Data on provincial shipments made by food and beverage processors⁶ are given in Table 4R – these data are also used to compute κ_t^{PC} in the next section.

Capital cost allowance (CCA) rates are presented separately in Table 5R. The CCA rate represents the maximum proportion of un-depreciated capital that the federal income tax regulations allow corporations to claim when calculating taxable income. Since the 1960s there have been several changes to the number of classes of assets defined in the regulations, but allowable rates for any class of assets have remained the same, once established. On several occasions between 1961 and 1997 there were changes in the applicable class for certain asset types. The data presented in Table 5R, while limited to a selection of years between 1961 and 1997, are annotated regarding class changeover dates for the affected

⁵These tables and those referred to subsequently in this chapter appear at the end of the document Appendix E.

⁶Up until the 1980's, shipments data for the food industry were not separated from data for the beverage industry. So food and beverage shipments are used instead.

assets. These changeover dates are then used in the construction of CCA time series in the next section.

Rates for local taxes (κ_t^{LL} and κ_t^{LB}) are not available as time series, although it is possible to compute what amounts to an estimated annual average rate for these two types of taxes. The raw data needed to do this are presented in Table 6R. Discount rate data are also given in this table.

Decay rates by asset type are presented in Table 7R. Note that these are constant over time.

4.2.3 OTHER RAW DATA

Data needed to derive observed quantities of property capital are presented in Table 8aR and Table 8bR – these tables give the current dollar value and capital stock deflators for end-year net stocks constructed using geometric decay.⁷ Tables 9aR and Table 9bR present the same type of data for other capital. Current dollar expenditure data for labour, energy, materials and services – from the KLEMS database – are presented in Table 10R.

⁷Capital stock deflators differ from investment deflators because they reflect the composition of the capital stock, which is comprised of more than one vintage of capital, with different market values for each vintage. On the other hand, the investment deflator is only for one vintage of capital – i.e. it is the price of a new capital item in the current year.

Gross output data are defined in current dollars as the value of shipments (sales) plus the value of any change in inventories [26, p.145, fn. 3]. The concept of gross output comes from the supply-demand balance identity

$$BEG_t + PROD_t - END_t \equiv SHIP_t + INTD_t ,$$

where: BEG_t is the quantity of inventories that producers hold at the beginning of year t , $PROD_t$ is the quantity of commodities produced in year t , END_t is the quantity of inventories held by producers at the end of year t , $SHIP_t$ is the quantity of manufacturing shipments (sales) in year t and $INTD_t$ is the quantity of intermediate inputs (drawn from beginning inventories or production) used in the production of output in year t .⁸ Thus, the left-hand side of the supply-demand balance identity represents gross supply and the right-hand side represents gross demand.

Gross output comes from a rearrangement of the supply-demand balance identity:

$$y_t = PROD_t \equiv SHIP_t + INTD_t + (END_t - BEG_t) ,$$

meaning that if no part of production is wasted or lost, gross output is equal to production, which in turn is defined as the sum of shipments, intermediate

⁸For example, flour produced by a miller might be sold to an enterprise in an industry other than food processing (e.g. to a wholesaler) or it could be sold to an enterprise that is also in the food processing industry (such as a bakery). In the former case, the flour would enter the identity as an intermediate input (i.e. in $INTD_t$) while in the latter case, it would enter as a shipment (i.e. in $SHIP_t$). The difference is important, since intermediate inputs are included in the materials (M) input component of the KLEMS data (along with materials purchased from outside the food processing industry) – these inputs are thus included both as part of the materials input and as part of gross output, while shipments only appear as part of gross output.

demand and change in inventory ($END_t - BEG_t$) in that year. The current dollar value of gross output for food processing and the output deflator needed to convert these data into real terms are given in Table 10R.⁹

Infrastructure capital stock data needed to construct the vector G_t are defined as stocks held by the Public Administration sector (NAICS code 910000)¹⁰ and cover a total of 21 asset groups. For property infrastructure capital, the current dollar value and capital stock deflators for end-year net stocks (constructed using geometric decay) are presented in Table 11aR and Table 11bR respectively. The same type of data for other infrastructure capital are given in Table 12aR and Table 12bR.¹¹

Knowledge spillovers are measured as stocks of R&D external to the food processing sector. Statistical agencies usually only report current dollar (nominal) expenditures on R&D of the type given in Table 13aR, although these expenditures are sometimes separated into categories such as ‘investments in machinery, equipment’ and ‘salaries’.

⁹Since the food processing industry is comprised of several sub-industries (in the KLEMS database there are seven of these), aggregation of output is valid if output in the sub-industries grew at approximately the same rate. While growth rates did vary between sub-industries, the rates of output growth for meat processing and for dairy processing – which together represented nearly 50% of industry output over the sample – were quite similar. The features of these sub-industry series provides support for the use of a single aggregate output.

¹⁰This sector is comprised of three subsectors: Federal Government Public Administration (NAICS code 911000); Provincial and Territorial Public Administration (NAICS code 912000); and Local, Municipal and Regional Public Administration (NAICS code 913000).

¹¹The distinction between property and other capital is not necessary for infrastructure, but this separation is convenient for presenting the infrastructure capital data. As it happens, the asset groups of most interest for this analysis (particularly engineering construction) are included in the property capital category.

To deflate nominal expenditures on R&D, the main task is to find an appropriate price for R&D investment. The simplest approach is to use a GDP deflator (see for example [34, p. 8]). This approach, however, will not be appropriate if the composition of R&D inputs is different from that underlying the GDP deflator [10, p. 131], and in such a case, use of the GDP deflator could lead to “substantial analytical and policy errors” [29, p. 124]. Instead, a more appropriate methodology would be to construct a price index that captures the cost of R&D by using expenditure shares and prices for cost components that are specific to R&D [22, p. 218], [29, pp. 124-125].

R&D price index data, constructed along the lines suggested above for Canadian R&D expenditures, are given in [4]. This series – which ends in 1987 – is extended to 1998 using data on the salaries of engineers and scientists.¹² These data are given in Table 13bR. For the United States, the series is the cost per scientist or engineer in R&D performing companies. These data are also presented in Table 13bR.

¹²The extension of the deflator index in this manner is based on the fact that salaries are the largest component of R&D expenditure. According to information in Statistics Canada publication 88-202, wages and salaries represented an average of 55% of non-capital expenditures and 49% of all expenditures on R&D in all of manufacturing between 1972 and 2000.

4.3 DERIVED DATA

4.3.1 INTRODUCTION

There are two categories of derivations covered in this section. The first category is the derivation of after-tax acquisition and hiring prices and R&D stocks. There are several steps involved in the derivation of after-tax acquisition and hiring prices, including:

- computation of an average provincial corporate income tax rate κ_t^{PC}
- computation of the corporate income tax rate Ξ_t^1
- estimation of property tax rate κ_t^{LL} , business tax rate κ_t^{LB} and net local tax rate Ξ_t^3
- creation of CCA rate time series and computation of tax effects of CCAs (net of investment tax credit) as a single rate Ξ_t^4
- computations of after-tax acquisition and hiring prices Q_{ut} , $u = 1, 2, \dots, 21$.

The other tasks involved in the first category of derivations are the derivation of observed input quantities and the construction of R&D stocks for each of the three categories of knowledge spillovers

The second category of derivations involves aggregation of:

- after-tax acquisition and hiring prices
- observed inputs
- infrastructure.

4.3.2 DERIVATION AFTER-TAX ACQUISITION/HIRING PRICES AND KNOWLEDGE SPILLOVERS

A time series of the average provincial corporate income tax rate is computed by first calculating shares of processor shipments by province using raw data from Table 4R. Then, the shares are used, along with provincial rates from Table 3R in the raw database, to create a weighted average provincial corporate income tax rate – the time series for this rate (κ_t^{PC}) is presented in Table 1D. This allows computation of the time series Ξ_t^1 , using raw time series data from Table 3R for κ_t^{FC} , κ_t^{FS} , κ_t^{FP} , ψ_t^M and the derived time series for κ_t^{PC} – the derived time series for Ξ_t^1 is presented in Table 1D as well.

As noted in Chapter 3, a wide range of tax rates and tax bases have been used to levy real property and business taxes in cities and municipalities across Canada. To illustrate this diversity, information on these taxes for five Canadian cities in 1968 are presented in the table below.¹³

¹³The year 1968 is chosen because that is the last year that the Dominion Bureau of Statistics (the precursor of Statistics Canada) documented mill rates and other data related to city and municipal real property and business tax levies. For 1969 and 1970, the Bureau used information obtained from a survey to provide real property tax data for all jurisdictions using a single metric: the rate of tax on the market value of property [20, p. 37]. The idea behind these derivations was to provide a straightforward way of making comparisons of tax rates across jurisdictions. This approach was dropped for 1971 and subsequent years, since it was judged that the method was “too simplistic to provide a satisfactory solution to the problem of comparability since it was directed only at eliminating the effects on mill rates of variations in assessment” [21, p. 39]. As a result, since 1970, no real property tax rate data have been reported in the publication; instead a table is provided that describes the way in which real property and business taxes are levied – see, for example, [40, pp. 57-61].

Rates for Real Property Tax and Business Tax:

Five Cities , 1968

Variable	Halifax	Montréal	Toronto	Winnepeg	Vancouver
PT method ¹	B	B	B	B ³	r ⁴
PT rate ²	46.9	41	104.45	88.18	48.98
BT method	0.5*B	r	B	r	r
BT rate	45 mills	11.5%	various%	6%-20%	7%

NOTES:

¹ 'PT' denotes 'property tax'; 'BT' denotes 'business tax';

'B' denotes 'base value' (unspecified base); 'r' denotes 'rental value'.

² All PT rates are in mills, which are dollars of tax per thousand dollars of base or rental value.

³ Buildings are taxed at 66% of B, land at 100% of B.

⁴ Buildings are taxed at 100% of B for municipal purposes, 75% of B for school purposes, land at 100% of B

SOURCE: [19, pp. 40-47]

Calculations made in the following year for the same five cities show that property tax rates are more similar across cities when presented as a proportion of market value rather than in mills. As the table below shows, the derived rates ranged from 2.36% to 4.38% in 1969.

Total Commercial Real Property Tax as a Proportion of

Market Value: Five Cities, 1969

Halifax	Montréal	Toronto	Winnipeg	Vancouver
4.38%	4.02%	3.75%	3.66%	2.36%

SOURCE: [20, pp. 38-40]

Data in the table above are useful as a benchmark range for comparison with rates derived for Canada and for that year using raw data from Table 6R. The derived rates are calculated by first adding revenues from provincial real property taxes and local real and personal property taxes together. Then, this value is divided by: (i) the total of value of residential and non-residential structures from the Statistics Canada National Balance Sheet, National Wealth Accounts,¹⁴ and to (ii) the value of land from the wealth account plus the value computed in (i). This approach over-simplifies both the actual mechanics of these taxes, as well as the marginal effects of them, but represents a compromise between a thorough analysis of local tax incidence (not the focus of this analysis) and the exclusion of local tax effects entirely. The results of these computations – i.e. estimates of κ_t^{LL} – are given in Table 1D. The estimated rate of property tax for 1969 including land is 1.4%, while that excluding land is 2%. Benchmark values (from the table above) are between 2.36% (Vancouver) and 4.38% (Halifax). Consequently, the derived value without land seems to be closer to the benchmark values (even though it

¹⁴Note:

- (i) ‘Non-residential structures’ are the sum of linear EYNS data for building construction and engineering construction for the whole Canadian economy, with the definitions of these variables the same as those in Table 8aR and Table 8bR in the raw database except that instead of geometric decay, linear decay is used to construct the end-year net stock.
- (ii) It is necessary to include residential structures in the denominator (the ‘tax base’) because property tax revenues are not separated into commercial and residential categories.
- (iii) Personal property wealth is not included in the denominator (the ‘tax base’) since, while taxes on personal property are included in the property tax revenue data, this element is a small element of the total.

appears to be an underestimate), so this is the series used when deriving after-tax acquisition prices for property capital inputs.

Estimated business tax rates are calculated simply as the ratio of business tax revenue data (from Table 6R) to the total value of non-residential structures. The derived business tax rate data (for κ_t^{LB}) are also given in Table 1D. Since local taxes are not included in taxable income, the net local tax rate Ξ_t^3 is the sum of the property and business tax rates weighted by the corporate income tax effect (i.e. $1 - \Xi_t^1$) – this is the last entry in Table 1D.

In order to make computations more straightforward, capital cost allowance rates from Table 5R are presented as time series in Table 2aD for γ_{kt} (property capital CCA rates) and Table 2bD for γ_{rt} (other capital CCA rates). These data reflect the changes in rates for those asset groups that moved to another CCA class between 1961 and 1997. The tax effects of capital cost allowances on acquisition cost are presented in Table 3aD for rates Ξ_{kt}^4 (property capital) and in Table 3bD for rates Ξ_{rt}^4 (other capital).

Observed property capital input quantities v_{kt} are derived by dividing the current dollar value of the stock for each asset group (from Table 8aR) by the capital stock deflator for that group (from Table 8bR). These derived data are presented in Table 4aD. Observed other capital input quantities v_{rt} – presented in Table 4bD – are derived in the same manner, using data from Table 9aR and Table 9bR.

Observed input quantities of non-capital inputs (v_{it}) are derived by dividing the current dollar expenditure data for labour, energy, materials and services – from Table 10R – by the hiring or acquisition prices for these variables – given

in Table 2R. These derived quantity data are given in Table 5D. Constant dollar gross output data – derived with raw data from the same tables used for non-capital inputs – are calculated by dividing current dollar value of gross output by the output price deflator; these derived data are also presented in Table 5D.

Knowledge spillovers are derived as stocks of R&D. The procedure used to calculate the R&D stocks follows that used for physical capital, i.e. the perpetual inventory method. In particular, the three stocks s_1, s_2 , and s_3 are computed using the formula

$$s_{rt} = x_{rt}^s + (1 - \delta_r^s)s_{rt-1} \quad , \quad r = 1, 2, 3, \quad (4.1)$$

where: s_1 is the R&D capital stock of all Canadian manufacturing industries excluding food processing; s_2 is the R&D capital stock of the Canadian federal government and s_3 is the R&D capital stock of food, kindred and tobacco products in the United States; $x_{rt}^s = c_{rt}^s/q_{rt}^s$ is the real expenditure on R&D for knowledge spillover r in year t (c_{rt}^s is the corresponding nominal expenditure – where c_{1t}^s is the nominal expenditure for all manufacturing less that for food processors – and q_{rt}^s is the deflator) and δ_r^s is the rate at which R&D capital decays.¹⁵ The values for c_{1t}^s, c_{2t}^s and c_{3t}^s are taken from Table 13aR of the raw database, while data for

¹⁵The rate of decay for R&D investment is more difficult to quantify than that for physical capital. Decay of ideas and methods can be viewed as a reduced level of services (measured as an incremental reduction in net income) attributable to a new product or process over time. Decay, which in this case resembles economic depreciation, accelerates as products or processes – resulting from the application of new ideas and methods – out-perform the old products or processes. Decay also occurs as innovations become more widely adopted. The latter effect will reduce the net income generated from an idea or method as the technology becomes diffused [25, p. 101]. A range for δ_r^s suggested in [5, p. 321] is [0.10, 0.15].

q_{1t}^s, q_{2t}^s (these are the same series) and q_{3t}^s are taken from Table 13bR of the raw database.

Since real investment data only begin in 1963, and the actual R&D stocks both prior to and on this date are not known, estimation of the stock of R&D involves not only a procedure for constructing a stock from investment data, but also the generation of a starting value for 1963. One way to do this is, for each knowledge spillover type (r), to assume an average rate of growth in the stock of R&D prior to 1963 (g_r^s) and with this datum, the assumed value for δ_r^s and the observed level of real investment in 1963 (x_{r1963}^s), impute a value for s_{r1962} .¹⁶ Then the perpetual inventory formula given above can be used to derive stock data for 1963 onwards.

If the stock of R&D capital for knowledge spillover r has increased at the rate g_r^s up to and including 1963, then

$$s_{r1963} = (1 + g_r^s)s_{r1962} \quad , \quad r = 1, 2, 3 . \quad (4.2)$$

Substitute (4.2) into (4.1) with the latter set at $t = 1963$. This gives

$$(1 + g_r^s)s_{r1962} = x_{r1963}^s + (1 - \delta_r^s)s_{r1962} \quad , \quad r = 1, 2, 3 . \quad (4.3)$$

The initial stock s_{r1962} is imputed by isolating this variable on the left-hand side of (4.3) to get

$$s_{r1962} = x_{r1963}^s / (\delta_r^s + g_r^s) \quad , \quad r = 1, 2, 3, \quad (4.4)$$

¹⁶This approach follows [5, p. 318].

and construction of the R&D stock data can proceed with the use of (4.1), starting with the value computed using (4.4). The results of these computations are presented in Table 6D.

4.3.3 AGGREGATION

To make estimation possible with the sample size available, it is necessary to reduce the number of inputs, infrastructure variables and spillover variables from the initial limits established earlier. To begin, property capital and other capital are aggregated into a single capital input. The after-tax user cost for this efficiency-adjusted capital input is specified as:

$$\omega_{\mathbb{N}_c t}^A = \Theta_{0\mathbb{N}_c t}^A + \Theta_{1\mathbb{N}_c t}^A q_{\mathbb{N}_c t} \quad , \quad u = 1, 2, \dots, N \quad , \quad (4.5)$$

where

$$\begin{aligned} \Theta_{0\mathbb{N}_c t}^A &= \Lambda_{\mathbb{N}_c t} (1/h_{\mathbb{N}_c}) [\phi_{\mathbb{N}_c} / (1 - \theta_{\mathbb{N}_c})] \left\{ [(1 - a_t d_{\mathbb{N}_c}) / (1 - a_t \mu_{\mathbb{N}_c})] \right. \\ &\quad \left. - (1 - a_t d_{\mathbb{N}_c} \theta_{\mathbb{N}_c}) / (1 - a_t \mu_{\mathbb{N}_c} \theta_{\mathbb{N}_c}) \right\} ; \end{aligned}$$

$$\Theta_{1\mathbb{N}_c t}^A = \Lambda_{\mathbb{N}_c t} (1/h_{\mathbb{N}_c}) (1 - d_{\mathbb{N}_c} a_t \theta_{\mathbb{N}_c}) / (1 - a_t \mu_{\mathbb{N}_c} \theta_{\mathbb{N}_c}) ;$$

$$\begin{aligned} \Lambda_{\mathbb{N}_c t} &= 1 - \psi_t^I - (1 + \rho_t) \left[\Xi_{\mathbb{N}_c t}^4 / (\rho_t + \gamma_{\mathbb{N}_c t}) \right. \\ &\quad \left. - \left(\sum_{k \in \mathbb{N}_d} q_{kt} v_{kt} / \sum_{j \in \mathbb{N}_c} q_{jt} v_{jt} \right) \Xi_t^3 / (\rho_t + \delta_{\mathbb{N}_d t}) \right] ; \end{aligned}$$

$$d_{\mathbb{N}_c} = 1 - \delta_{\mathbb{N}_c t} ;$$

$$\delta_{\mathbb{N}_c t} = \sum_{j \in \mathbb{N}_c} \delta_{jt} \left[q_{jt} v_{jt} / \sum_{j \in \mathbb{N}_c} q_{jt} v_{jt} \right] ;$$

$$\Xi_{\mathbb{N}_c t}^4 = (1 - \psi_t^I) \Xi_t^1 \gamma_{\mathbb{N}_c t} ;$$

$$\gamma_{\mathbb{N}_c t} = \sum_{j \in \mathbb{N}_c} \gamma_{jt} \left[q_{jt} v_{jt} / \sum_{j \in \mathbb{N}_c} q_{jt} v_{jt} \right] ;$$

and

$$\delta_{N_d t} = \sum_{k \in N_d} \delta_{kt} \left[q_{kt} v_{kt} / \sum_{k \in N_d} q_{kt} v_{kt} \right] .$$

The variable $\delta_{N_d t}$ is a weighted average depreciation rate for all capital in year t ; $\Xi_{N_c t}^4$ is the tax reduction effect of the capital cost allowance on all capital in year t ; $\gamma_{N_c t}$ is a weighted average of CCA rates in year t ; $\delta_{N_d t}$ is a weighted average depreciation rate for property capital in year t ; and $q_{N_c t}$ is the Fisher Ideal [16, p.116] acquisition price index for capital in year t (constructed using data from Table 1aR, Table 1bR, Table 5aD and Table 5bD).¹⁷ The results of these computations, namely the derived series for $\Xi_{N_c t}^4$, $\gamma_{N_c t}$, $\delta_{N_d t}$ and $q_{N_c t}$ are presented in Table 7aD. These data are then used in the estimation phase to derive the user costs $\omega_{N_c t}^A$ with the unknown coefficients ϕ_{N_c} , θ_{N_c} and h_{N_c} (each of these parameters are the all-capital equivalents of the parameters ϕ_i , θ_i and h_i that are defined earlier).

Energy, materials and services data are also combined to create a single input aggregate. The Fisher Ideal acquisition price series for this aggregate is presented in Table 7aD.

The Fisher Ideal aggregate observed capital input is calculated by first multiplying acquisition prices (Table 1aR and Table 1bR) by their respective observed input quantities (from Table 5aD and Table 5bD), and taking the sum of these

¹⁷Note that the weights used to compute $\delta_{N_c t}$ and $\gamma_{N_c t}$ are the ratios of the value of each type of capital to the value of total capital. Similarly the weights used to compute $\delta_{N_d t}$ are the ratio of each type of property capital to the value of total property capital respectively. Finally, the weight on the term $\Xi_t^3 / (\rho_t + \delta_{N_d t})$ is the ratio of the value of all property capital to the value of all capital.

values. This sum is then divided by the Fisher Ideal aggregate acquisition price from Table 7aD. This series is presented in Table 7bD.

A Fisher Ideal aggregate observed input quantity for energy, materials and services is calculated by first computing the product of the acquisition price data for each input from Table 2R and observed input quantity data from Table 6D and by taking the sum of these values. Then the sum of values is divided by the Fisher Ideal aggregate acquisition price for energy, materials and services from Table 7aD. This series is presented in Table 7bD.

For infrastructure, there are several ways to reduce the asset data to a single variable – one option is to aggregate over all asset types to create a single measure of infrastructure using data from Table 11aR, Table 11bR, Table 12aR and Table 12bR – the time series for this aggregate is given in Table 8bD. The other is to select an asset group or collection of asset groups that seems most important in providing the type of infrastructure services that food processors use. This involves a selection process based on calculations with the data in Table 11aR and Table 12aR. In particular, these calculations show that other capital represented between 3% and 5% of total infrastructure over the sample, so that other capital assets are not an important source of infrastructure services. Of the property capital asset groups, transport and sewers represented 60% of total property capital, and so an aggregate of these two asset groups is another possible way to measure infrastructure. Many other possible combinations could be computed, but these two aggregates – (i) all asset groups and (ii) transport and sewers only – are the only ones considered here. In the latter case the aggregate is constructed using data from Table 11aR and Table 11bR – this time series is given in Table 7bD.

4.4 ESTIMATION DATABASE

The estimation database is comprised of data selected from the raw database and the derived database. Each series in the database is given a variable name that then allows this series to be identified as a data variable by the software package used in the econometric analysis. In particular, the name for the aggregate acquisition price series for capital is q_1 – see Table 1E. The names for the tax variables in Table 1E are: itc (for ψ_t^I), rho (for ρ_t), xi_1 (for Ξ_t^1) gam_1 (for $\gamma_{N_c t}$), del_1Nd (for $\delta_{N_d t}$), xi_3 (for Ξ_t^3). The series del_1Nc is for $\delta_{N_c t}$. The final tax-related series in Table 1E is shr_1 – these are the values for the share

$$\sum_{k \in N_d} q_{kt} v_{kt} / \sum_{j \in N_c} q_{jt} v_{jt}$$

that appears in (4.5).

The remaining series in Table 1E are: the acquisition price for labour (q_2), the acquisition price for the aggregate of energy, materials and services (q_3), lagged values of the three acquisition prices (q1_L, q2_L and q3_L) and a vector of ones (one). This last series is used for intercept terms, when these appear in the estimated equations.

Observed input, output, infrastructure and spillover data for estimation are given in Table 2E. Observed input series for aggregate capital, labour and the aggregate of energy, materials and services have the variable names v_1, v_2 and v_3 respectively – lagged values of these data have the names v_1L, v_2L and v_3L respectively. The series y is gross output. The unit of measurement for each of these series is thousands of 1992 dollars.

The series g-1 and g-2 are Fisher Ideal quantity indexes for all public infrastructure and an aggregate of transport and sewers infrastructure respectively. Spillover series - s-1, s-2 and s-3 – are R&D stocks for Canadian manufacturing excluding food, the Canadian federal government and U.S. food processing respectively. Each of these series are scaled data, computed by dividing the constant dollar stock by its 1992 level.

The final series in Table 2E – t – is the time trend.

There are several features of the estimation database that are illustrated in the charts below. As Figure 4.1 shows, acquisition prices for capital and the energy, materials and services aggregate and the hiring price for labour increased more or less consistently from year to year over the whole sample, with acquisition prices fluctuating more than the hiring price for labour. The latter price, however, shows a much slower rate of annual increase in the last five years of the sample.

Another feature of the database is the trend in observed input-output ratios for capital, i.e. v_{1t}/y_t and v_{2t}/y_t – see Figure 4.2. Here, the difference in the annual changes of these variables is striking, with the former ratio increasing more-or-less consistently over the whole sample and the latter decreasing consistently. Since the material/output ratio is relatively constant between 1963 and 1997, the increase in capital intensity has come about at the expense of labour. This pattern is supported by the relative movement of acquisition/hiring prices illustrated below and the elasticity and other results given in the next chapter.

Figure 4.1 Acquisition/Hiring Prices, Canadian Food Processing Industry, 1963-1997

Figure 4.2 Capital/Output vs. Labour/Output Ratio, Canadian Food Processing Industry, 1963-1997

The pattern of input/output ratios of capital and labour shown in the previous chart is certainly due in part to changes in relative prices. As Figure 4.3 shows, the relative price of capital acquisitions to that of labour hirings has decreased substantially between the 1963 and 1997, with this decrease allowing from the mid-1980s on and reversing slightly in the last few years of the sample. When the effects of corporate income tax and local taxes are allowed for, the rate of decrease in the relative price of capital to labour was much more rapid over the first part of the sample.

The pattern of output and public infrastructure quantities over between 1963 and 1997 are illustrated in see Figure 4.4. Output increased at a higher annual rate before the early 1980s than after, but the rate of output growth seemed to recover in the last few years of the sample. On the other hand, public infrastructure increased consistently from year to year over the sample, with the rate of annual increase slowing slightly after the early 1980s.

The last feature to note about the data is the level of private capital (i.e. the observed capital used by food processors) relative to public infrastructure. This ratio – illustrated in Figure 4.5 – varied substantially over the sample, with the highest point in the late 1960s, and the lowest in the late 1970s. Since the early 1980s the ratio of private to public capital (for food processing) has been higher, but variable.

Acknowledgement *Thanks to J. Baldwin, T. Harchaoui, R. Landry, G. Lyttle and J.P. Maynard of Statistics Canada for providing much of the information used to create this database and for helping to resolve questions regarding the data. Thanks also to G. Cherwoniak for collecting most of the knowledge spillover data.*

Figure 4.3 Acquisition Price of Capital Relative to Hiring Price of Labour, Canadian Food Processing Industry, 1963-1997

Figure 4.4 Public Infrastructure Stock and Food Processing Industry Output, Canada, 1963-1997

Figure 4.5 Ratio of Private to Public Capital, Canadian Food Processing Industry, Canada, 1963-1997

CHAPTER 5

EMPIRICAL MODEL

5.1 FUNCTIONAL FORM

Several flexible functional forms could be used to estimate the model developed in Chapter 3.¹ Of these, the chosen form – the symmetric generalized McFadden (SGM) cost function – allows concavity to be imposed without at the same time reducing flexibility of the form [17, pp. 53,54].

The SGM cost function, with three inputs, one output, one type of infrastructure and one type of spillover and trend, has the following form:

$$\begin{aligned}
 C^{ASGM}(\omega_{1t}^A, \omega_{2t}^A, \omega_{3t}^A, y_t, G_t, S_t, t) = & \quad (5.1) \\
 & \sum_{i=1}^3 \alpha_i \omega_{it}^A + \left((1/2) \sum_{i=1}^3 \sum_{j=1}^3 \beta_{ij} \omega_{it}^A \omega_{jt}^A / \sum_{i=1}^3 b_i \omega_{it}^A \right) y_t \\
 & + \sum_{i=1}^3 \beta_{iy} \omega_{it}^A y_t + \beta_{yy} \left(\sum_{i=1}^3 b_i \omega_{it}^A \right) (y_t)^2 \\
 & + \alpha_G \left(\sum_{i=1}^3 b_i \omega_{it}^A \right) G_t + \sum_{i=1}^3 \beta_{iGy} \omega_{it}^A G_t y_t + \beta_{GGy} \left(\sum_{i=1}^3 b_i \omega_{it}^A \right) (G_t)^2 y_t \\
 & + \alpha_S \left(\sum_{i=1}^3 b_i \omega_{it}^A \right) S_t + \sum_{i=1}^3 \beta_{iSy} \omega_{it}^A S_t y_t + \beta_{SSy} \left(\sum_{i=1}^3 b_i \omega_{it}^A \right) (S_t)^2 y_t \\
 & + \alpha_t \left(\sum_{i=1}^3 b_i \omega_{it}^A \right) t + \sum_{i=1}^3 \beta_{ity} \omega_{it}^A t y_t + \beta_{tty} \left(\sum_{i=1}^3 b_i \omega_{it}^A \right) t^2 y_t \\
 & , \quad t = 1, 2, \dots, T,
 \end{aligned}$$

¹A flexible functional form provides “a second-order (differential) approximation to an arbitrary twice continuously differentiable function ... at a point ...” [15, p. 574, fn. 31].

where: $\beta_{ij} = \beta_{ij} \forall i, j$, and the each b_i ($i = 1, 2, \dots, N$) is a fixed exogenous weight.

Efficiency-adjusted input demands are obtained from the SGM cost function by applying expression (3.22) from Chapter 3 to it, i.e.

$$\begin{aligned}
 Z_i^{ASGM}(\omega_{1t}^A, \omega_{2t}^A, \dots, \omega_{3t}^A, y_t, G_t, S_t, t) = & \quad (5.2) \\
 & \alpha_i + \left(\sum_{j=1}^3 \beta_{ij} \omega_{jt}^A / \sum_{i=1}^3 b_i \omega_{it}^A \right) y_t \\
 & - (1/2) \left(b_i \sum_{i=1}^3 \sum_{j=1}^3 \beta_{ij} \omega_{it}^A \omega_{jt}^A / \left(\sum_{i=1}^3 b_i \omega_{it}^A \right)^2 \right) y_t \\
 & + \beta_{iy} y_t + \beta_{yy} b_i (y_t)^2 \\
 & + \alpha_G b_i G_t + \beta_{iGy} G_t y_t + \beta_{GGy} b_i (G_t)^2 y_t \\
 & + \alpha_S b_i S_t + \beta_{iSy} S_t y_t + \beta_{SSy} b_i (S_t)^2 y_t \\
 & + \alpha_t b_i t + \beta_{ity} t y_t + \beta_{tty} b_i t^2 y_t \\
 & i = 1, 2, \dots, 3 \quad , \quad t = 1, 2, \dots, T.
 \end{aligned}$$

Since, taken together, these demand functions contain all of the coefficients in the cost function, it is possible to estimate the system of demand equations without losing any information.

5.2 ESTIMATION

The variables z_{it} are unobservable, so direct estimation of demand equations (5.2) is not possible. Instead, expression (3.23) from Chapter 3 is used – with Z^A now replaced by Z^{ASGM} to reflect the specification (5.2) – so that the estimated equations are:

$$v_{it} = (1/h_i) Z_i^{ASGM} \begin{pmatrix} \cdot \\ t \end{pmatrix} + \mu_i v_{it-1} . \quad (5.3)$$

Equations (5.3) allow estimation of the coefficients in (5.2) using observed data.

Concavity is imposed on equations (5.2) using the procedure described in Appendix D. With the simplification that $\phi_i = 0 \forall i$, expression (3.24) in Chapter 3 becomes²

$$\omega_{it}^A = \Lambda_{it} [(1 - d_i a_t \theta_i) / (1 - a_t \mu_i \theta_i)] q_{it} . \quad (5.4)$$

These expressions for after-tax user costs of efficiency-adjusted inputs are entered directly into the concavity-constrained equations (5.2), and the result is then substituted into (5.3). Finally, to reduce any possible heteroskedasticity and to make calculations with the results more tractable, the resulting version of equation (5.3) is divided through by output (y_t).

Once the concavity and user cost elements are incorporated in the demand equations for efficiency-adjusted inputs, the outcome is a set of equations that are very nonlinear in coefficients. Using input 1 (capital) as an example (specifications for inputs 2 and 3 are similar), equation (5.3) has the form:³

²With $\phi_i = 0 \forall i$, the expectations process given by (2.15) in Chapter 2 simplifies to (for three inputs):

$$q_{it+1}^e = \theta_i q_{it} , \quad i = 1, 2, 3 .$$

Two things come about with this restriction. First, the only restriction on θ_i implied by the theory, i.e. that $\theta_i \neq 1 \forall i$, is no longer needed. Second, it means that the ratio of two expected prices will always be directly proportional to the observed ratio of these prices.

³The disembodied technical change terms are excluded from the estimated demand equations, but R&D spillover terms are included. While the theoretical model and SGM equations (5.2) allow for both technical change and spillover effects, in practice, one or the other should be chosen when estimating the model. In particular, the spillover variable captures the change in Canadian food processors's production technology arising from R&D that is external to those processors; this is precisely the type of effect that the variable 't' is meant to capture.

$$\begin{aligned}
v_{y1t} = & (1/h_1) \left\{ \alpha_1/y_t + \left(-(a_{11})^2 \Lambda_{1t} [(1 - d_1 a_t \theta_1) / (1 - a_t(1 - 1/h_1)\theta_1)] q_{1t} \right. \right. \\
& - (a_{11}a_{12}) \Lambda_{2t} [(1 - d_2 a_t \theta_2) / (1 - a_t(1 - 1/h_2)\theta_2)] q_{2t} \\
& \left. - (a_{11}a_{13}) \Lambda_{3t} [(1 - d_3 a_t \theta_3) / (1 - a_t(1 - 1/h_3)\theta_3)] q_{3t} \right) / \\
& \left(b_1 \Lambda_{1t} [(1 - d_1 a_t \theta_1) / (1 - a_t(1 - 1/h_1)\theta_1)] q_{1t} \right. \\
& + b_2 \Lambda_{2t} [(1 - d_2 a_t \theta_2) / (1 - a_t(1 - 1/h_2)\theta_2)] q_{2t} \\
& \left. + b_3 \Lambda_{3t} [(1 - d_3 a_t \theta_3) / (1 - a_t(1 - 1/h_3)\theta_3)] q_{3t} \right) \\
& + b_1 \left\{ -0.5 \left((-a_{11}^2) \left[\Lambda_{1t} [(1 - d_1 a_t \theta_1) / (1 - a_t(1 - 1/h_1)\theta_1)] q_{1t} \right]^2 \right. \right. \\
& - 2(a_{11}a_{12}) \left[\Lambda_{1t} [(1 - d_1 a_t \theta_1) / (1 - a_t(1 - 1/h_1)\theta_1)] q_{1t} \right] \\
& \quad \left[\Lambda_{2t} [(1 - d_2 a_t \theta_2) / (1 - a_t(1 - 1/h_2)\theta_2)] q_{2t} \right] \\
& - 2(a_{11}a_{13}) \left[\Lambda_{3t} [(1 - d_3 a_t \theta_3) / (1 - a_t(1 - 1/h_3)\theta_3)] q_{3t} \right] \\
& \quad \left[\Lambda_{3t} [(1 - d_3 a_t \theta_3) / (1 - a_t(1 - 1/h_3)\theta_3)] q_{3t} \right] \\
& \left. - (a_{12}^2 + a_{22}^2) \left[\Lambda_{2t} [(1 - d_2 a_t \theta_2) / (1 - a_t(1 - 1/h_2)\theta_2)] q_{2t} \right]^2 \right.
\end{aligned} \tag{5.5}$$

$$\begin{aligned}
& -2(a_{12}a_{13} + a_{22}a_{23}) \left[\Lambda_{2t} [(1 - d_2 a_t \theta_2) / (1 - a_t(1 - 1/h_2)\theta_2)] q_{2t} \right] \\
& \quad \left[\Lambda_{3t} [(1 - d_3 a_t \theta_3) / (1 - a_t(1 - 1/h_3)\theta_3)] q_{3t} \right] \\
& - (a_{13}^2 + a_{23}^2 + a_{33}^2) \left[\Lambda_{3t} [(1 - d_3 a_t \theta_3) / (1 - a_t(1 - 1/h_3)\theta_3)] q_{3t} \right]^2 \Big) / \\
& \quad \left(b_1 \Lambda_{1t} [(1 - d_1 a_t \theta_1) / (1 - a_t(1 - 1/h_1)\theta_1)] q_{1t} \right. \\
& \quad + b_2 \Lambda_{2t} [(1 - d_2 a_t \theta_2) / (1 - a_t(1 - 1/h_2)\theta_2)] q_{2t} \\
& \quad \left. + b_3 \Lambda_{3t} [(1 - d_3 a_t \theta_3) / (1 - a_t(1 - 1/h_3)\theta_3)] q_{3t} \right)^2 \\
& \quad + \beta_{1y} + \beta_{yy} b_1 y_t \\
& \quad + \alpha_G b_1 (G_t / y_t) + \beta_{1Gy} G_t + \beta_{GGy} b_1 (G_t)^2 \\
& \quad + \alpha_S b_1 + \beta_{1Sy} S_t + \beta_{SSy} b_1 (S_t)^2 \Big\}
\end{aligned}$$

$$+ (1 - 1/h_1) v_{y1t-1} + e_{1t}^v \quad , \quad i = 1, 2, \dots, 3 \quad , \quad t = 1, 2, \dots, T.$$

where $v_{y1t} = v_{1t}/y_t$ and $v_{y1t-1} = v_{1t-1}/y_t$.

Note that the variable e_{1t}^v is a random disturbance for the capital demand equation; the labour equation and the equation for the energy, materials and services aggregate have similar disturbances attached to them (these are denoted as e_{2t}^v and e_{3t}^v respectively).

These demand equations are estimated as a system along with the expectations equations:

$$q_{it+1} = \theta_i q_{it} + e_{it+1}^q \quad , \quad i = 1, 2, 3; \quad t = 1, 2, \dots, T-1 \quad (5.6)$$

where e_{it+1}^q is a random disturbance associated with the expectations equation for acquisition price i . The properties of the disturbances are discussed in the next section.

5.3 ECONOMETRICS

Since the demand for each efficiency-adjusted input is determined by the same processors and since the errors on these demands are generated in part by random deviations from the optimal levels of these inputs, there is likely to be some correlation between the error in the demand equation for one input and in that for another. Similarly, since expectations are made by the same processors, the expectations errors – between $E_t(q_{ut+1})$ formed in year t and the realization of this variable, q_{ut+1} , in year $t + 1$ – are assumed to be correlated with the optimization errors and vice versa. Thus, since the errors across equations are assumed to be correlated within any year, and since each equation shares some coefficients with the others, the econometric problem is to estimate a set of non-linear seemingly unrelated equations with lagged dependent variables. The system of equations may therefore be specified in the general notation as (see [24, pp. 698-699]):

$$\begin{aligned}
 v_{y1} &= \Phi_1(\beta', X) + e_1^v, \\
 v_{y2} &= \Phi_2^v(\beta', X) + e_2^v \\
 v_{y3} &= \Phi_3^v(\beta', X) + e_3^v \\
 q_1 &= \Phi_1^q(\beta', X) + e_1^q \\
 q_2 &= \Phi_2^q(\beta', X) + e_2^q \\
 q_3 &= \Phi_3^q(\beta', X) + e_3^q,
 \end{aligned} \tag{5.7}$$

where: v_{yi} and q_i , $i = 1, 2, 3$, are 1×34 vectors of observations on the dependent variable,⁴ β' is a 1×29 vector of coefficients to be estimated, X is a 34×22 matrix of observations on the regressors,⁵ and $e_1, \dots, e_6$ are 34×1 vectors of disturbances.

The disturbances are assumed to have the following features:⁶

$$\begin{aligned} E(e_{it}^v e_{js}^v) &= \sigma_{vvij}^2 \text{ for } t = s \text{ and zero otherwise;} \\ E(e_{it+1}^q e_{js+1}^q) &= \sigma_{qqij}^2 \text{ for } t = s \text{ and zero otherwise;} \\ E(e_{jt}^v e_{is+1}^q) &= \sigma_{vqij}^2 \text{ for } t = s \text{ and zero otherwise.} \end{aligned}$$

The system of nonlinear equations (5.1) can be estimated using a generalized least squares method that minimizes the sum of squared errors using pseudoregressors obtained from a linearization of each equation [24, pp. 699-700]. Since the linearization still requires the evaluation of gradients at a point, and since these gradients are a non-linear function of the coefficients that comprise β , numerical methods must be used to find a solution to the least squares problem. There are a variety of algorithms that could solve the problem, but success (convergence to a vector $\hat{\beta}$ that gives a global minimum) may depend upon the algorithm chosen [24, p.212].⁷ When convergence is reached, the resulting $\hat{\beta}$ computed is consistent and asymptotically efficient [24, p. 700].

⁴Due to the way in which the expectations equation is specified, the 35th observation must be dropped from the sample to allow for a lead on the acquisition prices.

⁵See Table1E and Table2E (the estimation database described in Chapter 4), noting that only one type of infrastructure is included in $C^{ASGM}(\cdot)$, as is only one type of spillover

⁶Some further details on some of the econometric aspects of this model are given in Appendix D.

⁷The package used for estimation of the model is SHAZAM v9.0 (Professional Edition) – the NL facility in SHAZAM uses a quasi-Newton method (Davidon-Fletcher-Powell) to compute the numerical solution.

Consistent estimation of the coefficient vector $\hat{\beta}$ and of the asymptotic covariance matrix of these parameters does not require that a distribution for the disturbances be specified. In fact, it is possible to say that $\hat{\beta}$ is asymptotically normal and efficient as well, without assuming anything about the distribution for the disturbances [23, p. 40].

5.4 ESTIMATION RESULTS

The results discussed here are for a version of the specification presented in the previous section, namely that with infrastructure and spillovers. The data used for the infrastructure (G) regressor are for all public infrastructure (series g-1 in the estimation database) and the data used for the spillover (S) regressor are the R&D stock for U.S. food processing (series s-3 in the estimation database).

The choice of values for the exogenous constants b_1, b_2, b_3 is essentially up to the researcher, although these are usually set to the sample mean levels. Following [18, p. 714], b_i is computed prior to estimation using sample averages of observed data:

$$b_i = v_i^{ave} / \sum_{k=1}^3 v_k^{ave}$$

where: $v_i^{ave} = \sum_{t=1}^T v_{it}/T$, $t = 1, 2, \dots, T$, $i = 1, 2, 3$; i.e., this is the average observed constant-dollar level of input i over the sample.

The initial starting values for the coefficients were set to levels that seemed plausible; in part, these were chosen to obtain convergence in early runs of the model. During first attempts to get solutions for the model, precision problems were encountered, since some coefficient estimates ran up against the machine precision limit during iteration. In some cases, the opposite was true – the

parameters became very large during iteration, so that the approximations to the Hessian matrix were affected. To correct for these problems, the regressors applied to several coefficients were scaled by 100000 during estimation. After estimates were achieved, the estimated coefficients were de-scaled (to get their true values); in essence this procedure did not affect the consistency of the estimates, just the ability of the machine to compute them. Note that elasticities and other post-estimation calculations are done with the de-scaled values. The scaling of coefficients is summarized in Table 5.1.

Table 5.1 Scalings of Coefficients for Estimation

regressor	coefficient affected	scaling factor	estimated coefficient	derived estimate of affected coefficient
$1/y_t$	α_u	100000	$\hat{\alpha}_u^{scal}$	$\hat{\alpha}_u = \hat{\alpha}_u^{scal}/100000$
$b_1 y_t$	β_{yy}	(1/100000)	$\hat{\beta}_{yy}^{scal}$	$\hat{\beta}_{yy} = 100000 * \hat{\beta}_{yy}^{scal}$
$b_1 (G_t/y_t)$	α_G	100000	$\hat{\alpha}_G^{scal}$	$\hat{\alpha}_G = \hat{\alpha}_G^{scal}/100000$
$b_1 (S_t/y_t)$	α_S	100000	$\hat{\alpha}_S^{scal}$	$\hat{\alpha}_S = \hat{\alpha}_S^{scal}/100000$

where $u = 1, 2, 3$.

With these settings and adjustments, the system converged after 1804 iterations, using the default criterion. The resulting coefficient estimates are presented in Table 5.2.

The overall fit for the six equations in the system was good, with R^2 statistics exceeding 0.99 for all equations excepting energy, materials and services demand. (A possible contributor to the relatively poor fit for this equation – the R^2 is 0.55 – is that the input-output ratio for this aggregate did not vary much during the sample, and so there was little in the way of change for the model to measure.)

Table 5.2 Estimated Coefficients

coefficient	estimate	standard	
		error	t-ratio
h_1	3.914	0.844	4.635
h_2	1.511	0.257	5.887
h_3	1.182	0.123	9.623
θ_1	1.028	0.004	247.900
θ_2	1.040	0.006	186.920
θ_3	1.031	0.007	158.210
α_1^{scal}	49.772	19.739	2.522
α_2^{scal}	60.104	12.249	4.907
α_3^{scal}	51.232	42.417	1.208
a_{11}	-0.043	0.172	-0.250
a_{12}	0.294	0.099	2.960
a_{13}	0.318	0.311	1.024
a_{22}	-3.5×10^{-06}	9.006	-3.9×10^{-07}
a_{23}	-3.5×10^{-06}	9.395	-3.8×10^{-07}
a_{33}	9.5×10^{-10}	0.326	2.9×10^{-09}
β_{1y}	-0.011	0.205	-0.051
β_{2y}	0.338	0.235	1.436
β_{3y}	1.016	0.553	1.837
β_{yy}^{scal}	-0.002	0.002	-0.835
α_G^{scal}	-5.177	459.410	-0.011
β_{1Gy}	0.366	0.479	0.764
β_{2Gy}	-0.087	0.291	-0.298
β_{3Gy}	0.170	1.195	0.142
β_{GGy}	-0.204	0.548	-0.372
α_S^{scal}	-603.710	467.900	-1.290
β_{1Sy}	0.389	0.462	0.841
β_{2Sy}	0.398	0.277	1.437
β_{3Sy}	1.182	1.142	1.035
β_{SSy}	-0.253	0.486	-0.519

Three hypothesis tests – using the Wald test procedure – were performed on the parameters; these are summarized below.

No efficiency effects ($H_0: \hat{h}_1 = \hat{h}_2 = \hat{h}_3 = 1$). The Wald statistic for this joint test was 16.1, which with three degrees of freedom, exceeded the critical value (at the 5 per cent significance level) of 7.82. The null hypothesis (H_0) is therefore rejected.

No infrastructure effects ($H_0: \hat{\alpha}_G^{scal} = \hat{\beta}_{1Gy} = \hat{\beta}_{2Gy} = \hat{\beta}_{3Gy} = \hat{\beta}_{GGy} = 0$). The Wald statistic for this joint test was 40.6, which with five degrees of freedom, exceeded the critical value (at the 5 per cent significance level) of 11.07. The null hypothesis (H_0) is therefore rejected.

No spillover effects ($H_0: \hat{\alpha}_S^{scal} = \hat{\beta}_{1Sy} = \hat{\beta}_{2Sy} = \hat{\beta}_{3Sy} = \hat{\beta}_{SSy} = 0$). The Wald statistic for this joint test was 27.0, which with five degrees of freedom, exceeded the critical value (at the 5 per cent significance level) of 11.07. The null hypothesis (H_0) is therefore rejected.

5.5 EFFICIENCY COEFFICIENTS

The estimates for the efficiency coefficients $\hat{h}_1$, $\hat{h}_2$ and $\hat{h}_3$ indicate that efficiency-adjusted input quantities for all three inputs were higher than those observed for these inputs, on average, between 1963 and 1997. For capital, net additions were 3.9 times more productive than existing buildings and equipment. For labour, employees that added to the size of the food processing workforce had a marginal product that was about 1.5 times that of existing workers and their replacements.⁸

⁸In spite of the input-output ratio for labour falling in almost every year of the sample, from year to year there were net additions to and net reductions in the food processing workforce. Census of manufactures data suggest that total employment

For energy, materials and services, incremental additions of these inputs had a marginal product that was about 1.2 times that of existing quantities.

The large efficiency effect for capital relative to the other inputs means that, over the sample, where there were net increases in every year, the contribution of this input in production increased not only because of net additions, but also because those net additions had a higher marginal product than capital already in use or that was just replaced.

5.6 PRICE ELASTICITIES OF DEMAND FOR EFFICIENCY-ADJUSTED INPUTS

The formula for the own-price elasticity of demand for each efficiency-adjusted input is derived from the specific form (5.2), and is the empirical counterpart to (2.20a) from Chapter 2, where the latter is defined in after-tax terms. This elasticity is specified as:

$$\hat{\epsilon}_{iit}^{zw} = \left\{ \hat{\beta}_{ii} / b_t^{\hat{\omega}} - 2b_i \left(\sum_{j=1}^3 \hat{\beta}_{ij} \hat{\omega}_{jt}^A \right) / (b_t^{\hat{\omega}})^2 \right. \quad (5.8a)$$

$$\left. + b_i^2 \left(\sum_{k=1}^3 \sum_{r=1}^3 \hat{\beta}_{kr} \hat{\omega}_{kt}^A \right) / (b_t^{\hat{\omega}})^3 \right\} \left(\hat{\omega}_{it}^A / \hat{z}_{it}^{*Ay} \right) ,$$

$$\text{where: } b_t^{\hat{\omega}} = \sum_{k=1}^3 b_k \hat{\omega}_{kt}^A ;$$

$$\hat{\omega}_{it}^A = \Lambda_{it} \left[\left(1 - d_i a_t \hat{\theta}_i \right) / (1 - a_t \hat{\mu}_i \hat{\theta}_i) \right] q_{it} ;$$

$$\hat{\mu}_i = (1 - 1/\hat{h}_i) ;$$

$$\hat{z}_{it}^{*Ay} = \hat{h}_i (\hat{v}_{yit} - \hat{\mu}_i v_{yit-1}) ; \text{ and}$$

$$\hat{v}_{yit} \text{ is the fitted value of } v_{yit} .$$

in food processing was cyclical and showed a slight downward trend, but remained remarkably constant, given the pattern in the input-output ratio. It follows that the latter effect was due largely to the labour input not growing, on average, while output expanded (by about two hundred per cent between 1963 and 1996).

The estimated values of each $\hat{\beta}_{ij}$ are computed with the estimated coefficients $\hat{a}_{ij}$ using (7.1). Note that $\hat{z}_{it}^{*Ay}$ is the fitted input/output ratio, i.e. the ratio of efficiency-adjusted input i to output. The cross-price elasticities are derived similarly, i.e.

$$\begin{aligned} \hat{\epsilon}_{ijt}^{z\omega} = & \left\{ \hat{\beta}_{ij}/b_t^{\hat{\omega}} - \sum_{k=1}^3 \left(b_j \hat{\beta}_{ik} + b_i \hat{\beta}_{jk} \right) \hat{\omega}_{kt}^A / (b_t^{\hat{\omega}})^2 \right. \\ & \left. + b_i b_j \left(\sum_{k=1}^3 \sum_{r=1}^3 \hat{\beta}_{kr} \hat{\omega}_{kt}^A \hat{\omega}_{rt}^A \right) / (b_t^{\hat{\omega}})^3 \right\} \left(\hat{\omega}_{jt}^A / \hat{z}_{it}^{*Ay} \right) . \end{aligned} \quad (5.8b)$$

Notice that the elasticities are evaluated with the estimated parameters, estimated efficiency-adjusted input-output ratios and the estimated user costs of efficiency-adjusted inputs. The results of these calculations are presented in Table 5.3, Table 5.4 and Table 5.5.

Over the sample, the demand for efficiency-adjusted labour was more responsive to a change in its own price than the other two inputs, with the own-price elasticity generally growing in absolute value over time.⁹ The cross-price effects for capital and the energy, materials and services input on labour demand had almost the same magnitude early in the sample, but the latter input became much more important towards the end of the sample. This result suggests that labour demand by food processors became more responsive to the user cost of energy, materials and services. The cross-elasticities with respect to the user cost of energy, materials and services indicate that this input and labour were substitutes in production, and that the cross elasticity increased over time.

⁹Since all elasticities derived here are point estimates, it is reasonable for these to differ between years, since while the estimated coefficients do not change, data used in these calculations do change over the sample.

Table 5.3 Estimated Price Elasticities of Demand for Efficiency-Adjusted Capital, Canadian Food Processing Industry

year	elasticity with respect to user cost of:		
	capital	labour	ems
1963	-0.068	0.142	-0.074
1964	-0.075	0.155	-0.080
1965	-0.077	0.161	-0.084
1966	-0.077	0.162	-0.085
1967	-0.082	0.171	-0.088
1968	-0.083	0.174	-0.092
1969	-0.085	0.176	-0.092
1970	-0.088	0.184	-0.096
1971	-0.082	0.190	-0.108
1972	-0.075	0.187	-0.112
1973	-0.061	0.164	-0.103
1974	-0.057	0.152	-0.095
1975	-0.054	0.156	-0.102
1976	-0.054	0.173	-0.119
1977	-0.049	0.172	-0.123
1978	-0.042	0.158	-0.116
1979	-0.040	0.148	-0.109
1980	-0.039	0.147	-0.108
1981	-0.042	0.147	-0.105
1982	-0.042	0.154	-0.112
1983	-0.038	0.162	-0.124
1984	-0.037	0.160	-0.123
1985	-0.035	0.161	-0.126
1986	-0.034	0.162	-0.128
1987	-0.036	0.163	-0.128
1988	-0.036	0.164	-0.128
1989	-0.037	0.165	-0.129
1990	-0.038	0.170	-0.132
1991	-0.037	0.176	-0.139
1992	-0.035	0.179	-0.143
1993	-0.032	0.173	-0.141
1994	-0.032	0.165	-0.133
1995	-0.031	0.161	-0.130
1996	-0.029	0.155	-0.126
average	-0.052	0.164	-0.113
maximum	-0.029	0.190	-0.074
minimum	-0.088	0.142	-0.143

NOTE: 'ems' denotes energy, materials, services aggregate

Table 5.4 Estimated Price Elasticities of Demand for Efficiency-Adjusted Labour, Canadian Food Processing Industry

year	elasticity with respect to user cost of:		
	capital	labour	ems
1963	0.033	-0.069	0.036
1964	0.036	-0.074	0.038
1965	0.038	-0.079	0.041
1966	0.039	-0.082	0.043
1967	0.042	-0.086	0.045
1968	0.043	-0.090	0.047
1969	0.045	-0.094	0.049
1970	0.047	-0.099	0.051
1971	0.045	-0.105	0.060
1972	0.043	-0.107	0.064
1973	0.037	-0.099	0.062
1974	0.037	-0.099	0.062
1975	0.037	-0.106	0.069
1976	0.039	-0.125	0.086
1977	0.037	-0.132	0.095
1978	0.035	-0.131	0.096
1979	0.035	-0.129	0.095
1980	0.036	-0.135	0.099
1981	0.040	-0.140	0.101
1982	0.041	-0.150	0.109
1983	0.037	-0.161	0.123
1984	0.037	-0.162	0.125
1985	0.037	-0.167	0.130
1986	0.036	-0.169	0.133
1987	0.037	-0.169	0.132
1988	0.038	-0.172	0.134
1989	0.038	-0.174	0.136
1990	0.041	-0.181	0.140
1991	0.040	-0.191	0.151
1992	0.039	-0.198	0.159
1993	0.037	-0.196	0.160
1994	0.037	-0.192	0.154
1995	0.037	-0.192	0.156
1996	0.035	-0.190	0.155
average	0.039	-0.137	0.098
maximum	0.047	-0.069	0.160
minimum	0.033	-0.198	0.036

NOTE: 'ems' denotes energy, materials, services aggregate

**Table 5.5 Estimated Price Elasticities of Demand for Efficiency-
Adjusted EMS aggregate, Canadian Food Processing Industry**

year	elasticity with respect to user cost of:		
	capital	labour	ems
1963	-0.004	0.008	-0.004
1964	-0.004	0.008	-0.004
1965	-0.004	0.009	-0.005
1966	-0.004	0.009	-0.005
1967	-0.005	0.010	-0.005
1968	-0.005	0.010	-0.006
1969	-0.005	0.011	-0.006
1970	-0.006	0.012	-0.006
1971	-0.006	0.014	-0.008
1972	-0.006	0.015	-0.009
1973	-0.005	0.012	-0.008
1974	-0.004	0.012	-0.007
1975	-0.005	0.014	-0.009
1976	-0.006	0.019	-0.013
1977	-0.006	0.021	-0.015
1978	-0.005	0.020	-0.015
1979	-0.005	0.018	-0.013
1980	-0.005	0.019	-0.014
1981	-0.006	0.020	-0.014
1982	-0.006	0.023	-0.017
1983	-0.007	0.028	-0.022
1984	-0.006	0.028	-0.022
1985	-0.006	0.029	-0.023
1986	-0.006	0.031	-0.024
1987	-0.007	0.031	-0.024
1988	-0.007	0.032	-0.025
1989	-0.007	0.033	-0.026
1990	-0.008	0.036	-0.028
1991	-0.009	0.041	-0.032
1992	-0.009	0.044	-0.035
1993	-0.008	0.043	-0.035
1994	-0.008	0.039	-0.032
1995	-0.007	0.038	-0.031
1996	-0.007	0.037	-0.030
average	-0.006	0.023	-0.017
maximum	-0.004	0.044	-0.004
minimum	-0.009	0.008	-0.035

NOTE: 'ems' denotes energy, materials, services aggregate

Similarly, capital was also a substitute for labour, but the responsiveness of demand for labour to a change in the user cost of capital was quite constant over the sample.

The own price elasticity for capital was smaller (in absolute value) than either of the cross elasticities, for all years of the sample and it decreased (in absolute value) over time so that, in 1992, it was about half its 1963 level. On the other hand, the cross elasticity with respect to labour was over twice the own elasticity (in absolute value) for every year of the sample, with this relative difference getting larger over time. This cross effect means that relative increases in the user cost of labour led to increases in capital intensity. Since the price of labour increased relative to the price of capital over most years of the sample, the capital-output ratio increased substantially – by nearly ninety per cent – between 1963 and 1997. Together, then, the movements in capital and labour mean that the mix of these inputs changed significantly over time – the capital-labour ratio increased by over three hundred and sixty per cent over the same period.¹⁰ Estimates of the cross-elasticity of capital with respect to the user cost of energy, materials and services indicates complementarity in production between this aggregate and capital.

The relatively low own-price and cross-price elasticities for energy, materials and services are due in part to the nature of food processing – primary inputs from the agricultural sector and inputs purchased from other sectors of the economy are used in more-or-less fixed proportions to produce food products. As a result, demand does not change much in response to changes in either the own price of this input or changes in the price of either capital or labour.

¹⁰While the input intensities of capital and labour changed quite dramatically over the sample period, the cost shares of these inputs remained quite constant, each input accounting for about 12-13% of total cost in each year.

5.7 ELASTICITIES OF DEMAND AND COST WITH RESPECT TO OUTPUT

The elasticity of demand for each efficiency-adjusted input with respect to output – see expression (2.24) in Chapter 2 – when applied to (5.2) and evaluated with after-tax variables is specified as follows :

$$\begin{aligned} \hat{\epsilon}_{it}^{zy} = & \left\{ \left(\sum_{j=1}^3 \hat{\beta}_{ij} \hat{\omega}_{jt}^A \right) / b_t^{\hat{\omega}} \right. \\ & - 0.5 \left(b_i \sum_{k=1}^3 \sum_{r=1}^3 \hat{\beta}_{kr} \hat{\omega}_{kt}^A \hat{\omega}_{rt}^A \right) / (b_t^{\hat{\omega}})^2 + \hat{\beta}_{iy} + 2\hat{\beta}_{yy} b_i y_t \\ & \left. + \hat{\beta}_{iGy} G_t + \hat{\beta}_{GGy} b_i G_t^2 + \hat{\beta}_{iSy} S_t + \hat{\beta}_{SSy} b_i S_t^2 \right\} / \hat{z}_{it}^{*Ay}. \end{aligned} \quad (5.9a)$$

The elasticity of cost with respect to output is derived by first using the fact that the estimated total cost of efficiency-adjusted inputs per unit of output, i.e. average cost, can be derived as:

$$c_t^A = \sum_{k=1}^3 \hat{\omega}_{it}^A \hat{z}_{it}^{*Ay}, \quad (5.10)$$

so that

$$\hat{\epsilon}_t^{c^Ay} = \sum_{k=1}^3 \hat{\omega}_{it}^A \hat{\epsilon}_{it}^{zy} \left(\hat{z}_{it}^{*Ay} / c_t^A \right). \quad (5.9b)$$

Estimated values for these elasticities are presented in Table 5.6.

The results in Table 5.6 indicate that an increase in output by processors would have led to an increase in all inputs in all years of the sample, and that these effects increased over time. The consequence is that, while the production technology was close to constant returns to scale in the early part of the sample, by the 1990s there were decreasing returns to scale.

**Table 5.6 Elasticity of Efficiency-Adjusted Inputs and
Total Cost with respect to Output, Canadian
Food Processing Industry**

year	elasticity with respect to output:			elasticity of cost w.r.t. output
	capital	labour	ems	
1963	0.450	0.361	1.142	0.986
1964	0.417	0.350	1.111	0.957
1965	0.432	0.356	1.104	0.952
1966	0.433	0.369	1.087	0.940
1967	0.439	0.365	1.081	0.933
1968	0.448	0.372	1.075	0.927
1969	0.479	0.387	1.081	0.932
1970	0.525	0.388	1.098	0.943
1971	0.553	0.395	1.093	0.942
1972	0.558	0.401	1.080	0.937
1973	0.588	0.432	1.087	0.964
1974	0.619	0.484	1.086	0.976
1975	0.696	0.515	1.128	1.011
1976	0.653	0.521	1.068	0.957
1977	0.663	0.547	1.054	0.951
1978	0.694	0.603	1.058	0.971
1979	0.720	0.633	1.066	0.986
1980	0.749	0.666	1.073	0.997
1981	0.788	0.694	1.094	1.018
1982	0.835	0.723	1.130	1.048
1983	0.870	0.741	1.153	1.068
1984	0.881	0.740	1.154	1.071
1985	0.893	0.732	1.155	1.070
1986	0.941	0.729	1.194	1.101
1987	0.987	0.699	1.229	1.123
1988	1.016	0.691	1.251	1.138
1989	1.067	0.703	1.298	1.176
1990	1.110	0.713	1.339	1.207
1991	1.130	0.742	1.362	1.226
1992	1.135	0.760	1.367	1.231
1993	1.143	0.782	1.376	1.246
1994	1.140	0.784	1.368	1.245
1995	1.117	0.778	1.339	1.223
1996	1.089	0.769	1.304	1.197
average	0.772	0.586	1.167	1.049
maximum	1.143	0.784	1.376	1.246
minimum	0.417	0.350	1.054	0.927

NOTE: 'ems' denotes energy, materials, services aggregate

Of the input effects, the elasticity for energy, materials and services is highest in all years – in any year a 1% increase in output would have led to between a 1% and a 1.3% increase in the use of inputs in this aggregate. The output elasticities for capital and labour also increased over the sample; the latter grew relatively more slowly though, so that by the end of the sample, the elasticity for capital was about 40% higher than that for labour, whereas it was only about 20% higher at the beginning. This difference amplified the shift from labour to capital, observed in the data, and at least partly accounted for already by responses of processors to changes in relative user cost of labour to capital.

5.8 ELASTICITIES OF DEMAND AND COST WITH RESPECT TO PUBLIC INFRASTRUCTURE

The elasticity of demand for each efficiency-adjusted input with respect to public infrastructure – see expression (2.29) in Chapter 2 – when applied to (5.2) and evaluated with after-tax variables is specified as follows :

$$\hat{\epsilon}_{it}^{zG} = \left[\hat{\beta}_{iGy} y_t + \hat{\alpha}_G b_i + 2\hat{\beta}_{GGy} b_i G_t y_t \right] G_t / \left(\hat{z}_{it}^{*Ay} y_t \right). \quad (5.11a)$$

The elasticity of cost with respect to public infrastructure is derived in a similar manner to the output elasticity, i.e.

$$\hat{\epsilon}_t^{cAG} = \sum_{k=1}^3 \hat{\omega}_{it}^A \hat{\epsilon}_{it}^{zG} \left(\hat{z}_{it}^{*Ay} / c_t^A \right). \quad (5.11b)$$

Estimated values for these elasticities are presented in Table 5.7.

Table 5.7 Elasticity of Efficiency-Adjusted Inputs and Total Cost with respect to Public Infrastructure, Canadian Food Processing Industry

year	elasticity with respect to public infrastructure			elasticity of cost w.r.t. public infrastructure
	capital	labour	ems	
1963	0.585	-0.085	0.033	0.035
1964	0.622	-0.089	0.034	0.036
1965	0.657	-0.098	0.034	0.036
1966	0.686	-0.108	0.034	0.037
1967	0.725	-0.116	0.034	0.038
1968	0.738	-0.123	0.034	0.037
1969	0.755	-0.132	0.034	0.037
1970	0.789	-0.142	0.034	0.037
1971	0.812	-0.158	0.033	0.032
1972	0.837	-0.172	0.031	0.028
1973	0.859	-0.187	0.029	0.024
1974	0.877	-0.214	0.025	0.020
1975	0.872	-0.230	0.021	0.013
1976	0.874	-0.264	0.017	0.001
1977	0.884	-0.298	0.011	-0.010
1978	0.899	-0.339	0.001	-0.023
1979	0.915	-0.366	-0.007	-0.029
1980	0.921	-0.406	-0.017	-0.042
1981	0.928	-0.439	-0.027	-0.051
1982	0.915	-0.461	-0.033	-0.063
1983	0.902	-0.491	-0.040	-0.081
1984	0.910	-0.515	-0.047	-0.090
1985	0.913	-0.543	-0.055	-0.102
1986	0.916	-0.560	-0.062	-0.112
1987	0.926	-0.574	-0.069	-0.119
1988	0.929	-0.594	-0.076	-0.128
1989	0.929	-0.616	-0.086	-0.141
1990	0.927	-0.642	-0.095	-0.154
1991	0.913	-0.678	-0.105	-0.175
1992	0.904	-0.712	-0.115	-0.192
1993	0.904	-0.736	-0.123	-0.203
1994	0.910	-0.756	-0.133	-0.208
1995	0.908	-0.786	-0.142	-0.219
1996	0.907	-0.811	-0.150	-0.226
average	0.851	-0.395	-0.028	-0.058
maximum	0.929	-0.085	0.034	0.038
minimum	0.585	-0.811	-0.150	-0.226

NOTE: 'ems' denotes energy, materials, services aggregate

According to these results, food processors were very responsive to changes in public infrastructure over the sample. A one per cent increase in public infrastructure stock would have led to an increase of between 0.6% and 0.9% increase in efficiency-adjusted capital input. The same proportionate increase in public infrastructure would have led to a reduction in labour input of between 0.1% and 0.9%. For energy, materials and services, the effect would have been smaller, varying between an increase of 0.03% to a decrease of 0.15%. The overall effect of a 1% increase in public infrastructure, i.e. on total cost of efficiency-adjusted inputs, ranged between an increase of about 0.04% to a decrease of about 0.23%.

Generally, increases in public infrastructure appear to have consistently increased capital use in food processing and decreased employment in the sector, with both effects getting larger over time. The effect of increases in public infrastructure on cost of production in food processing depends on the year. Early in the sample, increases in public infrastructure led to small effects in either direction. It appears that infrastructure investments only led to changes in the mix of inputs in the years between 1963 and 1983 but had little effect on cost. Since then, however, public infrastructure investment generated relatively larger cost reductions, so that by the mid 1990s a 1% increase in public infrastructure reduced cost of food processing by about 0.2%.

One way to determine whether the results presented above are reasonable is to compare them with those found elsewhere in different studies. Any unusual differences between these results and those found in the literature, while not necessarily rendering them suspect, will require some explanation, so that the cause of these differences can be determined. A brief survey of the relevant

literature is summarized on the following page, and a comparison is made between the overall outcome from these studies and the results obtained here.

Most studies fall into one of two categories: (a) production function approaches that measure the effect of public infrastructure on output and productivity directly,¹¹ and (b) cost function approaches that measure the effect of public infrastructure on cost, input demands and productivity.¹² The studies falling into category (b) are of primary interest here and are the only ones considered in this discussion, primarily because the methods used in these cases are compatible with those used here. In addition, only those studies that report effects of public infrastructure on cost as well as variable inputs (e.g. labour) are considered – studies that overlook the effect of public infrastructure on input choices are therefore excluded from the comparisons made here.¹³

On the basis of this survey of the literature, it is possible to say with a fair degree of certainty that the provision of public infrastructure has had two effects on production:

- (i) net investments in public infrastructure have led to reductions in the cost of production for manufacturing – holding all other things fixed; and
- (ii) these investments have led to reductions in the amount of labour used in manufacturing; these effects account in part for the reductions noted in (i).

¹¹Note that [41] fits into this category. This study, which is apparently the only one that has been done for Canada, finds that public infrastructure investments led to labour productivity gains over the 1946-1991 period.

¹²For a complete survey of the literature up until the mid-1990s, see [31, pp. 9-24].

¹³Note that the discussion here is limited to the effect of public infrastructure on cost of production. The effect on productivity growth is analogous, since if public infrastructure increases productivity growth, it also lowers cost of production. However, while all studies cited measure cost effects, some do not measure productivity effects; consequently, only cost effects are discussed here.

authors	study	coverage	country	effect of public infrastructure on:		
				cost	labour	capital
Shah (1992)	[39]	national, 26 industries	Mexico	<0 ¹	<0 ¹	<0 ¹
Conrad and Seitz (1994) ²	[13]	national, 3 sectors	Germany	<0	<0	>0
Nadiri&Mamuneas (1994)	[34]	national, 12 industries	USA	<0	<0	<0
Seitz&Licht (1995)	[38]	regional, manufacturing	Germany	<0	<0	>0
Nadiri&Mamuneas (1996)	[33]	national, 35 industries	USA	<0 ³	<0 ⁴	<0
Sturm (2001)	[40]	national, 2 sectors	Netherlands	<0 ⁵	<0 ⁵	<0 ⁵
Zugasti et al. (2001)	[43]	national, 25 industries	Spain	<0	<0	n/a
Rovolis&Spence (2002)	[37]	regional, manufacturing	Greece	<0	<0	>0

¹ This a long-run result (see [39, Table 4]).

² Two other unpublished papers by these authors are reviewed in [33]. They find the same results for West Germany as the ones reported here.

³ For six of these industries (primary, construction), the public infrastructure increased labour use. and increased cost.

⁴ This result applies to 21 out of 35 industries – all of these are manufacturing industries. The the remaining industries (all non-manufacturing), public infrastructure had a cost-increasing effect. (This may reflect oversupply of public infrastructure to these industries [33, p. 63].)

⁵ This result is for both sectors together ('total')

What makes these conclusions most convincing is that the results have been obtained for a wide range of conditions, i.e. different countries, degrees of industry aggregation, degrees of regional aggregation, length of data series, variables included in the cost functions and functional forms for the cost functions.¹⁴

The results obtained here for the effects of public infrastructure on labour are therefore consistent with the literature, i.e. where public infrastructure has been found to lead to reductions in labour use. The finding in this analysis for capital, i.e. that the provision of public infrastructure led to increased use of this input, is consistent with several of the studies surveyed, although about the same number of studies show the opposite effect. Finally, the results obtained here for the effect of public infrastructure on cost of production are, for the late 1970s onward, consistent with those found elsewhere, i.e. as in [32] and [31], for example.

¹⁴While not providing any information about the relative effects of public infrastructure on input use, [30] is another study that should be mentioned. This analysis looks at the effect of public infrastructure on the productivity of manufacturing in four U.S. regions. The results indicate, like those in the studies cited in the table above, that public infrastructure has been cost-reducing in all regions. Note that the approach taken in [30], as in several of the other studies cited here, is to refer to the ‘shadow value’ of public infrastructure. Since this is defined as $-\partial C/\partial G$, a positive shadow value is the same as a cost-reducing effect ($\partial C/\partial G < 0$) or negative elasticity of cost with respect to infrastructure ($\epsilon_t^{cG} < 0$). Also note that Catherine Lynde and James Richmond have published several papers that use cost functions as a basis for measurement of the economic effects of public infrastructure. However, their approach does not fit the one used here very well and their papers are therefore omitted. (See [31] for a review of two of their papers.)

5.9 ELASTICITIES OF DEMAND AND COST WITH RESPECT TO KNOWLEDGE SPILLOVERS

The elasticity of demand for each efficiency-adjusted input with respect to knowledge spillovers – see expression (2.30) in Chapter 2 where this has $M = 1$ and is evaluated with the coefficients from the estimated equations (5.2) – is specified as follows:

$$\hat{\epsilon}_{it}^{zS} = \left[\hat{\beta}_{iSy} y_t + \hat{\alpha}_S b_i + 2\hat{\beta}_{SSy} b_i S_t y_t \right] S_t / \left(\hat{z}_{it}^{*Ay} y_t \right). \quad (5.12a)$$

The elasticity of cost with respect to knowledge spillovers is derived in a similar manner to the output elasticity, i.e. as

$$\hat{c}_t^{cAS} = \sum_{k=1}^3 (\hat{\omega}_{it}^A) \hat{\epsilon}_{it}^{zS} \left(\hat{z}_{it}^{*Ay} / c_t^A \right). \quad (5.12b)$$

Estimated values for these elasticities over the sample are presented in Table 5.8. These results show that, over the sample, R&D spillovers from U.S. food processors induced decreases in capital use and increases in labour use by Canadian food processors. For capital, the effect of R&D spillovers apparently diminished over time, while for labour, they increased substantially. The signs and magnitude of these effects are by-and-large the opposite of the effects of public infrastructure, so R&D spillovers offset to some extent the increase in the capital/labour ratio induced both by net investments in public infrastructure and by changes in the relative after-tax user cost of capital relative to that for labour.

**Table 5.8 Elasticity of Efficiency-Adjusted Inputs and
Total Cost with respect to R&D Spillovers,
Canadian Food Processing Industry**

year	elasticity with respect to R&D spillovers:			elasticity of cost w.r.t. R&D spillovers
	capital	labour	ems	
1963	-0.727	-0.026	-0.286	-0.260
1964	-0.688	-0.003	-0.246	-0.222
1965	-0.660	0.012	-0.227	-0.204
1966	-0.613	0.026	-0.205	-0.182
1967	-0.595	0.045	-0.184	-0.162
1968	-0.570	0.053	-0.174	-0.152
1969	-0.558	0.059	-0.171	-0.148
1970	-0.558	0.074	-0.163	-0.139
1971	-0.517	0.096	-0.143	-0.116
1972	-0.477	0.119	-0.120	-0.092
1973	-0.465	0.126	-0.117	-0.090
1974	-0.428	0.141	-0.106	-0.080
1975	-0.443	0.138	-0.124	-0.094
1976	-0.350	0.187	-0.072	-0.037
1977	-0.310	0.220	-0.047	-0.011
1978	-0.285	0.249	-0.033	0.004
1979	-0.275	0.271	-0.022	0.015
1980	-0.258	0.303	-0.008	0.031
1981	-0.254	0.328	-0.001	0.040
1982	-0.269	0.328	-0.016	0.031
1983	-0.271	0.345	-0.019	0.036
1984	-0.260	0.375	-0.004	0.052
1985	-0.246	0.413	0.014	0.074
1986	-0.263	0.427	0.007	0.072
1987	-0.277	0.453	0.010	0.078
1988	-0.284	0.472	0.011	0.083
1989	-0.308	0.478	-0.005	0.072
1990	-0.328	0.487	-0.019	0.065
1991	-0.332	0.498	-0.028	0.065
1992	-0.326	0.519	-0.025	0.073
1993	-0.327	0.528	-0.026	0.073
1994	-0.318	0.552	-0.012	0.084
1995	-0.293	0.591	0.014	0.110
1996	-0.267	0.628	0.041	0.136
average	-0.394	0.280	-0.074	-0.023
maximum	-0.246	0.628	0.041	0.136
minimum	-0.727	-0.026	-0.286	-0.260

NOTE: 'ems' denotes energy, materials, services aggregate

R&D spillovers induced reductions in energy, materials and services in the early part of the sample, but this effect diminished in the latter half. Together, this effect and the effect of R&D spillovers on capital and labour means that the spillovers, while leading to reductions in the cost of production up to the late 1970s, increasingly led to increases in total cost since then. The cost effects are largely due to the growing effect on labour demand induced by the spillovers.

As with public infrastructure, the relevant studies to survey here are those that have involved estimation of a cost function to determine the effect of increases in external R&D to recipient firms or industries within any region or country. In relation to the literature on public infrastructure, there is a larger number of published studies regarding the effect of knowledge spillovers on cost and/or productivity, and there have been several surveys of this literature (see [11], [35]). While it is sometimes unclear from these surveys precisely what methodology has been used in each study, it is apparent that most analyses using cost functions have found that R&D spillovers are cost-reducing. Exceptions exist, however; in the context of R&D spillovers from Japan, some Canadian industries – including food processing – experienced increases in cost from these spillovers between 1962 and 1988 (see [8, pp.283-286]).

Generally speaking, cost reductions R&D spillovers can be interpreted as benefits from process innovations. In the case of food processing, an innovation of this type might be a packaging technology that reduces the material and labour input needed to produce a final product, thereby reducing cost. R&D spillovers from a product innovation, on the other hand, might lead to an increased use of labour,

materials and capital due to testing and development of the new product.¹⁵ It is likely that in Canadian food processing, the predominant type of R&D spillover has changed over time, with mostly process-oriented R&D spillovers from U.S. food processors in the first half of the sample but with mostly product-oriented spillovers in the second half.

5.10 VALUE TO FOOD PROCESSORS OF INCREASES IN PUBLIC INFRASTRUCTURE

One way that the effects of public infrastructure can be better understood is by determining the amount by which production costs change when infrastructure increases by a specific amount. For example, how would an investment in public infrastructure of 500 million dollars affect the expenditure by food processors on inputs required to produce a given amount of output?

The effect of a change in the stock of public infrastructure on cost is derived as:

$$dc_t^A = \left[\partial C^A \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial G_t \right] dG_t \quad (5.13)$$

where C^A is as defined by (3.21).

¹⁵A product R&D spillover that increases cost does not necessarily lead to lower profit. This depends on what happens in the product market, i.e. whether revenues by food processors increase or decrease when a new product is introduced.

Expression (5.13), however, doesn't reflect the nominal change, since dG_t is the change in constant dollars. Accordingly, define the nominal value of public infrastructure in year t as

$$G_t^n = w_t^G G_t, \quad (5.14a)$$

where w_t^G is the deflator for the public infrastructure stock. Then, with w_t^G fixed,

$$dG_t = dG_t^n / w_t^G. \quad (5.14b)$$

Substitution of (5.14b) into (5.13) gives the formula for measuring the effect of an increase in nominal public infrastructure net investment, namely

$$dc_t^A = \left[\partial C^A \left(\cdot \right) / \partial G_t \right] dG_t^n / w_t^G. \quad (5.13')$$

Thus, given an amount of the nominal increase (e.g., $dG_t^n = \$500\text{m}$), dc_t^A is the change (millions of dollars) in food processors's cost of production arising from that nominal increase in spending on public infrastructure. For example, in 1996, an additional \$500 million net investment in public infrastructure would have reduced the total after-tax cost of efficiency-adjusted inputs in food processing by \$13.2 million.^{16,17}

Another way of looking at the effect of the \$500 million net investment on the total cost of production for food processors is in relation to total before-tax

¹⁶An additional \$500 million net investment in 1996 would have represented a 0.18% increase in the total stock of public infrastructure, valued in current dollars.

¹⁷A \$13.2 million reduction in the total cost of efficiency-adjusted inputs in 1996 would have represented a 0.04% decrease. This percentage change in cost, when divided by the percentage increase in public infrastructure (0.18%) is -0.23, which is the same as the value of $\hat{c}_t^{c^A G}$ for 1996.

observed cost.¹⁸ In this case, the change in public infrastructure would have caused a reduction in observed before-tax total cost of \$21.1 million, a decrease of about 5%.

Both of the dollar values to food processors can also be represented in terms of a partial benefit-cost ratio. In particular, the benefit-cost ratio from the net investment is 0.026 when calculated with efficiency-adjusted after-tax cost effect and 0.042 when calculated with the before-tax observed cost effect.¹⁹ In other words, a net investment of one dollar in public infrastructure would have brought a benefit of between 2.6 cents and 4.2 cents to food processors, depending on which definition of total cost is used.

¹⁸This measure differs from total after-tax cost of efficiency-adjusted inputs in three ways. First, user costs for inputs and quantities of these inputs are measured without any adjustment for efficiency effects. Second, acquisition price expectations for capital are assumed to be static. Finally, the effects of taxes (for capital this includes the effect of corporate cost allowances, property taxes, etc.) are incorporated in user costs and then these user costs are translated into before-tax terms by, in each year t , dividing them by $(1 - \Xi_t^1)$. This means that the before-tax user costs for labour and the energy, materials and services input are just the hiring price q_{2t} and the acquisition price q_{3t} , respectively. For capital, the before-tax user cost is $\Lambda_{1t}q_{1t}(1 - a_t d_t)/(1 - \Xi_t^1)$.

¹⁹The benefit-cost ratio using after-tax cost effect is derived by dividing the cost saving (13.2 \$million) by the net investment (\$500 million). The before-tax benefit-cost ratio is derived by dividing the cost saving (21.1 \$million) by the net investment (\$500 million).

CHAPTER 6

TFPG MEASUREMENT AND DECOMPOSITION

6.1 INTRODUCTION

Total factor productivity growth ($TFPG$) is defined as the change in the quantity of output less the change in the quantity of input. This variable provides a useful way to measure economic performance, since if $TFPG$ is positive, fewer resources are used in the production of a given level of output in each future year. Similarly, provided that $TFPG$ is positive, the resource cost of achieving any particular level of economic growth will fall over time.

There are several possible sources of $TFPG$. A common explanation for productivity growth is technical change, since the adoption of new production technologies leads to resource savings. Another explanation is that for technologies with increasing returns to scale, increases in output require relatively fewer additional resources because these technologies operate more effectively at higher levels of output.

Other factors that are exogenous to producers can also lead to positive levels of $TFPG$. For example, if the stock of public infrastructure expands, say by the construction of a new highway that provides an alternative route, producers can expand production at a rate that exceeds the expansion of input use. The reason is that the new highway could mean that producers can increase shipments by

road without the same increase in resource costs (e.g. fuel) that they would have incurred had the highway not been built.

Similarly, knowledge spillovers from other sectors might lead to positive *TFPG* for producers in the recipient sector. An example is a production process developed by producers in one sector that is applicable in another. If the process leads to resource savings when it is adopted in the recipient sector, this knowledge spillover contributes to *TFPG*.

This chapter presents the framework needed to measure *TFPG* and the components described above, as well as estimates of these effects for the Canadian food processors between 1963 and 1997. The next section, which is based on [7], shows how information about the components of *TFPG* can be obtained from the cost function developed in Chapter 3. Then, with this framework and the specific form and estimates from Chapter 5, the relative importance of these components is calculated along with a measure of the bias involved when observed input growth is used instead of efficiency-adjusted input growth.

6.2 MEASUREMENT OF *TFPG*

TFPG between years t and t' , measured with cost-minimizing efficiency-adjusted input quantities, is defined as:

$$TFPG_{t,t'}^z = [y_{t'}/y_b - y_t/y_b] - [z_{t'}^{A*} - z_t^{A*}] \quad , \quad 1 \leq t < t' \leq T \quad (6.1)$$

where:

$$z_t^{A*} = \Phi^z(\omega_{1b}^A, \dots, \omega_{Nb}^A, \omega_{1t}^A, \dots, \omega_{Nt}^A; z_{1b}^{A*}, \dots, z_{Nb}^{A*}, z_{1t}^{A*}, \dots, z_{Nt}^{A*}) ;$$

$\Phi^z : \mathfrak{R}_+^{4N} \rightarrow \mathfrak{R}_+$ is a function that aggregates efficiency-adjusted input quantities into a single quantity index that is equivalent to a ratio of the aggregate input in year t (or t') to that in the reference year b , i.e. it is a measure of growth in the input aggregate between year b and t (or t'), and y_b, ω_{ib}^A , and z_{ib}^{A*} are reference output, reference after-tax user cost for efficiency-adjusted input i , and optimal efficiency-adjusted reference quantity of input i , respectively.¹ The reference point is comprised of ‘base values’ that in this case are averages of the observations in year t and t' .

6.3 DECOMPOSITION OF TFPG

A change in cost between year t and t' can be represented in terms of the cost function (3.21) – specified in Chapter 3 – at $\tau = 0$. Provided that the cost function is a second-order approximation, with second-order terms that are time invariant, it is possible to express this change using only the first-order derivatives of the cost function [14, p. 421]. In particular, the difference between the value of the cost function in year in t and that in t' is

¹Note: (i) that while the analysis is limited to three inputs, the more general number (N) is used in the various derivations in this chapter to make the theory more generally useful; and (ii) the function Φ^z (and Φ^v) below is expressed generally because the aggregate z_v^{A*} ($v = t, t'$) in (6.1) – and for the observed input aggregates v_v ($v = t, t'$) in (6.11) below – could be constructed using a variety of index number formulas. For the decomposition that follows, however, only one index formula is appropriate, namely (6.1) below.

$$\begin{aligned}
C^A \left(\begin{smallmatrix} \cdot \\ t' \end{smallmatrix} \right) - C^A \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) = \\
(1/2) \left\{ \sum_{i=1}^N \left[\partial C^A \left(\begin{smallmatrix} \cdot \\ t' \end{smallmatrix} \right) / \partial \omega_{it'}^A + \partial C^A \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial \omega_{it}^A \right] (\omega_{it'}^A - \omega_{it}^A) \right. \\
+ \left[\partial C^A \left(\begin{smallmatrix} \cdot \\ t' \end{smallmatrix} \right) / \partial y_{t'} + \partial C^A \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial y_t \right] (y_{t'} - y_t) \\
+ \sum_{k=1}^L \left[\partial C^A \left(\begin{smallmatrix} \cdot \\ t' \end{smallmatrix} \right) / \partial G_{kt'} + \partial C^A \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial G_{kt} \right] (G_{kt'} - G_{kt}) \\
+ \sum_{r=1}^M \left[\partial C^A \left(\begin{smallmatrix} \cdot \\ t' \end{smallmatrix} \right) / \partial S_{rt'} + \partial C^A \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial S_{rt} \right] (S_{rt'} - S_{rt}) \\
\left. + \left[\partial C^A \left(\begin{smallmatrix} \cdot \\ t' \end{smallmatrix} \right) / \partial t' + \partial C^A \left(\begin{smallmatrix} \cdot \\ t \end{smallmatrix} \right) / \partial t \right] (t' - t) \right\} .
\end{aligned} \tag{6.2}$$

Use of expression (3.22) from Chapter 3 allows the following derivations

$$\partial C^A \left(\begin{smallmatrix} \cdot \\ v \end{smallmatrix} \right) / \partial \omega_{iv}^A = z_{iv}^{A*} \quad , \quad v = t, t' \quad ; \quad i = 1, 2, \dots, N \quad , \tag{6.3}$$

where z_{iv}^{A*} is the optimal level of efficiency-adjusted input i in year v . In addition, since

$$c_v^A = C^A \left(\begin{smallmatrix} \cdot \\ v \end{smallmatrix} \right) = \sum_{i=1}^N \omega_{iv}^A z_{iv}^{A*} \quad , \quad v = t, t' , \tag{6.4}$$

substitution of (6.3) and (6.4) into (6.2) and use of the elasticity definitions (2.24)-(2.27) from Chapter 2 – in after-tax terms – leads to the following:

$$\begin{aligned}
\sum_{i=1}^N \omega_{it'}^A z_{it'}^{A*} - \sum_{i=1}^N \omega_{it}^A z_{it}^{A*} = \\
(1/2) \sum_{i=1}^N [z_{it'}^{A*} + z_{it}^{A*}] (\omega_{it'}^A - \omega_{it}^A) + DC^A \left(\begin{smallmatrix} \cdot \\ t, t' \end{smallmatrix} \right) ,
\end{aligned} \tag{6.5}$$

where $DC^A \left(\begin{smallmatrix} \cdot \\ t, t' \end{smallmatrix} \right)$ denotes

$$\begin{aligned} (1/2) \left\{ \left[\epsilon_{t'}^{C^A y} (c_{t'}^A / y_{t'}) + \epsilon_t^{C^A y} (c_t^A / y_t) \right] (y_{t'} - y_t) \right. \\ + \sum_{k=1}^L \left[\epsilon_{t'}^{C^A Gk} (c_{t'}^A / G_{kt'}) + \epsilon_t^{C^A Gk} (c_t^A / G_{kt}) \right] (G_{kt'} - G_{kt}) \\ + \sum_{r=1}^M \left[\epsilon_{t'}^{C^A Sr} (c_{t'}^A / S_{rt'}) + \epsilon_t^{C^A Sr} (c_t^A / S_{rt}) \right] (S_{rt'} - S_{rt}) \\ \left. + \left[\epsilon_{t'}^{C^A t} c_{t'}^A + \epsilon_t^{C^A t} c_t^A \right] (t' - t) \right\} , \end{aligned}$$

i.e. $DC^A \left(\begin{smallmatrix} \cdot \\ t, t' \end{smallmatrix} \right)$ is the set of terms in (6.2) that involve partial derivatives of the cost function $C^A(\cdot)$ with respect to non-price variables, expressed in terms of elasticities.

The terms involving z_{iv}^{A*} and ω_{iv}^A ($v = t, t'; i = 1, 2, \dots, N$) in (6.5) can be decomposed so that:

$$\begin{aligned} & \left[(1/2) \sum_{i=1}^N \omega_{it'}^A z_{it'}^{A*} + (1/2) \sum_{i=1}^N \omega_{it'}^A z_{it'}^{A*} \right. \\ & \quad \left. - (1/2) \sum_{i=1}^N \omega_{it}^A z_{it}^{A*} - (1/2) \sum_{i=1}^N \omega_{it}^A z_{it}^{A*} \right] \\ & - \left\{ (1/2) \sum_{i=1}^N \omega_{it'}^A z_{it}^{A*} + (1/2) \sum_{i=1}^N \omega_{it'}^A z_{it'}^{A*} \right. \\ & \quad \left. - (1/2) \sum_{i=1}^N \omega_{it}^A z_{it}^{A*} - (1/2) \sum_{i=1}^N \omega_{it}^A z_{it'}^{A*} \right\} = DC^A \left(\begin{smallmatrix} \cdot \\ t, t' \end{smallmatrix} \right) \end{aligned} \quad (6.6)$$

where the terms in the square brackets in (6.6) are just the left-hand side of (6.5) re-expressed somewhat differently, and the terms in parentheses are the expansion of the first set of terms on the right-hand side of (6.5).

Eliminate and combine terms in (6.6) to get:

$$\begin{aligned} & \sum_{i=1}^N \left[(\omega_{it'}^A + \omega_{it}^A) / 2 \right] z_{it'}^{A*} - \\ & \sum_{i=1}^N \left[(\omega_{it'}^A + \omega_{it}^A) / 2 \right] z_{it}^{A*} = DC^A \left(\begin{smallmatrix} \cdot \\ t, t' \end{smallmatrix} \right). \end{aligned} \quad (6.6')$$

Now define the variables that comprise the reference point, namely the average values:

$$\begin{aligned}
 \omega_{ib}^A &= (\omega_{it'}^A + \omega_{it}^A)/2 \quad , \quad i = 1, 2, \dots, N; \\
 z_{ib}^{A*} &= (z_{it'}^{A*} + z_{it}^{A*})/2 \quad , \quad i = 1, 2, \dots, N; \\
 y_b &= (y_{t'} + y_t)/2 \quad ; \\
 G_{kb} &= (G_{kt'} + G_{kt})/2 \quad , \quad k = 1, 2, \dots, L; \text{ and} \\
 S_{rb} &= (S_{rt'} + S_{rt})/2 \quad , \quad r = 1, 2, \dots, M.
 \end{aligned}$$

Reference-point total cost is thus $c_b^A = \sum_{i=1}^N \omega_{ib}^A z_{ib}^{A*}$ and the reference-point cost share for each input i is $s_{ib} = (\omega_{ib}^A z_{ib}^{A*})/c_b^A$, $i = 1, 2, \dots, N$.

Define the index of efficiency-adjusted input quantity growth (relative to the reference point b) for year v as:

$$\begin{aligned}
 z_v^{A*} &= \left(\sum_{i=1}^N \omega_{ib}^A z_{iv}^{A*} \right) / \left(\sum_{i=1}^N \omega_{ib}^A z_{ib}^{A*} \right) \\
 &= \sum_{i=1}^N \left[(\omega_{ib}^A z_{ib}^{A*}) / \left(\sum_{i=1}^N \omega_{ib}^A z_{ib}^{A*} \right) \right] (z_{iv}^{A*} / z_{ib}^{A*}) \\
 &= \sum_{i=1}^N s_{ib} (z_{iv}^{A*} / z_{ib}^{A*}), \quad v = t, t' \quad .
 \end{aligned} \tag{6.7}$$

Multiply each element of the summations in (6.6') by $(c_b^A z_{ib}^{A*}) / (c_b^A z_{ib}^{A*})$ and note that the result matches (6.1), so that (6.6') becomes:

$$\begin{aligned}
c_b^A (z_{t'}^{A*} - z_t^{A*}) &\equiv (1/2) \left\{ \left[\epsilon_{t'}^{CAy} (c_{t'}^A / y_{t'}) + \epsilon_t^{CAy} (c_t^A / y_t) \right] (y_{t'} - y_t) \right. \\
&\quad + \sum_{k=1}^L \left[\epsilon_{t'}^{CAGk} (c_{t'}^A / G_{kt'}) + \epsilon_t^{CAGk} (c_t^A / G_{kt}) \right] (G_{kt'} - G_{kt}) \\
&\quad + \sum_{r=1}^M \left[\epsilon_{t'}^{CASr} (c_{t'}^A / S_{rt'}) + \epsilon_t^{CASr} (c_t^A / S_{rt}) \right] (S_{rt'} - S_{rt}) \\
&\quad \left. + \left[\epsilon_{t'}^{CAt} c_{t'}^A + \epsilon_t^{CAt} c_t^A \right] (t' - t) \right\} .
\end{aligned} \tag{6.8}$$

Multiply the first set of terms in (6.8) by y_b/y_b , each element in the second set of terms by G_{kb}/G_{kb} and each element of the third set of terms by S_{rb}/S_{rb} . Multiply through the resulting expression by $-(1/c_b^A)$ and add $(y_{t'} - y_t)/y_b$ to both sides of the subsequent equation to get the following:

$$\begin{aligned}
[y_{t'}/y_b - y_t/y_b] - (z_{t'}^{A*} - z_t^{A*}) &= (y_{t'} - y_t)/y_b \\
&\quad - (1/2) \left\{ \left[\epsilon_{t'}^{CAy} (c_{t'}^A / c_b^A) / (y_{t'}/y_b) + \epsilon_t^{CAy} (c_t^A / c_b^A) / (y_t/y_b) \right] (y_{t'} - y_t) / y_b \right. \\
&\quad + \sum_{k=1}^L \left[\epsilon_{t'}^{CAGk} (c_{t'}^A / c_b^A) / (G_{kt'}/G_{kb}) + \epsilon_t^{CAGk} (c_t^A / c_b^A) / (G_{kt}/G_{kb}) \right] (G_{kt'} - G_{kt}) / G_{kb} \\
&\quad + \sum_{r=1}^M \left[\epsilon_{t'}^{CASr} (c_{t'}^A / c_b^A) / (S_{rt'}/S_{rb}) + \epsilon_t^{CASr} (c_t^A / c_b^A) / (S_{rt}/S_{rb}) \right] (S_{rt'} - S_{rt}) / S_{rb} \\
&\quad \left. + \left[\epsilon_{t'}^{CAt} (c_{t'}^A / c_b^A) + \epsilon_t^{CAt} (c_t^A / c_b^A) \right] (t' - t) \right\} .
\end{aligned} \tag{6.9}$$

Use definition (6.1) and some new notation, and consolidate terms in (6.9) to arrive at:

$$\begin{aligned}
TFPG_{t,t'}^z &= (1 - \epsilon_{t,t'}^{CAy}) (y_{t'} - y_t) / y_b \\
&\quad - \sum_{k=1}^L \epsilon_{t,t'}^{CAGk} (G_{kt'} - G_{kt}) / G_{kb} \\
&\quad - \sum_{r=1}^M \epsilon_{t,t'}^{CASr} (S_{rt'} - S_{rt}) / S_{rb} - \epsilon_{t,t'}^{CAt} (t' - t) ,
\end{aligned} \tag{6.10}$$

where:

$$\begin{aligned}\epsilon_{t,t'}^{CAy} &= (1/2) \left[\epsilon_{t'}^{CAy} (c_{t'}^A/c_b^A)/(y_{t'}/y_b) + \epsilon_t^{CAy} (c_t^A/c_b^A)/(y_t/y_b) \right] ; \\ \epsilon_{t,t'}^{CAGk} &= (1/2) \left[\epsilon_{t'}^{CAGk} (c_{t'}^A/c_b^A)/(G_{kt'}/G_{kb}) + \epsilon_t^{CAGk} (c_t^A/c_b^A)/(G_{kt}/G_{kb}) \right] ; \\ \epsilon_{t,t'}^{CASr} &= (1/2) \left[\epsilon_{t'}^{CASr} (c_{t'}^A/c_b^A)/(S_{rt'}/S_{rb}) + \epsilon_t^{CASr} (c_t^A/c_b^A)/(S_{rt}/S_{rb}) \right] ; \text{ and} \\ \epsilon_{t,t'}^{CA^t} &= (1/2) \left[\epsilon_{t'}^{CA^t} (c_{t'}^A/c_b^A) + \epsilon_t^{CA^t} (c_t^A/c_b^A) \right] .\end{aligned}$$

Note that the terms $\epsilon_{t,t'}^{CAy}$, $\epsilon_{t,t'}^{CAGk}$ ($k = 1, 2, \dots, L$), $\epsilon_{t,t'}^{CASr}$ ($r = 1, 2, \dots, M$), and $\epsilon_{t,t'}^{CA^t}$ can be viewed as weighted averages of the corresponding elasticities in t' and t , with the weights measured relative to the reference point.

Expression (6.10) shows $TFPG_{t,t'}^z$ to be equal to the sum of four components. The first component measures the effect of changes in scale on $TFPG_{t,t'}^z$; the second component measures the effect of changes in public infrastructure stocks on $TFPG_{t,t'}^z$; the third component measures the effect of changes in knowledge spillovers (R&D stocks) on $TFPG_{t,t'}^z$; and the fourth component measures the effect of changes in disembodied technology on $TFPG_{t,t'}^z$.

To estimate the size of the difference between $TFPG$ measured with efficiency-adjusted input indexes and that measured with observed input indexes, note that the latter is defined as:

$$TFPG_{t,t'}^v = [y_{t'}/y_b - y_t/y_b] - [v_{t'} - v_t] \quad , \quad 1 \leq t < t' \leq T \quad , \quad (6.11)$$

where

$$v_v = \Phi^v(\omega_{1b}^A, \dots, \omega_{Nb}^A, \omega_{1v}^A, \dots, \omega_{Nv}^A; v_{1b}, \dots, v_{Nb}, v_{1v}, \dots, v_{Nv}) \quad , \quad v = t', t$$

and $\Phi^v : \mathfrak{R}_+^{4N} \rightarrow \mathfrak{R}_+$ is a function that aggregates observed quantities into a single quantity index that is equivalent to a ratio of the aggregate observed input in year t to that at the reference point b .

Rearrange (6.1) to isolate the output growth term $[y_{t'}/y_b - y_t/y_b]$ – which is common to both measures of $TFPG$ – and substitute this rearranged version of (6.1) into (6.11) to get:

$$TFPG_{t,t'}^v = TFG_{t,t'}^z + [z_{t'}^{A*} - z_t^{A*}] - [v_{t'} - v_t] \quad , \quad 1 \leq t < t' \leq T . \quad (6.12)$$

In other words, $TFPG$ measured with observed inputs is comprised of the same four components identified above (which together make $TFPG_{t,t'}^z$), plus a fifth component, namely the difference between efficiency-adjusted input growth and observed input growth – this is the input efficiency effect. If, in aggregate, efficiency-adjusted input growth exceeds that of observed input growth, $TFPG_{t,t'}^v$ will increase, and vice versa.

6.4 RESULTS

The results for the application of (6.10) and (6.12) to the results from Chapter 5 are presented in Table 6.1 – these are averages of the year-over-year values of $TFPG_{t,t'}^v$ (observed TFG) and the corresponding components for five-year intervals between 1967 and 1996, averages for the pre- and post-OPEC crisis periods, and an average for the whole sample.² The advantage in taking averages of the data in this way is that some of the more persistent elements of observed TFG can be separated from the more transitory ones.

²Note that, because the disembodied technical change terms are not included in the estimated demand equations, efficiency-adjusted productivity growth, $TFPG_{t,t'}^z$, is comprised of the scale, public infrastructure and knowledge spillover components. Consequently, the estimated series for $TFPG_{t,t'}^z$ is the sum of the columns for these three components in Table 6.1.

**Table 6.1 Average Observed Total Factor Productivity Growth
and its Decomposition, Canadian Food Processing Industry**

period	observed TFPG	components of observed TFPG			
		scale	public infrastructure	knowledge spillovers	input efficiency
five-year intervals					
'67-71	0.5%	0.2%	-0.2%	0.5%	-0.0%
'72-76	0.4%	0.1%	-0.1%	0.2%	0.2%
'77-81	0.1%	0.1%	0.1%	-0.0%	-0.1%
'82-86	0.1%	-0.1%	0.2%	-0.2%	0.1%
'87-91	-0.1%	-0.1%	0.3%	-0.3%	-0.1%
'92-96	0.1%	-0.4%	0.4%	-0.1%	0.3%
pre- and post- OPEC					
1964-1973	0.5%	0.2%	-0.2%	0.5%	0.0%
1974-1996	0.1%	0.1%	0.1%	0.0%	0.0%
whole sample					
1964-1996	0.2%	-0.0%	0.1%	0.1%	0.1%

In some cases, the sum of components differs from observed TFPG due to rounding.

Note that efficiency-adjusted TFPG is equal to the sum of the scale, public infrastructure and knowledge spillover components

The results indicate that observed TFPG for the food industry was much lower in the later years of the sample than in the early years. In terms of the pre- and post-OPEC periods, observed TFPG fell from about 0.5% per year, on average, to around 0.1% per year, on average.

The main reason for the decline in observed TFPG is the spillover effect, which decreased from contributing about 0.5 percentage points in the first part of the sample to -0.1 percentage points at the end of the sample.³ Scale effects also showed this pattern. The effect of public infrastructure investment on observed TFPG seems to have offset some of the spillover and scale effects noted above in the latter part of the sample, but was insufficient to stop the decline in productivity growth. (In the 1967-1971 and 1972-1976 periods, however, public infrastructure growth had a negative effect on productivity growth.)

Input efficiency effects have varied between the periods for which the averages were computed, being positive in some cases and negative in others. In the 1992-1996 period, however, efficiency effects on observed TFPG were quite large and positive.

³One possible explanation for the change in effect of R&D spillovers on TFPG is that these spillovers were largely comprised of process-oriented innovations (which are cost-decreasing) in the earlier part of the sample but that in the latter part of the sample, the spillovers were largely comprised of product-oriented innovations (which can be cost-increasing).

The time-series estimates of observed TFPG and its components are presented in Table 6.2. These data – which are the series used to compute the averages given in Table 6.1 – are illustrated in Figures 6.1-6.4. Figure 6.1 shows that scale effects, while contributing to positive productivity growth, actually had a negative effect on growth in the later years of the sample.⁴

The effect of public infrastructure investment on observed TFPG follows a pattern that is opposite and more pronounced than that for scale – see Figure 6.2. Net investment in public infrastructure seems to have had a negative effect on observed TFPG prior to the late 1970s, but since then had become increasingly positive in its effect. Its contribution, however, has been insufficient to offset the effects from scale (given in the previous chart) and spillovers (in the chart that follows). The trend in this case has been clearly a positive one.

Knowledge spillovers, from net investment in R&D made by U.S. food and beverage processors, have had mixed effects on observed TFPG, as Figure 6.3 illustrates. In the first half of the sample, these effects were quite large and positive. On the other hand, since the late 1970s, R&D net investments by U.S. processors have had a negative effect on observed TFPG, although since the late 1980s this effect has become smaller.

⁴Notice that in this chart and the charts that follow, observed TFPG data are plotted using a two-year moving average representation - this smooths out the large year-to-year variations in TFPG. Notice, in addition, that when displayed as a two-year moving average, TFPG is markedly cyclical, with a duration of about seven years between peaks.

**Table 6.2 Observed Total Factor Productivity Growth and its Decomposition,
Canadian Food Processing Industry**

year	observed TFPG	components of observed TFPG			
		scale	public infrastructure	knowledge spillovers	input efficiency
1964	0.013	0.002	-0.001	0.007	0.004
1965	0.002	0.002	-0.002	0.007	-0.004
1966	0.004	0.002	-0.002	0.004	0.001
1967	0.008	0.003	-0.001	0.007	-0.001
1968	-0.003	0.001	-0.001	0.002	-0.005
1969	0.002	0.001	-0.002	0.003	-0.001
1970	0.010	0.002	-0.002	0.008	0.002
1971	0.008	0.002	-0.002	0.005	0.003
1972	0.009	0.002	-0.002	0.003	0.005
1973	-0.001	0.000	-0.002	0.002	-0.002
1974	0.003	0.001	-0.002	0.002	0.002
1975	-0.005	-0.000	-0.001	0.003	-0.007
1976	0.015	0.001	-0.000	0.001	0.013
1977	0.005	0.002	0.000	0.001	0.002
1978	0.002	0.001	0.001	0.000	-0.000
1979	-0.002	0.000	0.001	-0.000	-0.003
1980	0.001	0.000	0.002	-0.001	0.000
1981	-0.004	-0.000	0.002	-0.002	-0.005
1982	-0.003	0.000	0.002	-0.001	-0.004
1983	0.006	-0.000	0.002	-0.001	0.005
1984	0.004	-0.002	0.002	-0.002	0.005
1985	0.002	-0.002	0.003	-0.003	0.004
1986	-0.004	-0.000	0.002	-0.003	-0.003
1987	-0.003	-0.002	0.003	-0.005	0.001
1988	-0.004	-0.002	0.003	-0.003	-0.002
1989	-0.004	0.000	0.003	-0.003	-0.005
1990	-0.001	0.000	0.004	-0.002	-0.002
1991	0.005	0.000	0.004	-0.001	0.002
1992	0.006	-0.002	0.004	-0.001	0.005
1993	0.002	-0.001	0.004	-0.001	0.000
1994	0.002	-0.005	0.004	-0.002	0.004
1995	-0.001	-0.007	0.004	-0.002	0.003
1996	-0.002	-0.006	0.004	-0.002	0.003

Figure 6.1 Observed TFPG and Scale Component, Canadian Food Processing Industry

Figure 6.2 Observed TFPG and Public Infrastructure Component, Canadian Food Processing Industry

Figure 6.3 Observed TFPG and R&D Spillover Component,
Canadian Food Processing Industry

Figure 6.4 Observed TFPG and Input Efficiency Component,
Canadian Food Processing Industry

Figure 6.4 shows that input efficiency effects (represented as 2-year moving average data) have been the most important determinants of year-to-year variability in observed TFPG. On the other hand, these effects do not appear to have trended upwards or downwards, so that the average effect on observed TFPG has been close to zero – this observation is consistent with the data presented above, particularly the averages for the pre- and post-OPEC periods.

CHAPTER 7

CONCLUSION

This chapter provides a brief review of the salient features of the theory, data, estimation and TFPG decomposition elements of the analysis, and draws on these elements to demonstrate the manner in which the objectives of the dissertation have been met – namely to measure the effect of public infrastructure provision on the input use, cost of production and total factor productivity growth of food processors in Canada.

The theoretical framework used – this is outlined in Chapter 3 – is an extended version of the basic theory – given in Chapter 2 – to incorporate the effect of corporate income and local taxes on after-tax user costs of efficiency-adjusted inputs. The user costs have the full set of tax instruments embodied in them so that it is possible to measure the contribution that any tax instrument (such as the level of a capital cost allowance) makes to the after-tax user cost of any input. The after-tax user costs are the prices in a dual cost function that has public infrastructure and knowledge spillovers incorporated as exogenous variables.

The data used to measure the variables in the theoretical model are for the period 1963-1997. Three inputs are specified: capital, labour and an aggregate of energy, materials and services. Aggregation of capital requires the specification of aggregate tax instruments, and procedures are established to do this. Knowledge

spillovers, measured as R&D capital stocks are constructed using expenditure and deflator data.

The empirical implementation of the model, which uses a version of the symmetric generalized McFadden functional form for the cost function, incorporates three inputs – capital, labour and intermediate inputs (namely, energy, materials and services), one type of infrastructure (an aggregate of all asset types) and one knowledge spillover effect (R&D stock for U.S. food processors). The system of three input demand equations is estimated along with the acquisition price expectations equations for those inputs. The econometric specification is nonlinear due to the incorporation of input efficiency effects, the endogenous determination of after-tax user costs of efficiency-adjusted inputs, and the imposition of concavity.

The estimation results show that the model fits the data well. The estimated efficiency coefficients indicate that net additions of capital were 3.9 times more productive than existing capital; net additions of labour and intermediate materials were 1.5 and 1.2 times more productive, respectively. The hypothesis that infrastructure has no effect on cost is rejected. The estimated public infrastructure elasticities have several features. The key elasticity – that of total cost with respect to public infrastructure – has estimated values that, while negative on average, vary from being slightly positive in the early part of the sample to being increasingly negative in the latter part. In other words, these estimates indicate that public infrastructure was cost-reducing for food processors only from the late 1970s onwards, but that the overall effect was consistent with the hypothesis that public infrastructure was cost-reducing.

Changes in public infrastructure also led to changes in the mix of inputs used by food processors, inducing reductions in labour use and increases in capital use. Moreover, these effects are both consistent in sign and generally increasing in magnitude over the course of the sample so that, whereas an increase in public infrastructure of one per cent would have increased capital demand by food processors by 0.6% in 1963, the same proportionate increase in public infrastructure in 1996 would have increased capital demand by 0.9%. Similarly, a one per cent increase in public infrastructure in 1963 would have decreased labour demand by less than 0.1% – by 1996 the same proportionate increase would have led to a reduction the labour input by over 0.8%.

The estimated effects of public infrastructure – on Canadian food processors' cost, demand for capital and demand for labour – are consistent with most of the previous work done using similar methods. In this regard, the outcome of the analysis could possibly be extrapolated from the specific case of food processing to the more general statement: while public infrastructure provision tends to lower costs of production, it appears to do this in part by changing the way in which that production is achieved, and particularly by inducing reductions in employment.

Estimated TFPG for Canadian food processors was about 0.2% per year on average between 1964 and 1996, but apparently followed a decreasing trend over the course of the sample. TFPG also seems to have been cyclical, with several peaks and troughs over the 30 years or so for which these estimates were made. Public infrastructure growth has enhanced TFPG; the estimates indicate that, on average, this component raised TFPG by 0.1 percentage points. Public infrastructure has provided an important offset to the largely negative effects of scale

and knowledge spillovers on TFPG – without increases in public infrastructure, TFPG would have been considerably lower in the last 15 years of the sample.

To sum up, public infrastructure provision by Canada's municipal, provincial and federal governments has lowered the production cost of Canadian food processors, on average. This reduction in cost, which offset productivity-reducing effects caused by changes in scale and U.S. R&D, came about in part from induced changes in input use arising from public infrastructure investments. In particular, food processors employed relatively fewer workers and used relatively more capital than they otherwise would have done.

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APPENDIX A. DERIVING OBSERVED QUANTITY OF DURABLE INPUTS

The derivations in this Appendix show how (2.2) – in Chapter 2 – can be re-expressed as an infinite stream of past investments, i.e. as

$$v_{it} = x_{it} + \sum_{\iota=1}^{\infty} (1 - \delta_i)^{\iota} x_{it-\iota} \quad , \quad i = 1, 2, \dots, N \quad , \quad (\text{A1.1})$$

where (A1.1) is the well-known formula used to compute capital stock under the assumption of geometric decay (see [3, p. 229]).

To derive (A1.1), first suppose that investment begins only three years before year t , and that prior to this, investments for input i were zero. Then, beginning with a ‘seed’ of initial investment x_{it-3} (meaning that $v_{it-3} = x_{it-3}$), use (2.2) to derive the level of v_i for year $t - 2$, i.e.

$$v_{it-2} = x_{it-2} + (1 - \delta_i)x_{it-3} \quad (\text{A1.2a})$$

Similarly, for year $t - 1$,

$$v_{it-1} = x_{it-1} + (1 - \delta_i)[x_{it-2} + (1 - \delta_i)x_{it-3}] \quad (\text{A1.2b})$$

so substitution of these expressions into (A1.1) gives

$$v_{it} = \sum_{\iota=0}^3 (1 - \delta_i)^{\iota} x_{it-\iota} \quad (\text{A1.3})$$

Now, suppose that investment begins in year $t - T$, where $T \geq 3$. Then, extension of the 3-year result leads to:

$$v_{it} = x_{it} + \sum_{\iota=1}^{T-1} (1 - \delta_i)^{\iota} x_{it-\iota} + (1 - \delta_i)^T x_{it-T} \quad (\text{A1.4})$$

Given that $(1 - \delta_i) < 1$, providing $x_{it-T} \leq X_i \forall T$ – where X_i is some real number chosen to ensure that the second inequality holds – then

$$\lim_{T \rightarrow \infty} (1 - \delta_i)^T x_{it-T} = 0,$$

and so in the limit (A1.4) becomes (A1.1).

Just as (A1.1) can be derived with successive substitutions of (2.2), (2.2) can be derived with (A1.1). In particular, since by (A1.1),

$$v_{it-1} = x_{it-1} + \sum_{\ell=1}^{\infty} (1 - \delta_i)^{\ell} x_{it-1-\ell}, \quad (\text{A1.5})$$

multiplication of both sides of (A1.5) by $1 - \delta_i$ gives

$$(1 - \delta_i)v_{it-1} = (1 - \delta_i)x_{it-1} + \sum_{\ell=2}^{\infty} (1 - \delta_i)^{\ell} x_{it-\ell}. \quad (\text{A1.6})$$

The right-hand side of (A1.6), though, is just the second term on the right-hand side of (A1.1). Thus, substituting (A1.6) for this second term in (A1.1) gives

$$v_{it} = x_{it} + (1 - \delta_i)v_{it-1}, \quad (\text{A1.7})$$

which is the same as (2.2).

APPENDIX B. MODELLING CAPITAL COST ALLOWANCES

For any given capital acquisition, the CCA allowance component for that asset will persist indefinitely into the future (although the allowance will tend to zero quite quickly) or until the asset is retired/sold.¹ For example, the table below shows how acquisitions in years t , $t + 1$, $t + 2$ and $t + 3$ lead to a stream of future allowances.²

acquisition	CCA allowance component in year:			
	t	$t + 1$	$t + 2$	$t + 3$
x_{jt}	$\gamma_{jt}c_{jt}^x$	$\gamma_{jt}(1 - \gamma_{jt})c_{jt}^x$	$\gamma_{jt}(1 - \gamma_{jt})^2c_{jt}^x$	$\gamma_{jt}(1 - \gamma_{jt})^3c_{jt}^x$
x_{jt+1}	0	$\gamma_{jt}c_{jt+1}^x$	$\gamma_{jt}(1 - \gamma_{jt})c_{jt+1}^x$	$\gamma_{jt}(1 - \gamma_{jt})^2c_{jt+1}^x$
x_{jt+2}	0	0	$\gamma_{jt}c_{jt+2}^x$	$\gamma_{jt}(1 - \gamma_{jt})c_{jt+2}^x$
x_{jt+3}	0	0	0	$\gamma_{jt}c_{jt+3}^x$

Note: $c_{jt+\tau}^x = q_{jt+\tau}x_{jt+\tau}(1 - \psi_t^I)$, $\tau = 0, 1, 2, \dots$; $q_{jt+\tau}x_{jt+\tau}\psi_t^I$ is the amount of investment tax credit claimed in year $t + \tau$ against the purchase cost of asset type j in that year.

Notice that for purposes of this illustration, the CCA rate γ_{jt} is assumed to remain constant, as is the investment tax credit rate ψ_t^I . Periodic changes in

¹For purposes of this analysis, the sale/retirement of assets is not allowed for; instead, assets are assumed to depreciate geometrically (i.e. following a declining balance formula), so that even very far into the future, some vestige of the original investment will remain as part of the capital stock for that asset class.

²See [28, pp. 70-71] for a textbook treatment of capital cost allowances in the declining balance case. Note that half-year rules are not considered here.

these rates or changes in the CCA class for a particular type of capital can be accommodated but are omitted to make the illustration more straightforward.

The value of CCAs claimable on planned acquisitions in years $t + 1$, $t + 2$ and $t + 3$ are thus given by:

$$\begin{aligned}\mathfrak{X}_{jt}^x &= \gamma_{jt}\mathfrak{c}_{jt}^x \\ \mathfrak{X}_{jt+1}^x &= \gamma_{jt}(1 - \gamma_{jt})\mathfrak{c}_{jt}^x + \gamma_{jt}\mathfrak{c}_{jt+1}^x ; \\ \mathfrak{X}_{jt+2}^x &= \gamma_{jt}(1 - \gamma_{jt})^2\mathfrak{c}_{jt}^x + \gamma_{jt}(1 - \gamma_{jt})\mathfrak{c}_{jt+1}^x + \gamma_{jt}\mathfrak{c}_{jt+2}^x ; \text{ and} \\ \mathfrak{X}_{jt+3}^x &= \gamma_{jt}(1 - \gamma_{jt})^3\mathfrak{c}_{jt}^x + \gamma_{jt}(1 - \gamma_{jt})^2\mathfrak{c}_{jt+1}^x + \gamma_{jt}(1 - \gamma_{jt})\mathfrak{c}_{jt+2}^x + \gamma_{jt}\mathfrak{c}_{jt+3}^x ;\end{aligned}$$

Extension of these series leads to:

$$\begin{aligned}CCA_{t+\tau} &= \gamma_{jt}(1 - \gamma_{jt})^\tau\mathfrak{c}_{jt}^x + \gamma_{jt}(1 - \gamma_{jt})^{\tau-1}\mathfrak{c}_{jt+1}^x \\ &\quad + \dots + \gamma_{jt}(1 - \gamma_{jt})\mathfrak{c}_{jt+\tau-1}^x + \gamma_{jt}\mathfrak{c}_{jt+\tau}^x \\ &= \gamma_{jt} \sum_{\iota=0}^{\tau} (1 - \gamma_{jt})^\iota \mathfrak{c}_{jt+\tau-\iota}^x .\end{aligned}$$

APPENDIX C. AFTER-TAX ACQUISITION AND HIRING PRICES

C.1 Introduction

This Appendix provides details on two aspects of the optimization problem (3.15): (1) the separation of financial decisions from production decisions that allows this optimization to take place; and (2) the specification of after-tax acquisition and hiring prices.³

Regarding (1), the derivations here show that this separation is possible when both of the following conditions hold: (1a) the weighted average rate of return to debt and equity in any year is not correlated with the return in any other year; and (1b) the rate of return in any year is not correlated with after-tax net income (excluding debt payments) in any other year. When conditions (1a) and (1b) hold, and when processors have static expectations of the discount rate, it is shown that maximization of after-tax net income (excluding debt payments), given a production plan and exogenous output prices, is equivalent to maximization of the sum of debt and equity. This means that, in the minimization problem (3.15), the discount rate can be treated as if it were an exogenous variable, since this rate is set by financial decisions.

Regarding (2), the input cost portion in any year of after-tax net income (excluding debt payments) is separated into two parts: (2a) the effect of acquisitions of capital prior to that year on that years after-tax input cost; and (2b)

³Note that this analysis provides a discrete version of the model developed in [6] and elaborates on some of its elements.

the effect of capital acquisitions made in any year on input cost in that year and every year in the future. Since acquisition decisions underlying part (2a) have already been made, they have no effect at the margin. Specification of after-tax acquisition prices are therefore based only on elements related to (2b).

Finally, when conditions (1a) and (1b) are met, minimization of the present value the after-tax acquisition and hiring cost of inputs by processors is equivalent to maximization of the sum of debt and equity.

C.2 Equivalence of Optimization Problems

Consider the after-tax flow of funds identity:

$$p_t y_t + I_t^{\mathfrak{B}} + P_t^{\mathfrak{N}} I_t^{\mathfrak{N}} = \sum_{u=1}^N q_{ut} x_{ut} + \mathfrak{D}_t + r_t \mathfrak{B}_{t-1} + \mathfrak{W}_t^C + \mathfrak{W}_t^L \quad (\text{C1.1})$$

where: $I_t^{\mathfrak{B}}$ is the nominal value of new debt (e.g. bond issues less retirements) in year t – interest payments are not made on this debt until the following year; $P_t^{\mathfrak{N}}$ is the average market price of shares in year t ; $I_t^{\mathfrak{N}}$ is the number of share issues, net of repurchases in year t – dividends are not paid to holders of these shares until the following year;⁴ and $\mathfrak{D}_t$ is the dividend payout to holders of shares at the beginning of year t – this payout is on the number of shares carried over from the previous year, $\mathfrak{N}_{t-1}$. (All other variables have been defined elsewhere.)

Modify (3.7) to define adjusted taxable income (i.e. without interest payments deducted from revenue) as:⁵

⁴Note that $I_t^{\mathfrak{N}}$ could include any change in retained earnings.

⁵Interest paid is deducted from total revenue in determining net income for income tax purposes, and therefore taxable income – see (3.7). Here, this expense ($\mathfrak{X}_t^{\mathfrak{B}}$) is adding back into net income to allow the after-tax flow of funds identity to be separated into finance-related and production-related variables.

$$\mathcal{J}_t^{T \setminus \mathfrak{B}} = \mathcal{J}_t^T + \mathfrak{X}_t^B . \quad (\text{C1.2})$$

Accordingly, total corporate income tax payable can be defined as:⁶

$$\mathfrak{W}_t^C = \mathfrak{W}_t^{C \setminus \mathfrak{B}} - \Xi_t^1 \mathfrak{X}_t^B , \quad (\text{C1.3})$$

where $\mathfrak{W}_t^{C \setminus \mathfrak{B}} = \Xi_t^1 \mathcal{J}_t^{T \setminus \mathfrak{B}} - \mathfrak{W}_t^{FI}$.

Substitution of (C1.3) into (C1.1), replacement of $\mathfrak{X}_t^B$ with $r_t \mathfrak{B}_{t-1}$ and rearrangement gives an equivalent expression for after-tax flow of funds identity:

$$\begin{aligned} p_t y_t - \sum_{u=1}^N q_{ut} x_{ut} - \mathfrak{W}_t^{C \setminus \mathfrak{B}} - \mathfrak{W}_t^L & \quad (\text{C1.1}') \\ \equiv \mathfrak{D}_t + (1 - \Xi_t^1) r_t \mathfrak{B}_{t-1} - P_t^{\mathfrak{M}} I_t^{\mathfrak{M}} - I_t^{\mathfrak{B}} . \end{aligned}$$

Now all the production-related variables are placed on the left-hand side of the flow of funds identity, and all the finance-related variables on the right-hand side.

⁶Note that this expression is based on several substitutions. In particular, substitution of (3.8a)-(3.8e) into (3.9), substitution of the thus-revised (3.9) and (3.10) into (3.11), and use of the definition of Ξ_t^1 gives:

$$\mathfrak{W}_t^C = \Xi_t^1 \mathcal{J}_t^T - \mathfrak{W}_t^{FI} .$$

Since by (C1.2),

$$\mathcal{J}_t^T = \mathcal{J}_t^{T \setminus \mathfrak{B}} - \mathfrak{X}_t^B ,$$

it follows that

$$\mathfrak{W}_t^C = \Xi_t^1 \mathcal{J}_t^{T \setminus \mathfrak{B}} - \Xi_t^1 \mathfrak{X}_t^B - \mathfrak{W}_t^{FI} .$$

Define adjusted corporate income tax payable (i.e. the amount payable without the tax effect of interest payments) as:

$$\mathfrak{W}_t^{C \setminus \mathfrak{B}} = \Xi_t^1 \mathcal{J}_t^{T \setminus \mathfrak{B}} - \mathfrak{W}_t^{FI} ,$$

so that

$$\mathfrak{W}_t^C = \mathfrak{W}_t^{C \setminus \mathfrak{B}} - \Xi_t^1 \mathfrak{X}_t^B .$$

Concentrating now on the right-hand side of (C1.1'), note that the total value of equity and debt in year t is:

$$\mathfrak{A}_t = P_t^{\mathfrak{N}} \mathfrak{N}_t + \mathfrak{B}_t . \quad (\text{C1.4})$$

In a manner analogous to capital stock accumulation, the accumulation formulas for equity and debt can be specified as:

$$\mathfrak{N}_t = \mathfrak{N}_{t-1} + I_t^{\mathfrak{N}} , \quad (\text{C1.5a})$$

and

$$\mathfrak{B}_t = \mathfrak{B}_{t-1} + I_t^{\mathfrak{B}} \quad (\text{C1.5b})$$

respectively. Multiply through (C1.5a) by $P_t^{\mathfrak{N}}$ and substitute this revised expression as well as (C1.5b) into (C1.4), to get:

$$\mathfrak{A}_t = P_t^{\mathfrak{N}} \mathfrak{N}_{t-1} + P_t^{\mathfrak{N}} I_t^{\mathfrak{N}} + \mathfrak{B}_{t-1} + I_t^{\mathfrak{B}} . \quad (\text{C1.6})$$

Now, deduct $\mathfrak{A}_{t-1}$ from both sides of (C1.6) and substitute (C1.4) – lagged one year – for $\mathfrak{A}_{t-1}$ on the right-hand side of the resulting expression. This gives the following:

$$\Delta \mathfrak{A}_t = \Delta P_t^{\mathfrak{N}} \mathfrak{N}_{t-1} + P_t^{\mathfrak{N}} I_t^{\mathfrak{N}} + I_t^{\mathfrak{B}} , \quad (\text{C1.7})$$

where: ‘ $\Delta \mathfrak{A}_t$ ’ denotes ‘ $\mathfrak{A}_t - \mathfrak{A}_{t-1}$ ’ and likewise $\Delta P_t^{\mathfrak{N}} = P_t^{\mathfrak{N}} - P_{t-1}^{\mathfrak{N}}$. Using (C1.7), substitute for the term ‘ $-P_t^{\mathfrak{N}} I_t^{\mathfrak{N}} - I_t^{\mathfrak{B}}$ ’ in (C1.1'). This gives:

$$\Gamma_t = \mathfrak{D}_t + \Delta P_t^{\mathfrak{N}} \mathfrak{N}_{t-1} + (1 - \Xi_t^1) r_t \mathfrak{B}_{t-1} - \Delta \mathfrak{A}_t \quad (\text{C1.8})$$

where: $\Gamma_t = p_t y_t - \sum_{u=1}^N q_{ut} x_{ut} - \mathfrak{M}_t^{C \setminus \mathfrak{B}} - \mathfrak{M}_t^L$.

Multiply the first two terms on the right-hand side of (C1.8) by

$$[(P_{t-1}^{\mathfrak{N}} \mathfrak{N}_{t-1}) / \mathfrak{A}_{t-1}] [\mathfrak{A}_{t-1} / (P_{t-1}^{\mathfrak{N}} \mathfrak{N}_{t-1})] ,$$

and the third term on the right-hand side of (C1.8) by $\mathfrak{A}_{t-1} / \mathfrak{A}_{t-1}$. The resulting expression is

$$\Gamma_t = (\varpi_{t-1}^{\mathfrak{N}} \rho_t^{\mathfrak{N}} + \varpi_{t-1}^{\mathfrak{B}} \rho_t^{\mathfrak{B}}) \mathfrak{A}_{t-1} - \Delta \mathfrak{A}_t \quad (\text{C1.9})$$

where: $\rho_t^{\mathfrak{N}} = \mathfrak{D}_t / (P_{t-1}^{\mathfrak{N}} \mathfrak{N}_{t-1}) + \Delta P_t^{\mathfrak{N}} / P_{t-1}^{\mathfrak{N}}$ is the average rate of return that is paid to holders of equity in year t ; $\rho_t^{\mathfrak{B}} = (1 - \Xi_t^1) r_t$ is the net rate of return paid to holders of debt in year t ; $\varpi_{t-1}^{\mathfrak{N}} = (P_{t-1}^{\mathfrak{N}} \mathfrak{N}_{t-1}) / \mathfrak{A}_{t-1}$ is the share of total equity and debt accounted for by equity in year $t - 1$; and $\varpi_{t-1}^{\mathfrak{B}} = \mathfrak{B}_{t-1} / \mathfrak{A}_{t-1}$ is the share of total equity and debt accounted for by debt in year $t - 1$.

Expression (C1.9) equates after-tax net income from production activities (excluding interest payments and their tax effect) with the weighted average after-tax return to debt and equity less the change in debt and equity. Denote the weighted average rate of return as:

$$\rho_t = \varpi_{t-1}^{\mathfrak{N}} \rho_t^{\mathfrak{N}} + \varpi_{t-1}^{\mathfrak{B}} \rho_t^{\mathfrak{B}} . \quad (\text{C1.10})$$

Note that this is the discount rate that appears in the optimization problem (3.15) and in subsequent derivations.

With the use of (C1.10), (C1.9) can be re-expressed as:

$$\Gamma_t = \rho_t \mathfrak{A}_{t-1} - \Delta \mathfrak{A}_t . \quad (\text{C1.9}')$$

Substitute $\mathfrak{A}_t - \mathfrak{A}_{t-1}$ for $\Delta \mathfrak{A}_t$ in (C1.9'), and rearrange the resulting expression get:

$$\mathfrak{A}_t = (1 + \rho_t) \mathfrak{A}_{t-1} - \Gamma_t . \quad (\text{C1.11})$$

Expression (C1.11) is a first-order difference equation which can be solved using successive substitutions, the first two of which are specified in detail below.

- **First Substitution.** Shift (C1.11) forward one year and take expectations.⁷ This gives:

$$\mathfrak{A}_{t+1}^e = [(1 + \rho_{t+1}) \mathfrak{A}_t]^e - \Gamma_{t+1}^e , \quad (\text{C1.12a})$$

Multiply through (C1.11) by $(1 + \rho_{t+1})$ and take expectations of this result to get

$$\begin{aligned} [(1 + \rho_{t+1}) \mathfrak{A}_t]^e &= [(1 + \rho_{t+1}) (1 + \rho_t)]^e \mathfrak{A}_{t-1} \\ &\quad - [(1 + \rho_{t+1}) \Gamma_t]^e . \end{aligned} \quad (\text{C1.12b})$$

Substitute (7.1) into (C1.12a) to obtain

$$\begin{aligned} \mathfrak{A}_{t+1}^e &= [(1 + \rho_{t+1}) (1 + \rho_t)]^e \mathfrak{A}_{t-1} \\ &\quad - [(1 + \rho_{t+1}) \Gamma_t]^e - \Gamma_{t+1}^e . \end{aligned} \quad (\text{C1.12c})$$

This completes the first substitution.

- **Second Substitution.** Shift (C1.11) forward two years and take expectations to get:

$$\mathfrak{A}_{t+2}^e = [(1 + \rho_{t+2}) \mathfrak{A}_{t+1}]^e - \Gamma_{t+1}^e . \quad (\text{C1.13a})$$

⁷It is assumed that expectations are always made at the beginning of year t . These expectations are represented by the operator E_t . Note that since the realizations are assumed to occur at the very beginning of the year, $E_t(m_t) = m_t$. For compactness, $E_t(m_{t+v})$, is usually denoted by m_{t+v}^e .

Shift (C1.11) forward one year, multiply this expression by $(1 + \rho_{t+2})$ and take expectations. This gives

$$\begin{aligned} [(1 + \rho_{t+2}) \mathfrak{A}_{t+1}]^e &= [(1 + \rho_{t+2}) (1 + \rho_{t+1}) \mathfrak{A}_t]^e \\ &\quad - [(1 + \rho_{t+2}) \Gamma_{t+1}]^e . \end{aligned} \quad (\text{C1.13b})$$

Substitute (C1.13b) into (C1.13a) to obtain

$$\begin{aligned} \mathfrak{A}_{t+2}^e &= [(1 + \rho_{t+2}) (1 + \rho_{t+1}) \mathfrak{A}_t]^e \\ &\quad - [(1 + \rho_{t+2}) \Gamma_{t+1}]^e - \Gamma_{t+2}^e . \end{aligned} \quad (\text{C1.13c})$$

Now multiply (C1.11) by $(1 + \rho_{t+2}) (1 + \rho_{t+1})$ and take expectations the resulting expression to get

$$\begin{aligned} [(1 + \rho_{t+2}) (1 + \rho_{t+1}) \mathfrak{A}_t]^e &= \\ &\quad [(1 + \rho_{t+2}) (1 + \rho_{t+1}) (1 + \rho_t)]^e \mathfrak{A}_{t-1} - \\ &\quad [(1 + \rho_{t+2}) (1 + \rho_{t+1}) \Gamma_t]^e . \end{aligned} \quad (\text{C1.13d})$$

Substitution of (C1.13d) into (7.1) yields

$$\begin{aligned} \mathfrak{A}_{t+2}^e &= [(1 + \rho_{t+2}) (1 + \rho_{t+1}) (1 + \rho_t)]^e \mathfrak{A}_{t-1} \\ &\quad - [(1 + \rho_{t+2}) (1 + \rho_{t+1}) \Gamma_t]^e \\ &\quad - [(1 + \rho_{t+2}) \Gamma_{t+1}]^e - \Gamma_{t+2}^e . \end{aligned} \quad (\text{C1.13e})$$

This completes the second substitution.

When continued in this manner, these substitutions lead to, for year $t + T_M$,

$$\begin{aligned} \mathfrak{A}_{t+T_M} &= \left[\prod_{v=0}^{T_M} (1 + \rho_{t+v}) \right]^e \mathfrak{A}_{t-1} \\ &\quad - \sum_{v=0}^{T_M-1} \left\{ \left[\prod_{\iota=v+1}^{T_M} (1 + \rho_{t+\iota}) \right] \Gamma_{t+v} \right\}^e - \Gamma_{t+T_M}^e . \end{aligned} \quad (\text{C1.14})$$

Divide through (C1.14) by $\left[\prod_{v=0}^{T_M} (1 + \rho_{t+v})\right]^e$ and rearrange to get:

$$\begin{aligned} \mathfrak{A}_{t-1} = \sum_{v=0}^{T_M} \left\{ \left[\prod_{\iota=v+1}^{T_M} (1 + \rho_{t+\iota}) \right] \Gamma_{t+v} \right\}^e & \quad (\text{C1.14}') \\ / \left[\prod_{v=0}^{T_M} (1 + \rho_{t+v}) \right]^e & \\ - \mathfrak{A}_{t+T_M}^e / \left[\prod_{v=0}^{T_M} (1 + \rho_{t+v}) \right]^e & . \end{aligned}$$

Separation of the financial decisions from the production decisions requires assumptions about the independence of the weighted average rate of return ρ between years, and the independence of ρ and Γ between years. In particular, suppose the following two conditions hold:

- (I) $\rho_{t+\iota}$ and $\rho_{t+\iota'}$ are not correlated (are independent), $\iota = 0, 1, 2, \dots$; $\iota' = 0, 1, 2, \dots$; $\iota' \neq \iota$; and
- (II) $\Gamma_{t+\iota}$ and $\rho_{t+\iota'}$ are not correlated (are independent), $\iota = 0, 1, 2, \dots$; $\iota' = 0, 1, 2, \dots$; $\iota' \neq \iota$.

Condition (I) requires that the weighted average rate of return be intertemporally independent (i.e. that the weighted average rate of return in any given year is uncorrelated with that in any other year). Condition (II) requires that the weighted average rate of return and after-tax net income (less the effect of interest payments) also be intertemporally independent. Note that condition (II) does not rule out contemporaneous correlation between Γ and ρ .

With conditions (I) and (II) imposed, it is possible to simplify the expected values in (C1.14'). In particular, the denominator for the first set of terms in (C1.14') can be simplified as follows

$$\left[\prod_{v=0}^{T_M} (1 + \rho_{t+v}) \right]^e = \prod_{v=0}^{T_M} (1 + \rho_{t+v}^e) , \quad (\text{C1.15a})$$

and the numerator for the first set of terms in (C1.14') can be simplified in the following manner, i.e.

$$\begin{aligned} \sum_{v=0}^{T_M} \left\{ \left[\prod_{\iota=v+1}^{T_M} (1 + \rho_{t+\iota}) \right] \Gamma_{t+v} \right\}^e \\ = \sum_{v=0}^{T_M} \left[\prod_{\iota=v+1}^{T_M} (1 + \rho_{t+\iota}^e) \right] \Gamma_{t+v}^e . \end{aligned} \quad (\text{C1.15b})$$

For the last set of terms in (C1.14'), use of expression (C1.15a) leads to, providing $\mathfrak{A}_{t+T_M}^e$ is a finite number, the following result:

$$\lim_{T_M \rightarrow \infty} \left[\prod_{v=0}^{T_M} (1 + \rho_{t+v}^e)^{-1} \right] \mathfrak{A}_{t+T_M}^e = 0 . \quad (\text{C1.15c})$$

Together, (C1.15a), (C1.15b) and (C1.15c) mean that (C1.14') simplifies to

$$\mathfrak{A}_{t-1} = \sum_{v=0}^{\infty} \left[\prod_{\iota=0}^v (1 + \rho_{t+\iota}^e)^{-1} \right] \Gamma_{t+v}^e . \quad (\text{C1.16})$$

The left-hand side of (C1.16) is the total value of debt and equity in year $t - 1$. The right-hand side is the present value of an infinite stream of expected after-tax net income from production activities (less the effect of interest payments).

If producers have static expectations of the weighted average rate of return, then $\rho_{t+\iota}^e = \rho_t$, $\iota = 1, 2, \dots$ and (C1.16) reduces to

$$\mathfrak{A}_{t-1} = \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} \Gamma_{t+v}^e . \quad (\text{C1.16}')$$

Expression (C1.16') equates the present value of after-tax net income (less interest payment components), with the current value of debt plus equity. Thus, maximization of after-tax net income (less interest payment components) can be carried out without reference to financial decisions (i.e. regarding the mix of debt and equity). Moreover, by virtue of the fact that static expectations of the rate of return are assumed, the discount rate ρ_t can be treated as an exogenous variable in the minimization problem (3.15).

C.3 Specification of After-Tax Acquisition and Hiring Prices

To derive the expected after-tax acquisition and hiring cost of the production plan, and thereby the after-tax acquisition and hiring prices, use the fact that

$$\sum_{u=1}^N q_{ut}x_{ut} = \sum_{i \in \mathbb{N}_b} q_{it}x_{it} + \sum_{k \in \mathbb{N}_d} q_{kt}x_{kt} + \sum_{r \in \mathbb{N}_e} q_{rt}x_{rt} ,$$

to first decompose Γ_{t+v} as follows:⁸

⁸To obtain this expression, substitute (3.5) into (3.6) and the resulting expression as well as (3.1) and (3.2) into (3.7). Then use (C1.2) along with the definition of $\mathfrak{W}_t^{C\backslash \mathfrak{B}}$, as well as (3.8e) and (3.6), to derive an expanded version of Γ_t using the definition given with (C1.8). Then collect terms by input type (non-capital, property capital and non-property capital) to get (C1.17).

$$\Gamma_{t+v} = (1 - \Xi_{t+v}^1) p_{t+v} y_{t+v} - (1 - \Xi_{t+v}^1) \sum_{i \in \mathbb{N}_b} q_{it+v} x_{it+v} \quad (\text{C1.17})$$

$$\begin{aligned} & - \sum_{k \in \mathbb{N}_d} (1 + \Xi_{kt+v}^2) q_{kt+v} x_{kt+v} \\ & - \Xi_{t+v}^3 \sum_{k \in \mathbb{N}_d} \left(\sum_{\iota=1}^{\infty} q_{kt+v-\iota} (1 - \delta_k)^\iota x_{kt+v-\iota} \right) \\ & + \sum_{k \in \mathbb{N}_d} \sum_{\iota=1}^{\infty} \Xi_{kt+v-\iota}^4 q_{kt+v-\iota} x_{kt+v-\iota} \\ & - \sum_{r \in \mathbb{N}_e} (1 - \psi_{t+v}^I) q_{rt+v} x_{rt+v} \\ & + \sum_{r \in \mathbb{N}_e} \sum_{\iota=0}^{\infty} \Xi_{rt+v-\iota}^4 q_{rt+v-\iota} x_{rt+v-\iota} \quad , \\ & v = 0, 1, 2, \dots \end{aligned}$$

where

$$\begin{aligned} \Xi_{t+v}^1 &= \kappa_{t+v}^{FC} (1 + \kappa_{t+v}^{FS}) - \kappa_{t+v}^{FP} - \psi_{t+v}^M + \kappa_{t+v}^{PC} ; \\ \Xi_{kt+v}^2 &= \Xi_{t+v}^3 - \Xi_{kt+v}^4 - \psi_{t+v}^I ; \\ \Xi_{t+v}^3 &= (1 - \Xi_{t+v}^1) (\kappa_{t+v}^{LL} + \kappa_{t+v}^{LB}) ; \text{ and} \\ \Xi_{kt+v-\iota}^4 &= \Xi_{t+v}^1 \gamma_{kt} (1 - \gamma_{kt})^\iota (1 - \psi_{t+v-\iota}^I) . \end{aligned}$$

The variable Ξ_{t+v}^1 is the total corporate tax rate (i.e. the combination of rates underlying (3.11) in year $t+v$); Ξ_{kt+v}^2 is a rate that captures three effects from the acquisition of property capital type k in year $t+v$, namely net local taxes, the reduction in corporate tax payable from the CCA (net of investment tax credit) and the reduction in corporate tax payable due to the investment tax credit claimed; Ξ_{t+v}^3 is the net local tax rate;⁹ and $\Xi_{kt+v-\iota}^4$ ($\Xi_{rt+v-\iota}^4$) is a rate which

⁹Net local taxes are defined as: the actual local taxes (sum of property and business taxes) levied on the property, less the corporate tax effect of these local taxes. In the latter case, this is the amount by which corporate income tax is reduced because local

captures the reduction in corporate tax from the capital cost allowance (net of investment tax credit) on an acquisition of property (non-property) capital in year $t + v - \iota$.

Notice that, for all capital inputs, past acquisitions represent part of CCA component of after-tax cost in any given year, since these allowances are based on the original expenditure when acquiring the assets. In addition, for property capital inputs, the market value of that capital is a function both of the depreciated price for and the quantity of past acquisitions. Since both of these components are not influenced by current or future acquisitions, they should not affect the decision in any year related to the optimal amount of each capital type to acquire in that year.¹⁰

Current acquisitions, on the other hand, will qualify for CCAs and investment tax credits (if any) in the current year and will qualify for CCAs in future years. As a result, the decision to acquire capital in the current year will have both current and future corporate income tax implications. In much the same manner, property acquisitions in the current year will affect the amount of local taxes payable in the following and each future year.

Given these characteristics after-tax cost elements, and given that the output level (and therefore total revenue) is exogenous in year t and each year in the future,¹¹ it is possible to divide Γ_{t+v} as defined by (C1.17) into three components: tax payments are deducted from total revenue when arriving at taxable income – see (3.7)

¹⁰While not influencing current decisions, these components will, however, have an impact on after-tax net income and are therefore important when determining after-tax total cost and after-tax profits.

¹¹This exogeneity comes from the production plan, which is set and underlies the optimization problem (3.15).

(i) **After-tax revenue in $t + v$** . This component of Γ_{t+v} is

$$\Gamma_{t+v}^1 = (1 - \Xi_{t+v}^1) p_{t+v} y_{t+v} \quad , \quad v = 0, 1, 2, \dots \quad (\text{C1.18a})$$

(ii) **The effect of past acquisitions in $t + v$** . This component of Γ_{t+v} is

$$\begin{aligned} \Gamma_{t+v}^2 = & -\Xi_{t+v}^3 \sum_{k \in \mathbb{N}_d} \left(\sum_{\iota=1}^{\infty} q_{kt+v-\iota} (1 - \delta_k)^\iota x_{kt+v-\iota} \right) \\ & + \sum_{k \in \mathbb{N}_d} \sum_{\iota=1}^{\infty} \Xi_{kt+v-\iota}^4 q_{kt+v-\iota} x_{kt+v-\iota} \\ & + \sum_{r \in \mathbb{N}_e} \sum_{\iota=1}^{\infty} \Xi_{rt+v-\iota}^4 q_{rt+v-\iota} x_{rt+v-\iota} \quad , \quad v = 0, 1, 2, \dots \end{aligned} \quad (\text{C1.18b})$$

(iii) **The effect of current acquisitions/hirings in $t + v$** . This component of Γ_{t+v} is

$$\begin{aligned} \Gamma_{t+v}^3 = & - (1 + \Xi_{t+v}^1) \sum_{i \in \mathbb{N}_b} q_{it+v} x_{it+v} \\ & - \sum_{k \in \mathbb{N}_d} (1 + \Xi_{kt+v}^2) q_{kt+v} x_{kt+v} \\ & - \sum_{r \in \mathbb{N}_e} (1 - \psi_{t+v}^I) q_{rt+v} x_{rt+v} \\ & + \sum_{r \in \mathbb{N}_e} \Xi_{rt+v}^4 q_{rt+v} x_{rt+v} \quad , \\ & v = 0, 1, 2, \dots \end{aligned} \quad (\text{C1.18c})$$

The components Γ_{t+v}^2 and Γ_{t+v}^3 defined above are now used to illustrate how a capital acquisition in year t will have effects both on current and future after-tax costs. This illustration is divided into two parts – the first looks at a case where the acquisition is an item of property capital while in the second part, the acquisition is an item of other capital. Consider:

1. **An investment in property capital in year t** (x_{kt}). Note that x_{kt} will appear in Γ_t^3 but not in $\Gamma_{t+1}^3, \Gamma_{t+2}^3 \dots$. On the other hand it will appear in

$\Gamma_{t+1}^2, \Gamma_{t+2}^2 \dots$ but not in Γ_t^2 . (In the latter case, the discussion is limited to the effect on Γ_{t+1}^2 – effects on Γ^2 in years after $t+1$ can be derive analogously.)

These effects are summarized as follows:

(a) The part of Γ_t^3 that involves x_{kt} is:

$$\Gamma_{kt}^3 = -(1 + \Xi_{kt}^2)q_{kt}x_{kt} \quad , \quad . \quad (C1.19a)$$

This term captures the acquisition cost itself as well as the tax effect of the capital cost allowance from it, the net local tax effect of its purchase and the investment tax credit that can be claimed on it in year t .

(b) The part of Γ_{t+1}^2 that involves x_{kt} is:

$$\Gamma_{kt+1}^2 = -\Xi_{t+1}^3 q_{kt}(1 - \delta_k)x_{kt} + \Xi_{kt}^{4Ft} q_{kt+1}x_{kt} \quad ,$$

where: $\Xi_{kt+1}^{4Ft} = \Xi_{t+1}^1 \gamma_{kt}(1 - \gamma_{kt})(1 - \psi_t^I)$ is the corporate income tax reduction from the capital cost allowance for x_{kt} in year $t+1$. Thus, the acquisition x_{kt} has two effects on after-tax cost in year $t+1$: it has net local taxes levied on it, based on its value in that year (the first term), and it yields a reduction in taxes from the capital cost allowance on it (the second term).

It is possible, based on 1(b), to compute a present value in year t of all future tax effects of the property capital acquisition x_{kt} , i.e.

$$\Gamma_{kt}^{2P} = \left(- \sum_{\nu=1}^{\infty} (1 + \rho_t)^{-\nu} \left[\Xi_{t+\nu}^3 q_{kt}(1 - \delta_k)^{\nu} \quad , \quad (C1.19b) \right. \right. \\ \left. \left. + \Xi_{kt+\nu}^{4Ft} q_{kt} \right] \right) x_{kt} \quad ,$$

where: $\Xi_{kt+\iota'}^{4Ft} = \Xi_{t+\iota'}^1 \gamma_{kt} (1 - \gamma_{kt})^{\iota'} (1 - \psi_t^I)$ is the tax reduction from the capital cost allowance in year $t + \iota'$ from a property capital acquisition made in year t (i.e. x_{kt}).¹²

Now consider:

2 An acquisition of other capital in year t (x_{rt}). This acquisition will appear in Γ_t^3 but not in $\Gamma_{t+1}^3, \Gamma_{t+2}^3 \dots$ and it will appear in $\Gamma_{t+1}^2, \Gamma_{t+2}^2 \dots$ but not in Γ_t^2 . These effects are summarized as follows.

(a) The element in Γ_t^3 that involves x_{rt} is:

$$\Gamma_{rt}^3 = -(1 - \psi_t^I) q_{rt} x_{rt} + \Xi_{rt}^4 q_{rt} x_{rt} \quad , \quad r \in \mathbb{N}_e \quad . \quad (\text{C1.19c})$$

The first item in this element is the acquisition cost less the investment tax credit for x_{rt} and the second item is the tax effect of the capital cost allowance on x_{rt} in the year of purchase.

(b) The element in $\Gamma_{t+\iota'}^2$ that involves x_{rt} (for any year $t + \iota'$ in the future) is:

$$\Xi_{rt+\iota'}^{4Ft} q_{rt} x_{rt} \quad , \quad r \in \mathbb{N}_e \quad ; \quad \iota' = 1, 2, \dots$$

where: $\Xi_{rt+\iota'}^{4Ft} = \Xi_{t+\iota'}^1 \gamma_{rt} (1 - \gamma_{rt})^{\iota'} (1 - \psi_t^I)$ is the tax reduction effect of the capital cost allowance in year $t + \iota'$ for an acquisition of other capital made in year t (i.e. x_{rt}).

¹²Sometimes the present value of future CCA's, i.e. the term

$$\sum_{\iota'=1}^{\infty} (1 + \rho_t)^{-\iota'} \Xi_{kt+\iota'}^{4Ft} q_{kt} x_{kt}$$

is called a tax shield [28, p. 71].

Based on 2(b), the future tax effects of the acquisition of other capital x_{rt} in year t can also be represented as a present value in that year, i.e.

$$\Gamma_{rt}^{2P} = \left(\sum_{\iota'=1}^{\infty} (1 + \rho_t)^{-\iota'} \Xi_{rt+\iota'}^{4Ft} q_{rt} \right) x_{rt} , \quad (C1.19d)$$

$$r \in \mathbb{N}_e .$$

Finally, consider:

3. **An acquisition or hiring of a non-capital input** (x_{it}). The current and only effect of this acquisition or hiring in year t is simply:

$$\Gamma_{it}^3 = \left[(1 - \Xi_t^1) q_{it} \right] x_{it} , \quad i \in \mathbb{N}_b . \quad (C1.19e)$$

Now combine the current and present value components for property capital – (C1.19a) and (C1.19b) as follows:

$$\Gamma_{kt}^{2P} + \Gamma_{kt}^3 = -Q_{kt} x_{kt} , \quad k \in \mathbb{N}_d ; \quad v = 0, 1, 2, \dots \quad (C1.20a)$$

where:

$$Q_{kt} = \left(1 + \Xi_{kt}^2 - \sum_{\iota'=1}^{\infty} (1 + \rho_t)^{-\iota'} \Xi_{kt+\iota'}^{4Ft} \right. \quad (C1.21)$$

$$\left. + \sum_{\iota'=1}^{\infty} (1 + \rho_t)^{-\iota'} \left[\Xi_{t+\iota'}^3 (1 - \delta_k)^{\iota'} \right] \right) q_{kt} ,$$

$$k \in \mathbb{N}_d ; \quad v = 0, 1, 2, \dots$$

Expression (C1.21) is the specification for the after-tax acquisition price of property capital.

Combine the current and present value components for other capital – (C1.19c) and (C1.19d) – to get:

$$\Gamma_{rt}^{2P} + \Gamma_{rt}^3 = -Q_{rt}x_{rt} \ , \ r \in \mathbb{N}_e ; \ v = 0, 1, 2, \dots \quad (\text{C1.20b})$$

where:

$$\begin{aligned} Q_{rt} = & \left[1 - \psi_t^I - \Xi_{rt}^4 \right. \\ & \left. - \sum_{\iota'=1}^{\infty} (1 + \rho_t)^{-\iota'} \Xi_{rt+\iota'}^{4Ft} \right] q_{rt} \\ & , \ r \in \mathbb{N}_e ; \ v = 0, 1, 2, \dots \end{aligned} \quad (\text{C1.22})$$

Expression (C1.22) is the specification for the after-tax acquisition price of other capital.

Re-express (C1.19e) as

$$\Gamma_{it}^3 = -Q_{it}x_{it} \ , \ i \in \mathbb{N}_b ; \ v = 0, 1, 2, \dots , \quad (\text{C1.20c})$$

where:

$$Q_{it} = (1 - \Xi_t^1) q_{it} \ , \ i \in \mathbb{N}_b ; \ v = 0, 1, 2, \dots \quad (\text{C1.23})$$

Expression (C1.23) is the specification for the after-tax acquisition or hiring price of a non-capital input.

Since

$$\Gamma_{t+v} = \Gamma_{t+v}^1 + \Gamma_{t+v}^2 + \Gamma_{t+v}^3 \ , \ v = 0, 1, 2, \dots , \quad (\text{C1.17}')$$

substitute (C1.17') into (C1.16') to get:

$$\mathfrak{A}_{t-1} = \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} (\Gamma_{t+v}^1 + \Gamma_{t+v}^2 + \Gamma_{t+v}^3) . \quad (\text{C1.16}'')$$

Using this decomposition, sum over all inputs in each class, and define the terms not only for an acquisition/hiring in year t but more generally for all years of the production plan. Then (C1.16'') can be re-expressed as:

$$\begin{aligned} \mathfrak{A}_{t-1} = & \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} \Gamma_{t+v}^1 \\ & + \sum_{i \in \mathbb{N}b} \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} \Gamma_{it+v}^3 \\ & + \sum_{k \in \mathbb{N}d} \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} (\Gamma_{kt+v}^{2P} + \Gamma_{kt+v}^3) \\ & + \sum_{r \in \mathbb{N}e} \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} (\Gamma_{rt+v}^{2P} + \Gamma_{rt+v}^3) , \end{aligned} \quad (\text{C1.16''})$$

or, with after-tax acquisition and hiring prices as

$$\begin{aligned} \mathfrak{A}_{t-1} = & \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} \Gamma_{t+v}^1 \\ & - \sum_{v=0}^{\infty} (1 + \rho_t)^{-v} \sum_{u=1}^N Q_{ut+v} x_{ut+v} . \end{aligned} \quad (\text{C1.16''''})$$

Given a discount rate, a set of output levels, $y_t, y_{t+1}, y_{t+2}, \dots$, and a set of after-tax output prices $(1 - \Xi_t^1) p_t, (1 - \Xi_{t+1}^1) p_{t+1}, (1 - \Xi_{t+2}^1) p_{t+2}, \dots$, taking expectations of expression (C1.16''') shows that minimization of the expected present value of after-tax acquisition and hiring cost at time t , is equivalent to maximizing the expected value of debt and equity in at the beginning of year t . Thus the objective function with $\tau = v$ is:

$$E_t \left\{ \sum_{\tau=0}^{\infty} a_t^\tau \left(\sum_{u=1}^N Q_{ut+\tau} x_{ut+\tau} \right) \right\} ,$$

which is the objective function (3.15).

APPENDIX D. IMPOSING CONCAVITY AND OTHER ECONOMETRIC DETAILS

The SGM cost function is not necessarily concave in user costs of efficiency-adjusted inputs, ω_{it}^A . In particular, the symmetric matrix

$$B = \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{12} & \beta_{22} & \beta_{23} \\ \beta_{13} & \beta_{23} & \beta_{33} \end{bmatrix},$$

which is comprised of the coefficients β_{ij} in the demand equations, may not be negative semi-definite. This property is imposed on B by triangularization, i.e. by imposing the equality $B = -AA'$, where A is a lower triangular matrix [17, pp. 52,54].

Define the transpose of A as:

$$A' = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ 0 & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}.$$

so that

$$-AA' = \begin{bmatrix} -a_{11}^2 & -a_{11}a_{12} & -a_{11}a_{13} \\ -a_{11}a_{12} & -(a_{12}^2 + a_{22}^2) & -(a_{12}a_{13} + a_{22}a_{23}) \\ -a_{11}a_{13} & -(a_{12}a_{13} + a_{22}a_{23}) & -(a_{13}^2 + a_{23}^2 + a_{33}^2) \end{bmatrix},$$

which means that each β_{ij} in B is replaced with the corresponding element of $-AA'$:¹³

$$\begin{aligned}
 \beta_{11} &= -a_{11}^2 \\
 \beta_{12} &= -a_{11}a_{12} \\
 \beta_{13} &= -a_{11}a_{13} \\
 \beta_{22} &= -(a_{12}^2 + a_{22}^2) \\
 \beta_{23} &= -(a_{12}a_{13} + a_{22}a_{23}) \\
 \beta_{33} &= -(a_{13}^2 + a_{23}^2 + a_{33}^2) .
 \end{aligned} \tag{D1.1}$$

The disturbance covariance matrix of the system is

$$\Sigma = \begin{bmatrix} \sigma_{vv11}^2 & \sigma_{vv12}^2 & \sigma_{vv13}^2 & \sigma_{vq11}^2 & \sigma_{vq12}^2 & \sigma_{vq13}^2 \\ \sigma_{vv12}^2 & \sigma_{vv22}^2 & \sigma_{vv23}^2 & \sigma_{vq21}^2 & \sigma_{vq22}^2 & \sigma_{vq23}^2 \\ \sigma_{vv13}^2 & \sigma_{vv23}^2 & \sigma_{vv33}^2 & \sigma_{vq31}^2 & \sigma_{vq32}^2 & \sigma_{vq33}^2 \\ \sigma_{vq11}^2 & \sigma_{vq21}^2 & \sigma_{vq31}^2 & \sigma_{qq11}^2 & \sigma_{qq12}^2 & \sigma_{qq13}^2 \\ \sigma_{vq12}^2 & \sigma_{vq22}^2 & \sigma_{vq32}^2 & \sigma_{qq12}^2 & \sigma_{qq22}^2 & \sigma_{qq23}^2 \\ \sigma_{vq13}^2 & \sigma_{vq23}^2 & \sigma_{vq33}^2 & \sigma_{qq13}^2 & \sigma_{qq23}^2 & \sigma_{qq33}^2 \end{bmatrix}$$

The components of β and X for the specification of (5.3) with technical change excluded are given on the following page. Note that v_{u0} is an initial observation

¹³An identification restriction on A is specified in [17, p. 54], namely that $A'\omega_m^A = 0_3$, where

$$\omega_m^A = [\omega_{1m}^A, \omega_{2m}^A, \omega_{3m}^A]' ,$$

(a vector of reference user costs) and $0_3 = [0, 0, 0]'$. This means that the coefficients a_{11} and a_{22} become functions of the off-diagonal coefficients and that $a_{33} = 0$. There appears to be no compelling reason for the imposition of this restriction (all the coefficients in A can be retrieved without it), so A is not modified in this manner.

(from 1962), $u = 1, 2, 3$. Also note that the exogenous constants $b_1, b_2, b_3, d_1, d_2, d_3$ are not incorporated in either the β vector or X matrix for simplicity. A more complete definition of the system would incorporate these constants either as weights in the coefficient vector or the observations matrix.

$$\beta = \begin{bmatrix} h_1 \\ h_2 \\ h_3 \\ \theta_1 \\ \theta_2 \\ \theta_3 \\ \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ a_{11} \\ a_{12} \\ a_{13} \\ a_{22} \\ a_{23} \\ a_{33} \\ \beta_{1y} \\ \beta_{2y} \\ \beta_{3y} \\ \beta_{yy} \\ \alpha_G \\ \beta_{1Gy} \\ \beta_{2Gy} \\ \beta_{3Gy} \\ \beta_{GGy} \\ \alpha_S \\ \beta_{1Sy} \\ \beta_{2Sy} \\ \beta_{3Sy} \\ \beta_{SSy} \end{bmatrix}, \quad X' = \begin{bmatrix} \Lambda_{11} & \Lambda_{12} & \cdots & \Lambda_{1T-1} \\ \Lambda_{21} & \Lambda_{22} & \cdots & \Lambda_{2T-1} \\ \Lambda_{31} & \Lambda_{32} & \cdots & \Lambda_{3T-1} \\ a_1 & a_2 & \cdots & a_{T-1} \\ q_{12} & q_{13} & \cdots & q_{1T} \\ q_{22} & q_{23} & \cdots & q_{2T} \\ q_{32} & q_{33} & \cdots & q_{3T} \\ q_{11} & q_{12} & \cdots & q_{1T-1} \\ q_{21} & q_{22} & \cdots & q_{2T-1} \\ q_{31} & q_{32} & \cdots & q_{3T-1} \\ y_1 & y_2 & \cdots & y_{T-1} \\ G_1 & G_2 & \cdots & G_{T-1} \\ S_1 & S_2 & \cdots & S_{T-1} \\ v_{10} & v_{11} & \cdots & v_{1T-2} \\ v_{20} & v_{21} & \cdots & v_{2T-2} \\ v_{30} & v_{31} & \cdots & v_{3T-2} \end{bmatrix}$$

APPENDIX E. RAW, DERIVED AND ESTIMATION DATABASE TABLES

Table 1aR. Acquisition Prices for Property Capital, Food Processing Industry, 1961-2000

	Investment deflators, property capital (buildings, engineering construction): 1992=1									
	Industrial Bldg 4001	Commercial Bldg 4002	Oil Non-Res Bldg 4004	Transport 5002	Waterworks 5003	Sewage 5004	Oil and Gas 5007	Other 5009		
yr1	q1	q2	q3	q4	q5	q6	q7	q8		
1961	0.203	0.216	0.210	0.161	0.156	0.155	0.142	0.191		
1962	0.200	0.212	0.208	0.167	0.161	0.160	0.146	0.192		
1963	0.207	0.220	0.216	0.169	0.167	0.166	0.150	0.196		
1964	0.210	0.223	0.221	0.169	0.168	0.168	0.152	0.195		
1965	0.220	0.233	0.233	0.195	0.180	0.180	0.161	0.205		
1966	0.235	0.249	0.248	0.217	0.191	0.191	0.170	0.218		
1967	0.246	0.260	0.259	0.200	0.201	0.201	0.182	0.231		
1968	0.242	0.256	0.257	0.205	0.201	0.201	0.181	0.228		
1969	0.257	0.272	0.273	0.214	0.211	0.211	0.193	0.238		
1970	0.270	0.286	0.286	0.228	0.222	0.221	0.203	0.251		
1971	0.285	0.302	0.305	0.255	0.255	0.255	0.233	0.294		
1972	0.299	0.336	0.338	0.280	0.274	0.274	0.250	0.313		
1973	0.350	0.363	0.361	0.318	0.299	0.298	0.271	0.341		
1974	0.432	0.444	0.443	0.388	0.356	0.355	0.334	0.409		
1975	0.455	0.502	0.508	0.462	0.403	0.403	0.394	0.472		
1976	0.466	0.514	0.517	0.500	0.446	0.445	0.425	0.511		
1977	0.480	0.528	0.529	0.528	0.469	0.469	0.452	0.543		
1978	0.505	0.550	0.549	0.582	0.501	0.501	0.496	0.596		
1979	0.560	0.598	0.596	0.617	0.523	0.521	0.524	0.623		
1980	0.643	0.668	0.663	0.680	0.562	0.561	0.565	0.687		
1981	0.699	0.764	0.762	0.797	0.688	0.688	0.692	0.864		
1982	0.749	0.820	0.820	0.867	0.719	0.718	0.731	0.880		
1983	0.741	0.797	0.797	0.922	0.756	0.754	0.755	0.863		
1984	0.746	0.788	0.780	0.976	0.772	0.769	0.769	0.890		
1985	0.779	0.809	0.807	0.922	0.789	0.787	0.769	0.918		
1986	0.816	0.834	0.829	0.957	0.809	0.805	0.769	0.977		
1987	0.876	0.892	0.888	0.911	0.857	0.855	0.769	0.977		
1988	0.937	0.950	0.940	0.949	0.865	0.858	0.769	0.976		
1989	0.997	1.008	0.996	0.980	0.921	0.923	0.769	1.017		
1990	1.027	1.040	1.032	1.021	0.970	0.958	0.769	1.039		
1991	0.997	1.000	0.999	0.989	0.994	0.990	0.769	1.035		
1992	1.000	1.000	1.000	1.000	1.000	1.000	0.769	1.000		
1993	1.007	0.999	1.000	1.003	1.033	1.027	1.000	1.024		
1994	1.035	1.022	1.022	1.025	1.064	1.062	1.000	1.062		
1995	1.065	1.052	1.051	1.076	1.066	1.064	1.000	1.064		
1996	1.089	1.070	1.070	1.131	1.106	1.105	1.000	1.105		
1997	1.111	1.102	1.084	1.110	1.106	1.130	1.000	1.132		
1998	1.138	1.110	1.106	1.135	1.158	1.164	1.000	1.162		
1999	1.180	1.134	1.128	1.158	1.190	1.177	1.000	1.175		
2000	1.180	1.147	1.134	1.177	1.268	1.199	1.000	1.198		

SOURCE: Statistics Canada

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These are investment deflators, calculated by dividing current dollar investment by constant dollar investment. Food processors didn't make any investments in waterworks in 1997 and in oil/gas construction in 1985-2000.

To ensure a continuous series for these assets, growth rates for all manufacturing deflators are used to impute between years.

The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

See Table 1c for the subgroups that comprise each group.

Table 1B.R. Acquisition Prices for Other Capital, Food Processing Industry, 1961-2000

	Investment deflators, other capital (machinery and equipment): 1992=1										Furniture 7004	Other Mach/Equip 7005
	Computers Etc. 6002	Tractors/Field Equip 6011	Autos/Parts 6201	Trucks/Parts 6203	Oth Transport Equip 7001	Processing Equip 7002	Comm Equip 7003					
Year	q9	q10	q11	q12	q13	q14	q15	q16	q17			
1961	31.488	0.345	0.594	0.338	0.305	0.253	0.476	0.841	0.345			
1962	30.985	0.357	0.568	0.340	0.304	0.247	0.465	0.821	0.348			
1963	30.840	0.357	0.550	0.330	0.232	0.250	0.444	0.912	0.341			
1964	31.556	0.357	0.558	0.341	0.314	0.269	0.455	0.816	0.360			
1965	31.844	0.370	0.548	0.338	0.320	0.279	0.465	0.827	0.379			
1966	31.600	0.377	0.552	0.346	0.332	0.289	0.476	0.843	0.386			
1967	32.468	0.392	0.559	0.352	0.326	0.285	0.492	0.862	0.384			
1968	31.538	0.392	0.557	0.351	0.319	0.276	0.508	1.028	0.374			
1969	33.295	0.426	0.585	0.378	0.346	0.300	0.556	0.891	0.394			
1970	33.235	0.435	0.585	0.379	0.351	0.318	0.577	0.912	0.402			
1971	32.064	0.408	0.560	0.365	0.344	0.308	0.556	0.821	0.389			
1972	32.431	0.423	0.572	0.378	0.354	0.319	0.588	0.836	0.394			
1973	33.691	0.448	0.585	0.399	0.383	0.350	0.625	0.868	0.421			
1974	31.531	0.492	0.600	0.428	0.453	0.393	0.659	0.924	0.475			
1975	31.216	0.541	0.606	0.436	0.507	0.445	0.690	0.992	0.516			
1976	27.800	0.571	0.631	0.465	0.535	0.481	0.737	0.992	0.538			
1977	23.619	0.597	0.672	0.506	0.564	0.524	0.778	0.961	0.600			
1978	16.086	0.641	0.694	0.536	0.597	0.569	0.879	0.930	0.638			
1979	13.855	0.723	0.756	0.594	0.642	0.632	0.926	1.010	0.690			
1980	8.473	0.707	0.714	0.567	0.625	0.618	0.769	0.932	0.656			
1981	6.973	0.748	0.793	0.623	0.679	0.695	0.804	0.938	0.741			
1982	6.739	0.789	0.817	0.658	0.737	0.754	0.887	1.014	0.795			
1983	4.753	0.833	0.854	0.694	0.777	0.781	0.956	1.001	0.815			
1984	4.123	0.866	0.893	0.744	0.793	0.836	1.007	0.999	0.874			
1985	3.369	0.865	0.836	0.787	0.793	0.889	1.036	1.044	0.928			
1986	2.839	0.916	1.015	0.852	0.895	0.926	1.077	1.054	0.993			
1987	2.336	0.913	1.028	0.868	0.932	0.926	1.089	1.099	0.986			
1988	2.113	0.919	1.048	0.896	0.963	0.921	1.089	1.073	0.970			
1989	1.738	0.935	1.098	0.935	0.989	0.949	1.056	1.097	0.998			
1990	1.544	0.943	1.110	0.964	1.017	0.965	1.058	1.133	1.010			
1991	1.178	0.978	1.024	0.987	1.019	0.986	1.027	1.025	0.998			
1992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000			
1993	0.955	1.072	1.019	1.044	1.001	1.055	1.006	1.017	1.042			
1994	0.874	1.129	1.061	1.106	1.030	1.115	0.984	1.036	1.096			
1995	0.756	1.172	1.122	1.184	1.116	1.159	0.941	1.050	1.132			
1996	0.598	1.216	1.204	1.229	1.129	1.203	0.993	1.050	1.170			
1997	0.529	1.286	1.225	1.256	1.181	1.244	1.036	1.098	1.190			
1998	0.484	1.438	1.356	1.454	1.349	1.467	1.153	1.179	1.399			
1999	0.417	1.660	1.431	1.562	1.447	1.604	1.230	1.255	1.530			
2000	0.362	1.673	1.488	1.663	1.512	1.685	1.236	1.344	1.612			

SOURCE: Statistics Canada

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These are investment deflators, calculated by dividing current dollar investment by constant dollar investment

Food processors didn't make any investments tractors/field equipment in 1985 nor between 1991 and 1996

To ensure a continuous series for these asset group, growth rates for agriculture deflators are used to

impute between years.

The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

See Table 1C.R for the subgroups that comprise each group

Table 1cR Components of Capital Asset Groups

Capital Type/ Asset Group Code/ Subgroup Code	Asset Group and Subgroup Description
PROPERTY CAPITAL	
4001	Industrial Buildings
1001	Plants for MFG
1006	Warehouses, refrigerated storage, freight terminals
1007	Grain Elevator and Terminals
1008	Maintenance Garages, Workshops, Equipment Storage Facilities
1009	Railway Shops, Engine Houses
4002	Commercial Buildings
1011	Service Stations (including self-serve & car washes)
1012	Automotive Dealerships
1013	Office buildings
1014	Hotels, Motels, Convention Centers
1015	Restaurants, Fast Food Outlets, Bars, Nightclubs
1016	Shopping Centers, Plazas, Malls, stores
1018	Theaters, Performing Arts & Cultural Centers
1019	Indoor Recreational Buildings (i.e. sport comp., clubhouse, covered stadiums)
4003	Institutional Buildings
1201	Schools (Incl. Tech., Vocational) Colleges, Universities & Other Educational buildings
1202	Student Residence (Excl. residential Construction)
1203	Churches & Other Religious Building
1204	Hospitals, Health Centres, Clinic & Other Health care (excl. resident. const)
1205	Nursing Homes, Homes for the Aged
1206	Day Care Centers
1207	Libraries
1209	Penitentiaries, Detention Centers & Courthouses
1210	Museums, Science Centers, Public Archives
1211	Fire Stations, Halls
1212	Post Offices
1299	Other Institutional Governmental
4004	Oth Non-Residential Buildings
1004	Laboratories, Research & Development centers
1010	Aircraft Hangars
1021	Farm Building
1022	Bunkhouses, Dormitories, Camp cookeries, Camps
1099	Other Industrial & Commercial
1208	Historical Sites
1214	Armouries, Barracks, Drill Halls & Other Military Type Structures
1999	Other Building Construction
2201	Passenger Terminals - Air, Boat, Bus, Rail, and Other
3001	Broadcasting and Communication Buildings
3401	Mine buildings including headframes, ore bins, ventilation structures, backfill plants etc.
3402	Mine buildings for beneficiation treatment of minerals (excluding smelters and refineries)
SOURCE:	Statistics Canada
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NOTE:	These codes and descriptions were contained in the file List+of+Asset_Codes.xls received from R. Landry

Table 1cR(cont'd) Components of Capital Asset Groups

Capital Type/ Asset Group Code/ Subgroup Code	Asset Group and Subgroup Description
PROPERTY CAPITAL	
5001	Marine Construction
2001	Docks,Wharves,Piers,Terminals(coal,oil,natural gas,containers,gen. cargo)
2002	Dredging and Pile Driving
2003	Breakwaters
2004	Canals and Waterways
2099	Other Marine Construction
5002	Transportation Construction
2202	Highways,roads,streets,incl.:Logging road,signs,guardrail,lighting,etc.
2203	Runways including Lighting
2204	Rail Track and Roadbeds incl.: Signals and Interlockers
2205	Bridges, Trestles, Overpasses
2206	Tunnels
2299	Other Transportation
5003	Waterworks Construction
2401	Reservoirs(including Dams)
2402	Trunk and Distribution Mains
2412	Water pumping stations and filtrations plants
2413	Water storage tanks
2499	Other Waterworks Construction
5004	Sewage Construction
2601	Sewage Treatment and disposal Plants Incl.: Pumping Stations
2602	Sanitary & Storm Sewers,Trunk & Collection Lines,Open Storm Ditches
2603	Lagoons
2699	Other Sewage system Construction
5005	Electrical Power Construction
2801	Electric Power Construction
2811	Production plant - steam
2812	Production plant - nuclear
2813	Production plant - hydraulic
2814	Overhead cables and lines including poles, towers and all related parts and costs capitalized to this account
2815	Underground cables and lines including trenching, tunnels and all related parts and costs capitalized to this account
2816	Overhead cables and lines including poles, towers and all related parts and costs capitalized to this account
2817	Underground cables and lines including trenching, tunnels and all related parts and costs capitalized to this account
2899	Other construction (not specified else where)
SOURCE:	Statistics Canada
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NOTE:	These codes and descriptions were contained in the file List+of+Asset_Codes.xls received from R. Landry

Table 1cR(cont'd) Components of Capital Asset Groups

Capital Type/ Asset Group Code/ Subgroup Code	Asset Group and Subgroup Description
PROPERTY CAPITAL	
5006	Communications Construction
3002	Telephone & Cablevision lines, Underground & Marine Cables
3003	Communication Towers, Antennae, Earth Stns. incl. Dishes for State. etc.
3099	Other Communication
5007	Oil and Gas Construction
1002	Oil Refineries
1003	Natural Gas Processing Plants
3201	Gas Mains and Services
3202	Pumping Stations, Oil
3203	Pumping Stations, Gas
3204	Bulk Storage
3205	Oil Pipelines
3206	Gas Pipelines
3216	Exploration Drilling
3217	Development Drilling
3218	Production Facilities in Oil and Gas Engineering
3219	Enhanced Recovery Projects
3220	Drilling Expenditures, pre-mining, research and other costs
3221	Geological and Geophysical Expenditures
3299	Other Oil & Gas Facilities
5008	Mining Construction
3403	Mine shafts, drifts, raises, adits and other below surface workings (e.g., declines, ramps)
3404	Tailing disposal systems, settling ponds
3411	Minesite exploration
3412	Minesite development
3413	Exploration and Deposit Appraisal - Off mine sites
5009	Other Construction
1005	pollution, abatement & control
1017	Parking lots & Parking Garages
1020	Outdoor Recreational (i.e. parks, open stadi. golf courses, ski resorts)
1213	Waste Disposal Facilities
2005	Irrigation & Land Reclamation Projects
4999	Other Engineering Construction
5999	Other Construction (1999/ Other buildings)
SOURCE:	Statistics Canada
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NOTE:	These codes and descriptions were contained in the file List+of+Asset_Codes.xls received from R. Landry

Table 1cR(cont'd) Components of Capital Asset Groups

Capital Type/ Asset Group Code/ Subgroup Code	Asset Group and Subgroup Description
OTHER CAPITAL	
6002	Computers, Associated Hardware & Word Processors
6011	Tractors of all types & Other Field Equip. (truck tractors - see 6203)
6201	Automobiles and Major Replacement Parts
6203	Trucks, Vans, Truck Tractors, Truck Trailers & Major Replacement Parts
7001	Other Transportation Equipment
6015	Industrial Containers (transportable types used for transp. materials, liquids, gases)
6202	Buses (all types) & Major Replacement Parts
6204	All - Terrain Vehicles & Major Replacement Parts
6205	Locomotives, Rolling Stock, Street & Subway Cars, Other Rapid Transit & Maj. Parts
6206	Ships & boats & Major Replacement Parts
6207	Aircraft, Helicopters, Aircraft Engines & Other Major Replacement Parts
6299	Other Transportation Equipment
7002	Processing Equipment
6402	Computer-assisted process for production process
6602	Non-computer assisted process for production process
7003	Communication Equipment
6403	Computer-assisted process for communication and related equipment
6603	Non-computer assisted process for communication and related equipment
7004	Furniture
6001	Office furniture, furnishing (e.g. desks, chairs)
6003	Non-Office furniture, furnishings & fixtures (e.g. recreational equip. etc)
SOURCE: Statistics Canada	
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NOTE: These codes and descriptions were contained in the file List+of+Asset_Codes.xls received from R. Landry	

Table 1cR(cont'd) Components of Capital Asset Groups

Capital Type/ Asset Group Code/ Subgroup Code	Asset Group and Subgroup Description
OTHER CAPITAL	
7005	Other Machinery and Equipment
6004	Scientific, Professional & Medical Devices (Incl. measuring,controlling,lab eqp.)
6005	Heating,Electrical,Plumbing,Air Conditioning & Refrigeration Equipment
6006	Pollution Abatement & Control Equipment
6007	Safety & Security Equipment (Incl. Firearms)
6008	Sanitation Equipment
6009	Motors,Generators,Transformers,Turbines,Compressors & Pumps of all types
6010	Heavy Construction Equip. (e.g.loading, hauling mixing, paving, grating)
6012	Capitalized Tooling & Other Tools (hand,power, industrial)
6013	Drilling and Blasting Equipment
6014	Salvage Equipment
6016	Navigational aids and weather measurement equipment
6027	Raise borers, raise climbers
6028	Underground load, haulage and dump equipment (e.g., slusher, muck cars)
6029	Mine hoists, cages, ropes and skips
6401	Computer-assisted process for material handling
6410	Production process - Crushers, grinders
6411	Production process - Flotation, cyanidation
6412	Production process - Gravitational concentrating devices
6413	Production process - other
6499	Other computer-assisted process machinery and equipment
6601	Non-computer assisted process for material handling
6610	Production process - Crushers, grinders
6611	Production process - Flotation, cyanidation
6612	Production process - Gravitational concentrating devices
6613	Production process - other
8999	Other Machinery and Equipment (not specified elsewhere)
9001	Gas Generators and turbines
9002	Steam and vapor turbines
9010	Electric motors and generators
9011	Electric transformers, static converters and inductors
9012	Electric switchgear and switching apparatus
9013	Electric control and protective equipment
9015	Measuring, checking or automatically controlling instruments and apparatus
9091	Electricity meters
9092	Electric water heaters
9093	Nuclear reactor parts and fuel elements and heavy water
9094	Hydraulic turbines
9095	Boilers
9099	Other machinery and equipment
SOURCE:	Statistics Canada
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NOTE:	These codes and descriptions were contained in the file List+of+Asset_Codes.xls received from R. Landry

**Table 2R. Hiring and Acquisition Prices of Non-Capital Inputs,
Canadian Food Processing Industry, 1961-1997**

Price Index: 1961=1				
year	Labour	Energy	Purchased & Intermediate Materials	Services
yr3	qn1	qn2	qn3	qn4
1961	1.000	1.000	1.000	1.000
1962	1.051	1.009	1.047	1.035
1963	1.099	1.029	1.083	1.052
1964	1.141	1.017	1.069	1.063
1965	1.205	1.020	1.083	1.088
1966	1.306	1.009	1.154	1.117
1967	1.353	1.022	1.142	1.161
1968	1.428	1.057	1.145	1.211
1969	1.562	1.044	1.209	1.246
1970	1.675	1.083	1.232	1.286
1971	1.788	1.120	1.254	1.330
1972	1.950	1.204	1.394	1.403
1973	2.133	1.292	1.788	1.520
1974	2.484	1.664	2.136	1.725
1975	2.918	1.966	2.297	1.937
1976	3.367	2.408	2.220	2.088
1977	3.695	2.849	2.357	2.233
1978	3.980	3.185	2.695	2.387
1979	4.367	3.428	3.133	2.574
1980	4.895	3.858	3.376	2.840
1981	5.575	5.078	3.620	3.198
1982	6.240	5.947	3.658	3.423
1983	6.757	6.769	3.645	3.511
1984	7.137	7.148	3.862	3.681
1985	7.274	7.611	3.822	3.783
1986	7.539	6.722	3.913	3.884
1987	7.802	7.138	3.966	3.989
1988	8.191	6.875	4.062	4.173
1989	8.509	6.769	4.090	4.321
1990	9.044	7.436	4.073	4.429
1991	9.479	7.260	3.949	4.484
1992	9.951	7.230	3.995	4.507
1993	10.138	7.542	4.231	4.600
1994	10.108	7.885	4.447	4.659
1995	10.345	7.740	4.626	4.833
1996	10.338	7.912	4.823	4.954
1997	10.461	8.020	4.895	5.031

SOURCE: Statistics Canada (KLEMS database)

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NOTE: Each hiring or acquisition price is calculated by dividing the expenditure series from the KLEMS database by the quantity index series. The bold headings are used as part of derived data procedures and allow each series to have a unique code.

Table 3R. Federal and Provincial Corporate Income Tax Rates, 1960-1997

year	federal corporate income tax (a,b,h)				provincial corporate income tax: basic rates (c,e,i,j,p)											
	basic rate(a,e)	corporate surtax (d,o)	federal tax abatement	manufacturing & processing profits credit(f)	investment tax credit (g,r,s,t)											
		t1	t2	t3	t4	t5	B.C.	Alb.(m,n)	Sask.	Man.	Ontario(g)	Quebec(k)	N.B.	N.S.	PEI	Nfld
1964	50.0%	0.0%	9.0%	0.0%	0.0%	9.0%	9.0%	10.0%	10.0%	11.0%	10.0%	9.0%	9.0%	9.0%	9.0%	9.0%
1961	50.0%	0.0%	9.0%	0.0%	0.0%	9.0%	9.0%	10.0%	10.0%	11.0%	10.0%	9.0%	9.0%	9.0%	9.0%	9.0%
1962	50.0%	0.0%	9.0%	0.0%	0.0%	9.0%	9.0%	10.0%	10.0%	11.0%	12.0%	9.0%	9.0%	9.0%	9.0%	9.0%
1963	50.0%	0.0%	9.0%	0.0%	0.0%	9.0%	9.0%	10.0%	10.0%	11.0%	12.0%	9.0%	9.0%	9.0%	9.0%	9.0%
1964	50.0%	0.0%	9.0%	0.0%	0.0%	9.0%	9.0%	10.0%	10.0%	11.0%	12.0%	9.0%	9.0%	9.0%	9.0%	9.0%
1965	50.0%	0.0%	9.0%	0.0%	0.0%	9.0%	9.0%	10.0%	10.0%	11.0%	12.0%	9.0%	9.0%	9.0%	9.0%	9.0%
1966	50.0%	0.0%	9.0%	0.0%	0.0%	9.0%	9.0%	10.0%	10.0%	11.0%	12.0%	9.0%	9.0%	9.0%	9.0%	9.0%
1967	50.0%	0.0%	10.0%	0.0%	0.0%	10.0%	10.0%	10.0%	10.0%	11.0%	12.0%	10.0%	10.0%	10.0%	10.0%	12.0%
1968	50.0%	0.0%	10.0%	0.0%	0.0%	10.0%	10.0%	10.0%	10.0%	11.0%	12.0%	10.0%	10.0%	10.0%	10.0%	12.0%
1969	50.0%	3.0%	10.0%	0.0%	0.0%	10.0%	10.5%	10.0%	13.0%	12.0%	12.0%	10.0%	10.0%	10.0%	10.0%	13.0%
1970	50.0%	3.0%	10.0%	0.0%	0.0%	10.0%	11.0%	10.0%	13.0%	12.0%	12.0%	10.0%	10.0%	10.0%	10.0%	13.0%
1971	48.3%	1.5%	10.0%	0.0%	0.0%	10.0%	11.0%	10.0%	13.0%	12.0%	12.0%	10.0%	10.0%	10.0%	10.0%	13.0%
1972	46.5%	0.0%	10.0%	0.0%	0.0%	10.0%	11.0%	11.0%	13.0%	12.0%	12.0%	10.0%	10.0%	10.0%	10.0%	13.0%
1973	49.0%	0.0%	10.0%	9.0%	0.0%	12.0%	11.0%	12.0%	13.0%	12.0%	12.0%	10.0%	10.0%	10.0%	10.0%	13.0%
1974	48.0%	0.0%	10.0%	8.0%	0.0%	12.0%	11.0%	12.0%	13.0%	12.0%	12.0%	10.0%	10.0%	10.0%	10.0%	13.0%
1975	47.0%	0.0%	10.0%	7.0%	2.6%	13.0%	11.0%	12.0%	13.0%	12.0%	12.0%	10.0%	10.0%	10.0%	10.0%	13.0%
1976	46.0%	0.0%	10.0%	6.0%	5.0%	15.0%	11.0%	12.0%	14.0%	12.0%	12.0%	10.0%	12.0%	10.0%	10.0%	14.0%
1977	46.0%	0.0%	10.0%	6.0%	5.0%	15.0%	11.0%	14.0%	15.0%	12.0%	12.0%	12.0%	12.0%	10.0%	10.0%	14.0%
1978	46.0%	0.0%	10.0%	6.0%	5.0%	15.0%	11.0%	14.0%	15.0%	13.0%	12.0%	12.0%	12.0%	10.0%	10.0%	14.0%
1979	46.0%	0.0%	10.0%	6.0%	7.0%	15.0%	11.0%	14.0%	15.0%	13.0%	12.0%	12.0%	12.0%	10.0%	10.0%	14.0%
1980	46.0%	5.0%	10.0%	6.0%	7.0%	15.0%	11.0%	14.0%	15.0%	13.0%	13.0%	12.0%	13.0%	10.0%	10.0%	15.0%
1981	46.0%	5.0%	10.0%	6.0%	7.0%	16.0%	11.0%	14.0%	15.0%	13.0%	13.0%	14.0%	13.0%	10.0%	10.0%	15.0%
1982	46.0%	5.0%	10.0%	6.0%	7.0%	16.0%	11.0%	14.0%	16.0%	14.0%	5.5%	14.0%	15.0%	10.0%	10.0%	16.0%
1983	46.0%	2.5%	10.0%	6.0%	7.0%	16.0%	11.0%	14.0%	16.0%	14.0%	5.5%	14.0%	15.0%	10.0%	10.0%	16.0%
1984	46.0%	0.0%	10.0%	6.0%	7.0%	16.0%	11.0%	16.0%	16.0%	14.0%	5.5%	15.0%	15.0%	10.0%	10.0%	16.0%
1985	46.0%	2.5%	10.0%	6.0%	7.0%	16.0%	6.5%	16.0%	16.0%	14.0%	5.5%	15.0%	15.0%	10.0%	10.0%	16.0%
1986	46.0%	5.0%	10.0%	6.0%	5.0%	16.0%	5.0%	17.0%	17.0%	14.0%	5.8%	15.0%	15.0%	10.0%	10.0%	16.0%
1987	45.5%	3.0%	10.0%	6.0%	5.0%	15.0%	8.0%	17.0%	17.0%	14.5%	5.9%	15.0%	15.0%	10.0%	10.0%	16.0%
1988	42.0%	3.0%	10.0%	2.0%	3.0%	14.0%	9.0%	17.0%	17.0%	14.5%	5.9%	16.0%	15.0%	15.0%	15.0%	16.5%
1989	38.0%	3.0%	10.0%	2.5%	0.0%	14.0%	9.0%	15.0%	17.0%	14.5%	6.2%	16.0%	15.0%	15.0%	15.0%	16.5%
1990	38.0%	3.0%	10.0%	3.5%	0.0%	14.0%	9.0%	15.0%	17.0%	14.5%	6.3%	16.0%	16.0%	15.0%	15.0%	17.0%
1991	38.0%	3.0%	10.0%	4.5%	0.0%	15.0%	15.0%	15.0%	17.0%	14.5%	6.3%	17.0%	16.0%	15.0%	15.0%	17.0%
1992	38.0%	3.0%	10.0%	5.0%	0.0%	16.0%	15.0%	17.0%	17.0%	14.5%	8.9%	17.0%	16.0%	15.0%	15.0%	17.0%
1993	38.0%	3.0%	10.0%	6.0%	0.0%	16.5%	14.5%	17.0%	17.0%	13.5%	8.9%	17.0%	16.0%	7.5%	7.5%	7.5%
1994	38.0%	3.0%	10.0%	7.0%	0.0%	16.5%	14.5%	17.0%	17.0%	13.5%	8.9%	17.0%	16.0%	7.5%	7.5%	7.5%
1995	38.0%	4.0%	10.0%	7.0%	0.0%	16.5%	14.5%	17.0%	17.0%	13.5%	8.9%	17.0%	16.0%	7.5%	7.5%	5.0%
1996	38.0%	4.0%	10.0%	7.0%	0.0%	16.5%	14.5%	17.0%	17.0%	13.5%	8.9%	17.0%	16.0%	7.5%	7.5%	5.0%
1997	38.0%	4.0%	10.0%	7.0%	0.0%	16.5%	14.5%	17.0%	17.0%	13.5%	9.2%	17.0%	16.0%	7.5%	7.5%	5.0%

NOTE: The bold headings are used as part of derived data procedures and allow each series to have a unique code.

NOTE: The bold headings are used as part of derived data procedures and allow each series to have a unique code.

TABLE 3R - DATA NOTES:

- (a) These reflect maximum rates, i.e. for those businesses in the highest profit category
(a') Between 1960 and 1966, Quebec took advantage of a provision that increased the abatement rate to 10% in lieu of federal grants to universities in that province. - see CTF(1963, p. 34)
- (b) From 1941 to 1962, a system of 'tax rentals' gave provinces a fixed proportion of federal tax revenues; only Ontario and Quebec collected their own corporate tax over this period. For the 1962-1966 tax years, the 'tax rentals' arrangement was replaced by a tax collection arrangement, where provinces set a tax at least as high as the standard abatement rate of 9%. Over this period, only Ontario, Quebec, Saskatchewan and Manitoba set rates higher than 9%, with Quebec receiving a 10% abatement rate (see Note (a)) - CTF(1963, p. 34).
- Note that all provincial rates are maximum rates, i.e. for those businesses in the highest profit category.
- (c) In 1967, the federal government raised the abatement rate to 10% for all provinces, and eliminated grants to universities. As a result, all provinces raised their rates to at least 10%, with Newfoundland joining Ontario, Manitoba and Saskatchewan at 11% and Quebec remaining at 12% - see CTF(1987, p. 59). This arrangement was set for the period 1 April 1967 to 31 March 1972 - see CTF(1971, p. 75)
- (d) The federal surtax, imposed for 1969-1971 is applied to the standard rate, i.e. with a standard rate of 50% and a surtax of 3% the rate increases to 0.5*(1.03)=51.5% - see CTF(1971, p. 75). For 1980-1983, the surtax is applied after the 10% provincial abatement has been deducted, i.e. for 1980, with a standard rate of 46%, an abatement rate of 10% and a surtax of 3%, the rate is $(0.46-0.1)/1.05=37.08\%$. For 1985, a 5% surtax was imposed from July 1 on. Assuming income equally distributed through the year, this averages to a 2.5% annual rate - see CTF(1985, p. 124).
- (e) Alberta raised its corporate income tax rate to 11% (from 10%), effective July 1, 1969
(e') Between July 1, 1971 and December 31, 1971, the standard corporate tax rate was reduced by 7 per cent. - see CTF(1974, pp. 70-71).
- (f) Since January 1, 1973, the federal Income Tax Act has given a tax credit, deductible from federal taxes otherwise payable for corporations that earn manufacturing or processing profits [Lahey(1984, p.219); CTF(1975b, p. 75)]. The intent of this provision 'was to create an effective tax rate of 40% ... for the manufacturing component of corporate income' (Arnold et al.(1986, p. 264))
- (g) In 1980 and subsequent years the rate for Ontario is for manufacturing and processing - see CTF(1981, p. 100); CTF(1983, p. 113); CTF(1985, p. 129); CTF(1987, pp. 10:22-10:23); CTF(1989, p. 10:23).
- (h) For 1987 and 1988, the rates are calculated for a calendar year, based on different rates for the January1-June 30 and July1-December 31 periods - See CTF(1989, p. 10:17, Table 10.6)
- (i) For Newfoundland, a rate of 17% came into effect July 1, 1989. Assuming income equally distributed through the year, the average rate for 1989 is $0.5*16\%+0.5*17\%$
- (j) In 1988 and 1989 the rate for Alberta is for manufacturing and processing, the rate for all other corporations is 15% - see CTF(1989, p. 10:21, Table 10.8)
- (k) In 1982 and subsequent years, the rate for Quebec is for manufacturing and processing corporations; some years include the effects of surtaxes levied by the Quebec government and all rates are for calendar year when more than one rate applies for a calendar year e.g. one for January to June and another from July to December - see CTF(1983, pp 113-114); CTF(1985, p.128); CTF(1987, pp. 10:21-10:22); CTF(1989, p. 10:22)
- (l) On July 1 the credit rate was 3% (1989), 4% (1990), 5% (1991), 6% (1992) and 7% (1993) - these rates are based on the difference between the 'effective federal rate' and the 'effective manufacturing and processing rate' - see CCH(1995, p. 576, para 9310). Assuming income equally distributed through the year, the average rates for 1990-1993 are 3.5%, 4.5%, 5.5% and 6.5% respectively
- (m) Beginning April 1, 1985, Alberta introduced a new rate for manufacturing and processing corporations, reflected here for 1985 and subsequent years. Annual rates are derived from more than one rate assuming income equally distributed through the year - see CTF(1985, p. 129)
- (n) From April 1, 1990, Alberta reduced the tax rate for manufacturers/processors to 6% - see CTF(1991, p. 7:31)
- (o) The 1995 federal budget raised the surtax to 4%. It is calculated on the standard rate after the provincial abatement but before the manufacturing reduction is made - see CTF(1995, p. 4:2)
- (p) Note that for all provinces, where any has a specific rate for manufacturing and processing, that rate is reported here rather than the general rate
- (q) Considering only the ITC for new productive facilities in non-specified regions of Canada
Over part of this period and past it, ITCs for regions (e.g. Atlantic) or types of investment (e.g. R&D) have been introduced, but due to their specialized nature are not included here
once it was claimed, 'the base for the capital cost allowance was reduced by the amount of the investment tax credit claimed' [Boadway and Kitchen(1984, p. 146)]. Also note that for the 1975-77 period, the maximum claimable in reduced taxes was \$15,000 plus 50% of the tax payable in excess of \$15,000.
- (s) The ITC provision began on June 24, 1975, so the rate of 5% for this year is pro-rated.
- (t) From April 19, 1983 on, investments made are fully deductible (i.e. not subject to \$15,000 limit)

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Table 4R. Manufacturing Shipments by the Food and Beverage Industry, 1961-200*

Manufacturing Shipments ('000\$)										
year	BC	Alberta	Sask.	Manitoba	Ontario	Quebec NB	NS	PEI	Nfld	
yr5	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10
1961	399777	383367	173687	291080	2034876	1302243	132669	123822	23255	40440
1962	429217	422632	180621	308674	2204355	1411251	147594	136662	26124	45351
1963	458657	461896	187554	326269	2373835	1520260	162519	149501	28994	50261
1964	488097	501161	194488	343863	2543314	1629268	177444	162341	31864	55171
1965	503652	512667	200629	352003	2701290	1708628	170942	179288	32711	65994
1966	570279	584738	220674	384708	2927978	1894353	182604	191102	35298	69920
1967	584428	635347	216576	406062	3064451	2029293	188901	193072	40438	70297
1968	605194	677814	215181	418128	3118031	2097973	203564	216119	40494	81415
1969	630451	708488	225489	453462	3319688	2286050	224369	229831	44758	100733
1970	648971	761722	251032	479388	3485350	2377939	241588	232748	51496	106661
1971	701650	834990	258980	495920	3693712	2466054	258621	240033	45373	113536
1972	801322	987888	302846	560945	4098548	2721702	290689	271799	53858	116018
1973	996651	1248932	352333	720561	4930235	3245057	345913	320122	67911	146705
1974	1166293	1465845	445667	813591	5893425	3919886	446131	362300	74317	148698
1975	1204003	1683686	435141	874047	6664619	4431493	482220	421450	84232	175251
1976	1296807	1714907	490967	926707	6872660	4714948	484812	463197	90891	233175
1977	1519894	2059479	486593	985190	7473541	4934881	507002	518222	104765	309834
1978	1784019	2424229	559194	1093976	8556531	5789481	580207	661650	133663	369259
1979	2064371	2824697	711725	1253155	9933797	6518759	663316	767289	165876	466922
1980	2172109	3025456	778054	1308892	11136254	7421738	803831	844734	182418	482278
1981	2485533	3594736	871697	1443041	12503949	8310145	863448	951538	186658	551691
1982	2448957	3552717	880068	1510206	12849221	8788801	961738	880233	193971	592663
1983	2536238	3535578	923971	1599648	13575382	8931736	984079	893314	210158	591527
1984	2737791	3909314	877872	1647645	14415276	9656563	1021100	886063	202129	595786
1985	3011888	3872284	888755	1858875	15045498	9748898	1051864	974468	204858	618973
1986	3224821	3768378	871308	1862019	15796236	10166416	1166358	1215911	225923	656653
1987	3369184	4268677	1087645	1858356	16636745	10313436	1274860	1343465	262709	821380
1988	3400038	4508879	1103676	1814690	17526812	10720436	1300839	1409886	266014	804443
1989	3472507	4636291	1195565	1725833	18068213	10863737	1306542	1394241	292487	707870
1990	3660090	4888763	1161265	1641311	17867101	11172543	1312143	1386521	288481	696609
1991	3721644	4782655	1113255	1568518	17804140	11143657	1335013	1500148	326244	657231
1992	4043454	4738841	1059923	1592029	18755579	11013619	1396493	1628486	364937	528480
1993	4105101	4316459	1068228	1608059	16263097	9458488	1200921	1439841	365567	531330
1994	4110548	4801537	949550	1673510	16970758	9391848	1223517	1643620	372592	539421
1995	4203101	5779794	1107561	1760930	18217996	9624687	1395090	1536684	382568	506642
1996	4358577	6354436	1171863	1952116	18836377	9940764	1523634	1541247	466618	529729
1997	4401208	6293949	1344427	2072398	19798286	11081812	1514357	1600331	446976	700426
1998	4484555	6687439	1637960	2341111	20181149	11773991	1633839	1854542	528622	626386
1999	4451498	7374499	1753641	2363751	21063440	11691730	1590328	1728726	637831	851294
2000	4724473	8081094	1717552	2673634	22191900	11909449	1959365	2252754	770645	954047
2001	4815446	9186258	1808492	3027469	23160488	12670531	1954160	2245118	853615	990322

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lustry (1970 SIC code 1)

for 1982-1992:

Statistics Canada, CANSIM II database, Table 304-0002 - Manufacturing shipments, by Standard Industrial Classification, 1980 (SIC)
sum of shipments for Food industries [10] and Beverage industries [11]

for 1993-1997:

Statistics Canada, CANSIM II database, Table 304-0015 - Manufacturing shipments, by North American Industry Classification System (NAICS),
sum of computed annual total for food industry and for beverage industry

NOTES:

Sum of provincial shipments is not total Canadian shipments due to territorial shipments being excluded from the entries here.

Data for 1962 and 1963 are imputed

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

[illegible]

Notes

- (1) All classes reflect declining balance depreciation even though in some cases, alternative classes that allow accelerated (straight line) depreciation at higher rates exist. (For example, classes 19 and 21 "provide for capital cost allowances essentially on the straight line method at rates greatly in excess of the rates at which capital cost allowances are allowed by the diminishing balance method. Under Classes 19 and 21 a maximum of 50% of the cost of new machinery and equipment may be deducted in computing income of a taxation year, whereas the deduction permitted under Class 8 is 20% of the undepreciated capital cost of such property" [CCH(1978, p. 188)].)
- (2) Class 1 (4%) if acquired before May 1976, class 17 (8%) if acquired after May 1976 - see CCH(1978, p. 194, fn. 32,34)
- (3) Note that prior to 1976, no explicit class fitting the asset group 'Computers Etc' existed. Class 17 appears to have provided the closest approximation, in specifying property acquired before May 26 1976 that is a "telephone system, telegraph system, or part thereof" - see DOJ(2001). Computers appeared specifically in Class 10 as 'general-purpose electronic data processing equipment' acquired after May 25, 1976.
- (4) Buildings are in Class 1 from 1988 on - they are no longer Class 3 due to stipulation in the Regulations that Class 3 applies only to "Property not included in any other class that is ...acquired by the taxpayer (i) before 1988" [Stikeman(1997, p. 2476)]. See also CCRA(1991).
- (5) While neither the waterworks, sewage nor oil and gas asset groups fit exactly into Class 2 (i.e. they are not identified directly), the type of equipment used for these purposes seems to match the types of equipment described under the Class 2 heading and so the CCA for Class 2 is applied to these asset groups.
- (6) Since the 'other' engineering construction assets group is a residual category, the more conservative allowance (i.e. that for Class 1) is chosen here.
- (7) The industrial buildings and other non-residential buildings asset groups probably best fit Class 6 rather than Class 3 prior to 1979, after which the Regulations do not provide a class for buildings constructed of galvanized iron or corrugated metal - the type of materials often used for industrial buildings, sheds etc. Since all buildings end up in Class 1 from 1988 on, these two groups of assets are placed in the Class 1 category from 1979 on.
- (8) Trucks acquired prior to December 6, 1991, seem to best fit Class 10, but trucks acquired after this date seem to best fit Class 16, which specifies "a truck or a truck or tractor designed for hauling freight, and that is primarily so used by the taxpayer ... and that has a "gross vehicle weight rating" excess of 11,788 kg.
- (9) Note that prior to 1976, no class fit the asset group 'Comm Equip' very well, but Class 17 came closest appears to have provided the closest approximation, in specifying property acquired before May 26 1976 that is a "telephone system, telegraph system, or part thereof" - see DOJ(2001). It also specifies that "property not included in any other class, acquired after May 25, 1976 that is ... telephone, telegraph or data communication switching equipment ..." - see DOJ(2001) and so seems to be the appropriate Class after May 25 1976.

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Table 6R. Canadian Property Tax and Business Tax Revenues, Canadian Property Wealth and the Discount Rate, 1961-1999

Property and Business Tax Revenues, Canada: Million \$C				Property Wealth, Canada (million \$C)				discount rate
year	provincial	real property	local	Residential	Non-residential	Land		
	property tax	and personal property tax		business tax	structures		structures	
yr7	pt1	pt2	pt3	pt4	pt5	pt6	r	
1961	9	1443	158.73	29923	47115	28098	5.48%	
1962	9	1574	173.14	31587	49924	29882	5.45%	
1963	10	1658	182.38	33987	53763	32037	5.37%	
1964	11	1773	195.03	37359	57578	35073	5.50%	
1965	12	1956	215.16	41490	64392	39123	5.68%	
1966	23	2172	238.92	45923	72763	43769	6.50%	
1967	36	2381	261.91	49751	79433	47863	7.09%	
1968	41	2659	292.49	54004	84270	51622	7.92%	
1969	44	2963	325.93	59460	92997	56336	8.75%	
1970	50	3191	351.01	65375	102088	61446	9.18%	
1971	46	3431	377.41	74240	114991	69265	8.35%	
1972	66	3776	415.36	88826	126142	80582	8.30%	
1973	57	3982	438.02	110379	145191	98722	8.47%	
1974	71	4367	480.37	130374	181291	121502	10.17%	
1975	74	5076	558.36	147006	211394	140314	10.76%	
1976	88	6050	665.5	164762	231755	157040	10.48%	
1977	96	6829	751.19	181443	254018	178129	9.71%	
1978	159	7492	824.12	202530	280359	203478	10.10%	
1979	118	8382	922.02	227329	317576	238016	10.91%	
1980	143	8997	989.67	258231	365788	277898	13.28%	
1981	473	10706	1084	288954	426378	312066	16.32%	
1982	1042	11500	1260	308722	471870	319707	15.86%	
1983	1480	12232	1330	330534	483814	331039	12.74%	
1984	1196	13050	1428	351148	504174	346600	13.50%	
1985	1139	13897	1507	378416	529497	352272	11.74%	
1986	1047	15024	1658	423013	551377	380758	10.36%	
1987	1012	16286	1755	477398	576255	420715	10.71%	
1988	1082	17675	1901	527764	616359	466314	10.93%	
1989	1161	19534	2198	570810	659667	526185	10.81%	
1990	1543	21304	2386	604512	697258	538680	11.91%	
1991	1740	22974	2546	632423	695409	566248	10.80%	
1992	1905	24604	2850	665119	697054	590702	9.90%	
1993	1961	25512	2876	702350	709171	623218	8.85%	
1994	2687	25469	2898	736771	737411	663984	9.44%	
1995	2956	25737	2945	755408	759741	674447	9.02%	
1996	2953	26322	2915	774417	788671	700788	8.11%	
1997	3074	27125	2961	802849	819199	739910	6.95%	
1998	3106	28819	1206	835706	846982	774047	6.22%	
1999	3287	29419	1252	873317	874138	817314	6.64%	

SOURCES:

tax data

1961-1980: Statistics Canada (CANSIM II), Table 384-0028 - Indirect taxes, annual

1981-1999: Statistics Canada (CANSIM II), Table 384-0007 - Indirect taxes, annual

wealth data

1961-1999: Statistics Canada (CANSIM II), Table 378-0005 - National balance sheet, national wealth accounts

discount rate

1961-1977: Statistics Canada (CANSIM II), Table 176-0043 - Financial market statistics, McLeod, Young and Weir bond yield average: 10 industrials

1978-1999: Statistics Canada (CANSIM II), Table 176-0043 - Financial market statistics, Scotia Capital Inc. - average weighted yield: all corporations long-term

NOTES:

Data for taxes 1961-1980 are sum of provincial and territorial data in each year.

Local business tax data for 1961-1980 are imputed - no data on this

tax prior to 1981 are reported in Statistics Canada tables. The average for 1981-1997 is 11% of real property and personal property tax (with a minimum ratio of 10.1% and a maximum ratio of 11.6%). The business tax data for 1961-1980 are therefore imputed as 11% of real property and personal property tax revenue).

Discount rate data converted to annual within CANSIMII facility using average of monthly rates

Table 7R. Geometric Decay Rates for Property and Other Capital by Asset Group, Food Industry

Capital Type/ Asset Group	Asset Group Code	Decay Rate
Property Capital		
Industrial Buildings	4001	0.0314
Commercial Buildings	4002	0.0262
Other Non-residential Buildings	4004	0.0249
Transportation Structures	5002	0.0225
Waterworks Structures	5003	0.0225
Sewage Structures	5004	0.0225
Oil and Gas Structures	5007	0.0225
Other Structures	5009	0.0225
Other Capital		
Computers, Associated hardware	6002	0.2729 before 1978
Computers, Associated hardware	6002	0.3119 1978 & after
Tractors & Other Field Equipment	6011	0.1452
Automobiles and Major Replacement Parts	6201	0.1725
Trucks, Vans, etc.	6203	0.1725
Other Transportation Equipment	7001	0.1725
Processing Equipment	7002	0.1072
Communication Equipment	7003	0.1100
Furniture	7004	0.1179
Other Machinery & Equipment	7005	0.1473

SOURCE

Fraumeni, B. (1997) "The Measurement of Depreciation in the U.S. National Income and Product Accounts", Survey of Current Business, July, 7-23.

Table 8aR. Current Dollar Geometric End-Year Net Stock of Property Capital, Food Processing Industry, 1961-2000

yr8	Industrial Bldg		Commercial Bldg		property capital (buildings, engineering construction): '000\$					Oil and Gas		Other
	4001		4002		Oil Non-Res Bldg	Transport	Waterworks	Sewage		5007	5009	
	ck1	ck2	ck3	ck4	ck5	ck6	ck7	ck8				
1961	482263	42437	16248	1802	577	5940	789	10274				
1962	502620	43966	17080	1847	589	6057	778	10287				
1963	537634	48858	18315	1944	618	6337	785	10557				
1964	559055	49098	19163	1983	628	6431	790	10636				
1965	608553	53217	20942	2106	683	6992	805	11027				
1966	686618	59797	23502	2229	772	7829	840	11997				
1967	746221	64852	25455	2329	865	8690	881	12806				
1968	763360	66435	26176	2460	903	9032	880	13042				
1969	831616	72528	28483	2645	961	9572	922	13833				
1970	909706	79384	31112	2786	1035	10255	946	14818				
1971	995970	86505	34107	3227	1198	11852	1082	17403				
1972	1059857	97683	38185	3438	1322	13045	1120	18477				
1973	1283596	109810	42211	3878	1493	14695	1178	20295				
1974	1618899	137526	52993	5024	1870	18319	1411	24838				
1975	1731407	158033	61498	5840	2225	21710	1621	29085				
1976	1813353	165478	63670	6227	2546	24758	1717	31252				
1977	1913156	174088	66559	7477	3064	29616	1806	35102				
1978	2068637	186302	70879	8059	3416	32907	1890	38621				
1979	2360208	209588	79056	8713	3696	35546	2023	42216				
1980	2828185	242413	91999	9612	3991	38332	2209	47342				
1981	3173110	285991	108624	11110	4740	45368	2416	53842				
1982	3495603	314960	119942	11776	5353	51131	2617	58059				
1983	3533806	314456	118805	12273	5538	55669	2766	59385				
1984	3549730	313734	117237	12174	5801	55218	2747	59766				
1985	3738342	326601	120909	12298	5887	55960	2710	61033				
1986	4023613	348033	127517	12533	6068	57595	2835	62211				
1987	4337429	375089	137190	12691	6288	59561	2904	64539				
1988	4709391	408425	147447	13864	6484	61322	2977	70246				
1989	5130027	444416	160175	14458	6660	62893	3062	70246				
1990	5311629	466801	166842	14540	6803	64155	3067	71886				
1991	5237779	460307	164177	14127	6856	64563	3006	70303				
1992	5267498	466729	164799	13831	6934	65220	2984	66501				
1993	5297133	471087	164425	14187	6934	65134	2953	67930				
1994	5456742	484156	168224	15546	7148	67023	2969	73455				
1995	5627402	506517	173279	16254	7256	67852	2896	73932				
1996	5933804	530311	182676	17681	7540	70494	2912	79005				
1997	6124288	544230	181052	20181	7553	83741	2905	79609				
1998	6306382	557393	184325	20682	7796	88541	2890	82487				
1999	6498364	572338	188181	21972	7961	94681	2835	84617				
2000	6646016	578453	187229	23847	8064	100081	2808	85558				

SOURCE: Statistics Canada

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The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

See Table 1cR for the subgroups that comprise each group

Table 8bR. Geometric End-Year Net Stock Deflators for Property Capital, Food Processing Industry, 1961-2000

yr9	property capital (buildings, engineering construction): capital deflators, 1992=1									
	Industrial Bldg 4001	Commercial Bldg 4002	Off Non-Res Bldg 4004	Transport 5002	Waterworks 5003	Sewage 5004	Oil and Gas 5007	Other 5009		
	pk1	pk2	pk3	pk4	pk5	pk6	pk7	pk8		
1961	0.204	0.217	0.210	0.163	0.159	0.159	0.151	0.195		
1962	0.202	0.214	0.210	0.166	0.161	0.161	0.152	0.193		
1963	0.206	0.219	0.216	0.171	0.166	0.166	0.155	0.196		
1964	0.209	0.223	0.220	0.175	0.171	0.171	0.159	0.198		
1965	0.219	0.233	0.232	0.186	0.179	0.179	0.165	0.203		
1966	0.234	0.248	0.247	0.198	0.188	0.189	0.174	0.216		
1967	0.243	0.258	0.257	0.201	0.197	0.197	0.184	0.227		
1968	0.242	0.256	0.257	0.206	0.200	0.200	0.186	0.228		
1969	0.255	0.271	0.271	0.218	0.212	0.212	0.198	0.240		
1970	0.271	0.288	0.288	0.225	0.221	0.221	0.207	0.251		
1971	0.287	0.304	0.306	0.257	0.253	0.253	0.240	0.293		
1972	0.299	0.336	0.337	0.273	0.271	0.271	0.254	0.310		
1973	0.352	0.367	0.363	0.309	0.295	0.295	0.273	0.337		
1974	0.432	0.445	0.442	0.389	0.351	0.351	0.334	0.405		
1975	0.452	0.501	0.505	0.441	0.397	0.397	0.392	0.465		
1976	0.467	0.515	0.517	0.473	0.435	0.435	0.423	0.499		
1977	0.480	0.529	0.529	0.515	0.461	0.461	0.455	0.534		
1978	0.505	0.552	0.550	0.553	0.487	0.487	0.488	0.580		
1979	0.555	0.596	0.590	0.608	0.530	0.530	0.534	0.634		
1980	0.637	0.663	0.658	0.680	0.579	0.579	0.591	0.711		
1981	0.697	0.762	0.760	0.777	0.641	0.641	0.664	0.805		
1982	0.749	0.820	0.820	0.829	0.703	0.703	0.729	0.863		
1983	0.749	0.806	0.806	0.875	0.773	0.774	0.779	0.886		
1984	0.749	0.794	0.793	0.888	0.780	0.780	0.787	0.904		
1985	0.778	0.811	0.807	0.904	0.794	0.794	0.800	0.926		
1986	0.823	0.841	0.836	0.927	0.826	0.826	0.840	0.942		
1987	0.873	0.891	0.885	0.926	0.856	0.856	0.875	0.980		
1988	0.932	0.943	0.933	0.963	0.899	0.899	0.923	1.023		
1989	0.996	1.004	0.994	1.002	0.938	0.938	0.951	1.034		
1990	1.026	1.037	1.031	1.029	0.981	0.981	0.982	1.069		
1991	0.997	1.000	1.000	1.001	0.994	0.994	0.992	1.040		
1992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
1993	1.008	1.001	1.001	1.000	1.021	1.021	1.021	1.021		
1994	1.034	1.020	1.020	1.022	1.058	1.058	1.058	1.058		
1995	1.067	1.054	1.053	1.069	1.063	1.064	1.064	1.064		
1996	1.087	1.068	1.068	1.141	1.102	1.102	1.103	1.102		
1997	1.115	1.088	1.087	1.175	1.131	1.131	1.132	1.131		
1998	1.139	1.110	1.108	1.166	1.160	1.160	1.161	1.160		
1999	1.163	1.131	1.129	1.196	1.173	1.173	1.174	1.173		
2000	1.187	1.143	1.139	1.261	1.197	1.197	1.198	1.197		

SOURCE: Statistics Canada

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CONTACT: The capital stock deflators are calculated by dividing current dollar stock by constant dollar stock.

NOTES: The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

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See Table 1cR for the subgroups that comprise each group

Table 9aR. Current Dollar Geometric End-Year Net Stock of Other Capital, Food Processing Industry, 1961-2000

	other capital (machinery and equipment): '000\$											Furniture	Other Mach/Equip
	Computers Etc.	Tractors/Field Equip	Autos/Parts	Trucks/Parts	Oth Transport Equip	Processing Equip	Comm Equip						
	6002	6011	6201	6203	7001	7002	7003					7004	7005
yr10	ck9	ck10	ck11	ck12	ck13	ck14	ck15					ck16	ck17
1961	15013	1	39652	74306	20307	157343	16					58723	271330
1962	14402	2	42472	76875	21918	165856	16					53905	290501
1963	13510	3	44856	78947	18242	165484	16					71261	297257
1964	13987	4	50503	88557	26187	193301	18					44779	321898
1965	14028	4	53628	90691	27693	211780	19					43186	348219
1966	15406	6	56747	94918	29985	240183	21					41542	388140
1967	17406	7	59428	98558	31891	259641	24					41902	399888
1968	17003	9	66054	101252	32991	269539	26					42734	399355
1969	17150	10	68594	108329	35780	295141	29					42803	418212
1970	18186	10	70410	110333	37308	326703	32					42467	435200
1971	24239	11	69798	113284	39963	332296	33					45397	452117
1972	31155	12	71587	120435	42719	348505	36					45053	472217
1973	36632	13	68251	134417	47649	383831	41					45782	508233
1974	43369	15	69647	155362	60709	450586	47					49880	600297
1975	48985	17	64099	170754	68967	507761	50					53482	663249
1976	50357	19	61935	193668	74482	558120	56					56484	706928
1977	48621	20	57789	222192	78048	627627	62					59606	773973
1978	43179	22	54665	245925	86186	707776	74					61889	853621
1979	48448	25	51001	291518	98401	811045	80					71416	956506
1980	62304	27	49441	306070	106751	907690	77					75476	997450
1981	59614	30	47520	317526	107162	1122319	286					81485	1011178
1982	73324	30	46439	316759	113354	1427445	512					92636	1044882
1983	69064	33	48550	308907	118666	1651830	726					1030196	1030196
1984	73805	37	51118	308126	108688	1908403	911					104574	1038441
1985	77089	39	50901	301846	108584	2167887	1072					116070	1050581
1986	71325	44	47489	283198	102699	2423819	1202					126861	1005041
1987	79792	54	42158	249441	111287	2723232	2507					129036	934444
1988	82464	100	35659	221487	155804	2944705	3156					141559	888545
1989	84876	117	32918	197945	180657	3308014	4170					151765	866735
1990	108937	131	31226	168233	181016	3630480	7180					153815	824841
1991	106844	103	26445	147719	172945	3852681	7302					145763	780533
1992	134642	78	22017	133317	157602	4063711	7634					141525	733611
1993	159369	62	18588	123877	147742	4286916	7485					147396	748468
1994	174047	50	12465	131513	143425	4540817	7523					144512	764666
1995	157797	40	9429	134904	140541	4826769	11423					141806	776443
1996	161221	31	7925	120283	132224	5006344	19074					139098	732743
1997	168433	70	7658	98942	125190	5259979	17885					130110	698613
1998	221025	82	6677	93631	122290	5547087	20643					122800	697076
1999	260203	88	5827	84975	112352	5474271	22063					112558	661623
2000	289653	94	5876	78764	107947	5624570	22494					110645	655713

SOURCE: Statistics Canada

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See Table 1cR for the subgroups that comprise each group

Table 9bR. Geometric End-Year Net Stock Deflators for Other Capital, Food Processing Industry, 1961-2000

	other capital (machinery and equipment): capital deflators, 1992=1									
	Computers Etc. 6002	Tractors/Field Equip 6011	Autos/Parts 6201	Trucks/Parts 6203	On Transport Equip 7001	Processing Equip 7002	Comm Equip 7003	Furniture 7004	Other Mach/Equip 7005	
yr11	pk9	pk10	pk11	pk12	pk13	pk14	pk15	pk16	pk17	
1961	29.606	0.318	0.561	0.288	0.239	0.451	1.650	0.332	0.332	
1962	29.954	0.333	0.551	0.329	0.240	0.449	1.558	0.345	0.345	
1963	29.364	0.333	0.527	0.316	0.240	0.427	2.131	0.344	0.344	
1964	31.360	0.355	0.558	0.340	0.314	0.289	0.454	1.339	0.364	
1965	31.875	0.364	0.550	0.339	0.321	0.280	0.457	1.274	0.383	
1966	31.622	0.375	0.554	0.333	0.289	0.289	0.470	1.191	0.390	
1967	32.656	0.388	0.564	0.354	0.329	0.287	0.498	1.152	0.390	
1968	32.989	0.410	0.583	0.368	0.334	0.289	0.527	1.135	0.394	
1969	34.150	0.435	0.600	0.388	0.355	0.308	0.566	1.129	0.411	
1970	34.159	0.440	0.602	0.390	0.362	0.327	0.594	1.101	0.420	
1971	34.587	0.440	0.604	0.394	0.372	0.332	0.603	1.119	0.426	
1972	34.911	0.454	0.617	0.407	0.382	0.344	0.637	1.045	0.435	
1973	35.115	0.469	0.610	0.416	0.399	0.365	0.660	0.977	0.453	
1974	33.464	0.517	0.636	0.454	0.481	0.417	0.701	0.981	0.509	
1975	32.444	0.562	0.630	0.453	0.528	0.482	0.716	0.968	0.548	
1976	28.797	0.589	0.654	0.482	0.555	0.498	0.762	0.968	0.574	
1977	24.379	0.616	0.723	0.558	0.582	0.541	0.802	0.941	0.624	
1978	16.748	0.671	0.779	0.612	0.622	0.582	0.820	0.935	0.671	
1979	14.278	0.742	0.779	0.604	0.665	0.658	0.820	0.874	0.706	
1980	9.021	0.750	0.819	0.643	0.685	0.718	0.829	0.891	0.752	
1981	7.200	0.779	0.849	0.683	0.766	0.783	0.920	0.957	0.814	
1982	7.003	0.819	0.889	0.723	0.809	0.814	0.994	0.958	0.847	
1983	4.950	0.867	0.899	0.770	0.820	0.865	1.039	0.980	0.899	
1984	4.264	0.899	0.924	0.827	0.855	0.922	1.071	1.026	0.958	
1985	3.516	0.915	0.971	0.868	0.875	0.943	1.094	1.048	0.998	
1986	2.890	0.930	1.034	0.884	0.891	0.944	1.110	1.067	1.005	
1987	2.381	0.928	1.047	0.884	0.935	0.932	1.100	1.075	0.999	
1988	2.138	0.929	1.060	0.906	0.935	0.969	1.067	1.096	1.023	
1989	1.757	0.945	1.110	0.946	1.000	0.979	1.074	1.127	1.040	
1990	1.566	0.958	1.126	0.979	1.037	0.979	1.074	1.127	1.040	
1991	1.188	0.998	1.032	0.996	1.029	0.995	1.035	1.029	1.008	
1992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1993	0.948	1.045	1.011	1.036	1.006	1.047	0.999	1.011	1.033	
1994	0.860	1.113	1.043	1.087	1.040	1.096	0.968	1.022	1.076	
1995	0.742	1.162	1.101	1.162	1.101	1.138	0.924	1.044	1.112	
1996	0.563	1.172	1.133	1.157	1.101	1.132	0.935	1.010	1.101	
1997	0.491	1.200	1.138	1.187	1.080	1.155	0.950	1.006	1.114	
1998	0.400	1.221	1.119	1.200	1.112	1.210	0.952	0.991	1.153	
1999	0.313	1.210	1.072	1.184	1.080	1.200	0.921	0.957	1.143	
2000	0.265	1.216	1.090	1.215	1.097	1.231	0.902	0.980	1.172	

SOURCE: Statistics Canada

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The capital stock deflators are calculated by dividing current dollar stock by constant dollar stock

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See Table 1cR for the subgroups that comprise each group

**Table 10R. Expenditures on Non-Capital Inputs, Current Dollar
Value of Gross Output and Output Price Index,
Food Processing Industry, 1961-1997**

year	Expenditure, '000\$				Gross Output	
	Labour	Energy	Purchased & Intermediate		value	price
			Materials	Services	'000\$	1961=1
yr12	cn1	cn2	cn3	cn4	cy	py
1961	710991	51292	2847590	554319	4506969	1.000
1962	747322	49017	3081208	587957	4845658	1.031
1963	775471	49183	3318404	620889	5170138	1.065
1964	828750	53200	3504894	663300	5534678	1.071
1965	890730	57562	3653994	687239	5806218	1.083
1966	978643	67432	4015339	731061	6301360	1.136
1967	1046761	61968	4173691	779320	6622053	1.144
1968	1107068	64136	4259945	813905	6810733	1.157
1969	1179595	66237	4551617	889499	7288161	1.224
1970	1260301	63566	4823080	935516	7663695	1.253
1971	1331726	68787	5018762	965706	8085475	1.274
1972	1452021	76548	5807615	1063576	9126117	1.385
1973	1582601	82780	7419384	1183150	11197593	1.682
1974	1813894	108619	9135738	1373985	13435851	1.980
1975	2118928	130546	9843562	1537834	14810561	2.209
1976	2415634	159620	10075866	1685980	15790788	2.203
1977	2671127	195226	11091120	1862756	17336224	2.328
1978	2928976	220959	13042588	2070268	19992444	2.613
1979	3254373	256820	15387642	2345533	23119570	2.959
1980	3615088	299304	17275324	2690356	25703246	3.203
1981	3997219	375546	18980396	3101318	28680983	3.512
1982	4306961	441999	18993645	3295156	29598748	3.665
1983	4542895	471438	19131282	3440725	30534761	3.763
1984	4712714	476314	20587049	3809772	32867913	3.950
1985	4965463	495207	20746563	4093146	34074449	3.978
1986	5251782	480284	21169164	4434834	35400165	4.113
1987	5535185	473065	22021007	4733185	37375839	4.259
1988	5946310	472900	22953181	5045741	38752776	4.362
1989	6193168	462275	23377791	5196671	39674474	4.476
1990	6386598	483280	23199761	5242022	40480155	4.567
1991	6497003	499847	22179698	5260637	40448525	4.573
1992	6861801	518196	22450139	5371054	41080465	4.606
1993	6866751	542331	23992852	5462374	42463665	4.739
1994	6920111	589895	25560237	5684941	44925683	4.916
1995	7055358	562696	27440723	6107127	47235218	5.026
1996	7240163	570883	29325563	6989375	50448575	5.216
1997	7289197	596851	30470177	7319238	52108509	5.304

SOURCE: Statistics Canada (KLEMS database)

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NOTES: Current dollar value of gross output is equal to the sum of expenditures on all inputs (including capital) in the KLEMS database.
The price for gross output is calculated by dividing current dollar value of output by the quantity index for gross output in the KLEMS database.
The bold headings are used as part of derived data procedures and allow each series to have a unique code.

Table 11aR. Current Dollar Geometric End-Year Net Stock of Infrastructure Property Capital, Public Administration Sector, 1961-2000

	Property capital (buildings, engineering construction): 000\$											
	Industrial Bldg 4001	Commercial Bldg 4002	Institutional Bldg 4003	Oil Non-Res Bldg 4004	Marine 5001	Transport 5002	Waterworks 5003	Sewage 5004	Electric Power 5005	Communication 5006	Oil and Gas 5007	Other 5009
yr13	cg1	cg2	cg3	cg4	cg5	cg6	cg7	cg8	cg9	cg10	cg11	cg12
1961	27,292	152,267	140,975	101,291	708,408	657,317	456,698	174,066	279,509	208,286	17,568	157,897
1962	27,629	156,996	144,810	102,223	745,527	717,625	463,588	182,341	284,999	203,387	17,768	165,381
1963	28,127	164,014	150,406	106,431	802,946	800,472	519,427	203,955	239,975	200,065	19,108	173,788
1964	29,875	173,526	157,382	108,101	848,130	869,785	545,132	218,950	234,712	200,989	20,432	181,135
1965	31,663	190,784	171,438	116,332	926,030	1,033,599	594,034	242,933	301,960	220,713	21,445	203,947
1966	35,098	214,087	191,208	126,328	1,014,791	1,170,507	648,851	267,317	321,652	225,059	22,728	223,970
1967	37,678	232,946	206,751	134,080	1,107,725	1,203,639	704,084	295,699	350,529	247,414	24,169	242,794
1968	38,613	240,581	212,861	137,049	1,159,973	1,250,150	740,120	312,708	365,321	262,815	24,531	255,857
1969	41,662	261,609	230,978	146,084	1,274,624	1,382,231	820,162	340,661	404,437	283,263	25,524	268,460
1970	44,637	286,099	251,216	157,735	1,388,137	1,485,950	894,725	379,453	438,449	301,222	26,728	282,435
1971	48,513	313,262	274,854	170,321	1,590,659	1,704,467	1,000,699	438,451	497,829	330,512	30,255	305,224
1972	52,029	353,473	291,280	181,188	1,762,152	1,886,155	1,092,298	482,183	517,990	363,953	32,701	334,288
1973	61,095	394,342	357,377	201,137	2,031,132	2,216,746	1,235,438	557,303	567,397	394,777	35,280	441,093
1974	75,371	503,025	438,309	281,283	2,638,484	3,037,491	1,528,110	679,978	693,104	457,424	42,181	538,933
1975	84,918	604,770	468,313	293,927	3,202,638	3,504,282	1,800,629	806,864	750,028	493,085	49,732	640,215
1976	91,310	642,651	527,324	310,047	3,561,799	3,772,751	1,989,659	928,532	839,985	503,308	53,654	713,412
1977	98,090	682,262	578,149	329,638	3,895,201	4,152,919	2,144,947	1,029,698	884,272	525,255	56,500	781,346
1978	105,305	732,814	627,187	353,024	4,292,511	4,596,166	2,315,612	1,133,345	932,270	612,881	64,195	868,427
1979	117,492	809,770	708,981	387,215	4,702,443	5,096,105	2,542,915	1,288,836	1,025,359	638,871	72,784	967,681
1980	132,269	927,193	800,148	435,156	5,352,071	5,874,739	2,837,644	1,486,125	1,142,089	611,637	84,735	1,104,014
1981	151,373	1,063,106	890,986	488,187	6,352,461	7,052,509	3,234,066	1,656,792	1,287,065	636,127	94,462	1,271,875
1982	165,687	1,236,384	990,375	531,897	6,999,272	7,563,144	3,560,230	1,899,323	1,337,010	662,429	1,006,74	1,442,285
1983	165,974	1,247,852	1,015,707	535,658	7,392,944	7,965,285	3,806,854	2,106,022	1,367,060	670,776	1,006,09	1,524,644
1984	185,486	1,335,347	1,086,282	574,070	8,206,394	8,894,018	4,165,466	2,411,867	1,434,471	678,630	1,134,21	1,656,779
1985	175,009	1,434,906	1,159,678	618,125	8,899,107	9,594,172	4,372,246	2,529,276	1,476,686	684,874	1,216,45	1,767,689
1986	194,703	1,567,943	1,256,803	656,953	9,336,163	8,875,923	4,509,763	2,645,945	1,510,980	688,875	1,216,45	1,885,339
1987	215,876	1,679,543	1,369,146	705,364	10,141,341	9,294,182	4,785,213	2,814,271	1,581,259	681,932	1,349,50	1,976,679
1988	235,675	1,703,269	1,517,285	786,580	10,652,569	9,785,937	5,061,166	3,035,088	1,612,559	778,880	1,494,50	2,086,629
1989	257,154	1,886,121	1,628,895	806,470	11,200,646	10,256,639	5,283,310	3,350,433	1,662,201	853,347	1,590,54	2,206,268
1990	289,180	2,033,596	1,628,895	795,755	11,132,777	10,006,296	5,428,310	3,350,433	1,662,201	853,347	1,590,54	2,206,268
1991	281,483	2,033,596	1,628,895	795,755	11,132,777	10,006,296	5,428,310	3,350,433	1,662,201	853,347	1,590,54	2,206,268
1992	268,009	2,088,132	1,675,026	812,425	11,518,740	10,228,869	5,521,665	3,440,833	1,542,661	883,371	2,254,62	2,071,139
1993	275,739	2,130,369	1,713,042	829,692	11,910,777	10,391,038	5,627,662	3,574,237	1,530,000	953,127	2,284,91	2,138,940
1994	286,631	2,232,802	1,790,337	863,429	12,488,152	10,731,594	5,841,038	3,763,134	1,581,721	961,144	2,328,71	2,250,762
1995	300,808	2,363,283	1,868,591	901,702	12,834,374	11,613,827	5,951,194	3,891,300	1,562,047	946,352	2,384,82	2,338,926
1996	312,037	2,458,137	1,965,652	935,017	13,461,446	12,370,945	6,175,678	4,093,481	1,639,977	945,083	2,440,205	2,511,454
1997	362,549	2,583,961	2,055,069	958,412	13,861,111	12,924,160	6,324,501	4,228,844	1,639,977	945,083	2,440,205	2,511,454
1998	352,665	2,708,294	2,146,829	986,930	14,179,002	12,841,384	6,411,148	4,394,237	1,639,977	945,083	2,440,205	2,511,454
1999	368,375	2,846,791	2,236,303	1,016,169	14,396,290	13,367,321	6,450,664	4,422,085	1,639,977	945,083	2,440,205	2,511,454
2000	388,321	2,992,047	2,327,396	1,040,499	14,532,300	14,147,584	6,567,879	4,415,613	1,622,461	867,942	2,605,666	2,605,666

Source: Statistics Canada

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The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

See Table 1aR for the subgroups that comprise each group

Table 11bR. Geometric End-Year Net Stock Deflators for Infrastructure Property Capital, Public Administration Sector, 1961-2000

property capital (buildings, engineering construction): capital deflators, 1992=1																							
Industrial Bldg		Commercial Bldg		Institutional Bldg		Oil Non-Res Bldg		Marine		Transport		Waterworks		Sewage		Electric Power		Communication		Oil and Gas		Other	
4001	cp91	4002	cp92	4003	cp93	4004	cp94	5001	cp95	5002	cp96	5003	cp97	5004	cp98	5005	cp99	5006	cp910	5007	cp911	5008	cp912
1961	0.212	0.222	0.216	0.228	0.212	0.216	0.216	0.144	0.144	0.180	0.156	0.167	0.168	0.167	0.156	0.168	0.168	0.257	0.257	0.161	0.161	0.183	
1962	0.210	0.221	0.215	0.226	0.210	0.215	0.215	0.145	0.145	0.180	0.156	0.169	0.170	0.169	0.156	0.170	0.170	0.259	0.259	0.162	0.162	0.184	
1963	0.215	0.225	0.220	0.230	0.215	0.220	0.220	0.150	0.150	0.195	0.164	0.174	0.173	0.174	0.164	0.173	0.173	0.261	0.261	0.165	0.165	0.188	
1964	0.217	0.229	0.223	0.234	0.223	0.223	0.223	0.153	0.153	0.199	0.167	0.177	0.175	0.177	0.167	0.175	0.175	0.263	0.263	0.168	0.168	0.190	
1965	0.227	0.239	0.245	0.239	0.245	0.239	0.239	0.160	0.160	0.225	0.176	0.186	0.179	0.186	0.176	0.179	0.179	0.268	0.268	0.175	0.175	0.198	
1966	0.243	0.256	0.249	0.262	0.249	0.249	0.249	0.167	0.167	0.241	0.185	0.195	0.188	0.195	0.185	0.188	0.188	0.279	0.279	0.184	0.184	0.208	
1967	0.253	0.266	0.260	0.272	0.260	0.260	0.260	0.177	0.177	0.235	0.194	0.206	0.202	0.206	0.194	0.202	0.202	0.300	0.300	0.196	0.196	0.220	
1968	0.253	0.265	0.259	0.271	0.259	0.259	0.259	0.178	0.178	0.234	0.196	0.208	0.206	0.208	0.196	0.206	0.206	0.313	0.313	0.198	0.198	0.222	
1969	0.266	0.279	0.273	0.286	0.273	0.273	0.273	0.189	0.189	0.242	0.207	0.220	0.218	0.220	0.207	0.218	0.218	0.336	0.336	0.210	0.210	0.234	
1970	0.279	0.294	0.301	0.286	0.294	0.286	0.286	0.200	0.200	0.254	0.220	0.234	0.230	0.234	0.220	0.230	0.230	0.354	0.354	0.222	0.222	0.249	
1971	0.295	0.308	0.317	0.303	0.308	0.303	0.303	0.223	0.223	0.276	0.241	0.260	0.263	0.260	0.241	0.263	0.263	0.416	0.416	0.253	0.253	0.278	
1972	0.310	0.333	0.332	0.316	0.333	0.316	0.316	0.239	0.239	0.290	0.258	0.279	0.279	0.279	0.258	0.279	0.279	0.435	0.435	0.268	0.268	0.296	
1973	0.351	0.357	0.382	0.359	0.359	0.359	0.359	0.266	0.266	0.325	0.285	0.303	0.308	0.303	0.285	0.308	0.308	0.460	0.460	0.291	0.291	0.323	
1974	0.420	0.437	0.452	0.435	0.437	0.435	0.435	0.334	0.334	0.431	0.344	0.349	0.380	0.349	0.344	0.380	0.380	0.516	0.516	0.355	0.355	0.383	
1975	0.456	0.501	0.475	0.475	0.475	0.475	0.475	0.392	0.392	0.481	0.396	0.395	0.437	0.395	0.396	0.437	0.437	0.572	0.572	0.417	0.417	0.443	
1976	0.474	0.500	0.489	0.500	0.489	0.489	0.489	0.423	0.423	0.504	0.430	0.433	0.469	0.433	0.430	0.469	0.469	0.596	0.596	0.447	0.447	0.477	
1977	0.494	0.521	0.528	0.494	0.521	0.505	0.505	0.449	0.449	0.541	0.455	0.458	0.499	0.458	0.455	0.499	0.499	0.639	0.639	0.480	0.480	0.508	
1978	0.523	0.542	0.555	0.528	0.542	0.530	0.530	0.482	0.482	0.584	0.484	0.484	0.538	0.484	0.484	0.538	0.538	0.769	0.769	0.516	0.516	0.555	
1979	0.569	0.580	0.612	0.577	0.580	0.577	0.577	0.517	0.517	0.632	0.526	0.531	0.597	0.531	0.526	0.597	0.597	0.818	0.818	0.567	0.567	0.604	
1980	0.633	0.647	0.676	0.648	0.676	0.648	0.648	0.576	0.576	0.715	0.581	0.579	0.675	0.581	0.579	0.675	0.675	0.807	0.807	0.634	0.634	0.676	
1981	0.716	0.750	0.734	0.724	0.750	0.734	0.734	0.667	0.667	0.842	0.653	0.653	0.771	0.653	0.653	0.771	0.771	0.867	0.867	0.719	0.719	0.760	
1982	0.768	0.811	0.792	0.781	0.811	0.792	0.792	0.719	0.719	0.887	0.711	0.698	0.811	0.711	0.698	0.811	0.811	0.934	0.934	0.780	0.780	0.822	
1983	0.756	0.796	0.779	0.779	0.779	0.779	0.779	0.744	0.744	0.920	0.751	0.752	0.838	0.751	0.752	0.838	0.838	0.979	0.979	0.798	0.798	0.832	
1984	0.734	0.783	0.780	0.772	0.783	0.772	0.772	0.759	0.759	0.962	0.772	0.772	0.866	0.772	0.772	0.866	0.866	1.016	1.016	0.829	0.829	0.861	
1985	0.753	0.794	0.790	0.790	0.790	0.790	0.790	0.787	0.787	0.995	0.804	0.813	0.901	0.813	0.804	0.901	0.901	1.055	1.055	0.863	0.863	0.908	
1986	0.821	0.832	0.825	0.830	0.832	0.830	0.830	0.835	0.835	0.978	0.832	0.832	0.937	0.832	0.832	0.937	0.937	1.094	1.094	0.882	0.882	0.919	
1987	0.891	0.879	0.866	0.876	0.866	0.876	0.876	0.869	0.869	0.956	0.851	0.851	0.962	0.851	0.851	0.962	0.962	1.082	1.082	0.895	0.895	0.948	
1988	0.956	0.927	0.918	0.928	0.918	0.928	0.928	0.932	0.932	0.983	0.895	0.895	1.008	0.895	0.895	1.008	1.008	1.092	1.092	0.935	0.935	0.983	
1989	1.023	0.993	0.987	0.993	0.987	0.993	0.993	0.959	0.959	1.015	0.936	0.941	1.023	0.941	0.936	1.023	1.023	1.101	1.101	0.963	0.963	1.018	
1990	1.046	1.030	1.024	1.027	1.030	1.027	1.027	1.003	1.003	1.043	0.982	0.982	1.072	0.980	0.980	1.072	1.072	1.104	1.104	0.993	0.993	1.052	
1991	0.996	0.999	0.998	0.998	0.999	0.998	0.998	0.983	0.983	0.996	0.987	0.987	1.038	0.996	0.996	1.038	1.038	1.041	1.041	0.997	0.997	1.027	
1992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1993	1.015	1.004	1.008	1.007	1.008	1.007	1.007	1.018	1.018	0.999	1.018	1.018	1.019	0.999	1.018	1.019	1.019	1.018	1.018	1.018	1.018	1.018	
1994	1.032	1.022	1.028	1.030	1.022	1.030	1.030	1.048	1.048	1.013	1.048	1.048	1.052	1.013	1.047	1.052	1.052	1.051	1.051	1.049	1.049	1.047	
1995	1.061	1.053	1.061	1.061	1.053	1.061	1.061	1.064	1.064	1.073	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	
1996	1.079	1.069	1.080	1.080	1.069	1.080	1.080	1.103	1.103	1.126	1.103	1.103	1.135	1.103	1.104	1.135	1.135	1.101	1.101	1.103	1.103	1.104	
1997	1.106	1.088	1.105	1.103	1.088	1.103	1.103	1.135	1.135	1.159	1.136	1.136	1.159	1.136	1.136	1.159	1.159	1.135	1.135	1.136	1.136	1.136	
1998	1.129	1.109	1.124	1.128	1.109	1.124	1.124	1.159	1.159	1.141	1.159	1.141	1.161	1.141	1.141	1.161	1.161	1.160	1.160	1.159	1.159	1.159	
1999	1.151	1.132	1.147	1.147	1.132	1.147	1.147	1.171	1.171	1.174	1.171	1.171	1.173	1.171	1.171	1.173	1.173	1.173	1.173	1.172	1.172	1.171	
2000	1.182	1.153	1.165	1.170	1.153	1.170	1.170	1.161	1.161	1.228	1.161	1.161	1.182	1.161	1.156	1.182	1.182	1.179	1.179	1.164	1.164	1.156	

SOURCE: Statistics Canada

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The capital stock deflators are calculated by dividing current dollar stock by constant dollar stock

The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

See Table 1cR for the subgroups that comprise each group

Table 12aR. Current Dollar Geometric End-Year Net Stock of Other Infrastructure Capital, Public Administration Sector, 1961-2000

yr15	other capital (machinery and equipment): '000\$											
	Computers Etc.	Tractors/Field Equip	Autos/Parts	Trucks/Parts	Off Transport Equip	Processing Equip	Comm Equip	Furniture	Other Mach/Equip			
	6002	6011	6015	6016	6017	7002	7003	7004	7005			
	cg13	cg14	cg15	cg16	cg17	cg18	cg19	cg20	cg21			
1961	88326	7560	79069	72066	138274	2358	62922	205812	167334			
1962	88786	8230	88126	76378	147750	2610	64757	195247	190006			
1963	79023	7594	86356	73572	150073	2536	58787	250045	190175			
1964	89362	8843	106861	92130	190173	3148	68658	167388	225895			
1965	93701	9241	112747	97090	219533	3509	73548	163795	248181			
1966	101013	10107	121838	106049	257685	4018	86570	158226	274479			
1967	116427	11121	130669	116343	277887	4600	98907	161789	302242			
1968	129095	11720	135228	125244	302049	5258	110435	160458	327157			
1969	133888	12244	130306	132088	321621	5872	115090	158387	349868			
1970	141234	12369	122295	138718	333887	6653	121166	159293	375735			
1971	154895	12645	124969	148903	343760	7574	130390	167186	414401			
1972	168806	14026	144576	171491	362625	8592	156475	165949	457289			
1973	192947	16223	169630	203929	354802	10957	182020	177895	542618			
1974	221066	22283	225212	267800	419616	14422	226614	201140	675794			
1975	252131	30645	281390	316425	502783	18472	294771	232798	836522			
1976	246383	35781	300463	357108	568633	20938	350642	250894	933277			
1977	231870	40042	311765	402713	649892	23722	400160	258162	1071771			
1978	195688	44830	320775	437246	702882	27446	484719	254360	1212740			
1979	192755	47101	320098	457694	759526	31213	495965	266454	1317043			
1980	179941	50019	313055	464461	812810	37427	471806	278430	1488947			
1981	273055	48060	267411	454594	908346	40619	506509	300151	1563109			
1982	398761	51474	247266	496812	1071104	46470	610297	358847	1779349			
1983	436773	54548	231655	522985	1244554	50049	759302	394811	1941686			
1984	563481	56183	227788	549647	1504803	59621	947731	442503	2211511			
1985	668751	58153	225350	615814	1761421	67155	1096535	507664	2465084			
1986	814691	62560	242828	680066	1859904	74765	1323365	582830	2790901			
1987	940198	63747	293586	741981	1775872	75490	1497337	665184	2869956			
1988	1172528	64715	315897	827094	1711547	79752	1659854	747837	3030203			
1989	1392391	69647	331777	910877	1711115	86998	1833004	834378	3303401			
1990	1628172	67898	335021	904764	1702947	91113	2094629	930423	3482547			
1991	1556374	67445	270614	886481	1597085	90950	2236871	863254	3416845			
1992	1659571	72397	260886	869010	1533427	94065	2370625	891768	3520907			
1993	2006781	79661	273008	893201	1591585	100113	2654355	960452	3803167			
1994	2123322	83982	273872	903058	1600559	104708	2764139	987092	4048362			
1995	2200428	83175	281155	917707	1594514	107518	2775684	976944	4119313			
1996	2022631	73992	233559	830153	1433441	97452	2709796	879616	3768819			
1997	2069088	71091	218688	780564	1358460	119630	2979858	847482	3786023			
1998	1855604	68190	217547	774380	1334636	118874	2860481	806652	3729129			
1999	1756910	65430	204742	750494	1192521	109951	2644913	758372	3495488			
2000	1973678	60808	189927	716026	1110267	107749	2476336	723020	3314612			

SOURCE: Statistics Canada

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NOTES: The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

See Table 1cR for the subgroups that comprise each group

Table 12bR. Geometric End-Year Net Stock Deflators for Other Infrastructure Capital, Public Administration Sector, 1961-2000

	other capital (machinery and equipment): capital deflators, 1992=1									
	Computers Etc. 6002	Tractors/Field Equip 6011	Autos/Parts 6201	Trucks/Parts 6203	On Transport Equip 7001	Processing Equip 7002	Comm Equip 7003	Furniture 7004	Other Mach/Equip 7005	
yr16	cp13	cp14	cp15	cp16	cp17	cp18	cp19	cp20	cp21	
1961	28.191	0.301	0.532	0.291	0.259	0.240	0.438	1.628	0.287	
1962	29.432	0.333	0.540	0.310	0.272	0.248	0.453	1.593	0.304	
1963	28.087	0.315	0.500	0.289	0.263	0.243	0.421	2.142	0.295	
1964	32.220	0.361	0.570	0.336	0.308	0.292	0.479	1.412	0.343	
1965	33.395	0.371	0.572	0.341	0.325	0.308	0.493	1.364	0.366	
1966	33.527	0.390	0.582	0.353	0.340	0.322	0.515	1.287	0.379	
1967	35.299	0.419	0.606	0.370	0.355	0.324	0.556	1.270	0.387	
1968	35.741	0.439	0.629	0.387	0.369	0.324	0.585	1.219	0.390	
1969	36.230	0.464	0.635	0.401	0.394	0.337	0.614	1.175	0.400	
1970	36.840	0.476	0.649	0.412	0.411	0.363	0.652	1.150	0.416	
1971	36.796	0.468	0.644	0.414	0.433	0.360	0.646	1.184	0.420	
1972	37.459	0.495	0.664	0.434	0.460	0.373	0.687	1.111	0.433	
1973	38.417	0.519	0.672	0.452	0.451	0.404	0.724	1.082	0.461	
1974	37.539	0.586	0.722	0.507	0.497	0.473	0.782	1.101	0.533	
1975	39.157	0.683	0.771	0.545	0.580	0.561	0.857	1.179	0.616	
1976	34.983	0.727	0.804	0.586	0.646	0.607	0.917	1.192	0.651	
1977	25.773	0.761	0.857	0.639	0.720	0.661	0.967	1.174	0.713	
1978	20.440	0.828	0.896	0.685	0.743	0.724	1.104	1.107	0.768	
1979	16.861	0.886	0.934	0.725	0.787	0.771	1.106	1.121	0.797	
1980	11.098	0.927	0.948	0.743	0.814	0.814	0.993	1.091	0.817	
1981	7.719	0.830	0.884	0.683	0.774	0.776	0.871	1.040	0.762	
1982	7.374	0.860	0.902	0.715	0.823	0.829	0.947	1.136	0.807	
1983	5.193	0.914	0.943	0.758	0.889	0.856	1.019	1.138	0.843	
1984	4.284	0.916	0.943	0.782	0.924	0.865	1.018	1.105	0.863	
1985	3.529	0.922	0.968	0.830	0.990	0.929	1.052	1.133	0.918	
1986	3.020	0.968	1.084	0.899	1.031	0.994	1.138	1.170	1.004	
1987	2.476	0.962	1.087	0.909	1.024	0.994	1.160	1.172	1.011	
1988	2.231	0.968	1.107	0.934	1.019	0.986	1.148	1.160	1.011	
1989	1.823	0.979	1.156	0.970	1.025	1.008	1.100	1.180	1.029	
1990	1.620	0.992	1.167	1.003	1.042	1.020	1.104	1.194	1.046	
1991	1.196	1.005	1.039	0.998	1.013	1.008	1.043	1.047	1.006	
1992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1993	0.953	1.051	1.014	1.040	1.051	1.054	1.009	1.013	1.048	
1994	0.865	1.115	1.046	1.093	1.106	1.103	0.981	1.018	1.084	
1995	0.734	1.150	1.089	1.153	1.119	1.120	0.916	1.013	1.108	
1996	0.526	1.108	1.072	1.104	1.111	1.036	0.853	0.924	1.034	
1997	0.464	1.145	1.080	1.128	1.017	1.059	0.879	0.933	1.075	
1998	0.362	1.132	1.016	1.120	1.010	1.046	0.835	0.879	1.076	
1999	0.270	1.095	0.943	1.064	0.947	0.995	0.775	0.818	1.025	
2000	0.225	1.096	0.939	1.077	0.949	1.005	0.751	0.822	1.036	

SOURCE: Statistics Canada

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The capital stock deflators are calculated by dividing current dollar investment by constant dollar investment.

The numeric codes below each asset group description is that used by Statistics Canada to identify groups in their database.

The bold headings are used as part of derived data procedures and allow each series to have a unique code.

See Table 1cR for the subgroups that comprise each group

Table 13aR. Nominal R&D Expenditures in Canada and USA, Selected Sectors, 1963-1998

	R&D Expenditures, Canada (Million \$C)			R&D Expenditures, USA (Million \$US)			
	All			Food, kindred & tobacco products (3)(4)			
	Industries (1)	Manufacturing	Food Processing	Federal Government (2)	All Industries		
1963	176	164	4	246	130		12630
1964	229	210	5	282	141		13512
1965	285	265	7	340	151		14185
1966	313	289	9	381	153		15548
1967	333	304	9	445	183		16385
1968	339	303	10	515	167		17469
1969	369	334	10	529	185		18474
1970	408	361	11	613	230		18067
1971	413	369	11	653	240		18320
1972	462	387	12	694	259		19552
1973	503	422	12	766	269		21249
1974	613	507	16	835	298		22887
1975	700	560	19	903	335		24187
1976	755	601	21	1003	355		26997
1977	857	663	21	1071	415		29825
1978	1006	789	25	1164	472		33304
1979	1266	993	27	1217	528		38226
1980	1571	1239	36	1387	620		44505
1981	2124	1692	41	1678	719		51830
1982	2489	1950	52	1939	704		58650
1983	2602	2012	52	2282	783		65268
1984	3022	2242	52	2566	898		74800
1985	3633	2583	57	2451	1011		84239
1986	4022	2705	63	2549	1054		87823
1987	4340	2920	63	2685	1206		92155
1988	4623	3183	65	2906	1164		97015
1989	4779	3288	61	3033	1225		102055
1990	5169	3532	62	3227	1317		109727
1991	5355	3573	58	3404	1277		116952
1992	5742	3660	60	3687	1386		119110
1993	6424	4015	68	3677	1345		117400
1994	7567	4524	85	3657	1476		119595
1995	7991	4913	96	3465	1566		132103
1996	7997	5041	91	3391	1564		144687
1997	8744	5711	88	3379	1787		157539
1998	9676	6430	90	3578	1711		169180

SOURCES:

Canadian Data

Statistics Canada

Industrial Research and Development

Catalogue # 88-202

(these data obtained as file: Historical Tables3.4 and 5 (1963-2002).xls from Statistics Canada)

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Statistics Canada

Federal Scientific Activities

Catalogue # 88-204

U.S. Data

National Science Foundation, IRIS database

data obtained as downloaded EXCEL file "H-25.xls" accessed via url: <http://caspar.nsf.gov>

NOTES:

(1) All Industries is sum of: Agriculture, Fishing and Logging; Mining and Oil Wells; Manufacturing; Construction; Utilities; and Services)

(2) For 1996-1999 the Federal R&D expenditure are revised estimates. For 2000, the datum is a preliminary figure.

(3) Until 1984, tobacco products was included with "Other manufacturing industries."

(4) From 1982-1986 and from 1988-1990 data were withheld to avoid disclosing operations of individual companies.

For these years the data were imputed by multiplying data for all industries for these years by 0.012.

This proportion is based on the observed ratio of food, kindred and tobacco product R&D expenditure to that for all industries between 1956 and 1981 as well as between 1991 and 1998

**Table 13bR. R&D Deflators for Canada
and the USA, 1963-1998**

	R&D Deflator		USA 1992=1
	Canada : manufacturing 1992=1	Canada : all industries 1992=1	
yr100	ps1	ps2	ps3
1963	0.341	0.341	0.239
1964	0.349	0.352	0.250
1965	0.363	0.366	0.256
1966	0.379	0.381	0.274
1967	0.396	0.397	0.279
1968	0.414	0.416	0.291
1969	0.429	0.430	0.300
1970	0.442	0.445	0.306
1971	0.446	0.448	0.324
1972	0.480	0.481	0.350
1973	0.530	0.528	0.375
1974	0.595	0.595	0.401
1975	0.631	0.630	0.421
1976	0.682	0.678	0.457
1977	0.712	0.708	0.480
1978	0.748	0.745	0.509
1979	0.818	0.816	0.553
1980	0.906	0.905	0.601
1981	1.000	1.000	0.658
1982	1.077	1.074	0.714
1983	1.132	1.126	0.735
1984	1.153	1.128	0.785
1985	1.177	1.172	0.825
1986	1.199	1.194	0.814
1987	1.258	1.259	0.816
1988	1.343	1.344	0.838
1989	1.483	1.484	0.852
1990	1.625	1.626	0.895
1991	1.725	1.727	0.941
1992	1.794	1.795	1.000
1993	1.855	1.856	0.971
1994	1.860	1.861	0.997
1995	1.943	1.945	1.060
1996	2.020	2.021	1.066
1997	2.067	2.068	1.086
1998	2.042	2.043	1.099

SOURCES:**Canadian Data**

Bernstein, J.I.(1992),"Price Indexes for Canadian Industrial Research and Development Expenditures", Working Paper 92-01, Services, Science and Technology Division, Statistics Canada
(for 1963-1987)

Statistics Canada, CANSIM II

For 1963-1982, data are from Table 281-0021 and are defined as 'Average weekly earnings, all employees' (dollars), for the Engineering and scientific services sector

For 1982-1998, data are from Table 281-0006 and are 'average weekly earnings of employees' (dollars) for the Architectural, engineering and other scientific and technical services sector.

U.S. Data

National Science Foundation, IRIS database
data obtained as downloaded EXCEL file 'H-18.xls' accessed via
url: <http://caspar.nsf.gov>

NOTES:

CANSIM data are averages of monthly series on average weekly earnings and are used to impute deflator data for 1988-1998.

The raw annualized CANSIM series are first scaled to 1981=1 (the year the salary and deflator series share) and then spliced.

The dollar values of salaries in 1983, however, are quite different, suggesting that the two salary series are not very compatible. In combining the two in this manner, the assumption is that while the levels may differ, the rates of change are the same.

The deflator data from Bernstein(1992) are then imputed using the annual change in the salaries series.

Table 1D. Derived Tax Rates, 1961-1997

year	derived rate: provincial corporate income tax	derived rate: corporate income tax	derived property tax rate		derived business tax rate	net local tax rate
			without land	with land		
yr99	kap_pc	xi_1	kap_prop	kap_none	kap_bus	xi_3
1961	10.2%	51.2%	1.9%	1.4%	0.3%	1.1%
1962	10.7%	51.7%	1.9%	1.4%	0.3%	1.1%
1963	10.7%	51.7%	1.9%	1.4%	0.3%	1.1%
1964	10.7%	51.7%	1.9%	1.4%	0.3%	1.1%
1965	10.7%	51.7%	1.9%	1.4%	0.3%	1.1%
1966	10.7%	51.7%	1.8%	1.4%	0.3%	1.1%
1967	11.0%	51.0%	1.9%	1.4%	0.3%	1.1%
1968	11.0%	51.0%	2.0%	1.4%	0.3%	1.1%
1969	11.6%	51.6%	2.0%	1.4%	0.4%	1.1%
1970	11.6%	53.1%	1.9%	1.4%	0.3%	1.1%
1971	11.6%	51.3%	1.8%	1.3%	0.3%	1.1%
1972	11.7%	48.9%	1.8%	1.3%	0.3%	1.1%
1973	11.9%	41.9%	1.6%	1.1%	0.3%	1.1%
1974	11.8%	41.8%	1.4%	1.0%	0.3%	1.0%
1975	11.9%	41.9%	1.4%	1.0%	0.3%	1.0%
1976	12.2%	42.2%	1.5%	1.1%	0.3%	1.1%
1977	12.4%	42.4%	1.6%	1.1%	0.3%	1.1%
1978	12.7%	42.7%	1.6%	1.1%	0.3%	1.1%
1979	13.1%	43.1%	1.6%	1.1%	0.3%	1.1%
1980	13.0%	43.0%	1.5%	1.0%	0.3%	1.0%
1981	13.2%	45.5%	1.6%	1.1%	0.3%	1.0%
1982	11.9%	44.2%	1.6%	1.1%	0.3%	1.0%
1983	11.7%	44.0%	1.7%	1.2%	0.3%	1.1%
1984	11.7%	42.9%	1.7%	1.2%	0.3%	1.1%
1985	11.4%	41.4%	1.7%	1.2%	0.3%	1.1%
1986	11.6%	42.8%	1.6%	1.2%	0.3%	1.1%
1987	12.0%	43.7%	1.6%	1.2%	0.3%	1.1%
1988	12.0%	43.3%	1.6%	1.2%	0.3%	1.1%
1989	12.0%	38.7%	1.7%	1.2%	0.3%	1.2%
1990	12.0%	37.7%	1.8%	1.2%	0.3%	1.3%
1991	12.8%	37.4%	1.9%	1.3%	0.4%	1.4%
1992	13.6%	37.8%	1.9%	1.4%	0.4%	1.5%
1993	13.1%	36.3%	1.9%	1.4%	0.4%	1.5%
1994	13.2%	35.3%	1.9%	1.3%	0.4%	1.5%
1995	13.2%	35.3%	1.9%	1.3%	0.4%	1.5%
1996	13.2%	35.7%	1.9%	1.3%	0.4%	1.4%
1997	13.2%	35.7%	1.9%	1.3%	0.4%	1.4%

Notes: The average provincial corporate income tax rate is a weighted average derived using provincial basic rate data from Table 3R and shipments data from Table 4R. The corporate income tax rate is the federal basic rate (with the corporate surtax rate applied to it) less federal tax abatement rate and less the rate for manufacturing an processing tax credit, plus the average provincial basic rate derived here. Data for all but the last item are drawn from Table 3R. In the notation used in the model: The derived property tax rate without land is derived by adding provincial property tax and real property&personal tax revenues together and dividing this sum by the combined value of non-residential structures and residential structures - all of these data are taken from Table 6R. The derived property tax rate with land is derived in the same way as that without land except that the value of land is included in the denominator. The net local tax rate takes into account the fact that local taxes are not included in taxable income, so

Table 2aD. Capital Cost Allowance Rate Time Series, Property Capital, 1961-1997

	property capital (buildings, engineering construction): capital cost allowance rate						
	Industrial Bldg 4001	Commercial Bldg 4002	Other Non-Res Bldg 4004	Transport 5002	Waterworks 5003	Sewage 5004	Oil and Gas 5007
yr17	cca1	cca2	cca3	cca4	cca5	cca6	cca7
1961	10%	5%	10%	4%	6%	6%	6%
1962	10%	5%	10%	4%	6%	6%	6%
1963	10%	5%	10%	4%	6%	6%	6%
1964	10%	5%	10%	4%	6%	6%	6%
1965	10%	5%	10%	4%	6%	6%	6%
1966	10%	5%	10%	4%	6%	6%	6%
1967	10%	5%	10%	4%	6%	6%	6%
1968	10%	5%	10%	4%	6%	6%	6%
1969	10%	5%	10%	4%	6%	6%	6%
1970	10%	5%	10%	4%	6%	6%	6%
1971	10%	5%	10%	4%	6%	6%	6%
1972	10%	5%	10%	4%	6%	6%	6%
1973	10%	5%	10%	4%	6%	6%	6%
1974	10%	5%	10%	4%	6%	6%	6%
1975	10%	5%	10%	4%	6%	6%	6%
1976	10%	5%	10%	8%	6%	6%	6%
1977	10%	5%	10%	8%	6%	6%	6%
1978	10%	5%	10%	8%	6%	6%	6%
1979	4%	5%	4%	8%	6%	6%	6%
1980	4%	5%	4%	8%	6%	6%	6%
1981	4%	5%	4%	8%	6%	6%	6%
1982	4%	5%	4%	8%	6%	6%	6%
1983	4%	5%	4%	8%	6%	6%	6%
1984	4%	5%	4%	8%	6%	6%	6%
1985	4%	5%	4%	8%	6%	6%	6%
1986	4%	5%	4%	8%	6%	6%	6%
1987	4%	5%	4%	8%	6%	6%	6%
1988	4%	4%	4%	8%	6%	6%	6%
1989	4%	4%	4%	8%	6%	6%	6%
1990	4%	4%	4%	8%	6%	6%	6%
1991	4%	4%	4%	8%	6%	6%	6%
1992	4%	4%	4%	8%	6%	6%	6%
1993	4%	4%	4%	8%	6%	6%	6%
1994	4%	4%	4%	8%	6%	6%	6%
1995	4%	4%	4%	8%	6%	6%	6%
1996	4%	4%	4%	8%	6%	6%	6%
1997	4%	4%	4%	8%	6%	6%	6%

NOTES:

The data here are drawn from Table 5R.
Using information in the notes from the 'Classes and Rates' table, the following changeover years and before/after rates for the relevant property capital asset groups are:

Asset Group	Rate before	Rate after	Switch year
Industrial Buildings	10%	4%	1979
Commercial Buildings	5%	4%	1988
Oth Non-Res Buildings	10%	4%	1979
Transportation Structures	4%	8%	1976

Table 2bD. Capital Cost Allowance Rate Time Series, Other Capital, 1961-2000

	other capital (machinery and equipment): capital cost allowance rate								
	Computers Etc. 6002	Tractors/Field Equip 6011	Autos/Parts 6201	Trucks/Parts 6203	Oth Transport Equip 7001	Processing Equip 7002	Comm Equip 7003	Furniture 7004	Other Mach/Equip 7005
yr18	cca9	cca10	cca11	cca12	cca13	cca14	cca15	cca16	cca17
1961	8%	30%	30%	30%	30%	20%	8%	20%	20%
1962	8%	30%	30%	30%	30%	20%	8%	20%	20%
1963	8%	30%	30%	30%	30%	20%	8%	20%	20%
1964	8%	30%	30%	30%	30%	20%	8%	20%	20%
1965	8%	30%	30%	30%	30%	20%	8%	20%	20%
1966	8%	30%	30%	30%	30%	20%	8%	20%	20%
1967	8%	30%	30%	30%	30%	20%	8%	20%	20%
1968	8%	30%	30%	30%	30%	20%	8%	20%	20%
1969	8%	30%	30%	30%	30%	20%	8%	20%	20%
1970	8%	30%	30%	30%	30%	20%	8%	20%	20%
1971	8%	30%	30%	30%	30%	20%	8%	20%	20%
1972	8%	30%	30%	30%	30%	20%	8%	20%	20%
1973	8%	30%	30%	30%	30%	20%	8%	20%	20%
1974	8%	30%	30%	30%	30%	20%	8%	20%	20%
1975	8%	30%	30%	30%	30%	20%	8%	20%	20%
1976	30%	30%	30%	30%	30%	20%	8%	20%	20%
1977	30%	30%	30%	30%	30%	20%	8%	20%	20%
1978	30%	30%	30%	30%	30%	20%	8%	20%	20%
1979	30%	30%	30%	30%	30%	20%	8%	20%	20%
1980	30%	30%	30%	30%	30%	20%	8%	20%	20%
1981	30%	30%	30%	30%	30%	20%	8%	20%	20%
1982	30%	30%	30%	30%	30%	20%	8%	20%	20%
1983	30%	30%	30%	30%	30%	20%	8%	20%	20%
1984	30%	30%	30%	30%	30%	20%	8%	20%	20%
1985	30%	30%	30%	30%	30%	20%	8%	20%	20%
1986	30%	30%	30%	30%	30%	20%	8%	20%	20%
1987	30%	30%	30%	30%	30%	20%	8%	20%	20%
1988	30%	30%	30%	30%	30%	20%	8%	20%	20%
1989	30%	30%	30%	30%	30%	20%	8%	20%	20%
1990	30%	30%	30%	30%	30%	20%	8%	20%	20%
1991	30%	30%	30%	30%	30%	20%	8%	20%	20%
1992	30%	30%	30%	40%	30%	20%	8%	20%	20%
1993	30%	30%	30%	30%	30%	20%	8%	20%	20%
1994	30%	30%	30%	40%	30%	20%	8%	20%	20%
1995	30%	30%	30%	40%	30%	20%	8%	20%	20%
1996	30%	30%	30%	40%	30%	20%	8%	20%	20%
1997	30%	30%	30%	40%	30%	20%	8%	20%	20%

NOTES:

The data here are drawn from Table 5R.
Using information in the notes from the 'Classes and Rates' table, the following changeover years and before/after rates for the relevant other capital asset groups are:

Asset Group	Rate before	Rate after	Switch year
Computers, etc.	8%	30%	1976
Trucks/Parts	30%	40%	1992

Table 3aD. Tax Effects of Capital Cost Allowance in Current Year (Measured as Rate), Property Capital, 1961-1997

yr19	property capital (buildings, engineering construction): tax effect of capital cost allowance in current year as rate									
	Industrial Bldg 4001	Commercial Bldg 4002	Off Non-Res Bldg 4004	Transport 5002	Waterworks 5003	Sewage 5004	Oil and Gas 5007	Other 5009		
	ccat1	ccat2	ccat3	ccat4	ccat5	ccat6	ccat7	ccat8		
1961	5.1%	2.6%	5.1%	2.0%	3.1%	3.1%	3.1%	2.0%		
1962	5.2%	2.6%	5.2%	2.1%	3.1%	3.1%	3.1%	2.1%		
1963	5.2%	2.6%	5.2%	2.1%	3.1%	3.1%	3.1%	2.1%		
1964	5.2%	2.6%	5.2%	2.1%	3.1%	3.1%	3.1%	2.1%		
1965	5.2%	2.6%	5.2%	2.1%	3.1%	3.1%	3.1%	2.1%		
1966	5.2%	2.6%	5.2%	2.1%	3.1%	3.1%	3.1%	2.1%		
1967	5.1%	2.5%	5.1%	2.0%	3.1%	3.1%	3.1%	2.0%		
1968	5.1%	2.5%	5.1%	2.0%	3.1%	3.1%	3.1%	2.0%		
1969	5.2%	2.6%	5.2%	2.1%	3.1%	3.1%	3.1%	2.1%		
1970	5.3%	2.7%	5.3%	2.1%	3.2%	3.2%	3.2%	2.1%		
1971	5.1%	2.6%	5.1%	2.1%	3.1%	3.1%	3.1%	2.1%		
1972	4.9%	2.4%	4.9%	2.0%	2.9%	2.9%	2.9%	2.0%		
1973	4.2%	2.1%	4.2%	1.7%	2.5%	2.5%	2.5%	1.7%		
1974	4.2%	2.1%	4.2%	1.7%	2.5%	2.5%	2.5%	1.7%		
1975	4.2%	2.1%	4.2%	1.7%	2.5%	2.5%	2.5%	1.7%		
1976	4.1%	2.1%	4.1%	3.3%	2.5%	2.5%	2.5%	1.6%		
1977	4.0%	2.0%	4.0%	3.2%	2.4%	2.4%	2.4%	1.6%		
1978	4.1%	2.0%	4.1%	3.2%	2.4%	2.4%	2.4%	1.6%		
1979	1.6%	2.0%	1.6%	3.3%	2.5%	2.5%	2.5%	1.6%		
1980	1.6%	2.0%	1.6%	3.2%	2.4%	2.4%	2.4%	1.6%		
1981	1.7%	2.1%	1.7%	3.4%	2.5%	2.5%	2.5%	1.7%		
1982	1.6%	2.1%	1.6%	3.3%	2.5%	2.5%	2.5%	1.6%		
1983	1.6%	2.0%	1.6%	3.3%	2.5%	2.5%	2.5%	1.6%		
1984	1.6%	2.0%	1.6%	3.2%	2.4%	2.4%	2.4%	1.6%		
1985	1.5%	1.9%	1.5%	3.1%	2.3%	2.3%	2.3%	1.5%		
1986	1.6%	2.0%	1.6%	3.2%	2.4%	2.4%	2.4%	1.6%		
1987	1.6%	2.0%	1.6%	3.3%	2.4%	2.4%	2.4%	1.6%		
1988	1.6%	1.6%	1.6%	3.3%	2.5%	2.5%	2.5%	1.6%		
1989	1.5%	1.5%	1.5%	3.0%	2.2%	2.2%	2.2%	1.5%		
1990	1.5%	1.5%	1.5%	3.0%	2.3%	2.3%	2.3%	1.5%		
1991	1.5%	1.5%	1.5%	3.0%	2.2%	2.2%	2.2%	1.5%		
1992	1.5%	1.5%	1.5%	3.0%	2.3%	2.3%	2.3%	1.5%		
1993	1.5%	1.5%	1.5%	2.9%	2.2%	2.2%	2.2%	1.5%		
1994	1.4%	1.4%	1.4%	2.8%	2.1%	2.1%	2.1%	1.4%		
1995	1.4%	1.4%	1.4%	2.8%	2.1%	2.1%	2.1%	1.4%		
1996	1.4%	1.4%	1.4%	2.9%	2.1%	2.1%	2.1%	1.4%		
1997	1.4%	1.4%	1.4%	2.9%	2.1%	2.1%	2.1%	1.4%		

NOTES: These rates are computed using corporate tax rate data from Table 1D, CCA time series data from Table 2D and the investment tax credit rate data from Table 3R.
The rate is computed for each asset group as follows

Table 3bD. Tax Effects of Capital Cost Allowance in Current Year (Measured as Rate), Other Capital, 1961-1997

	other capital (machinery and equipment): tax effect of capital cost allowance in current year as rate									
	Computers Etc. 6002	Tractors/Field Equip 6011	Autos/Parts 6201	Trucks/Parts 6203	Oth Transport Equip 7001	Processing Equip 7002	Comm Equip 7003	Furniture 7004	Other Mach/Equip 7005	
y20	ccat9	ccat10	ccat11	ccat12	ccat13	ccat14	ccat15	ccat16	ccat17	ccat17
1961	4.1%	15.4%	15.4%	15.4%	15.4%	10.2%	4.1%	10.2%	10.2%	10.2%
1962	4.1%	15.5%	15.5%	15.5%	15.5%	10.3%	4.1%	10.3%	10.3%	10.3%
1963	4.1%	15.5%	15.5%	15.5%	15.5%	10.3%	4.1%	10.3%	10.3%	10.3%
1964	4.1%	15.5%	15.5%	15.5%	15.5%	10.3%	4.1%	10.3%	10.3%	10.3%
1965	4.1%	15.5%	15.5%	15.5%	15.5%	10.3%	4.1%	10.3%	10.3%	10.3%
1966	4.1%	15.5%	15.5%	15.5%	15.5%	10.3%	4.1%	10.3%	10.3%	10.3%
1967	4.1%	15.3%	15.3%	15.3%	15.3%	10.2%	4.1%	10.2%	10.2%	10.2%
1968	4.1%	15.3%	15.3%	15.3%	15.3%	10.2%	4.1%	10.2%	10.2%	10.2%
1969	4.1%	15.5%	15.5%	15.5%	15.5%	10.3%	4.1%	10.3%	10.3%	10.3%
1970	4.3%	15.9%	15.9%	15.9%	15.9%	10.6%	4.3%	10.6%	10.6%	10.6%
1971	4.1%	15.4%	15.4%	15.4%	15.4%	10.3%	4.1%	10.3%	10.3%	10.3%
1972	3.9%	14.7%	14.7%	14.7%	14.7%	9.8%	3.9%	9.8%	9.8%	9.8%
1973	3.3%	12.6%	12.6%	12.6%	12.6%	8.4%	3.3%	8.4%	8.4%	8.4%
1974	3.3%	12.6%	12.6%	12.6%	12.6%	8.4%	3.3%	8.4%	8.4%	8.4%
1975	3.4%	12.6%	12.6%	12.6%	12.6%	8.4%	3.4%	8.4%	8.4%	8.4%
1976	12.3%	12.3%	12.3%	12.3%	12.3%	8.2%	3.3%	8.2%	8.2%	8.2%
1977	12.1%	12.1%	12.1%	12.1%	12.1%	8.0%	3.2%	8.0%	8.0%	8.0%
1978	12.2%	12.2%	12.2%	12.2%	12.2%	8.1%	3.2%	8.1%	8.1%	8.1%
1979	12.3%	12.3%	12.3%	12.3%	12.3%	8.2%	3.3%	8.2%	8.2%	8.2%
1980	12.0%	12.0%	12.0%	12.0%	12.0%	8.0%	3.2%	8.0%	8.0%	8.0%
1981	12.7%	12.7%	12.7%	12.7%	12.7%	8.5%	3.4%	8.5%	8.5%	8.5%
1982	12.3%	12.3%	12.3%	12.3%	12.3%	8.2%	3.3%	8.2%	8.2%	8.2%
1983	12.3%	12.3%	12.3%	12.3%	12.3%	8.2%	3.3%	8.2%	8.2%	8.2%
1984	12.0%	12.0%	12.0%	12.0%	12.0%	8.0%	3.2%	8.0%	8.0%	8.0%
1985	11.5%	11.5%	11.5%	11.5%	11.5%	7.7%	3.1%	7.7%	7.7%	7.7%
1986	11.9%	11.9%	11.9%	11.9%	11.9%	8.0%	3.2%	8.0%	8.0%	8.0%
1987	12.2%	12.2%	12.2%	12.2%	12.2%	8.1%	3.3%	8.1%	8.1%	8.1%
1988	12.3%	12.3%	12.3%	12.3%	12.3%	8.2%	3.3%	8.2%	8.2%	8.2%
1989	11.2%	11.2%	11.2%	11.2%	11.2%	7.5%	3.0%	7.5%	7.5%	7.5%
1990	11.3%	11.3%	11.3%	11.3%	11.3%	7.5%	3.0%	7.5%	7.5%	7.5%
1991	11.2%	11.2%	11.2%	11.2%	11.2%	7.5%	3.0%	7.5%	7.5%	7.5%
1992	11.3%	11.3%	11.3%	11.3%	11.3%	7.6%	3.0%	7.6%	7.6%	7.6%
1993	10.9%	10.9%	10.9%	10.9%	10.9%	7.3%	2.9%	7.3%	7.3%	7.3%
1994	10.6%	10.6%	10.6%	10.6%	10.6%	7.1%	2.8%	7.1%	7.1%	7.1%
1995	10.6%	10.6%	10.6%	10.6%	10.6%	7.1%	2.8%	7.1%	7.1%	7.1%
1996	10.7%	10.7%	10.7%	14.3%	10.7%	7.1%	2.9%	7.1%	7.1%	7.1%
1997	10.7%	10.7%	10.7%	14.3%	10.7%	7.1%	2.9%	7.1%	7.1%	7.1%

NOTE: These rates are computed using corporate tax rate data from Table 1D, CCA time series data from Table 2D and the investment tax credit rate data from Table 3R.
The rate is computed for each asset group as follows

Table 4aD. Property Capital Observed Input Quantity, Food Processing Industry, 1961-2000

yr23	property capital (buildings, engineering construction): observed input ('000 1992 dollars)									
	Industrial Bldg 4001	Commercial Bldg 4002	Oth Non-Res Bldg 4004	Transport 5002	Waterworks 5003	Sewage 5004	Oil and Gas 5007	Other 5009		
	v1	v2	v3	v4	v5	v6	v7	v8		
1961	2385547	195970	77248	11046	3622	37286	5209	52652		
1962	2489723	205015	81243	11151	3663	37656	5123	53220		
1963	2603660	213877	84855	11358	3721	38118	5053	53794		
1964	2673694	220500	86965	11354	3674	37640	4966	53614		
1965	2778213	228795	90169	11311	3820	39107	4881	54251		
1966	2939466	240942	95266	11248	4088	41516	4834	55439		
1967	3067123	251433	99234	11573	4382	44040	4780	56341		
1968	3159987	259498	102024	11941	4512	45124	4727	57282		
1969	3256156	267631	104911	12147	4529	45115	4659	57676		
1970	3356954	275969	107934	12370	4677	46328	4576	58955		
1971	3471108	284580	111374	12578	4733	46791	4503	59370		
1972	3546398	290712	113237	12584	4880	48141	4407	59642		
1973	3641728	299221	116281	12549	5058	49775	4310	60162		
1974	3749419	308908	119768	12919	5322	52140	4218	61366		
1975	3826981	315304	121721	13252	5605	54694	4131	62589		
1976	3884101	321025	123076	13163	5859	56985	4058	62610		
1977	3983951	328871	125811	14525	6649	64257	3966	65793		
1978	4093297	337213	128932	14563	7012	67535	3876	66566		
1979	4255689	350273	133933	14338	6967	67005	3786	66575		
1980	4439180	365379	139912	14139	6891	66187	3735	66603		
1981	4549486	375189	142981	14295	7399	70811	3638	66920		
1982	4666074	383885	146201	14209	7617	72742	3592	67265		
1983	4715572	389960	147393	14019	7548	71969	3549	67000		
1984	4736660	394932	147751	13714	7438	70803	3491	66090		
1985	4806644	402572	149892	13601	7415	70471	3388	65912		
1986	4889050	411590	152530	13527	7347	69729	3373	66061		
1987	4967384	420772	155040	13704	7326	69392	3318	65850		
1988	5055343	431064	157952	14400	7213	68219	3224	68660		
1989	5149666	442725	161091	14433	7097	67019	3220	68275		
1990	5175616	450239	161798	14124	6936	65408	3123	67236		
1991	5251087	460080	164232	14115	6898	64961	3030	67580		
1992	5267498	466729	164799	13831	6934	65220	2984	66501		
1993	5255411	470401	164206	14192	6790	63782	2893	66522		
1994	5278032	474611	164881	15217	6754	63336	2808	69415		
1995	5272269	480794	164548	15210	6823	63894	2723	69517		
1996	5456905	496669	171057	15498	6639	63944	2641	71664		
1997	5494686	500421	166590	17180	6678	74044	2567	70388		

NOTE: These series are computed by dividing current dollar geometric end-year net stock data from Table 8aR with geometric end-year net stock deflator data from Table 8bR.

Table 4bD. Other Capital Observed Input Quantity, Food Processing Industry, 1961-2000

other capital (machinery and equipment): observed input ('000 1992 dollars)									
Computers Etc. 6002	Tractors/Field Equip 6011	Autos/Parts 6201	Trucks/Parts 6203	Oth Transport Equip 7001	Processing Equip 7002	Comm Equip 7003	Furniture 7004	Other Mach/Equip 7005	
v9	v10	v11	v12	v13	v14	v15	v16	v17	
507	4	70646	232525	70474	658334	35	35591	818055	
481	7	77068	233472	74342	691845	36	34609	841392	
460	9	85131	249527	82016	690652	38	33445	865171	
446	11	90491	260145	83426	717914	40	33455	884373	
440	12	97518	267262	86194	757010	41	33889	910160	
487	16	102487	273758	90124	829973	45	34876	945149	
533	19	105359	278938	96912	905025	48	36389	999538	
515	21	113304	275249	98808	933905	50	37652	1013751	
502	22	114271	279178	100910	957997	52	37924	1017753	
532	23	116956	282659	103142	997841	53	38579	1035658	
701	24	115518	287290	107502	999907	54	40574	1062147	
892	27	116117	295757	111906	1014378	57	43111	1086324	
1043	29	118793	323091	119383	1050444	63	48869	1122439	
1296	29	109454	341840	126318	1079837	67	50837	1178655	
1510	31	101699	376847	130738	1098857	70	55344	1211215	
1749	32	94771	401970	134248	1119712	74	58353	1230701	
1994	32	83347	425747	134119	1160877	77	63345	1240827	
2578	33	75654	440410	138602	1195741	80	69754	1271392	
3393	34	65506	476612	148701	1245290	84	76363	1326438	
6906	36	65006	506839	160532	1379847	93	86321	1412403	
8280	38	58055	493756	152702	1563440	345	91439	1344273	
10470	37	54670	463485	145283	1821970	557	96961	1283701	
13954	38	54614	427455	138279	2029371	730	101607	1216929	
17310	41	55330	400246	132549	2206879	877	106741	1154976	
21925	32	52402	365074	127060	2350832	1001	113173	1096672	
24676	47	45940	326304	117184	2569833	1098	121078	1007201	
33518	58	40256	282101	124840	2885721	2259	120966	930238	
38577	108	33654	244457	166895	3160587	2868	131713	869616	
48317	124	29651	209322	180743	3449347	3907	138514	846967	
69542	137	27735	171924	174498	3709742	6687	136460	792828	
89965	103	25618	148310	168143	3872544	7052	141654	774334	
134642	78	22017	133317	157602	4063711	7634	141525	733611	
168148	59	18379	119551	146802	4093651	7495	145818	724327	
202459	45	11949	120953	137866	4142254	7774	141432	710941	
212703	35	8560	116091	127665	4242611	12366	135789	698516	
286403	26	6993	103972	124089	4421858	20401	137773	665311	
343087	59	6730	84806	115926	4552154	18832	129375	627250	

NOTE: These series are computed by dividing current dollar geometric end-year net stock data from Table 9aR with geometric end-year net stock deflator data from Table 9bR.

Table 5D. Observed Quantities of Non-Capital Inputs and Gross Output, Food Processing Industry, 1961-1997

year	quantity in 1992 dollars				Gross Output Quantity (1992 dollars)
	Labour	Energy	Purchased & Intermediate Materials	Services	
yr27	vn1	vn2	vn3	vn4	y
1961	7074780	370831	11376776	2498192	20760816
1962	7076092	351396	11756500	2560665	21644867
1963	7021411	345591	12238286	2659387	22362914
1964	7225029	378352	13097813	2813156	23808194
1965	7354978	407909	13477676	2846199	24699754
1966	7453943	483404	13906838	2950428	25560217
1967	7697278	438161	14604148	3024560	26663740
1968	7715514	438650	14869936	3029298	27109071
1969	7514645	458902	15044503	3216468	27417503
1970	7486421	424260	15644672	3277650	28182954
1971	7410147	444014	15994513	3272836	29232187
1972	7410021	459548	16647230	3416623	30349485
1973	7384594	463204	16574835	3508829	30661959
1974	7266295	471935	17088356	3590719	31260213
1975	7224465	479998	17120631	3578565	30888777
1976	7138741	479295	18129643	3638659	33021148
1977	7193279	495487	18797750	3759713	34302566
1978	7322899	501499	19335120	3909570	35241706
1979	7415567	541706	19623241	4106653	35996624
1980	7348858	560901	20443762	4269954	36967463
1981	7134119	534685	20948780	4370538	37620666
1982	6867959	537336	20744412	4337854	37200965
1983	6690219	503537	20968714	4416649	37382306
1984	6570525	481770	21297523	4664448	38332120
1985	6792699	470393	21687235	4875810	39457699
1986	6931402	516603	21611643	5145514	39649353
1987	7059442	479128	22183520	5347411	40427410
1988	7223743	497321	22573977	5448919	40925489
1989	7242376	493735	22833721	5420546	40830027
1990	7027123	469865	22758075	5333691	40829889
1991	6820246	497776	22436928	5287291	40740304
1992	6861801	518196	22450139	5371054	41080465
1993	6739740	519848	22657888	5351393	41271568
1994	6812650	540847	22962686	5498978	42094328
1995	6786273	525584	23698862	5695077	43294054
1996	6968894	521642	24294554	6358648	44548285
1997	6933712	538035	24870903	6556219	45256270
ave63-97	7144200	483403	19246243	4295694	34990505

NOTE: Each input series is derived by dividing current dollar data (from Table 10R) by price data from (Table 2R). Gross output quantity is derived by dividing the current dollar value of output by the output price (both series are from Table 10R). 1963-1997 average for capital, EMS input used as b_i in estimation of SGM

**Table 6D. Derived Stocks of R&D Capital (Knowledge Spillovers),
Canadian Manufacturing (Excluding Food), Canadian
Federal Government, U.S. Food Processors, 1963-1997**

year	'000 1992 \$C		
	Canadian Manufacturing Excl. Food	Canadian Federal Government	U.S. Food Processors '000 1992\$US
yr30	s1	s2	s3
1963	2685329	4129221	3107645
1964	2869332	4310441	3205184
1965	3150520	4593134	3314622
1966	3419192	4904796	3376701
1967	3652850	5288710	3525477
1968	3814831	5733802	3571193
1969	3998290	6104382	3651837
1970	4190040	6565684	3856024
1971	4364964	7037047	4019281
1972	4491425	7422849	4155977
1973	4591511	7759966	4250120
1974	4729335	7998447	4356011
1975	4876268	8232703	4498105
1976	4995804	8477033	4599827
1977	5148346	8717958	4774411
1978	5397517	8972984	4985295
1979	5768391	9118005	5191477
1980	6231867	9283676	5444425
1981	6948462	9569125	5720530
1982	7667971	9938609	5847721
1983	8249432	10473662	6036763
1984	8910512	11176827	6274327
1985	9719408	11591685	6559201
1986	10464723	11987954	6870416
1987	11166410	12322160	7318439
1988	11813415	12635514	7610234
1989	12217285	12783334	7906532
1990	12520767	12850205	8192077
1991	12680391	12894156	8320289
1992	12784887	12958125	8458245
1993	12995735	12995429	8574647
1994	13432648	13010721	8768697
1995	13896343	12840869	8931172
1996	14262631	12592438	9058421
1997	14844365	12337422	9345121

NOTE: These stocks are calculated using data from Tables 13aR and 13bR.
Starting stocks are imputed using a 3% growth rate and decay rate of 0.15 along
with investment data for 1963 derived with data from Tables 13aR and 13bR.
The imputed 1962 stock values computed in this manner are:
2607116 for s1;
4008953 for s2; and
3017131 for s3.
For 1963 and later years, the perpetual inventory method is used
to calculate that year's stock.

**Table 7aD. Elements of Aggregate User Cost for Efficiency-Adjusted Capital Input,
Aggregate Acquisition Price for Energy, Materials and Services,
Canadian Food Processing Industry , 1961-1997**

year	all capital: weighted average capital cost allowance rate $\gamma_{N,t}$	all capital: weighted average decay rate $\delta_{N,t}$	all capital: weighted average tax effect of capital cost allowance rate $\tau_{N,t}$	property capital: weighted average decay rate $\delta_{P,t}$	all capital: Fisher Ideal aggregate acquisition price index (1992=1) $Q_{N,t}$	energy, materials & services: Fisher Ideal aggregate acquisition price index (1992=1)
1961	0.16028	0.09032	0.08205	0.01428	0.39658	0.24037
1962	0.16065	0.09048	0.08309	0.01425	0.39062	0.25117
1963	0.15953	0.08924	0.08250	0.01449	0.39281	0.25912
1964	0.16146	0.09050	0.08350	0.01426	0.40555	0.25676
1965	0.16069	0.08978	0.08312	0.01440	0.41811	0.26051
1966	0.15900	0.08818	0.08223	0.01478	0.43002	0.27477
1967	0.15807	0.08750	0.08058	0.01496	0.43937	0.27500
1968	0.15863	0.08773	0.08086	0.01488	0.43114	0.27790
1969	0.15792	0.08683	0.08150	0.01508	0.45597	0.29156
1970	0.15652	0.08553	0.08319	0.01535	0.46971	0.29829
1971	0.15429	0.08429	0.07921	0.01578	0.46929	0.30452
1972	0.15332	0.08409	0.07491	0.01591	0.48545	0.33515
1973	0.15014	0.08133	0.06283	0.01672	0.53364	0.41649
1974	0.14765	0.07921	0.06179	0.01729	0.59422	0.49423
1975	0.14771	0.07959	0.06032	0.01711	0.62843	0.53591
1976	0.15164	0.08021	0.06086	0.01689	0.63391	0.53032
1977	0.15248	0.08085	0.06136	0.01660	0.64211	0.56512
1978	0.15264	0.08123	0.06198	0.01647	0.63555	0.63863
1979	0.12380	0.08110	0.04967	0.01650	0.68024	0.73173
1980	0.11921	0.07835	0.04772	0.01729	0.68732	0.79223
1981	0.11727	0.07640	0.04959	0.01749	0.74665	0.86088
1982	0.11775	0.07620	0.04840	0.01727	0.79803	0.88203
1983	0.11945	0.07655	0.04890	0.01687	0.79294	0.88707
1984	0.12223	0.07773	0.04876	0.01630	0.81515	0.93755
1985	0.12278	0.07766	0.04724	0.01611	0.85081	0.93607
1986	0.12109	0.07606	0.04818	0.01629	0.88641	0.95377
1987	0.11954	0.07469	0.04967	0.01648	0.91705	0.97029
1988	0.11736	0.07327	0.04924	0.01678	0.94561	0.99599
1989	0.11683	0.07261	0.04515	0.01682	0.98760	1.00775
1990	0.11734	0.07278	0.04419	0.01666	1.00963	1.01220
1991	0.11859	0.07311	0.04439	0.01636	0.99610	0.99034
1992	0.12056	0.07358	0.04554	0.01618	1.00000	1.00000
1993	0.12192	0.07452	0.04422	0.01588	1.02555	1.05060
1994	0.12263	0.07488	0.04329	0.01574	1.06534	1.09608
1995	0.12288	0.07465	0.04342	0.01563	1.09931	1.13752
1996	0.12105	0.07358	0.04325	0.01588	1.12681	1.18061
1997	0.12056	0.07321	0.04303	0.01590	1.15408	1.19831

Notes: All Fisher Ideal aggregates computed with batch files in SHAZAM project:
food_aftax_aggr.shp

**Table 7bD. Aggregate Observed Inputs, Food Processing
and Aggregate Infrastructure Variables, 1961-1997**

year	all capital: Fisher Ideal aggregate observed quantity (‘000 \$1992) $\sum_{i=1}^n p_i x_{it}$	energy, materials, services: Fisher Ideal aggregate observed quantity (‘000 \$1992)	all infrastructure Fisher Ideal aggregate (‘000 \$1992)	transport, sewers infrastructure: Fisher Ideal aggregate (‘000 \$1992)
1961	3013628	14366190	60704463	47112608
1962	3149988	14803448	63073707	49932890
1963	3272273	15392390	67067197	52815457
1964	3372480	16441011	68264877	56083745
1965	3534112	16885321	72298710	59201567
1966	3787059	17519496	77056929	62485667
1967	3979066	18236287	79863591	65735892
1968	4097976	18488615	82908023	68668731
1969	4191521	18889261	86999755	71807054
1970	4355264	19518462	91013752	74880614
1971	4536809	19878021	96966124	78773128
1972	4673001	20730237	102144254	82862230
1973	4920380	20853596	108331438	86687026
1974	5392630	21484616	118629359	90258636
1975	5613730	21481111	124864577	93622029
1976	5891060	22479759	132633337	96471969
1977	6290339	23267805	141497483	99461224
1978	6890591	24010483	153445426	102367321
1979	7375183	24585564	161177501	105080521
1980	8204851	25579673	170832894	107554958
1981	8552153	26086400	179349203	110245405
1982	8872736	25771006	184224092	112615582
1983	9146748	25977031	189767607	114698624
1984	9302906	26529929	195030397	116583646
1985	9486606	27065194	200728813	119120741
1986	9710535	27348608	205339695	121549631
1987	10052199	28060948	210191711	123919969
1988	10408087	28586454	214968331	126177670
1989	10798167	28813433	220607949	128681454
1990	11022987	28576431	226253779	131333315
1991	11256725	28212717	231646255	134084326
1992	11448577	28339389	236838761	136697802
1993	11467599	28552786	241415759	139159870
1994	11545791	29044479	246542625	141846304
1995	11620536	29986766	251645222	144786257
1996	12021752	31243019	255842929	146982084
1997	12161604	32033669	259107869	148754393

Notes: aggregate observed quantity indexes computed using sum of the product of acquisition price (no tax) and observed quantities across items in the aggregate
All Fisher Ideal aggregates computed with batch files in SHAZAM project: food_aftax_aggr.shp

Table 8aD. Elements of Aggregate User Cost for Efficiency-Adjusted Capital Input, Aggregate Acquisition
Price for Energy, Materials and Services, Food Processing, 1961-1997

year	all capital: weighted average capital cost allowance rate $\gamma_{M,t}^w$	all capital: weighted average decay rate $\delta_{M,t}^w$	all capital: weighted average tax effect of capital cost allowance rate $\tau_{M,t}^w$	property capital: weighted average decay rate $\delta_{K,t}^p$	Fisher Ideal aggregate acquisition price index (1992=1) $Q_{M,t}^F$	all capital: aggregate after-tax acquisition price components (1992=1) $Q_{M,t}^A$	all capital: aggregate after-tax acquisition price calc. w. asset group after-tax prices (1992=1) $Q_{M,t}^I$	energy, materials services: Fisher Ideal aggregate acquisition price (1992=1)	energy, materials services: aggregate after-tax acquisition price (1992=1)
1961	0.1603	0.0903	0.0820	0.0143	0.3966	0.3165	0.3057	0.2404	0.1885
1962	0.1607	0.0905	0.0831	0.0142	0.3906	0.3102	0.3057	0.2512	0.1949
1963	0.1595	0.0892	0.0825	0.0145	0.3928	0.3118	0.3012	0.2591	0.2011
1964	0.1615	0.0905	0.0835	0.0143	0.4056	0.3208	0.3107	0.2568	0.1992
1965	0.1607	0.0898	0.0831	0.0144	0.4161	0.3312	0.3214	0.2605	0.2021
1966	0.1590	0.0882	0.0822	0.0148	0.4300	0.3441	0.3380	0.2748	0.2132
1967	0.1581	0.0875	0.0806	0.0150	0.4394	0.3578	0.3505	0.2750	0.2166
1968	0.1586	0.0877	0.0809	0.0149	0.4311	0.3547	0.3489	0.2779	0.2189
1969	0.1579	0.0868	0.0815	0.0151	0.4560	0.3760	0.3709	0.2916	0.2267
1970	0.1565	0.0855	0.0832	0.0153	0.4697	0.3825	0.3784	0.2983	0.2246
1971	0.1543	0.0843	0.0792	0.0158	0.4693	0.3874	0.3814	0.3045	0.2381
1972	0.1533	0.0841	0.0749	0.0159	0.4855	0.4123	0.4042	0.3352	0.2754
1973	0.1501	0.0813	0.0628	0.0167	0.5336	0.4881	0.4735	0.4165	0.3892
1974	0.1477	0.0792	0.0618	0.0173	0.5942	0.5468	0.5341	0.4942	0.4619
1975	0.1477	0.0796	0.0603	0.0171	0.6284	0.5658	0.5667	0.5359	0.5002
1976	0.1516	0.0802	0.0609	0.0169	0.6339	0.5553	0.5343	0.5303	0.4922
1977	0.1525	0.0808	0.0614	0.0166	0.6421	0.5596	0.5271	0.5651	0.5234
1978	0.1526	0.0812	0.0620	0.0165	0.6356	0.5524	0.5250	0.6386	0.5876
1979	0.1238	0.0811	0.0497	0.0165	0.6802	0.5980	0.5956	0.7317	0.6686
1980	0.1192	0.0784	0.0477	0.0173	0.6873	0.6156	0.6078	0.7922	0.7251
1981	0.1173	0.0764	0.0496	0.0175	0.7467	0.6715	0.6615	0.8609	0.7544
1982	0.1178	0.0762	0.0484	0.0173	0.7980	0.7226	0.7125	0.8820	0.7909
1983	0.1195	0.0765	0.0489	0.0169	0.7929	0.7067	0.7009	0.8871	0.7980
1984	0.1222	0.0777	0.0488	0.0163	0.8152	0.7317	0.7257	0.9376	0.8603
1985	0.1228	0.0777	0.0472	0.0161	0.8508	0.7648	0.7592	0.9361	0.8819
1986	0.1211	0.0761	0.0482	0.0163	0.8864	0.7838	0.7787	0.9538	0.8770
1987	0.1195	0.0747	0.0497	0.0165	0.9171	0.8241	0.8065	0.9703	0.8773
1988	0.1174	0.0733	0.0492	0.0168	0.9456	0.8745	0.8585	0.9960	0.9083
1989	0.1168	0.0726	0.0452	0.0168	0.9876	0.9781	0.9484	1.0078	0.9935
1990	0.1173	0.0728	0.0442	0.0167	1.0096	1.0139	1.0117	1.0122	1.0141
1991	0.1186	0.0731	0.0444	0.0164	0.9961	1.0000	0.9976	0.9903	0.9957
1992	0.1206	0.0736	0.0455	0.0162	1.0000	1.0000	1.0000	1.0000	1.0000
1993	0.1219	0.0745	0.0442	0.0159	1.0256	1.0333	1.0304	1.0506	1.0760
1994	0.1226	0.0749	0.0433	0.0157	1.0653	1.0803	1.0761	1.0961	1.1395
1995	0.1229	0.0747	0.0434	0.0156	1.0993	1.1117	1.1076	1.1375	1.1821
1996	0.1210	0.0736	0.0433	0.0159	1.1268	1.1349	1.1271	1.1606	1.2193
1997	0.1206	0.0732	0.0430	0.0159	1.1541	1.1608	1.1494	1.1983	1.2383

Notes: All Fisher Ideal aggregates computed with batch files in SHAZAM project:
food_altax_aggr.shp

**Table 8bD. Aggregate Observed Inputs, Food Processing
and Aggregate Infrastructure Variables, 1961-1997**

year	all capital: Fisher Ideal aggregate observed quantity (‘000 \$1992)	energy,materials, services:Fisher Ideal aggregate observed quantity (‘000 \$1992)	all infrastructure Fisher Ideal aggregate (‘000 \$1992)	transport, sewers infrastructure: Fisher Ideal aggregate (‘000 \$1992)
1961	3013628	14366190	60704463	47112608
1962	3149988	14803448	63073707	49932890
1963	3272273	15392390	67067197	52815457
1964	3372480	16441011	68264877	56083745
1965	3534112	16885321	72298710	59201567
1966	3787059	17519496	77056929	62485667
1967	3979066	18236287	79863591	65735892
1968	4097976	18488615	82908023	68668731
1969	4191521	18889261	86999755	71807054
1970	4355264	19518462	91013752	74880614
1971	4536809	19878021	96966124	78773128
1972	4673001	20730237	102144254	82862230
1973	4920380	20853596	108331438	86687026
1974	5392630	21484616	118629359	90258636
1975	5613730	21481111	124864577	93622029
1976	5891060	22479759	132633337	96471969
1977	6290339	23267805	141497483	99461224
1978	6890591	24010483	153445426	102367321
1979	7375183	24585564	161177501	105080521
1980	8204851	25579673	170832894	107554958
1981	8552153	26086400	179349203	110245405
1982	8872736	25771006	184224092	112615582
1983	9146748	25977031	189767607	114698624
1984	9302906	26529929	195030397	116583646
1985	9486606	27065194	200728813	119120741
1986	9710535	27348608	205339695	121549631
1987	10052199	28060948	210191711	123919969
1988	10408087	28586454	214968331	126177670
1989	10798167	28813433	220607949	128681454
1990	11022987	28576431	226253779	131333315
1991	11256725	28212717	231646255	134084326
1992	11448577	28339389	236838761	136697802
1993	11467599	28552786	241415759	139159870
1994	11545791	29044479	246542625	141846304
1995	11620536	29986766	251645222	144786257
1996	12021752	31243019	255842929	146982084
1997	12161604	32033669	259107869	148754393

Notes: aggregate observed quantity indexes computed using sum of the product of acquisition price (no tax) and observed quantities across items in the aggregate
All Fisher Ideal aggregates computed with batch files in SHAZAM project: food_aftax_aggr.shp

Table1E. Estimation Database (Prices), Food Processing Industry, 1961-1997

year	q_1	shr_1	itc	rho	xi_1	gam_1	del_1Nd	xi_3	del_1Nc	q_2	q_3	q_1L	q_2L	q_3L	one
1963	0.3928	0.4747	0.0000	0.0537	0.5172	0.1595	0.0145	0.0108	0.0892	0.1104	0.2591	0.3906	0.1056	0.2512	1
1964	0.4056	0.4670	0.0000	0.0550	0.5172	0.1615	0.0143	0.0107	0.0905	0.1147	0.2568	0.3928	0.1104	0.2591	1
1965	0.4181	0.4716	0.0000	0.0568	0.5172	0.1607	0.0144	0.0106	0.0898	0.1211	0.2605	0.4056	0.1147	0.2568	1
1966	0.4300	0.4837	0.0000	0.0650	0.5172	0.1590	0.0150	0.0105	0.0882	0.1313	0.2748	0.4181	0.1211	0.2605	1
1967	0.4394	0.4895	0.0000	0.0709	0.5098	0.1581	0.0150	0.0108	0.0875	0.1360	0.2750	0.4300	0.1313	0.2748	1
1968	0.4311	0.4871	0.0000	0.0792	0.5097	0.1586	0.0149	0.0113	0.0877	0.1435	0.2779	0.4394	0.1360	0.2750	1
1969	0.4560	0.4935	0.0000	0.0875	0.5161	0.1579	0.0151	0.0112	0.0868	0.1570	0.2916	0.4311	0.1435	0.2779	1
1970	0.4697	0.5022	0.0000	0.0918	0.5315	0.1565	0.0153	0.0107	0.0855	0.1683	0.2983	0.4560	0.1570	0.2916	1
1971	0.4693	0.5166	0.0000	0.0835	0.5134	0.1543	0.0158	0.0105	0.0843	0.1797	0.3045	0.4697	0.1683	0.2983	1
1972	0.4855	0.5214	0.0000	0.0830	0.4886	0.1533	0.0159	0.0108	0.0841	0.1960	0.3352	0.4693	0.1797	0.3045	1
1973	0.5336	0.5467	0.0000	0.0847	0.4185	0.1501	0.0167	0.0109	0.0813	0.2143	0.4165	0.4855	0.1960	0.3352	1
1974	0.5942	0.5655	0.0000	0.1017	0.4185	0.1477	0.0173	0.0098	0.0792	0.2496	0.4942	0.5336	0.2143	0.4165	1
1975	0.6284	0.5605	0.0258	0.1076	0.4191	0.1477	0.0171	0.0099	0.0796	0.2933	0.5359	0.5942	0.2496	0.4942	1
1976	0.6339	0.5534	0.0500	0.1048	0.4225	0.1516	0.0169	0.0106	0.0802	0.3384	0.5303	0.6284	0.2933	0.5359	1
1977	0.6421	0.5443	0.0500	0.0971	0.4236	0.1525	0.0166	0.0109	0.0808	0.3713	0.5651	0.6339	0.3384	0.5303	1
1978	0.6356	0.5400	0.0500	0.1010	0.4275	0.1526	0.0165	0.0108	0.0812	0.4000	0.6386	0.6421	0.3713	0.5651	1
1979	0.6802	0.5406	0.0700	0.1091	0.4314	0.1238	0.0165	0.0105	0.0811	0.4389	0.7317	0.6356	0.4000	0.6386	1
1980	0.6873	0.5658	0.0700	0.1328	0.4305	0.1192	0.0173	0.0099	0.0784	0.4919	0.7922	0.6802	0.4389	0.7317	1
1981	0.7467	0.5729	0.0700	0.1632	0.4547	0.1173	0.0175	0.0099	0.0764	0.5603	0.8609	0.6873	0.4919	0.7922	1
1982	0.7980	0.5659	0.0700	0.1586	0.4420	0.1178	0.0173	0.0105	0.0762	0.6271	0.8820	0.7467	0.5603	0.8609	1
1983	0.7929	0.5528	0.0700	0.1274	0.4402	0.1195	0.0169	0.0110	0.0765	0.6790	0.8871	0.7980	0.6271	0.8820	1
1984	0.8152	0.5339	0.0700	0.1350	0.4290	0.1222	0.0163	0.0111	0.0777	0.7173	0.9376	0.7929	0.6790	0.8871	1
1985	0.8508	0.5274	0.0700	0.1174	0.4137	0.1228	0.0161	0.0114	0.0777	0.7310	0.9361	0.8152	0.7173	0.9376	1
1986	0.8864	0.5331	0.0700	0.1036	0.4278	0.1211	0.0163	0.0112	0.0761	0.7577	0.9538	0.8508	0.7310	0.9361	1
1987	0.9171	0.5390	0.0500	0.1071	0.4374	0.1195	0.0165	0.0110	0.0747	0.7841	0.9703	0.8864	0.7577	0.9538	1
1988	0.9456	0.5489	0.0300	0.1093	0.4325	0.1174	0.0168	0.0111	0.0733	0.8232	0.9960	0.9171	0.7841	0.9703	1
1989	0.9876	0.5497	0.0000	0.1081	0.3865	0.1168	0.0168	0.0124	0.0726	0.8551	1.0078	0.9456	0.8232	0.9960	1
1990	1.0096	0.5446	0.0000	0.1191	0.3766	0.1173	0.0167	0.0131	0.0728	0.9088	1.0122	0.9876	0.8551	1.0078	1
1991	0.9961	0.5347	0.0000	0.1080	0.3744	0.1186	0.0164	0.0139	0.0731	0.9526	0.9903	1.0096	0.9088	1.0122	1
1992	1.0000	0.5288	0.0000	0.0990	0.3777	0.1206	0.0162	0.0147	0.0736	1.0000	1.0000	0.9961	0.9526	0.9903	1
1993	1.0256	0.5192	0.0000	0.0885	0.3627	0.1219	0.0159	0.0150	0.0745	1.0188	1.0506	1.0000	1.0000	1.0000	1
1994	1.0653	0.5146	0.0000	0.0944	0.3530	0.1226	0.0157	0.0149	0.0749	1.0158	1.0961	1.0256	1.0188	1.0506	1
1995	1.0993	0.5109	0.0000	0.0902	0.3533	0.1229	0.0156	0.0148	0.0747	1.0397	1.1375	1.0653	1.0158	1.0961	1
1996	1.1268	0.5192	0.0000	0.0811	0.3573	0.1210	0.0159	0.0144	0.0736	1.0389	1.1806	1.0993	1.0397	1.1375	1
1997	1.1541	0.5198	0.0000	0.0695	0.3569	0.1206	0.0159	0.0143	0.0732	1.0513	1.1983	1.1268	1.0389	1.1806	1

Table2E: Estimation Database (Non-Price Variables), Food Processing Industry, 1961-1997

year2	v_1	v_2	v_3	v_1L	v_2L	v_3L	y	g_1	g_2	s_1	s_2	s_3	t
1963	3272273	7021411	15392390	3149988	7076092	14803448	22362914	0.2832	0.3864	0.2100	0.3187	0.3674	1
1964	3372480	7225029	16441011	3272273	7021411	15392390	23808194	0.2682	0.4103	0.2244	0.3326	0.3789	2
1965	3534112	7354978	16885321	3372480	7225029	16441011	24699754	0.3053	0.4331	0.2464	0.3545	0.3919	3
1966	3787059	7453943	17519496	3534112	7354978	16885321	25560217	0.3254	0.4571	0.2674	0.3785	0.3992	4
1967	3979066	7637278	18236287	3787059	7453943	17519496	26663740	0.3372	0.4809	0.2857	0.4081	0.4168	5
1968	4097976	7715514	18488615	3979066	7637278	18236287	27109071	0.3501	0.5023	0.2984	0.4425	0.4222	6
1969	4191521	7514645	18889261	4097976	7715514	18488615	27417503	0.3673	0.5253	0.3127	0.4711	0.4317	7
1970	4352624	7486421	19518482	4191521	7514645	18889261	28182354	0.3843	0.5478	0.3277	0.5067	0.4559	8
1971	4538809	7410147	19878021	4352624	7486421	19518482	29232187	0.4094	0.5763	0.3414	0.5431	0.4752	9
1972	4673001	7410021	20730237	4538809	7410147	19878021	30349485	0.4313	0.6062	0.3513	0.5728	0.4914	10
1973	4920380	7384594	20853596	4673001	7410021	20730237	30661959	0.4574	0.6342	0.3591	0.5988	0.5025	11
1974	5392630	7266295	21484616	4920380	7384594	20853596	31260213	0.5009	0.6603	0.3699	0.6173	0.5150	12
1975	5613730	7224465	21481111	5392630	7266295	21484616	30888777	0.5272	0.6849	0.3814	0.6353	0.5318	13
1976	5891060	7138741	22479759	5613730	7224465	21481111	33021148	0.5600	0.7057	0.3908	0.6542	0.5438	14
1977	6290339	7193279	23267805	5891060	7138741	22479759	34302566	0.5974	0.7276	0.4027	0.6728	0.5645	15
1978	6890591	7322899	24010483	6290339	7193279	23267805	35241706	0.6479	0.7489	0.4222	0.6925	0.5894	16
1979	7375183	7415567	24585564	6890591	7322899	24010483	35996624	0.6805	0.7687	0.4512	0.7037	0.6138	17
1980	8204851	7348858	25579673	7375183	7415567	24585564	36967463	0.7213	0.7868	0.4874	0.7164	0.6437	18
1981	8552153	7134119	26086400	8204851	7348858	25579673	37620666	0.7573	0.8065	0.5435	0.7385	0.6763	19
1982	8872736	6867959	25771006	8552153	7134119	26086400	37200965	0.7778	0.8238	0.5998	0.7670	0.6914	20
1983	9146748	6690219	25977031	8872736	6867959	25771006	37382306	0.8013	0.8391	0.6452	0.8083	0.7137	21
1984	9302906	6570525	26529929	9146748	6690219	25977031	38332120	0.8235	0.8529	0.6970	0.8625	0.7418	22
1985	9486606	6792699	27065194	9302906	6570525	26529929	39457699	0.8475	0.8714	0.7602	0.8945	0.7755	23
1986	10052199	6931402	27348608	9486606	6792699	27065194	39649353	0.8670	0.8892	0.8185	0.9251	0.8123	24
1987	1052199	7059442	28060948	9710535	6931402	27348608	40427410	0.8875	0.9065	0.8734	0.9509	0.8652	25
1988	1048087	7223743	28586454	10052199	7059442	28060948	40925489	0.9077	0.9230	0.9240	0.9751	0.8997	26
1989	10798167	7242376	28813433	10408087	7223743	28586454	40830027	0.9315	0.9414	0.9556	0.9865	0.9348	27
1990	11022987	7027123	28576431	10798167	7242376	28813433	40829889	0.9553	0.9608	0.9793	0.9917	0.9685	28
1991	11256725	6820246	28212717	11022987	7027123	28576431	40740304	0.9781	0.9809	0.9918	0.9951	0.9837	29
1992	11448577	6861801	28339389	11256725	6820246	28212717	41060465	1.0000	1.0000	1.0000	1.0000	1.0000	30
1993	11467599	6739740	28552786	11448577	6861801	28339389	41271568	1.0193	1.0180	1.0165	1.0029	1.0138	31
1994	11545791	6812650	29044479	11467599	6739740	28552786	42094328	1.0410	1.0377	1.0507	1.0041	1.0367	32
1995	11620536	6786273	29986766	11545791	6812650	29044479	43294054	1.0625	1.0592	1.0869	1.0559	1.0559	33
1996	12021752	6968894	31243019	11620536	6786273	29986766	44548285	1.0802	1.0752	1.1156	0.9718	1.0710	34
1997	12161604	6933712	32033669	12021752	6968894	31243019	45256270	1.0940	1.0882	1.1611	0.9521	1.1049	35