THE UNIVERSITY OF CALGARY

The Use of Tax Reforms in Evaluating the Effects of Taxation on Investment

by

James Townsend

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF ARTS

DEPARTMENT OF ECONOMICS

CALGARY, ALBERTA

AUGUST, 1995

THE UNIVERSITY OF CALGARY

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Use of Tax Reforms in Evaluating the Effects of Taxation on Investment" submitted by James Townsend in partial fulfillment of the requirements for the degree of Master of Arts.

Ken McKenzie

Supervisor, Dr. Kenneth J. McKenzie, Economics

Daniel V Gordon

Dr. Daniel V. Gordon, Economics

Michael Robinson

Dr. Michael Robinson, Management

Sept 7/95

Date

Abstract

A neoclassical investment model based upon the work of Auerbach and Hassett (1991) and Cummins and Hassett (1992) is estimated using Canadian data. A two-step procedure is used to overcome the problem of measuring the user cost perceived by firms due to uncertainty regarding future tax parameters. Auerbach and Hassett take advantage of the "natural experiment" provided by the American 1986 Tax Reform Act, after which, they argue, the user cost of capital is measurable to the econometrician due to the "permanent" nature of the reform. Canada underwent a similar tax reform in 1987, suggesting that a similar approach may be used to assess the impact of taxation on investment in a Canadian setting. Estimates are performed using firm-level panel data from the Compustat Industrial file and suggest that investment is much more responsive to taxes in Canada, perhaps implausibly so. Possible problems with the methodology are discussed.

Acknowledgments

I would like to thank Dr. Ken McKenzie, my supervisor, for his assistance and support.

I would also like to thank Dr. Herb Emery. I am grateful for his guidance and support over the last two years.

Dedications

To my parents.

Table Of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

1.1 Investment and Taxation

Many economists believe business investment in plants and equipment has important short- and long-run effects on the economy. Investment expenditures (the sum of expenditures on residential construction, business inventories and business fixed capital) make up a small but extremely volatile component of gross domestic product (GDP) in most industrialized countries. This volatility is believed to have important implications for the business cycle. In macroeconomic models, changes in investment lead to changes in aggregate demand, which may in turn lead to lower levels of output and employment. Spillover effects may then occur if changes in employment lead to additional changes in consumer demand. An understanding of investment behaviour may thus be a prerequisite to understanding the business cycle. In terms of long-run economic considerations, the size of the capital stock has long been associated with overall economic well-being. The size of a nation's capital stock is thought to be an important determinant of that nation's productive capacity. In Robert Solow's (1956) optimal growth model, Solow explicitly linked the per capita income of members of an economy to the per capita capital stock. In so far as investment in fixed capital represents the mechanism by which fixed capital is accumulated within an economy, an understanding of investment may be important in understanding long-term determinants of growth and national income within a country and in understanding differences in the standard of living between countries.

Federal and provincial governments in Canada have initiated numerous tax-based policies in an attempt to influence either short- or long-term investment behaviour on the part of business. Federal investment tax credits have been used in efforts at promoting regional development in the Atlantic provinces and Cape Breton. Investment tax credits have been used to encourage capital formulation in the manufacturing and processing industries. The federal government has also used corporate tax policy as a tool of stabilization policy. Corporate surtaxes have been dropped or scraped during economic slumps in an effort to promote business investment.

Taxation policy is shaped by considerations other than influencing levels of investment. The necessity of generating tax revenues and efforts at developing an equitable tax system have no doubt played an important role in shaping the corporate tax system. Nonetheless, it is clear that governments believe that they can influence investment behaviour through tax policy. This belief is partially rooted in economic theory. Theories of investment developed in the last 30 years or so have provided explicit relationships between tax variables and firm investment decisions. Of these, the most widely used is the neoclassical theory of investment. Yet despite an extensive literature on the theoretical effects of taxation on investment, most efforts at finding empirical verification of the theory have either failed to produce significant support for the premise that taxation can affect investment or have found that at best tax policy can have weak effects on investment.

1.2 Tax Reforms As Natural Experiments

The 1986 Tax Reform Act (TRA86) resulted in a major restructuring of the U.S. corporate tax system. Corporate tax rates were dropped, while the write-off lives for most capital assets were extended, reducing the tax savings realizable through depreciation allowances. At the time many believed, on the basis of neoclassical theory, that the changes would lead to decreased business investment. It was thus predicted that investment in fixed capital would fall in years subsequent to the tax reform. Contrary to expectations, investment in equipment and machinery increased as a share of GDP. Investment in buildings fell after the reform, despite beliefs that such assets had gained a favorable tax treatment with respect to equipment and machinery with the TRA. Based on this outcome, a number of economists were compelled to question the validity of existing investment theory.

Alan Auerbach and Kevin Hassett (1991) took advantage of the TRA as a natural experiment from which to evaluate the predictions of neoclassical theory. They argue that there are determinants of investment other than taxation and that prior to the tax reform investment in equipment and machinery was booming while investment in buildings was declining. They go on to argue that the tax reform did discourage investment; as a consequence of the tax change the boom was smaller than it might have been without the reform. To arrive at this result they used an innovative two-stage regression technique which allowed them to eliminate measurement errors in firm expectations prior to the reform. The present value of tax savings arising from depreciation allowances depends on future values of inflation and tax parameters. As these variables generally cannot be known with certainty at the time investment decisions are made, firms must base their decisions on expectations of these variables. The applied researcher generally cannot observe these expectations, and as such computations of these tax savings will consist of guesses which by necessity will differ by some error from the actual values firms use to make decisions. If such variables are then used as independent variables in a regression model of investment, the measurement errors will result in inconsistent estimates of the relevant parameters.

Auerbach and Hassett argue that after the reform the observation of expectations of future tax parameters was not a problem, as TRA86 was a major reform and further changes in the corporate tax system were thus not expected for some time. Auerbach and Hassett argue that after the reform firms and researchers alike know all the relevant tax parameters, and variables such as the tax savings due to depreciation that are computed after the tax reform are not likely to contain any great measurement errors. The two-stage technique they use allows them to use pre-reform data to estimate all parameters in the model except the coefficient of the tax term. Post-reform data can then be used to estimate the tax parameter alone, which results in a more precise measure of the tax coefficient than would result if post-reform data was used to estimate all of the parameters in the model.

In the 1987 Budget, the Canadian government introduced a tax reform very similar to TRA86. Statutory tax rates were dropped and depreciation lifetimes of assets extended. Measures were taken to broaden the number of firms paying taxes in a given year. Given that the 1987 tax reform parallels TRA86 in many aspects, the methodology of Auerbach and Hassett should be applicable to the 1987 Canadian tax reform. In this thesis, Canadian firm level data is used in connection with the 1987 tax reform to estimate an investment model similar to that of Auerbach and Hassett. This is very similar to the approach used by Cummins and Hassett (1992), in which the two-stage technique is applied to American firm level data. Resulting estimates are then compared with those of Auerbach and Hassett, and of Cummins and Hassett. It is also argued that there may be problems with the methodology employed by Auerbach, Cummins and Hassett that do not appear to have been fully recognized to date.

1.3 A Brief Overview

In chapter 2, the neoclassical model of investment is introduced. The neoclassical model, pioneered by Dale Jorgenson (1963), links the firm's investment decisions to an explicit dynamic optimization problem. The firm optimizes its net present value of cash flows by choosing the capital stock in each period so that the marginal product of capital equals the user cost of capital. The user cost of capital measures the cost to the firm of holding a physical asset for a single period and takes into account the cost of finance (through the required rate of return by shareholders and debt holders), the effects of depreciation and capital gains, and any effects that the corporate tax system may have on the purchase price and net return of capital. As will be noted, the neoclassical model is really a model of the optimal capital stock rather than of investment, as the dynamics of capital accumulation are not explicitly incorporated into the firm's optimization problem. A discussion on incorporating dynamics into the Jorgensonian model is deferred to chapter 3.

A number of problems with the neoclassical formulation have been pointed out, and these are also discussed in chapter 2. In the neoclassical model, investment decisions are treated as reversible, so that firms always have the option to sell capital goods and recover a significant portion of their original investment. There are numerous reasons to believe that this is not the case for many real world investment decisions. Section 3.6 provides a discussion on why investment decisions may not be fully reversible and mentions briefly possible implications of irreversibility on the investment decision.

In chapter 3, some of the attempts at finding empirical support for the neoclassical model are discussed. Studies have differed primarily in their treatments of dynamics and firm expectations. Using the terminology of Chirinko (1993), model dynamics have either been explicitly or implicitly introduced into the model. In implicit models, the dynamics of investment arise through *ad hoc* assumptions about lags between the time capital goods are ordered and the time they are received. Explicit models introduce dynamic elements directly into the firm's optimization problem. The usual approach is to assume that there are costs to the firm that result from adjusting the size of the capital stock and that these costs encourage the firm to change its capital stock only gradually.

The value of tax savings resulting from depreciation allowances depends on future values of tax parameters and inflation. Generally, future values of economic variables can not be known with certainty, so firms must base their investment decisions on expectations about the future. Various approaches have been taken in modeling the way that these expectations are formed, ranging in complexity from static expectations, where agents expect future values of a variable to be the same as the current variable, to rational expectations, where agents use all currently available information and a sound understanding of the workings of the economy to forecast future values of the variable that are on average the correct values. The shortcomings and implementation of various approaches at incorporating different models of expectations into investment models is discussed in section 3.4.

As was noted above, Auerbach and Hassett (1991) and Cummins and Hassett (1992) were able to find statistically and economically significant effects on taxation by using TRA86 as a natural experiment. Any economic study concerned with the effects of taxation on behaviour requires change, so that the response of economic agents to the change can be observed and possibly measured. A tax reform will generate this necessary change. Auerbach and Hassett also argue that the 1986 reform was a major reform and was expected to be long-lasting. As such, everyone knew what values tax parameters were going to last far into the future. Since everyone knows what the tax parameters will be in the future, it is no longer necessary to introduce a model of expectations that may lead to predictions about expectations that are much different from those of actual economic agents. Section 3.5 provides an extensive discussion on the methodology and results of Auerbach and Hassett and Cummins and Hassett.

Although capital is well-defined in models of firm behaviour, it is often difficult to produce measures of real world capital stock in terms that are consistent with economic models. Chapter 3 ends with a brief discussion on "real world" measures of capital and argues that these measures may not be consistent with those suggested by economic theory. Reasons include the lack of equivalency between different vintages of capital and difficulty in finding units with which to measure capital.

Chapter 4 provides a discussion of the sources that were used and the calculations that were necessary to construct the data set. Data for Canadian firms from Compustat was reported at a higher level of aggregation than that of American firms. As a consequence, a number of strong implicit assumptions are made in using such data. In particular, one precludes the possibility of substituting between the use of different assets in the productive process as relative tax treatments change. Tax variables are computed for firms using figures on industrial averages for tax parameters and the composition of assets. As will be noted, such computations make the implicit assumption that firms are representative of the industry as a whole; otherwise such computations will not accurately represent the tax variables that the firm actually faces and uses in making investment decisions.

Computations of the relevant tax parameters suggest that the changes resulting from the 1987 tax reform were quite modest. This suggests that the tax reform may not have had a large effect on investment, so that it may not be possible to use the reform to identify the effects of taxation on investment.

Chapter 5 presents and discusses the empirical results. Depending on first-stage model specifications, a statistically significant effect of taxation on investment was found only for firms in the manufacturing sector. Estimates seem to indicate that investment by such firms is much more responsive to changes in the tax system than is indicated in the research of either Cummins and Hassett, or Auerbach and Hassett. However, the degree of sensitivity is so high that there is reason to believe the estimates are implausible. Manufacturing firms are then used to estimate a model in which *ex post* measures of the pre-reform values of the tax parameter are used as proxies for the values actually used by firms in making decisions. Estimates of the tax coefficient tend to be closer to those found in the two previous works. However, with the exception of two specifications these estimates are not statistically significant. Chapter 5 concludes with discussions on why results may have differed from those found in the earlier research and on possible problems with the general estimation strategy.

Chapter 6 presents a summary of the methodology that was used and the results that were found using Canadian data. Suggestions are then provided for future research in the area.

CHAPTER 2: NEOCLASSICAL INVESTMENT THEORY

2.1 Introduction

In an attempt to understand the determinants of business fixed investment, economists have developed numerous models. These have included the accelerator model, in which the optimal level of capital is a fixed fraction of output, the cash flow model, in which the firm's internal cash flow is the predominant determinant of investment, the neoclassical model, in which the desired capital stock follows from a well-defined optimization problem and is determined by a variety of price variables, and Tobin's q model, in which the optimal capital stock is related to firm value. The neoclassical model has become the dominant model used by economists and policy makers in evaluating investment behavior because it follows from an explicit optimization problem and because it links the optimal capital stock explicitly to price variables such as tax parameters.

In this chapter, the neoclassical model of investment is derived and discussed. In section 2, a simple formulation of the model is presented, in which the firm faces no corporate taxation. The implicit assumptions of this formulation are noted and the conditions for the firm's optimal capital stock are derived and discussed. In section 3, a simple corporate tax system is introduced into the firm's optimization problem. In section 4, the tax system is broadened so as to allow the deductibility of interest payments from income. In section 5, risk is introduced into the model. Section 6 consists of a list of reasons that investment may be irreversible and a discussion on the possible implications of this irreversibility.

2.2 The Neoclassical Model of Investment

The neoclassical model of investment was introduced by Dale Jorgenson (1963) and has been used widely to analyze the effects of taxation on investment decisions. In the neoclassical framework[1], a firm combines K units of a capital good and L units of a variable input (labour) to produce output according to a convex production function, F(K,L). Output is sold at price p, where p is the price of the firm's output relative to the general price level in the economy. The firm may also purchase new capital goods at a price q and employ labour at a price w (where both are again relative prices). In both the input and output markets, the firm is assumed to be a price-taker. In the absence of taxes, the period t cash flow of the firm is

$$\pi_t = p_t F(K_t, L_t) - q_t I_t - w_t L_t \tag{2.1}$$

where I_t is gross investment.

Capital is assumed to wear out or become obsolete over time and it is recognized that a portion of investment involves replacing this worn out or obsolete capital equipment. Capital depreciation may be modeled in a number of ways, but the most common method is to assume that the capital stock undergoes geometric depreciation. Thus at the end of each period δK_t of the capital stock has worn out, where δ is the physical rate of depreciation (a number between zero and one). Under this depreciation scheme, a unit of capital that is t periods old will provide the equivalent service of $(1-\delta)^t$ units of new capital. As a consequence, it will also have the same value as $(1-\delta)^t$ units of new capital. For simplicity, a continuous time framework will be used for the remainder of this chapter. The capital stock at time t is given by:

$$K(t) = \int_0^t e^{-\delta(t-s)} I_s ds \tag{2.2}$$

Differentiating (2.2) with respect to t results in the following expression:

$$\dot{K} = I - \delta K \tag{2.3}$$

Expression (2.3) is the capital accumulation equation of the firm. It may be rewritten as:

$$I = \dot{K} + \delta K \tag{2.4}$$

---

1 The exact formulation of the neoclassical model seems to depend on the researcher (see for example Jorgenson (1963) and Boadway (1989)). Differences appear when the corporate tax system is introduced. The derivation presented here follows closely that of Auerbach (1983) and results in a user cost of capital term that is consistent with that used by Auerbach and Hassett (1991).

where $\dot{K}$ is net investment and δK is replacement investment.

Under certain well understood conditions, the optimization of the stakeholders' utility is consistent with the firm choosing investment and labour at each time so as to maximize the present value of the firm's cash flow over its lifetime:

$$\max_{\{I,L\}_t^{\infty}} V(t) = \int_t^{\infty} e^{-r(s-t)}[pF(K) - qI - wL]ds \qquad (2.5)$$

subject to the capital accumulation equation (2.4). r is the real cost of finance. The appropriate choice of r will depend on the financing opportunities of the firm . A firm may finance new investment in one of two ways. Bonds may be sold that pay a nominal rate of return i. Alternatively, the firm may retain earnings or issue new shares to finance new investment. In this case, the cost of finance will equal ρ, which is the shareholders' required nominal rate of return. If a firm finances a fraction of new investment β through debt financing and the remainder through equity financing, then the real cost of finance to the firm is:

$$r = \beta i + (1-\beta)\rho - \pi^e \qquad (2.6)$$

where π^e is the expected rate of inflation.

The firm's problem may be solved using techniques of dynamic optimization. For the problem specified by (2.4) and (2.5), the following Euler conditions must be satisfied at the optimum:

$$pF_L(K^*, L^*) = w \qquad (2.7a)$$

and

$$\rho F_K(K^*, L^*) = q(r + \delta - \frac{\dot{q}}{q}) \qquad (2.7b)$$

Equations (2.7a) and (2.7b) have familiar economic interpretations. Equation (2.7a) states that the firm should hire labour until the marginal product of labour exactly equals the cost of employing the marginal unit, which is the wage rate. Equation (2.7b) has a similar interpretation, stating the capital services should be employed until the marginal product of capital exactly equals the cost of employing that marginal unit. The right-hand side of equation (2.7b) is known as the user cost of capital. The firm wishes to hold a capital stock such that the return on the last unit of capital is just sufficient to cover the sum of the return r that the stakeholders require on an investment and the loss to the firm resulting from the economic depreciation of the physical asset, which is the physical rate of depreciation less the capital gain $\delta - \dot{q} / q$.

With the addition of an explicit production function, equations (2.7a) and (2.8b) can be used to find expressions that link capital and labour demand to the user cost of capital, the going wage rate, and technological parameters. Although capital and labour demand are determined simultaneously, it can been seen from equations (2.7a) and (2.7b) that given the assumptions made about the production technology that:

(i) the demand for either factor will increase as the relative price of output p increases;

(ii) the demand for either factor will decrease as the relative price of that input (the wage or the user cost of capital) increases; and

(iii) technological changes that increase the marginal product of a factor at a given level of employment will increase the demand for that capital good.

It is important to note also that investment decisions depend only on current conditions, since it is implicitly assumed that:

(a) the capital stock can be adjusted instantaneously. At any given time, the firm can adjust its capital stock to any level it desires; and

(b) investment is reversible, i.e., perfect markets exist for used capital and the firm can always sell any capital that it no longer desires on this market at cost.

As a consequence of these assumptions, capital is like labour, in that it is a variable input, the value of which may be selected independently each period.

Within this framework, investment consists of an instantaneous adjustment between capital stocks. Instantaneous adjustment is clearly not realistic, leading many to refer to the model presented above as a model of capital demand. Equations (2.7a) and (2.7b) do, however, provide some insight into some of the economic reasons that a firm may wish to adjust its capital stock. In particular, the desired capital stock depends on various prices (the interest rate and the prices of inputs and outputs), the rate of depreciation, and the existing technology.

To go from (2.7b) to an empirically testable model of investment requires the introduction of some dynamic elements. Common approaches include assuming that delivery lags result in partial adjustment according to some specified lag structure or introducing adjustment costs that force the firm to adjust its capital stock slowly. A full discussion on introducing dynamics into the neoclassical model is deferred to Chapter 3.

2.3 Taxes and the User cost of Capital

With several simplifying assumptions, the basic elements of a corporate tax system may be introduced into the neoclassical framework. A corporate income tax, a depreciation allowance and an investment tax credit (ITC) can all be readily introduced. It is possible to allow for the tax deductibility of interest payments as well. With the addition of a statutory tax rate τ and an ITC k_t, the firm's one period cash flow is:

$$\pi_t = (1-\tau)[pF(K,L) - wL] - qI + kI \tag{2.8}$$

If one also allows for a depreciation allowance and assumes that the firm will always be in a tax-paying position, and therefore always be able to claim those allowances, then the present discounted value of depreciation allowances for an asset purchased for one dollar in period s is:

$$\Gamma'(s) = \int_s^\infty e^{-(r+\pi)(u-s)} \tau_u D_u(u-s)du \tag{2.9}$$

where $D_u(u\text{-}s)$ is the period u write-off allowed for an asset of age u-s. Since such allowances are based on the nominal purchase price of the asset, the inflation rate must be added to get the appropriate discount rate. Letting $\Gamma=\Gamma'+k$, (2.8) may be rewritten as

$$\pi_t = (1-\tau)(pF(K,L) - wL) - (q-\Gamma)I \tag{2.10}$$

The firm's problem is again to maximize the net present value of cash flows

$$V(t) = \max_{\{i\}_t^\infty} \int_t^\infty e^{-r(s-t)}[(1-\tau)pF(K,L) - (q-\Gamma)I]ds \tag{2.11}$$

subject to the capital accumulation equation (2.4). From the resulting Hamiltonian, the following Euler conditions must hold at the optimum:

$$pF(K^*,L^*) = w \tag{2.12a}$$

$$pF(K^*,L^*) = q(1-\Gamma)[r+\delta - \frac{d(q(1-\Gamma))}{dt} / (q(1-\Gamma))] / (1-\tau) \tag{2.12b}$$

Equation (2.12a) is identical to (2.7a). The right-hand side of (2.12b) is the tax modified user cost of capital. Taxes have two major effects on the user cost of capital. Depreciation allowances and an ITC effectively lower the acquisition price of the asset that the firm faces from q to $q(1-\Gamma)$. Given the assumptions about the production function, this suggests that as depreciation allowances or the ITC are made more generous, capital accumulation will increase. The statutory tax requires that the marginal product associated with the last unit of capital be higher, since the revenue from the last unit of capital must now cover taxes, in addition to the stakeholders' required return and the economic depreciation of the capital asset. As such, as the statutory tax rate rises, a higher product from the last unit of capital is required. The term $(d[q(1-\Gamma)]/dt)/[q(1-\Gamma)]$ measures the effective capital gains of the asset. To see this, consider a firm which is about to purchase a unit of a capital good. If the firm purchased a new unit of capital, then with the applicable tax savings, the effective purchase price of the good would be $q(1-\Gamma)$. As a consequence, the most that the firm would ever pay for a used piece of capital is also $q(1-\Gamma)$. Alternatively, one can allow the same tax incentives to apply on old and new capital goods. In this case, the firm could receive q for an old unit of capital, but would then lose any tax savings associated with that unit of capital. An implicit assumption of this model is that the firm always undertakes positive investment. This follows from how tax incentives are introduced. Equation (2.10) implies that (1-Γ) applies on negative investment as well as positive investment. Yet clearly if a firm holds a capital good for a year and then disposes of it, not all tax savings will be lost. The tax credit and part of the depreciation allowance would have been realized last period.

Without taxes, the firm needs to know only current price variables and the expected inflation one period into the future to make decisions about the desired capital stock (this, of course, follows from the assumption of instantaneous adjustment). With the introduction of a depreciation allowance, tax savings depend on the values of tax parameters far into the future. As such, capital demand each for period will depend on firm expectations of future tax parameters at time t and (2.12b) should be written as

$$pF(K^*,L^*) = E_t\{q(1-\Gamma)[r+\delta-\frac{d(q(1-\Gamma))}{dt}/(q(1-\Gamma))]/(1-\tau)\} \tag{2.13}$$

where E_t is the period t expectations operator.

2.4 Tax Rules and the Real Cost of Finance

Under the Canadian corporate tax system, firms may deduct interest payments from their income for the purposes of taxation. In this case, the firm's cost of debt financing is reduced. Consider a firm with a debt load B. In the absence of tax deductibility debt, the interest payment is iB. The nominal cost of finance is then iB/B=i. If interest payments are deductible, then the firm must still pay iB in interest. However, the firm may deduct iB from its income for the purposes of taxation, resulting in a tax savings of τiB. Net of taxes, the interest payment is then iB-τiB=(1-τ)iB and the nominal cost of debt is then

$(1-\tau)iB/B=(1-\tau)i$. With tax deductibility of interest payments the formula for the real cost of finance of a firm is then

$$r = \beta(1-\tau)i + (1-\beta)\rho - \pi^e \tag{2.14}$$

2.5 Incorporating Risk into the Neoclassical Model

By using techniques of dynamic optimization to solve the firm's maximization problem, it is implicitly assumed that the firm has perfect foresight. Perfect foresight implies that the firm knows exactly what the values of the tax and price variables will be for all future periods. Given that the future is known, there is no risk in the neoclassical model. In principle, uncertainty could be introduced by introducing stochastic processes by which various prices evolve over time. The solution to the firm problem could then be found using methods of dynamic programming. In practice, researchers have resorted to *ad hoc* methods of introducing risk into the formulation set out in section 2.2.

When there is no corporate tax system, risk is introduced into the neoclassical model by assuming that the firm's cash flow is risky, and as such shareholders and creditors require a rate of return which includes a risk premium h. The real cost of finance faced by the firm is then,

$$r = \beta(i+h) + (1-\beta)(\rho+h) - \pi^e, \tag{2.15}$$

where i and ρ now indicate the nominal rates of return required by shareholders and creditors respectively on a riskfree asset. The incorporation of risk into the model when a corporate tax system is introduced is somewhat more complicated, since under the assumption that a firm is always in a position to claim depreciation allowances, the "cash-flow" indicated by (2.9) is riskless. A commonly used approach is use a riskfree interest rate to calculate the present value of depreciation allowances. The cash flow of the firm indicated by (2.10) is then treated as risky and discounted using a risk-adjusted real cost of finance. Introducing a risk premium h and assuming that interest payments are tax deductible results in the following expression for the risk-adjusted real cost of finance:

$$r = \beta(i + h)(1 - \tau) + (1 - \beta)(\rho + h) - \pi^e \tag{2.16}$$

2.6 Irreversibility of Investment

The neoclassical model assumes implicitly that investment is reversible. In the formulation in section 2.2, investment is not required to be positive, and as such a firm is always able to sell some portion of its existing capital stock. Equation (2.1) implies that the firm can then receive a price of q for each unit of productive services that it sells. As long as the investment good can be used to produce a variety of outputs, there is no reason that the price of the capital good will be closely correlated with the price of the output of the firm. As such the firm can always increase its present value by selling capital when the cost of holding capital exceeds the marginal product of capital. Such a situation may arise when the price of the output produced by the firm falls.

A number of situations may arise in which the firm is unable to "unload" capital which is no longer realizing a gain. If the quality of capital goods is uncertain and informational asymmetry exists in the market for used capital goods, then the price of a used unit of capital will be less than that of a new unit (this is a variant of Akerlof's (1970) market for "lemons"). Alternatively, it may be the case that capital goods are highly specialized, and as such can only be used in the production of a single good. In this case, if the price of output falls, then the price of the capital good will as well, since it is only usable in the production of that one good.

If investment is indeed irreversible, then the conditions for the optimal capital stock that were derived in sections 2.2 and 2.3 will no longer be applicable. Recent work by several researchers has focused on determining the implications of irreversibility for investment behaviour. In McKenzie (1994), a basic model developed by Bertola and

Caballero (1991) is augmented to include taxation. In this model, investment is both risky and fully irreversible. On the basis of this model, McKenzie concludes that the disincentives to invest that result from corporate taxation may be understated when irreversibility is ignored.

CHAPTER 3: EMPIRICAL METHODOLOGIES

3.1 Introduction

As was noted earlier, the neoclassical model that was presented in chapter 2 is really a model of optimal capital stock rather than a model of investment. The challenge for empiricists has been to use the Jorgensonian model to develop an econometric model of investment that may be estimated. The key differences between the various approaches that have been tried to date have been in the treatment of the dynamics of investment and in the way in which expectations about future variables are assumed to be formed.

In section 2 of this chapter, the benchmark model developed by Jorgenson and Hall (1971) is described and some of its shortcomings are discussed. In section 3, alternative approaches that have been undertaken in specifying the dynamics of investment are described. Section 4 consists of a brief discussion of the problem of incorporating firm expectations into investment models and some of the approaches that have been employed. In section 5 the modeling approach used by Auerbach and Hassett (1991) is described in detail. Auerbach and Hassett made use of tax reforms as natural experiments with which to evaluate the effects of taxation on investment. As will become apparent, while this approach is designed to overcome some of the difficulties associated with observing firm expectations, it is not obvious that it is in fact able to do so.

3.2 The Benchmark Model

A simple investment equation can be derived from the capital accumulation equation (2.4). In discrete time, this equation may be rewritten as

$$I_t = (K_t - K_{t-1}) + \delta K_{t-1} \tag{3.1}$$

If one assumes that the realized net investment consists of some fraction λ_t of the difference between the optimal capital stock and the actual last period capital stock, then (3.1) may be rewritten as

$$I_t = \lambda_t (K_t^* - K_{t-1}) + \delta K_{t-1} \tag{3.2}$$

With the addition of a stochastic error term and an explicit expression for K_t^*, (3.2) is an empirically testable investment function.

λ_t is the speed of adjustment parameter and may take on any value from 0 to 1. When λ_t is one, the capital stock adjusts instantaneously to the optimal level. When λ_t is zero, the capital stock never reaches the optimal level and investment just replaces depreciated capital. For intermediate values, the adjustment between actual and optimal levels of capital occurs gradually.

In order to go from Jorgenson's model of optimal capital stock to an implementable econometric model of investment, it is necessary to have expressions for K_t^* and the adjustment process (indicated by λ_t in (3.2)). Jorgenson and Hall (1967) used a Cobb-Douglas production function

$$Y = AK^{\alpha}L^{\beta} \tag{3.3}$$

which exhibits constant returns to scale ($\alpha+\beta=1$). Using equations (12.7b) and (3.3), the following optimal capital stock equation can be derived

$$K^* = \alpha(p_t / c_t)Y_t \tag{3.4}$$

If a firm were able to reach its desired level of capital stock in each period, then net investment would be

$$\Delta K_t = K_t - K_{t-1} = K_t^* - K_{t-1}^* \tag{3.5}$$

Jorgenson assumed that the firm would always order the entire difference in each period, but that delivery lags would result in a partial adjustment to the desired level of capital. Suppose that some amount of capital K_o was ordered in period o. Jorgenson assumed that in period t, the firm receives $\phi_t \Delta K_o$, where t=0,1,2,... and ϕ_t are positive fractions between zero and one that sum to one. Provided that in every period the firm orders the difference between last periods actual capital stock and this period's optimal capital stock, and assuming that orders are never canceled and the delivery lag depends only on the age of the order, net investment is given by

$$I_{nt} = \sum_{j=0}^{n} \phi_j \Delta K_{t-j} \tag{3.6}$$

By substituting (3.4) into (3.6), replacing net investment in (3.2) with the resulting expression and adding a stochastic error term, the following investment function may be derived

$$I_t = \sum_{j=0}^{n} \phi_j (\alpha \left[{}^{p}\!/_{c} \right] Y)_{t-j} + \delta K_{t-1} + \varepsilon_t \tag{3.7}$$

Equations like (3.7) have been estimated using both industry and firm level data

As Chirinko (1993) notes, numerous criticisms have been leveled against this formulation of the neoclassical model. Among these criticisms:

1) From the optimization problem in chapter 2, capital, labour, and output may be simultaneously solved for, once the production technology is specified. However, Jorgenson treats output as exogenous rather then endogenous, ignoring the fact that the endogeneity of output may bias the coefficient estimates;

2) Condition (2.12b) from which the optimal capital stock was derived under the assumption that the capital stock could adjust to new optimal levels instantaneously, but in the econometric model, a systematic delay process is introduced. Given the systematic nature of the delivery lags, there is no reason for the firm to exclude the lags from its optimization problem. If this is done, then the investment path generated by following condition (2.12b) may not be consistent with the optimal investment path.

The general finding among researchers using formulations like (3.7) is that levels of investment generally tend to be more sensitive to quantity variables (output and sales), with price variables having only modest effects. Chirinko points out that this result may be traceable to the use of different margins by firms and researchers or to other specification problems. (2.12b) is a marginal condition, and so the relevant price variables are those that apply to the last unit of capital. It is implicitly assumed that the cost of capital r is independent of the level of investment. However, it may well be the case that cost of capital, r, that is applicable to the last unit of investment differs significantly from the weighted average indicated by (2.6). In this case, the user cost that is calculated will incorrectly measure the price faced at the margin. Provisions in the tax code may also make it difficult to measure the taxes that are applicable on the last unit of capital.

Specification problems may include an insufficient amount of variation in the user cost. If the variation in investment due to changes in price variables is small compared to that due to changes in other variables or due to stochastic shocks, then estimates of the coefficient will be imprecise.

3.3 Dynamics

In the benchmark model, dynamics are introduced in an ad hoc manner. Lags between the time a firm wants and receives a particular capital stock are attributed to various sorts of delivery delays and the nature of these delays in then specified in a rather arbitrary manner. Efforts have been made to include dynamics explicitly in the firm's optimization process. The standard approach has been to assume that there are adjustment costs associated with new investment. In the adjustment cost approach, pioneered by Eisner and Strotz (1963), it is assumed that in order to install new plant and equipment, current operations must be shut down, resulting in the firm forgoing the value of current input. The total cost of I new capital goods is then:

$$\overline{q}(I)I = (q(1 + \phi(I)))I \tag{3.8}$$

where $\phi(I)$ represents the cost per dollar spent on actual investment goods that results from the disruption of operations required to install these new goods. $\phi(I)$ is assumed to be a convex function (ϕ',ϕ''>0). If q is replaced by q in the optimization problem, then condition (2.12b) is replaced by

$$pF(K^*,L^*) = \overline{q}(1-\Gamma)[r+\delta-\frac{d(\overline{q}(1-\Gamma))}{dt}/(\overline{q}(1-\Gamma))]/(1-\tau) \qquad (3.9)$$

Convex adjustment costs "force" the firm to smooth out investment over time, since convex adjustment costs result in large capital stock adjustments being extremely costly to the firm. As such, the inclusion of explicit expressions for ϕ and the production function in the optimization problem will result in an explicit expression for investment.

3.4 Expectations

The user cost expression (2.13) is dependent on future (and hence unrealized) variables. In particular, the present value of tax savings, Γ, depends on future tax parameters and rates of inflation. Unfortunately, firm expectations are unobservable and as such the user cost that the firm uses in making investment decisions is also unobservable. Studies have frequently used static expectations, whereby variables are assumed to have the same value in the future as today, or extrapolative expectations, whereby past and present values are used to forecast future values. In the case of static expectations, user cost terms can be calculated by using current tax and inflation parameters. This kind of scheme precludes the possibility of firms anticipating future tax changes.

Extrapolative schemes of forming expectations are frequently referred to as adaptive expectations. In an adaptive expectations formulation, the expected value at the start of period t of a variable x with a value that will be realized later in that period is given by

$$E_t x_t = E_{t-1}x_{t-1} + \theta(x_{t-1} - E_{t-1}x_{t-1}) \qquad (3.10)$$

In words, this states that the expected value of variable x in this period is equal to last period's expected value of x plus some fraction θ of the error between last period's actual and expected value of x. Thus if the agent under predicted last period's value of x, she would expect this period's value of x to be somewhat higher than her expected value of x for last period. Adaptive expectations may be reasonable in a environment in which variables are constantly fluctuating. The problem with adaptive expectations is that the expectations of an agent may adjust only gradually to systematic or one time changes in the economic environment, meaning that agents remain "fooled" by a change long after it has occurred. Suppose for example that for a long period of time x takes on the value x_o. As long as agents expected this value in the past, future expectations will correctly reflect the actual value of x. Now suppose that in period t the value of x increases from x_o to x_o+1 and remains at the new value forever. The period t forecast error will then be 1. Agents will expect x_{t+1} to be $x_o+\theta$, x_{t+2} to be $x_o+\theta(1-\theta)$, x_{t+2} to be $x_o+1-\theta+\theta^2$, etc. Only gradually do expectations converge to the actual value (with the time of converge depending on the value of θ).

Economists have objected to adaptive expectations on the grounds that it allows agents to make systematic errors over long periods of times. Since errors can be costly to economic agents, it is argued that agents will formulate expectations in a way that minimizes forecast errors. This idea is the basis of the concept of rational expectations. As Scarth (1988) explains, "It (rational expectations) does not mean that people make no forecast errors: it simply means that such errors have no serial correlation, no *systematic* component." (p.66). Expected values can then be thought to be distributed around the actual value of the variable by an error term with an expected value of zero and no autocorrelation.

Frequently in rational expectations models, it is assumed that agents have an understanding of how certain economic variables are determined and collect all the relevant information necessary to forecast the variable, using the model itself to determine expected values of the variable. In macroeconomic models, for example, agents may be aware of the decision rule by which monetary authorities adjust the money supply. Using this decision rule and other economic variables, they can then forecast the future price level.

Alternatively if one is doing an econometric study, one can assume that expected values are distributed with error around the actual *ex post* values of the variable. If *ex post* values are used instead of actual expectations, however, an error in measurement situation arises and subsequent estimates may not be consistent.

If expectations cannot be measured actively, an alternative approach would is to use an instrumental variable in place of the agent's expected value of some parameter. An instrumental variable is a variable which is highly correlated with the erroneously measured variable, but uncorrelated with the measurement error. If an appropriate instrument can be found, then a consistent estimate of the parameters of the econometric model in question can be made. However, it is frequently the case that appropriate instrumental variables are difficult to come across.

3.5 Using Tax Reforms to Assess the Effects of Taxation on Investment

Auerbach and Hassett (1991) made use of the Tax Reform Act (TRA) of 1986 as a natural experiment with which to evaluate the effects of changes in the corporate tax system on investment. The TRA represented a major change in U.S. tax policy, in which the statutory tax rate was lowered and the lifetimes of most assets were lengthened for the purpose of depreciation write-offs. Since the changes unambiguously increased the tax wedge ($1-\Gamma$), it was believed that the TRA would result in decreased investment, particularly in equipment and machinery. However, as was noted in the introductory chapter, investment in this category actually increased after the TRA came into effect. Auerbach and Hassett note that it may be premature to use this increase in investment as evidence that taxes have little or no influence on investment. The neoclassical model suggests that a number of factors other than taxes have the potential to influence investment decisions. Technological improvements, increases in the relative price of outputs, and declines in the relative prices of inputs all have the potential to lead to increased levels of investment. It is possible that increases in investment can be attributed to one or more of these factors, and that changes to the corporate tax system actually damped a "boom" in investment.

To isolate the effects of taxation on investment, it is first necessary to have a model that includes all the key determinants of investment. Auerbach and Hassett assume that investment is governed by the following reduced form equation:

$$\frac{I_t}{K_{t-1}} = X_t\beta + c_t\gamma + \varepsilon \tag{3.10}$$

I/K is the ratio of investment to last period's capital stock, X is a vector of explanatory variables which includes instrumental variables for technological improvements and c is the user cost of capital (see equation (2.13)). Auerbach and Hassett argue that expectations about tax parameters are generally not observable, and as such, the user cost of capital is also not observable. Under the Rational Expectations hypothesis, one could argue that the user cost used by firms is distributed around the *ex post* user cost, c^*, with some error ξ. However, if one were to replace c with c^* in equation (3.10), then one would be estimating a model in which there was an error in measurement problem with an independent variable. This would in turn lead to biased estimates of the coefficients, since errors in c^* are likely to be correlated with the error term in (3.10). Alternatively, one could use the instrumental variable approach described in section 3.4. However, finding an appropriate instrumental variable is likely to be a difficult task.

Auerbach and Hassett develop what they believe to be an innovative regression technique which allows them to eliminate the measurement errors associated with expectations without resorting to instrumental variables. Given time series data on investment across multiple industries, assets or firms, one could estimate an investment equation without the (unobservable) user cost term. In this case, one would estimate

$$\frac{I_t}{K_{t-1}} = X_t b + \upsilon \tag{3.11}$$

Given that a variable is missing, (3.11) is a misspecified model and b will be a biased estimate of β. It can be shown (see Appendix A) that the expected value of b is

$$E(b) = \beta + \pi\gamma \tag{3.12}$$

where π is the coefficient resulting from the auxiliary regression of c on X. It should be noted that π is in no way a unique parameter. No claim is being made that user cost terms are generated according to a process like

$$c = X\pi + \xi \tag{3.13}$$

Rather, the value π takes depends on the actual sample values of c and X and measures the extent to which c projects on the space spanned X. In the special case where c is orthogonal to X, π would be zero, and b would be an unbiased estimate of β. In the special case where c lies completely in the space spanned by X, the vector πX would equal exactly c.

Now suppose that one has investment data that begins prior to some major tax reform and extends beyond the reform. One could estimate (3.11) for the pre-reform years. This equation could then be used to forecast investment for a post reform year. The forecast error would be

$$I - \hat{I} = (X_a\beta + c_a\gamma + \varepsilon) - X(\beta + \pi_b\gamma) = (c_a - X_a\pi_b)\gamma + \varepsilon \tag{3.14}$$

where the subscript b indicates that a parameter estimate is based on pre-Reform data and the subscript a indicates the post-Reform values of the variable. Auerbach and Hassett argue that in the case of TRA86, the reform was sweeping and expected to be long-lasting and that immediately after the reform, tax parameters were expected to remain constant into the distant future. As such, the user cost could be observed immediately after the reform. Provided that one knows π, one could then use the cross-sectional feature of the data for a year (or years) past the reform to estimate γ.

The trick then is to find the value of π. To do this, Auerbach and Hassett assume that firms have rational expectations, which implies a firm's expected value of the user cost is distributed around the actual value, say c^*, with some random error ξ. The actual value is the *ex post* value and takes into account what the user cost is with the actual realization of tax parameters and inflation over time. With this assumption, c is given by

$$c = c^* + \xi \tag{3.15}$$

For some sample (c,X), c can be decomposed into two parts. Part of c projects onto the space spanned by X and can be constructed as a linear combination of X. c will then be the sum of the vector formed by this linear combination, πX, and a residual vector, e:

$$c = \pi X + e \tag{3.16}$$

Although this appears to be a regression equation, e is not a stochastic process. Nonetheless, π is given by $(X^TX)^{-1}X^Tc$, which has the same form as the OLS estimator one would use to estimate the parameter in (3.13) If one were to use c^* instead of c, then one would achieve the following estimate of π

$$\hat{\pi} = (X^TX)^{-1}X^Tc^* = (X^TX)^{-1}X^T(c - \xi) \tag{3.17}$$

The measurement error that results from using c^* instead of c is then incorporated into the estimation of π. If this estimation is then used in the second stage, the measurement error is then incorporated in the independent variable in the second stage regression:

$$I - \hat{I} = (c - X\hat{\pi})\gamma + \varepsilon = (c - X(\pi - (X^TX)^{-1}X^T\xi))\gamma + \varepsilon \tag{3.18}$$

Auerbach and Hassett claim that by using c^* in (3.17) one achieves an unbiased estimate of π . If (3.16) represented a stochastic process like (3.13), then this would indeed be true. The measurement error in the dependent variable would be combined with the stochastic term and one would get an unbiased estimate of π. In this case, the measurement error would have been effectively removed by the auxiliary regression. However, if (3.16) does not represent a stochastic process then all one accomplishes by using a two-stage process is to carry the measurement error through to the second stage regression.

The estimation strategy used by Auerbach and Hassett consists of two stages. In the first stage, pre-reform data across many years is used to estimate b and π. Using post-reform data, these parameters are then used to "forecast" values of I and c for a post-reform year. Regressing the forecast error in investment on the forecast error in the user cost in the second stage will then yield an estimate of γ. These "forecasts" are not true forecasts, since a variable has been excluded from the investment equation and no claim can be made that firms would ever actually forecast the user cost based on values of X. Rather the two stage process is believed to be a way of obtaining a precise estimate of γ. One could in principle simply pool the data for a post-reform year, when c is claimed to be known, and, provided that there was sufficient cross-sectional variation in the user cost term, estimate (3.10) directly. However, in this case n cross-sectional observations would be used to estimate k coefficient estimates, where k is the number of variables contained in the information set [X,c]. By breaking the regression into two stages, Auerbach and Hassett have reduced the number of coefficients that are estimated with the n cross-sectional observations to one (two if a constant is included in the second-stage regression). In the first-stage, cross sectional and longitudinal data is used to estimate b and π. If γ were known, then this would be equivalent to using the pre-reform data to achieve (given the number of observations that are available) a precise estimate of β. To complete the estimate of β, all that is needed is an estimate of γ. By including the information from the first-stage equation (π and b), one can use the n cross-sectional observations to estimate only one coefficient, γ.

Equation (3.13) may be explained in a somewhat more intuitive manner. The error resulting from forecasting can be attributed to two sources. One source will be the stochastic error, which is assumed to be distributed about zero. The second source results from the forecast error in the user cost. A portion of the investment forecast error may thus be viewed as correcting for the error in the user cost. Note that for identification of γ, the post-reform user cost should not be predicted well by the information set X. By using major tax reform like TRA86, this requirement should be satisfied.

The above methodology was first applied by Auerbach and Hassett (1991) using Bureau of Economic Analysis (BEA) data on real investment by asset and industry for the U.S. from 1947 to 1989. Explanatory variables consisted of a constant, a time-trend, the lagged own investment-capital ratio, the own relative capital goods price, the lagged before-tax cash-flow to capital ratio for industries using the asset, the lagged real interest rate and an oil-price series. As q (the relative price of capital) was included in X, the user cost term that was used was

$$c_t = (1-\Gamma)[r + \delta - \frac{d((1-\Gamma))}{dt} / ((1-\Gamma))] / (1-\tau) \tag{3.20}$$

Tax savings due to depreciation allowances were calculated by using realized tax provisions and rates of inflation. The assumption was made that after 1990 tax parameters and inflation would remain fixed at 1990 levels. Depending on whether the time trend was included or not and on whether or not outliers were dropped from the regression, Auerbach and Hassett found statistically significant estimates of γ ranging from -.43 to -1.00 for assets that may be categorized as equipment and machinery. They were unable to find statistically significant estimates of γ for assets that fall under the buildings category.

The methodology was later applied to firm level data by Cummins and Hassett (1992). Investment series were constructed using Compustat data for net stocks of machinery and equipment and for net stocks of buildings. Explanatory variables included lagged values of investment, a time trend, and a cash flow variable. Depending on whether a trend was included and on whether cash-flow surprises were included, statistically significant estimates of γ ranging from -1.06 to -1.33 for equipment and machinery and from -.575 to -.702 for buildings were found. These values imply an elasticity at the mean of gross investment to the tax parameters of -1.1 for equipment and -1.2 for buildings.

These estimates are linked to a structural model that was estimated in Auerbach and Hassett (1991a). In this model, a firm invests subject to quadratic adjustment costs (see section 3.3). If the production technology of the firm is assumed to exhibit constant returns to scale, then the coefficient of the user cost of capital term converges to the term $1/(c^*\phi)$, where ϕ is the coefficient of the quadratic term in the linear investment equation (this is equivalent to replacing $\phi(I)$ in equation 3.10 with ϕI) and c^* is the average value of the user cost of capital. Based on the their estimates and sample means, the results of Cummins and Hassett imply marginal adjustment costs of 28 cents per dollar of equipment investment and 35 cents per dollar of investment in equipment.

3.6 Measuring Capital and Investment

As was noted in chapter 2, there are a number of difficulties associated with the concept of capital. Empirical studies of investment are further complicated by issues of measuring this variable. In the neoclassical model, K is a vector of capital inputs. Each element of K represents the effective unit of service of some type of capital good. Investment is thus also measured in effective units of service and q is then the price of a unit of capital service. If one had investment data for some entity, measured in terms of productive units (this may or may not correspond to unit of the item in question, depending on whether or not different vintages of the good are equivalent when new), and in addition, knew the depreciation rate, then the capital stock could be estimated using equation (2.4) or its discrete time equivalent:

$$K(t) = \sum_{i=0}^{t} (1-\delta)^{(t-i)} I_i \tag{3.21}$$

In reality, however, stock and investment figures as measured by government and by industry are generally not measured in terms of units of service but instead in terms of expenditure. The usual method of constructing capital stock expenditures is according to the Perpetual Inventory Method (PIM). Stock estimates made using PIM may be in either nominal or real terms and may be either gross or net figures. Here the discussion will be confined to net estimates of the capital stock. Statistics Canada has compiled real and nominal stock estimates by industry that date back to 1926. Using annual investment expenditure data and the assumption that capital undergoes geometric depreciation, the time t real capital stock estimate is given by

$$K(t)=\sum_{-\infty}^{t}(1-\delta)^{(t-i)}I_i/q_i \tag{3.22}$$

Capital and investment are now measured in dollar terms and $q_i(s)$ is the price index for capital with respect to some base year s. The question is then when is an estimate provided by equation (3.22) consistent with the notion of capital as used in the neoclassical model? To produce a price index like $q_i(s)$ one first needs a basket of investment goods from the base year to use as a basis for comparison across years. The price index is found by calculating the nominal cost of this basket in every other year and dividing this cost by the nominal cost of the reference bundle in the base year. Assuming that the reference bundle is representative of the capital goods actually purchased in each period, then the term $(1-\delta)^{(t-i)}I_i/q_i(s)$ measures the amount of useful capital services from investment from period i in terms of year s constant dollars. Dividing this value by the nominal cost of the reference bundle will then measure the useful remaining services from goods accumulated in period i in terms of the equivalent number of new reference bundles. Provided that one knows the proportion of goods in the reference bundle, one could then decompose the bundle into remaining useful service of particular goods.

CHAPTER 4: DATA AND CALCULATIONS

4.1 Introduction

As was noted in chapter 2, in the neoclassical investment model, capital may either be assumed to be a homogenous good or, in the case where K is assumed to be a vector, a combination of different goods. In the latter case, the optimal amounts of each capital good must be determined simultaneously and the relevant price vector for the demand for each capital good will include the prices and the tax treatments of every asset type. Depending on the specification of the production function, the potential will then exist for the substitution between goods. From an econometric point of view, this poses a problem. Firm level investment data is rarely available at such a level of disaggregation. Typically firms will report figures for fixed capital expenditures and stocks. These may be sufficiently disaggregated that one may differentiate between investment in equipment and machinery and investment in buildings. Data at a finer level of disaggregation is generally not available to the applied researcher.

The general approach when using such data is to use survey data on the asset composition by industry and calculate price variables that are a weighted average of the prices of each asset used by the industry of the firm. There are a number of problems inherent with this kind of treatment:

1) By using a weighted average, one is implicitly assuming that the various assets are always purchased together in the ratio indicated by the weights. This is equivalent to not allowing substitutability across assets, or , in terms of the production technology, assuming that capital goods are perfect complements. Yet this is problematic as changes in tax parameters may be much more important in determining the relative levels of investment across asset types than they are in determining overall levels of investment by the firm.

2) Since the surveys from which asset composition estimates are done are performed infrequently, one is assuming that the same weights are appropriate for a number of observations. Even if one accepted the notion of perfect complements, changes in technology may result in new ratios over time.

3) Survey data will apply to the industry as a whole. Individual firms may use capital in ratios that different significantly from the industrial average and as such prices calculated using industrial averages will not be the appropriate ones for examining firm behaviour.

In this chapter, a description is provided of the type of data and calculations needed to estimate the investment model developed by Auerbach and Hassett. Section 2 describes the construction of investment and cash flow data. Section 3 describes the calculation of tax wedges by industry and asset type. Section 4 describes how the real required rates of return by industry were estimated. Section 5 discusses the calculation of user costs by asset type and the computation of a weighted user cost across asset types. In section 6, the construction of the remainder of the data set is discussed.

4.2 Investment and Cash Flow Data

As was the case with the study carried out by Cummins and Hassett, investment data was constructed from Compustat data. Unfortunately, for Canadian firms, data was not available for net stocks of buildings and net stocks of equipment and machinery. Instead, item A8 (Property, Plant, and Equipment (Net) - Total) was used, which consists of all tangible fixed property of the firm, net of accumulated depreciation, that was used in the production of revenue. As a consequence, the measure of capital stock consists of the sum of equipment and machinery, buildings, and land. Data was available from 1974 to 1990 for 150 companies scattered across eight industrial groupings. Table 4.1 provides a listing of the industrial groupings used.

Table 4.1: Industrial Classification of Firms

Communications
Construction
Manufacturing
Public Utilities
Retail Trade
Service
Transportation and Storage
Wholesale Trade

To go from stock figures to gross investment figures, net stocks were first differenced. By definition, this difference ΔK_t is net investment. Replacement investment was then calculated by multiplying last period's capital stock by an industry specific depreciation rate. The industry specific depreciation rate was arrived at by using the industry asset weights and asset-specific depreciation rates used by Jung (1989). The appropriate depreciation rate for industry i was thus

$$\delta_i = (w_{e,i}\delta_{e,i} + w_{b,i}\delta_{b,i}) / (w_{e,i} + w_{b,i} + w_{l,i}) \qquad (4.1)$$

where $w_{a,i}$ are the weights for asset a in industry i and $\delta_{a,i}$ are the depreciation rates appropriate for asset a in industry i; a=e, b, l for equipment,buildings, and land. Note that by definition land does not physically depreciate. Gross investment for firm j in industry i in year t is then given by

$$I_{j,i,t} = (K_{j,t} - K_{j,t-1}) + \delta_i K_{j,t-1} \qquad (4.2)$$

A problem arises in that capital stock figures come from corporate financial statements, which are compiled according to accounting protocol. They will thus not reflect the "true" economic value of the assets. That such figures are compiled according to the cost principle guarantees that there will be a discrepancy between reported values and the "true" economic value. Under the cost principle, assets are recorded on the balance sheet according to the nominal cost of the asset at the time of acquisition. Over time, a portion of this value is expensed due to wear on the asset. The net capital stock will then be the sum of the various balance sheet entries, less accumulated accounting depreciation to that point of time. Given that the value of an asset may change over time, either due to inflation or relative price changes, this measure will not reflect the true economic value of the capital stock. Suppose for example that the relative price of some asset remained constant over a period of sustained inflation. In this case, a net capital stock estimate compiled according to the cost principle will undervalue the capital stock. The estimate of the capital stock in period t, which is given by K=(Historical cost of capital stock less accumulated depreciation)/(Price of a unit of capital in period t), will then underestimate the true capital stock, which is given by K_t=(market value of remaining capital stock in period t)/(price of capital in period t). In so far as that the capital stock figure for a given period will consist of a variety of vintages of capital, one cannot simply apply a price index to the stock figure to get a real measure of the capital stock. If one had access to the firm's books, a price index for capital goods, and an estimate of δ_i, one could construct an economically consistent measure of the capital stock using equation (2.4).

As was noted earlier, under the assumption of geometric depreciation, one unit of an asset i of age t will provide productive services equivalent to $(1-\delta_i)^t$ units of a new asset and will thus have the value of $(1-\delta_i)^t$ units of a new asset. Since accounting methodology varies across firms and assets, no effort has been taken here to reconcile stock figures here with those implied by economic notions of depreciation. This in turn will lead to another source of measurement error that could bias any parameter estimates for the investment data that are arrived at using this data.

A cash flow figure for each firm was also constructed. Cash flow is defined as after tax income before extraordinary items plus depreciation and amortization (Compustat items 14 and 18). Both investment and cash flow figures were divided by last period's capital stock.

4.3 The Tax Wedge

In Canada, depending on the asset class, assets are written off on either a straight-line or declining balance for the purpose of capital cost allowances (CCA). Prior to 1981, the full purchase price (including installation and acquisition costs but net of any of applicable ITCs) of the asset could be used to determine the value of the depreciation allowance in the year of installation. From 1981 on, the half-year convention has applied, whereby the claim for CCA in the first year is limited to one-half the allowable rate. In the case of an asset with a lifetime of T years written off on a straight-line basis prior to the half-year rule, the discrete time equivalent to equation (2.9) is

$$\Gamma(s) = k_s + (1-k_s)\frac{1}{T}\sum_{i=s}^{T+s-1}\tau_i(1+r+\pi)^{-(i-s)} \tag{4.3a}$$

For assets purchased after the two year convention, the appropriate expression is

$$\Gamma(s) = k_s + (1-k_s)[\frac{\tau_s}{2T} + \frac{1}{T}\sum_{i=s+1}^{T+s-1}\tau_i(1+r+\pi)^{-(i-s)} + \frac{\tau_T / 2T}{(1+r+\pi)^T}] \tag{4.3b}$$

In the case of an asset purchased prior to the half-year convention that has a lifetime of T years and is written off according to a double declining balance, the present value of depreciation savings is

$$\Gamma(s) = k_s + (1-k_s)\alpha_s\sum_{i=s}^{\infty}(1+r+\pi)^{-(i-s)}(1-\alpha_s)^{(i-s)}\tau_i \tag{4.4a}$$

where α=2/T. With the half-year convention in place, the appropriate expression is

$$\Gamma(s) = k_s + (1-k_s)[\frac{\alpha_s\tau_s}{2} + (1-\frac{\alpha_s}{2})\alpha_s\sum_{i=s+1}^{\infty}(1+r+\pi)^{-(i-s)}(1-\alpha_s)^{(i-s)}\tau_i] \tag{4.4b}$$

To actually calculate values of $\Gamma(s)$ and subsequently the tax wedge, data from Jung (1989) was used. Tax and depreciation parameters were available by asset type for each industry grouping in Table 1 for the years 1975, 1980, 1985, and 1990.
Average values of α were calculated for equipment and machinery and for buildings using asset weights by industry and the existing tax provisions. Although changes were made to

the write-off lifetimes for some asset classes over the period spanned by these "snapshot" years, they were quite minor, and should have a negligible effect on estimates of α_S. Major changes in α_S occurred after 1987, when the extended write-off lifetimes of the 1987 tax reform came into affect. Values of α_S tend to take on one value for the pre-reform period (1974-1987) and another value after the reform (1988-1990).

Based on the eligibility of different assets for ITCs, effective values of k_S were estimated by asset for each industry. Major changes in the ITC system occurred in 1978, when a variety of assets used in manufacturing and processing became eligible for a 7% ITC , and in 1987-1989, when the ITC on a variety of capital goods used in manufacturing and processing was phased out. k_S was computed for years other than the "snapshot" years by taking into account these developments.

The corporate tax rate applicable to a particular industry was computed by using locational weights for each industry to determine an appropriate weighted provincial tax rate. This value was then added to the statutory federal tax rate, including surtaxes, to arrive at an industry specific tax rate. Changes in the statutory tax rate prior to 1988 were fairly minor, consisting of some adjustments to the corporate surtax and a small rate change in the mid 70's. These changes were incorporated in calculating tax rates for years other than those for which a "snapshot" was available.

In order to calculate ex-post values of $\Gamma(s)$, it was necessary to allow the discount factor to vary over time. In order to do this, one must replace the term $(1+r+\pi)^{-(s-i)}$ in equations (4.3) and (4.4) with

$$\prod_{j=1}^{i}(1+i_j^f), \tag{4.5}$$

where i^f_i is the nominal interest rate paid on a riskless asset.

As was noted in chapter 2, under the assumption that the firm is never in a tax loss situation, the cash flow associated with the CCA allowances is riskless. As such, the discount factor used in equation (4.4) was taken to be the nominal riskless rate; to calculate the present value of CCA savings for each year by industry, annual averages of the 90 day treasury bill rate were used. Figures 4.1 and 4.2 depict the *ex post* average tax wedge (defined as 1-Γ) for equipment and machinery and for buildings respectively across industries for the years 1974-1990. Tax wedges for all industrial groups tend to increase over the period of the sample, with increases being particularly large in the period 1985-1988. The increase from 1987 to 1988 is a result of the implementation of the tax reform measures of the 1987 budget. Since the changing tax parameters are included in ex post calculations of tax wedge, increases from 1985 to 1986 and from 1986 to 1987 are a consequence of the lower present value of depreciation write-offs for years after 1988 resulting from the lower statutory tax rate (depreciation lifetimes for assets purchased prior to 1988 were unaffected by the measures of the reform).

4.4 The Cost of Finance

In order to calculate the user cost of capital for firms according to (2.13), estimates of the real cost of finance, r, and the rate of depreciation, δ, are needed. The estimates of δ that were used are those from Jung (1989). Jung provides estimates of δ for equipment and machinery and for buildings for each of the two digit SIC (Standard Industrial Classification) groups in Table 4.1.

Industry specific costs of capital were estimated using the method of Jung (1989). The nominal cost of bond financing, i_t, was taken to be the interest rate paid on long-term corporate bonds (as available in the Bank of Canada Review). The nominal cost of equity financing, e_t, was based on a capital asset pricing model (CAPM), in which the required rate of return on equity is the sum of a riskless rate of return and an industry specific risk premium. For a riskless rate of return, the 90 day treasury bill rate was used (available from The Bank of Canada Review). Industry specific debt to equity ratios were taken from Jung (1989). The risk premiums used were based on sectoral CAPM estimates from Jog and Mintz (1989). Inflation rates were computed using the GDP deflator. The real cost of finance was then estimated according to the following formula:

$$r_i = \frac{1}{T}\sum_{i=1}^{T} \beta_i (1 - u_{i,t}) i_t + (1 - \beta_i) e_t - \pi_t \qquad (4.6)$$

The real cost of finance will depend on the expected rather than actual inflation rate. However, under the rational expectations hypothesis, agents will on average correctly anticipate inflation and this should be reflected in the nominal required rates of return. By averaging over a number of years, errors that are unsystematic in nature should cancel out.

The estimated real cost of finance for each industry group is shown in Table 4.2.

Table 4.2: Real Cost of Finance by Industry

Industry	Real Cost of Finance (r) (%)
Communications	5.04
Construction	8.64
Manufacturing	8.23
Public Utilities	5.50
Retail Trade	5.60
Services	5.25
Transportation and Storage	4.76
Wholesale Trade	5.88

It should be noted that the real cost of finance is likely not constant over the sample period. The cost of debt-financing varies with the corporate tax rate and thus, depending on features of the economy other the corporate tax system which determine i, a decrease in the statutory tax rate will increase the cost of finance. This variation is ignored for three reasons:

1) In the papers by Auerbach and Hassett (1991) and Cummins and Hassett (1992) a real cost of finance of .04 was assumed. Here a constant real rate of return is still employed, but by using industry specific costs of finance extra variation across industries is generated.

2) The estimates of the real costs of finance are not very precise. Individual terms of the summation in (4.5) varied considerably, with negative values observed for some years, and changes that result from taxes are not likely to be larger than the standard deviation in the measurement of the user cost . Suppose that debt makes up 50% of financing, the nominal return on debt is 12%, the nominal return on equity is 17% and the expected inflation rate is 5%. (These values are chosen because they represent upper values of actual realizations of variables in equation (4.5)). With a corporate tax rate of 50%, the real cost of finance would be (1-.5)(.12)(1-.5)+(1-.5)(.17)-.05=.065. If the corporate tax rate fell to 40% without changing any other parameters, then the real cost of finance would increase by (1-.5)(.12)(.1)=.006. Although a ten percent variation is not trivial, it is likely smaller than the standard deviation in r.

3) Inclusion of a real cost of finance that is a function of time will change the optimization problem in chapter 2, resulting in an extra term in the user cost term:

$$pF(K^*,L^*) = q(1-\Gamma)[r+\dot{r}+\delta-\frac{d(q(1-\Gamma))}{dt}/(q(1-\Gamma))]/(1-\tau) \qquad (4.7)$$

Given that r might depend on and vary with features of the economy that are unrelated to the corporate tax system, it would be difficult to identify changes in r over time. Year by year values of r could only be calculated if the expected inflation rate for a given year was known and if one could assume that nominal costs of debt and equity pick up this expected rate correctly.

4.5 The User Cost of Capital

Using the above data and expression (3.20), user cost terms were calculated for each of equipment and machinery, buildings, and land. The user cost of land was particularly straightforward, as there is no depreciation and no tax savings associated with this particular asset. Figure 4.3 shows the weighted user cost by industry for equipment and machinery. Figure 4.4 shows the weighted user cost by industry for buildings.

Figure 4.5 shows the weighted user cost by industry for land. After the 1987 tax reform, the user cost of equipment (figure 4.3) increases in four industries, declines in two, and remains largely unchanged in two. Overall, however, there is little difference between the pre- and post-reform user cost terms. Very similar results hold for the user cost of buildings (figure 4.4) and the weighted user cost across all asset types (figure 4.6). For land, which receives no depreciation write-off, the lower tax rate results in a lower user cost for all industries. For all other assets, the effect of the lower statutory tax rate appears to almost exactly offset the reduced tax savings resulting from the removal of ITCs and the extension of write-off lifetimes. The peaks in the user cost that occur over the sample tend to arise from the effective capital gains that result from one time changes in the tax system that affect the present value of tax savings. For example, the high user cost for equipment and machinery used in manufacturing in 1977 results from the eligibility of a number of assets for increased ITCs in 1978. The user cost in 1981 increases across industries due to a capital loss resulting from an increase in the corporate surtax.

Using asset weights, a weighted user cost of capital for each industry was computed. Weighted user costs by industry are shown in Figure 4.6. For most industries, the 1987 reform had little effect on the weighted user cost. The user cost fell briefly in these industries in 1987, as firms anticipated that the changes would reduce the tax savings on capital purchased after the reform. However, after 1988, user costs tend to level out to values near their pre-Reform value. As will be discussed below, this lack of variation in user cost make it difficult to interpret the empirical results.

4.6 Other Variables Used

The following variables were included in the information set denoted by the vector X in equation (3.10):

1) A lagged real interest rate. The 90-day treasury bill rate was used as the appropriate interest rate (CANSIM item D14007). The real interest rate was calculated by subtracting the annual rate of inflation from the annual average interest rate. The rate of inflation was calculated using the GDP deflator. In the derivation of neoclassical investment theory presented in chapter 2, it is assumed that the real cost of finance is constant over time. In the real world, financial markets tend to be volatile. By including this variable, the effects on the investment decision of instability in the financial market are captured.

2) The relative price of capital. The neoclassical theory suggests that the price of capital relative to the general price level is an important determinant of the optimal level of capital. Using figures on stocks of equipment and machinery in current and constant dollars for construction (CANSIM series D815186 and D817265), manufacturing (CANSIM series D814065 and D816144) and non-manufacturing (CANSIM series D814983 and D817062) industries, it was possible to build a price index for this class of assets for each of these three broad industrial classes. A measure of the price of capital relative to the overall price level, q, was then computed by dividing this index by an overall price index (the GDP deflator, CANSIM series D14476).

3) Oil prices. To take into account the possible effect of increases in the cost of inputs other than capital and labour, an oil price series was included. This was computed by dividing an oil price index (CANSIM series P490179) by the GDP price deflator to find the price of oil relative to the overall price level.

Figure 4.1: Tax Wedge for Equipment by Industry (1974-1990)

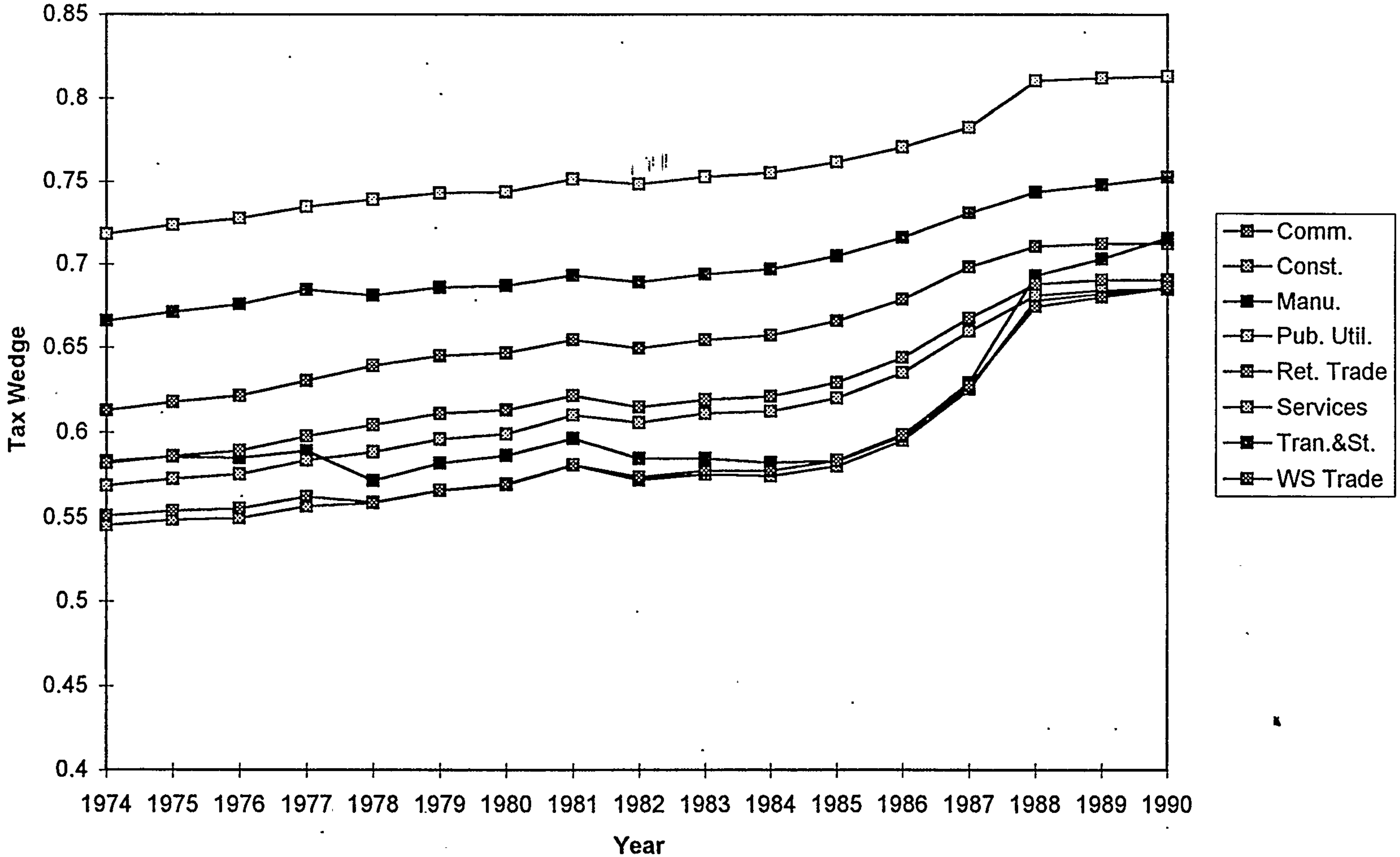


Figure 4.2: Tax Wedge For Buildings by Industry (1974-1990)

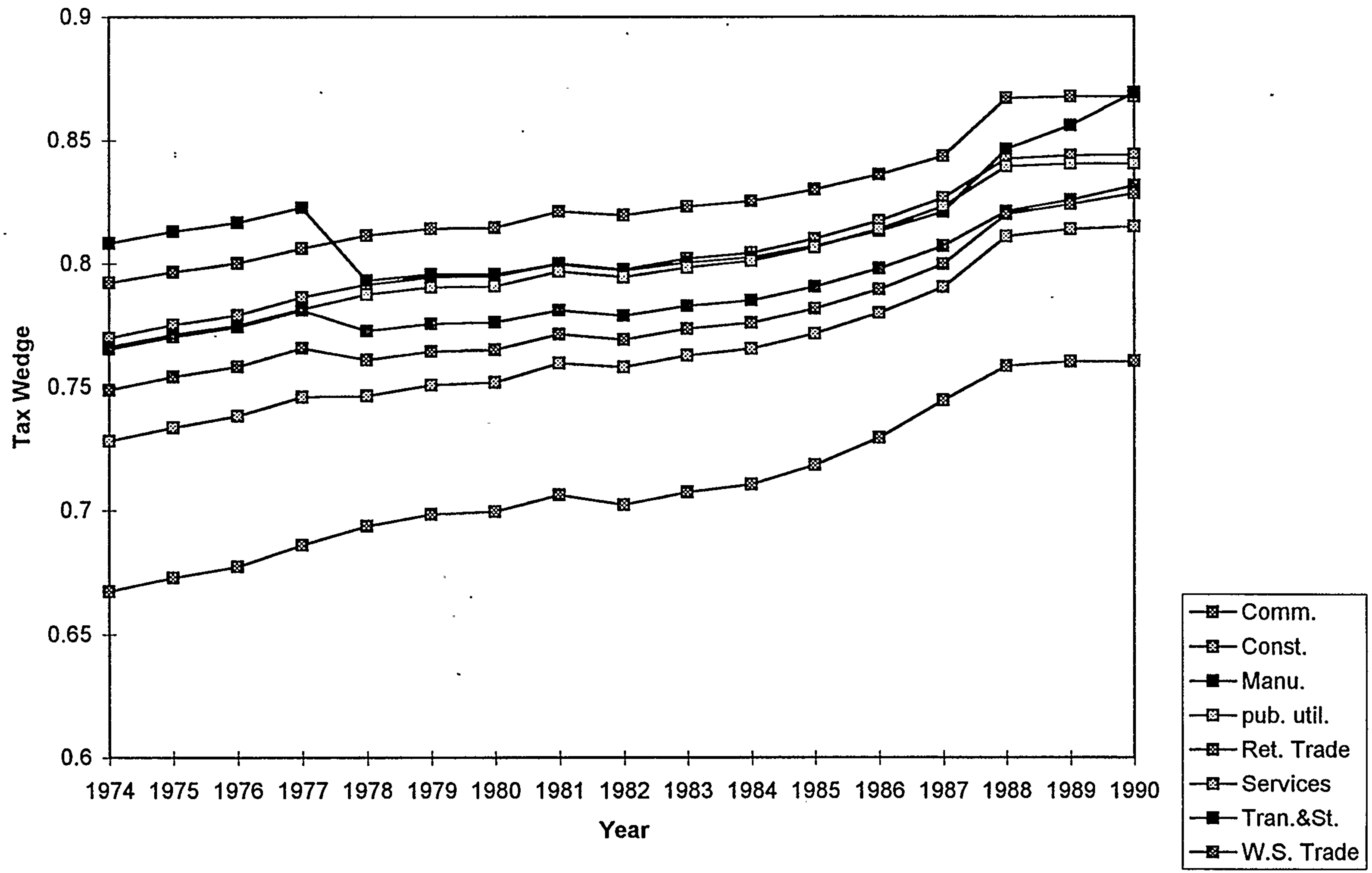


Figure 4.3: The User Cost of Equipment by Industry (1974-1990)

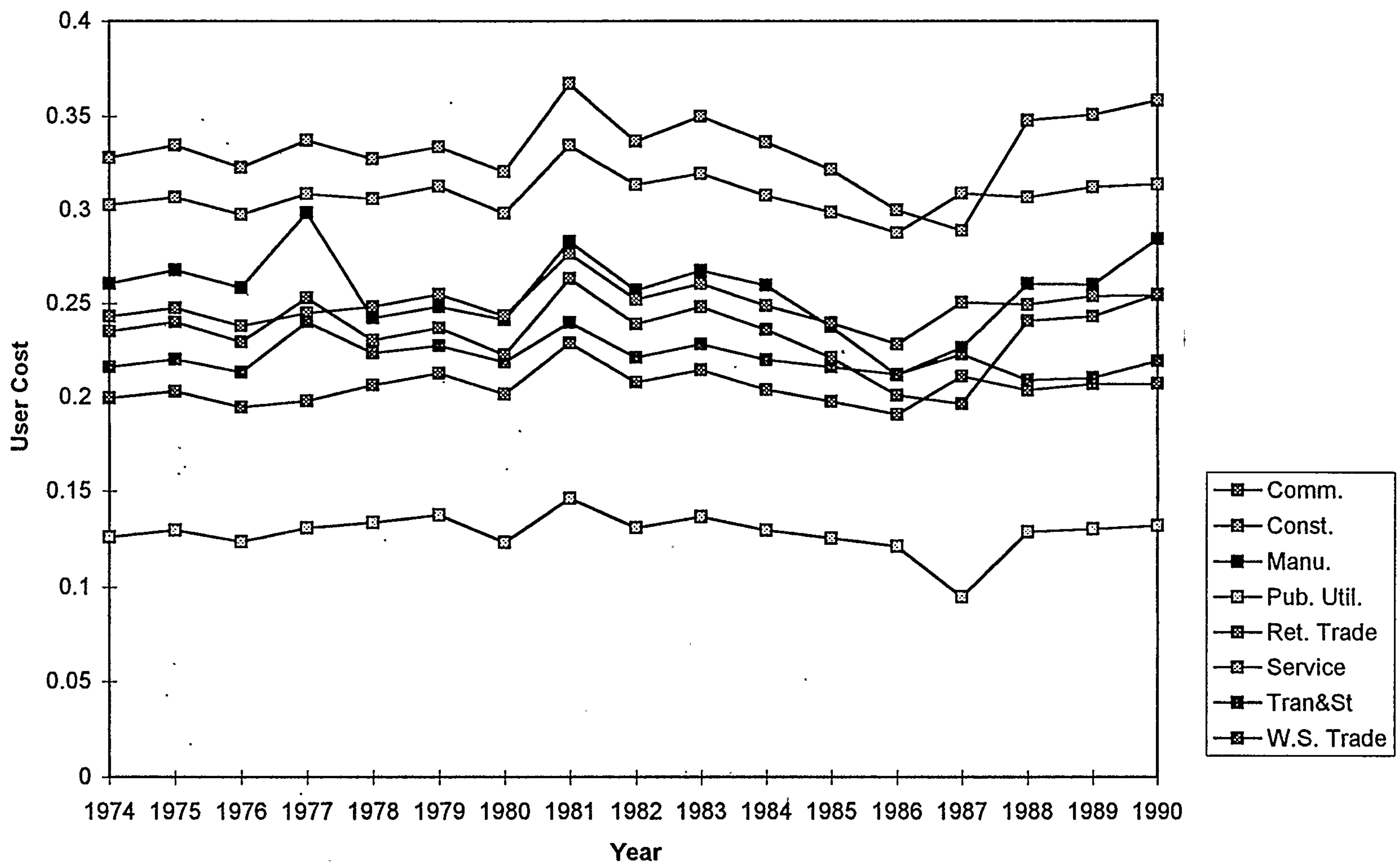


Figure 4.4: The User Cost of Buildings by Industry (1974-1990)

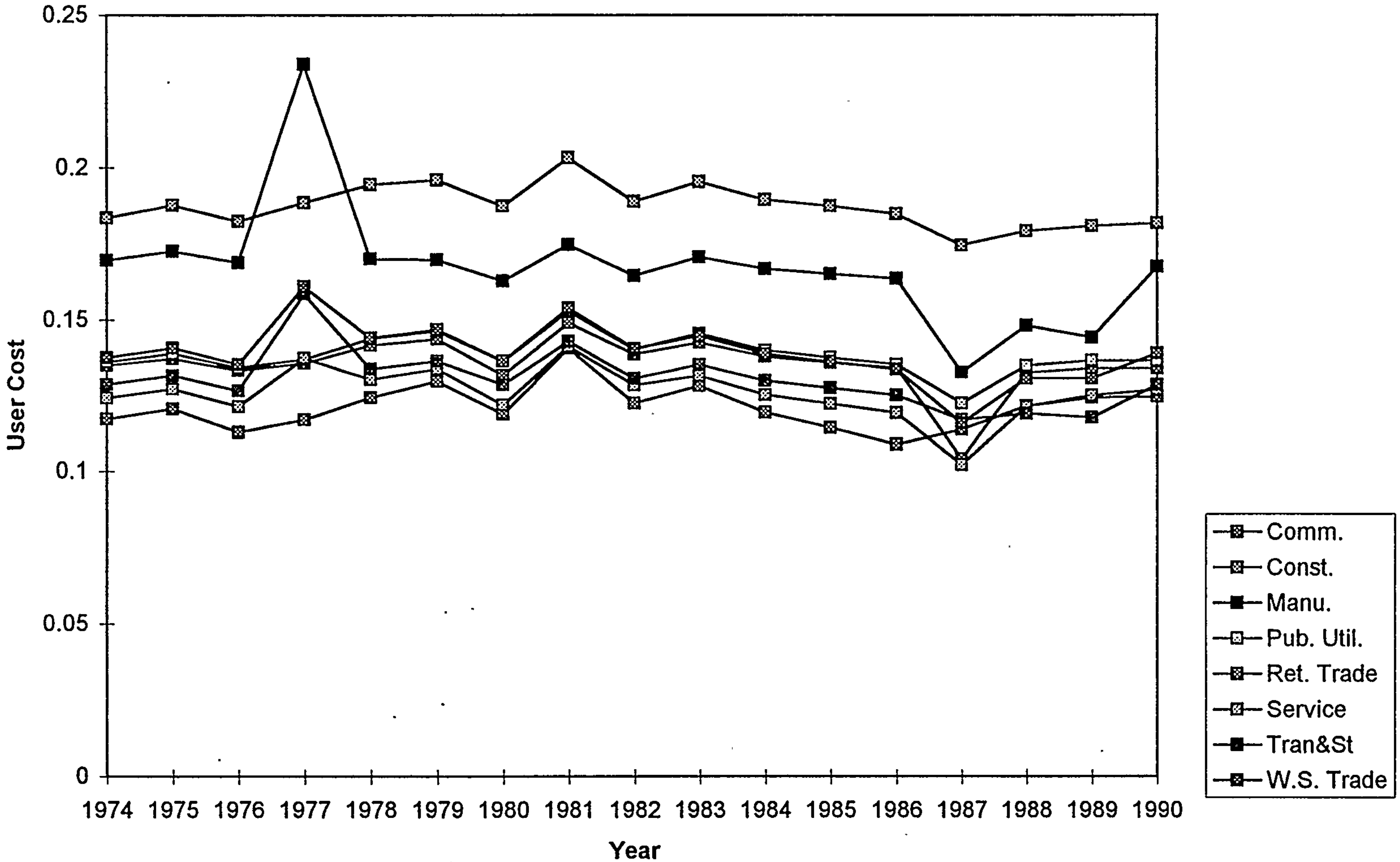


Figure 4.5: The User Cost of Buildings by Industry (1974-1990)

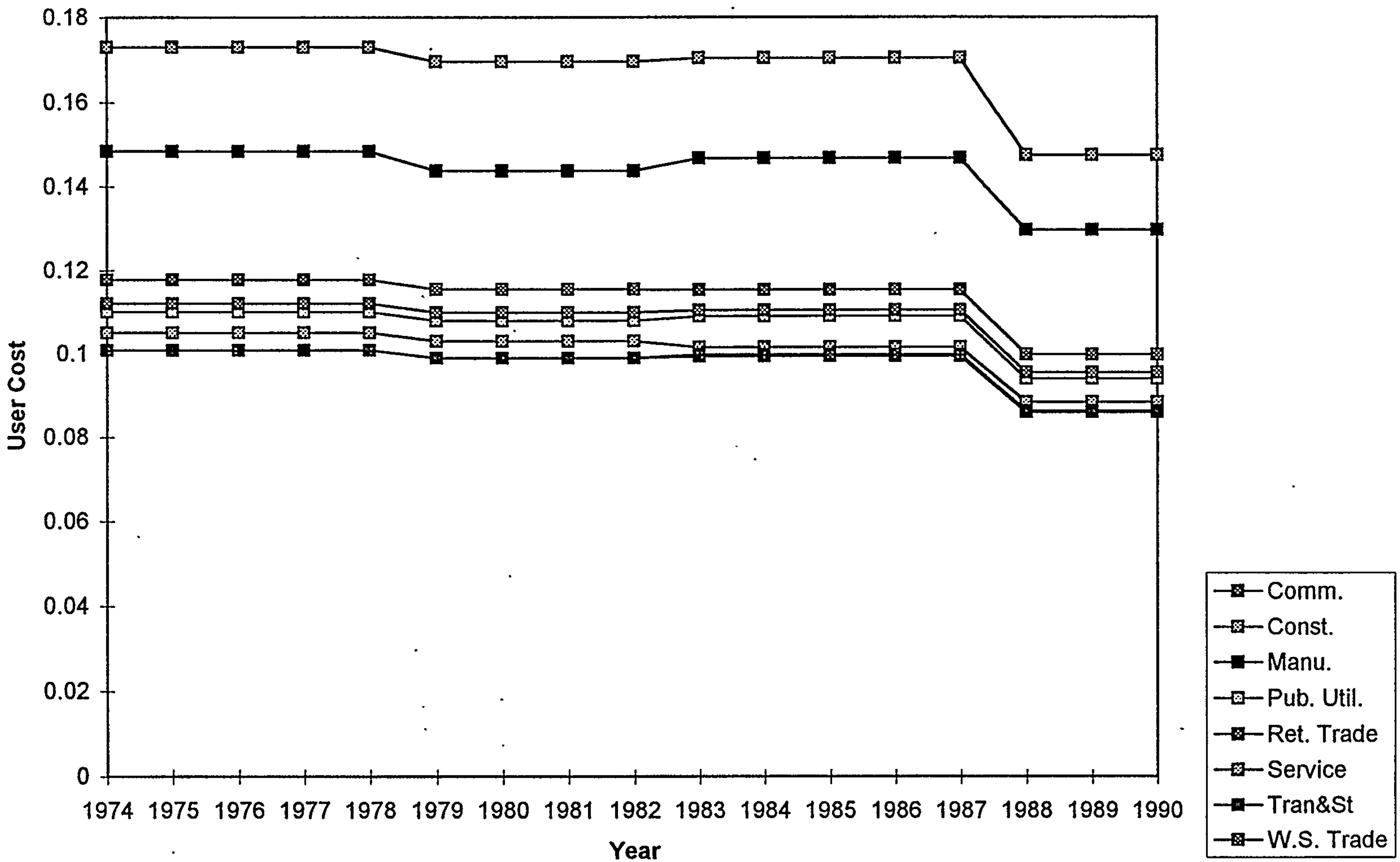
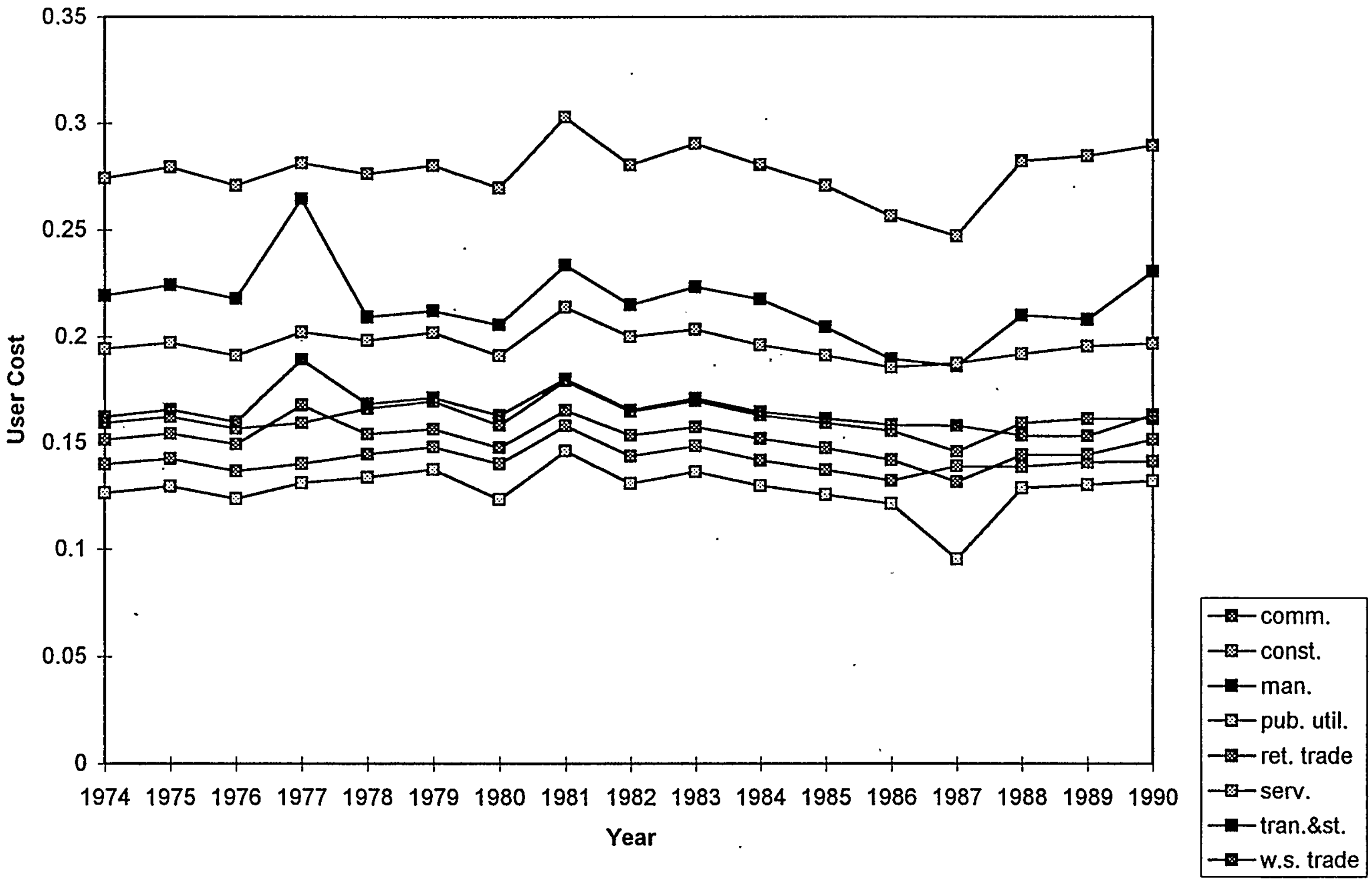


Figure 4.6: Weighted User Cost by Industry (1974-1990)



CHAPTER 5: RESULTS

5.1 Introduction

The two stage estimation procedure developed by Auerbach and Hassett presents the applied econometrician with a number of problems. By itself, the first stage regressions supply the researcher with little useful information. Since a coefficient has been knowingly excluded from the investment equation, estimates from the first stage are biased and provide no useful economic information on their own. Furthermore, a variety of tools that are commonly used to choose the "correct" model from among alternative specifications are no longer applicable, since the first stage model is not correctly specified under the null hypothesis. However, when combined with the second stage regression the results of the first stage regression can be used to recover unbiased estimates of both β and γ.

5.2 The Use of Panel Data and Pooling of Data

In econometrics, economic theory is usually first consulted in order to identify the determinants of some economic variable. Theory may suggest that variable I depends on variables X, Y, and Z:

$$I=f(X,Y,Z) \tag{5.1}$$

In some cases, theory may suggest directly the functional form of f(X,Y,Z) or it may be possible to make certain assumptions in the formulation of the problem that lead to a specific functional form. Frequently, however, econometricians simply assume that I is generated according to the following reduced form linear equation:

$$I = X\alpha + Y\beta + Z\gamma + \varepsilon \tag{5.2}$$

If I is generated repeatedly over time and α,β, and γ remain constant over time, then I at time t will be given by

$$I_t = X_t\alpha + Y_t\beta + Z_t\gamma + \varepsilon_t \qquad (5.3)$$

The process indicated by equation (5.3) may determine values of I (investment) for a single entity (a firm) or for multiple entities (firms). Suppose that one had data for multiple firms and that one was reasonably certain that the variables indicated by X, Y, and Z were the key determinants of I. X, Y, and Z may be either specific to a specific entity or faced by all entities in a given time period. In either case, one could not be sure *ex ante* that the value of I for a given entity is affected by changes in each variable in the same way. This would be equivalent to letting the coefficients of X, Y, and Z vary by observational unit (firm). In this case, (5.3) would be replaced by

$$I_{i,t} = X_{i,t}\alpha_i + Y_{i,t}\beta_i + Z_{i,t}\gamma_i + \varepsilon_{i,t} \qquad (5.4)$$

where i indicates the entity and t the time for which the observation of the variable is applicable.

Panel data consists of observations over time for a number of entities. Clearly such data is necessary to estimate a relationship like (5.4). It is often the case that the researcher either wishes to impose or test the restriction that some or all of the coefficients are equal across cross-sectional units. In this case, the appropriate procedure to follow is to estimate an equation like (5.4) separately for each entity and then test the hypothesis that the coefficients are simultaneously equal across cross-sectional units. If the hypothesis cannot then be rejected at reasonable level of significance, the data can be pooled and the model re-estimated with the coefficients restricted to being the same across all cross-sections.

In order to pool the forecast errors for investment and the user cost and estimate equation (3.13) as Auerbach and Hassett (1991) and Cummins and Hassett (1992) did, one must assume that γ is identical across all cross-sectional groups. β may either be constant or allowed to vary across cross-sectional units. Although the discussion in the proceeding paragraph suggests that the proper procedure to follow would be to estimate investment equations for each firm and then test to determine whether pooling and re-estimating the model was legitimate, this procedure is not possible given the nature of the first-stage regressor. b is a biased estimate of β, and to the extent that π depends on the actual sample set (c,X), it is not possible through testing to know if significant differences between estimates of b across entities arise from a difference in β or from differences in the sample set (c,X) across entities. The procedure that was followed then was to assume that β was identical for firms within each SIC industrial grouping but allowed to vary across groupings. Due to the small number of firms in the various non-manufacturing industries, γ was assumed to be identical for all firms in this broad category. γ was estimated separately for manufacturing firms. A Chow test was then used to determine the validity of pooling the forecasting errors for all firms and estimating γ for the joint sample.

5.3 Results of the First Stage Regression

In the first stage, firm data was pooled by industry and separate investment equations were estimated for each industry group in Table 4.1. Year by year observations of I/K and X were available for each firm in the sample. Observations were sorted according to the industry of the firm. The model was then estimated for each industry, with observations for each firm in the industry receiving equal weight. Numerous specifications were tried. Specifications differed in:

1) The treatment of outliers. For some estimations, the entire data set was used. Some firms exhibited values of I/K that were many standard deviations higher than the mean value of I/K. Following the approach of Cummins and Hassett, firms with values of I/K that were greater than one were deleted from the data set. The majority of the estimations were carried out for this reduced data set. It should be noted that this treatment of outliers is *ad hoc.*, and that by discarding observations important economic information may be lost. There are at least two alternative methods for dealing with outliers. One method involves estimating the model using a bounded influence estimator. In this

approach, the model is re-estimated with outliers receiving less weight that the remaining observations[2]. No observations are lost, but the determination of what constitutes an outlier remains somewhat arbitrary. A second possible treatment of outliers would be to assign a dummy variable to each observation for which I/K exceeded some specified value. In this case, the influence of outliers may be "absorbed" by the dummy and have a reduced effect on the remaining parameter estimates. This approach is in many ways as *ad hoc* as discarding outliers, as it is not clear what kind of economic meaning can be attached to the dummy variable.

2) The variables included as regressors. Certain variables (lagged cash flow to capital stock, real interest rates, relative price of capital, oil prices, and the user cost term) were included in all specifications that were estimated. Specifications differed in the order of lagged investment terms that were included as regressors and in whether or not a time trend was included. As was noted earlier, these variables were included as proxy variables to capture the effects of technological change on investment. It was not clear *ex ante* how these variables could best be used to represent technology, so multiple specifications were tried. The forecast errors and the ability of the model to explain pre-reform variability in the investment variable (as measured by the adjusted R^2) varied across specifications.

As was noted in section 3.5, the first stage model is deliberately misspecified. The exclusion of firms' expected user costs will result in a biased estimate of β, and so little economic meaning can be attributed to these estimates. A second problem that results from using a misspecified model is that traditional econometric tools for selecting among alternative econometric models , such as the Ramsey RESET test, are no longer valid. The strategy that is taken here then is to report the adjusted R^2, which is a measure of the extent to which the model is able to explain inner sample variation, and the average forecast

2 With the standard OLS estimator, the residual sum of squares is minimized. Outliers thus tend to exert a great deal of influence on the estimates. This influence is reduced when a bounded influence estimator is used, as the squared residual of an outlier receives less weight than the squared residual of other observations.

errors, which provides some idea of how well the resulting investment model is able to predict investment without the user cost term. The same statistics are provided for the auxiliary regression of the user cost on the information set X.

The first stage regressions were performed on the data set for 1974-1987. Forecasts of investment and the user cost were then made for 1989 and 1990. Table 5.1 shows the average forecast errors by industry and model when only 1989 is used. The same results are provided in Table 5.2 for the case where forecast errors for 1989 and 1990 are pooled. Adjusted R^2 statistics are also reported for the first stage regressions under each model specification. The number of firms in each industry are also indicated.

As can be seen from model #1 of each table, when outliers are not excluded, average investment forecast errors tend to be quite high for most industries. Deletion of outliers reduces the investment error for all industries save Services and Transportation and Storage. With the inclusion of additional variables, average forecast errors in investment tended to shrink for some industries and grow for others. Depending on the industry, the addition of extra variables may or may not have improved the ability of the model in explaining inner sample (i.e. pre-Reform) variation in investment. It is interesting to note, however , that the auxiliary regression of the user cost on the information set X tends to outperform the investment equation both in explaining pre-reform variation in the user cost (as demonstrated by the high adjusted R^2) and in forecasting post reform values (as indicated by the small forecast errors and standard deviations in the forecast errors).

5.4 Results of the Second Stage Regression

Due to the small number of firms in non-manufacturing industries and the large number of firms in manufacturing industries, forecasting errors were separated into a manufacturing and a non-manufacturing pool. The tax coefficient γ was then estimated for each pool and for the data set formed when these two groupings were pooled together. A

Chow test was performed to determine whether or not the coefficients in the two populations were equal, thereby legitimizing the pooling of the two samples. Table 5.3 shows the estimates of γ that result after the various first-stage model specifications when forecasts of investment and the user cost term are made for 1989 only. Table 5.4 shows the estimates of γ that result after the various first-stage model specifications when forecasts of investment and the user cost term are made for 1989 and 1990. Although (3.18) indicates that no constant should be present in the second stage equation, one was included in the estimation. If the variables upon which investment decisions are based have been correctly identified and measured and if (3.10) is in fact the "correct" investment model, then one would expect that in the second stage, the coefficient estimate for the constant would not be significantly different from zero.

Using only 1989 forecasts and deleting outliers, the second stage regressions yield similar results for the manufacturing pool, regardless of the first stage model specification that was used. Estimates of the coefficient and constant are statistically significant for all models except 1 and 3, and the coefficient of the user cost term is negative for all models except 1. At first glance the results are encouraging. The significant negative value for γ is consistent with an increase in the tax parameter in the user cost expression discouraging investment, which is consistent with the neoclassical model. However, upon closer investigation the results are much less encouraging. The coefficient on the user cost term is of a much larger magnitude than the values that Cummins and Hassett found for either buildings or machinery and equipment. The coefficient estimates for models 2 through 6 in Table 5.3 suggest implausibly high elasticities at the mean of investment with respect to tax parameters, with values ranging from -32 to -154. These values imply that investment is unrealistically sensitive to tax parameters. Moreover, the estimate of the constant is generally quite large, given that by excluding outliers the investment variable was forced to vary between -1 and 1 and considering that the constant was expected to be zero. These results suggest that problems may be present for the manufacturing pool with either the data or the specification of the investment model.

Results for non-manufacturing are also discouraging. Although some models result in estimates of γ that are negative and somewhat smaller than those found for manufacturing, none are statistically significant. Values are positive for some model specifications and tend to vary widely with the first stage regression. The estimate of the constant tends to be small and statistically insignificant, which is consistent with the neoclassical theory. Similar results hold for the estimates when manufacturing and non-manufacturing are pooled. In this case, only model 4 provides a statistically significant estimate of γ, and although it is much smaller than those found for manufacturing alone, it remains much higher than the values estimated by Cummins and Hassett.

The Ramsey Reset model specification test was performed on the second stage regression for each model specification. In this test, the second, third and fourth powers of the predicted value of the dependent variable that results from an initial regression are included as proxies for a missing variable in an estimation of the model that otherwise includes all the variables of the original specification. If the coefficients of these variables cannot be dismissed as statistically insignificant in subsequent testing, then this is taken as evidence that a variable is missing from the specification. Results of the Reset test when various powers of the predicted value of investment are included in Table 5.3. Regardless of the model specification used in the first stage, there is no indication of a missing variable in the second stage regression for manufacturing. Only model 2 for non-manufacturing industries passes all orders of the Reset test . This suggests that relevant variables have been excluded from the second stage regression for the non-manufacturing pool. It is not surprising then that when the two pools are combined, the second stage regression fails at least one order of the Reset test for all models except 1 and 2.

A Chow test was performed to test the hypothesis that the tax coefficient are identical for the manufacturing and non-manufacturing populations, thus legitimizing the pooling the two samples together to estimate γ. The Chow test assumes that the error terms for the manufacturing and non-manufacturing populations have the same variance; it is not clear that this condition will be true. The results of the Chow tests are mixed and depend on the first stage specification that was used. For models 2, 5, and 7, the hypothesis is rejected at the .05 level of significance, while for models 1, 3, 4, and 6 the hypothesis is accepted. Given the evidence that a variable is missing from the non-manufacturing model and the strong assumption that must be made about the variances of the two populations, it is not clear that this Chow test is legitimate.

The estimates are somewhat more promising when cross-sectional data from 1990 is included in the second-stage regression. For manufacturing, estimates of γ are much smaller than those found using only 1989 data, with values ranging from -2.51 to -3.61 depending on the first-stage model specification. For the majority of these estimations, estimate of the constant is small and statistically insignificant, which is consistent with expectations for the second stage regression. Unfortunately, the coefficient estimate is only statistically significant for models 2 and 4. The estimates still remain somewhat larger than those found by Cummins and Hassett, and imply elasticities at the mean of investment with respect to the tax variable of between -2.76 and -3.97. Although smaller than the results based on the 1989 data alone, these values continue to suggest that investment is extremely sensitive to taxes; again, implausibly so. For non-manufacturing industries, results are similar to those found using 1989 data alone. Estimates of the constant and user cost term are statistically insignificant and vary widely with the first stage specification. Estimates of γ range from -.115 to 2.63. The pooled data set also yields results similar to those found using only 1989 data, with coefficient and user cost terms being statistically insignificant.

Estimates of γ are small, with values ranging from -.716 to -2.78. For models 3 through 7 the values of the estimates are on the order of the values found by Cummins and Hassett.

Reset tests were performed for these model estimated using 1989-90 data. Manufacturing performed well, with most specifications passing the test. Models 2,4, and 5 failed only the third order test (unfortunately the statistically significant estimates of γ resulted from models 2 and 4). Models estimated using non-manufacturing industries and the pool of all industries also performed well, with only the fourth-order test on model 7 for each pool suggesting model mis-specification. For each model, a Chow test was performed, and in each case the hypothesis that manufacturing and non-manufacturing industries have separate values of the model parameters was rejected. This implies that the model estimated using the all industries is legitimate. Given that the number of observations in this pool exceeds that in the manufacturing pool, estimates arrived at with this pool should provide more precise estimates of γ. Although the estimates using this pool were consistent with the results of Cummins and Hassett for some model specifications, in no case did the estimate provide evidence that taxation has a statistically significant effect on investment.

5.5 Estimation Using The *Ex Post* Value of The User Cost as An Instrument

The methodology of Auerbach and Hassett was designed to overcome the difficulty in observing firms' expectations of future tax parameters and thus the difficulty of observing the tax portion of the user cost of capital. Auerbach and Hassett argue that *ex post* values of the user cost will, under the rational expectations hypothesis, be distributed around the actual expectations of firms with some error ξ. A regression using the *ex post* values will thus contain measurement errors, leading to inconsistent coefficient estimates. By using a two-stage technique, they attempt to eliminate this error in measurement problem. One could alternatively assume that the *ex post* values of the user cost term are an appropriate instrument for the values of the user cost that firms perceive in making decisions. In this case, one could then estimate (3.10) directly, using both the temporal and cross-sectional features of the data in a single regression. For comparative purposes, the model was re-estimated for the manufacturing pool using this approach. Results for the various model specifications is provided in Table 5.5.

Estimates of the user cost coefficient were smaller than those found using the forecasting methodology of Auerbach and Hassett. The coefficient estimates were only statistically significant when models 4 and 5 were used. Estimated values of γ ranged from -.383 to -1.81, which are much closer than the values found by Cummins and Hassett. Based on sample averages of .215 and .213 for the user cost and investment respectively, these estimates imply an elasticity at the mean of investment with respect to the tax portion of the user cost of between -.386 and -1.83.

At least three possible explanations exist for the large difference between the coefficient estimates achieved through the two-stage process of Auerbach and Hassett and those achieved by using *ex post* values of the user cost term as an instrument for firm expectations. The first possibility is that the *ex post* values of the user cost prior to 1988 (the post-reform period) contain measurement errors (i.e. are not sufficiently closely correlated with firms' perceived user costs). Measurement errors will lead to inconsistent estimates of the model. Provided that only the user cost variable contains measurement errors, a problem known as attenuation will arise, in which the user cost coefficient will be biased towards zero (the remaining coefficients will be biased in unknown directions). Certainly coefficients estimated using this methodology were much smaller than those found through the two step method, which is consistent with attenuation. On the other hand, as discussed earlier there is some question as to whether Auerbach and Hassett were successful in removing the measurement error from the second stage.

The second possibility is that the tax reform affected the tax system in ways that are not reflected by the tax parameters. As was noted, part of the intent of the 1987 tax reform was to broaden the tax base. Anti-avoidance measures were introduced that decreased the number of profitable firms that were able to avoid paying income tax in a given year. One possibility is that these measures resulted in changes to the coefficient structure (β,γ). In this case, the large coefficients found using the two-stage methodology might be measuring the results of a structural break. In the instrumental variables approach, the effects of a coefficient change would to some extent be masked, as the bulk of the data set is from the period before the reform.

In principle, the instrumental variables approach could be used to test for a structural break resulting from the change in tax parameters. By estimating the model before and after the reform, a Chow test could be used to test for a difference between the two models. Unfortunately, due to a high degree of correlation between independent variables in the post-reform data, the post-reform regression could not be estimated.[3] Instead, the sample was broken into a subsample for 1974-1984 and a subsample for 1985-1990 (1984/85 was the earliest break for which all the models in Table 5.3 could successfully be estimated). A Chow test was then performed to determine whether coefficients were stable over time. Results appear in the last row of table 5.3. For each specification, the null that the coefficients are the same before and after the break can be rejected at the .05 level. Unfortunately, by choosing the break so far before the reform, it is not clear that this structural break can be attributed to the tax reform. This does suggest however, that for what ever reasons, the coefficients in the investment model are not stable over time for manufacturing. Care should be taken in this interpretation, since the high degree of multicollinearity in the sample for 1985-1990 raises questions about the reliability of the coefficient estimates for this period. Furthermore, the Chow test is only valid if the

[3] For the post-reform period, the correlation coefficient between oil and the user cost was .95. For the interest rate and the price variable, the correlation coefficient was -.97.

variance of the error term in the investment equation is the same before and after the reform. This is a rather strong assumption. It was argued that after the reform, tax parameters were known with certainty. One might then expect the variance to shrink to reflect the notion that firms are making their decisions in a more certain economic environment.

There are two ways to deal with the possibility that the variance differs after the reform. One possibility would be to follow Watt (1978) and pre-test the hypothesis that the variance of the disturbance term is the same before and after the reform. If this hypothesis cannot be rejected, then one could procede with the Chow test. A second possibility would be to follow the Wald procedure proposed by Watt (1979). The Wald procedure makes no assumptions about the variance of the error structure and allows one to directly test the hypothesis that the coefficients are equal before and after the reform. To perform this test, one would estimate the model before and after the reform. The following test statistic would then be calculated:

$$J=(b_b-b_a)^T[s_b^2(X_b^TX_b)^{-1}+s_a^2(X_a^TX_a)^{-1}]^{-1}(b_b-b_a) \tag{5.5}$$

where b_i are the before (i=b) and after (i=a) reform estimates of the coefficients (β,γ), X_i, are the before and after reform vectors of independent variables (X,c) and s_i^2 are given by

$$s_i^2=e_i^Te_i/(N_i-k) \tag{5.6}$$

Under the null the limiting distribution of the test statistic given by (5.5) is a chi-square distribution with k degrees of freedom.

5.6 General Comments on the Methodology and Results

Using American data, Cummins and Hassett found that taxes had a statistically significant and plausible effect on investment. Based on the work done here with Canadian data, it is difficult to draw such conclusions. Using the 1989-90 forecast errors and the two-stage methodology, taxes were found to have statistically significant effect only when the model was estimated for the manufacturing pool. In this case, investment was found to be much more responsive to taxes then was found by Cummins and Hassett, perhaps implausibly so. Estimates for all industries when 1989-90 data was used resulted in values on the order of those found by Cummins and Hassett, but these values were not statistically significant. There are a number of possible reasons for the difference between the results presented here and those found by Cummins and Hassett. In addition, there are several issues regarding data construction and methodology that suggest that care must be taken in interpreting the results. Many of these issues have been discussed briefly in the previous three chapters. The following section reflects an attempt to deal with each of these issues.

5.6.1 Insufficient Variation in The Tax Variable

Auerbach and Hassett argue that the tax reform allows for the identification of γ in that it reduces the possibility of using the information set X to perfectly predict the user cost in the post-reform period. This would generally require that the user cost take on a significantly different value after the reform, which, from the point of view of estimation, would have the further advantage of producing variability in a variable which might otherwise have remained relatively constant over time. Unfortunately, as was shown in section 4.3, for most industries the user cost term did not change greatly with the tax reform. As tables 5.1 and 5.2 show, forecast errors for the user cost were quite small. This lack of variability in a key variable, combined with the fact that the information set X could be used to produce reasonably accurate forecasts of the user cost in the post reform period may have made it difficult to identify γ, which would then explain the failure under most specifications to get a statistically significant estimate of the tax coefficient.

5.6.2 Issues of Data Construction - Capital and Investment

The difficulties in constructing an appropriate measure of the capital stock of a firm were discussed in chapter 3. By using figures from financial statements as a measure of net capital stock, it is not clear what is being measured, since such figures are based on historical costs. Two firms reporting identical figures for net capital stocks could have stocks that would be very different in size if they were measured in the way that was consistent with the treatment of capital in the neoclassical model. For example, consider the case of two firms, say A and B. Let A acquire its entire stock at time o. At time t, its capital stock would be $K_A(1\text{-}\delta)^t$. If accountants measured depreciation correctly and used historical cost, then the book value of firm A's capital at time t would be $q_oK_A(1\text{-}\delta)^t$, where q_o is the price of a capital good in period o. Let B acquire its entire stock at time t-1. Again, if accountants measured depreciation correctly and used historical cost, then firm B's capital stock at time t would be $K_B(1\text{-}\delta)$ and the book value would be $q_{t\text{-}1}K_B(1\text{-}\delta)$. Now suppose that at time t, the book value of firm A's capital stock equals that of firm B's, so that $q_oK_A(1\text{-}\delta)^t = q_{t\text{-}1}K_B(1\text{-}\delta)$. To get a real measure of each firm's capital stock, one would have to divide the capital stock by a price index. Suppose that capital had undergone constant inflation over the period, such that $q_t=q_o(1+\pi)^t$. This implies that $q_oK_A(1\text{-}\delta)^t = q_o(1+\pi)^{t\text{-}1}K_B(1\text{-}\delta)$. Clearly if both stocks were measured in period o dollars, one would have to divide the right-hand expression in the previous expression by $(1+\pi)^{t\text{-}1}$. This implies that with respect to firm A, firm B's capital stock has been overstated. As well as failing to provide a consistent measure of the capital stock between firms, figures based on historical cost do not provide consistent measures of capital for a single firm for different years. Again assuming a constant rate of inflation, suppose a firm purchased K_1 capital goods in period 1 and K_2 capital goods in period 2. At the end of period 2, the capital stock of the firm would be $(1\text{-}\delta)K_1 + K_2$. However, using historical costs, it would be measured as $q_1(1\text{-}\delta)K_1 + q_2K_2 = q_2(1\text{-}\delta)K_1/(1+\pi) + q_2K_2$. If one then attempted to recover the capital stock by dividing by q_2, one would get $(1\text{-}\delta)K_1/(1+\pi) + K_2$. By failing to take into account inflation, one has effectively increased the depreciation rate in the measure of capital, and hence values based on historical costs will be biased downwards. This bias will increase with the proportion of the firm's existing capital stock that was acquired far into the past increases.

Persistent inflation will also bias the actual measurement of investment. Net and replacement investment will be measured at current prices, and as such a higher weight is placed on newly acquired capital than on capital accumulated in the past. In terms of investment goods, then, investment will be overstated. The combination of an upward bias on investment and a downward bias on capital stock figures suggest that the ratio of investment to capital that is computed using financial statements will be larger then the corresponding economic variable. Given this bias, increases in the investment rate that arise due to changes in the tax rate may be exaggerated. Ideally the applied researcher would like to use capital stock measures that are measured in real terms using depreciation rates that are consistent with economic notions of depreciation.

5.6.3 Issues of Data Construction - Industrial Averages Versus Firm-specific Values

The user cost term and gross investment figures were computed using a number of strong assumptions. Extensive use was made of industrial averages when calculating these figures. For a firm, however, the variable that is of importance for the purposes of decision making is the value that firm faces at the margin. The real cost of finance was computed using an industry specific ratio of debt to equity. It is unlikely that this ratio accurately reflects the actual financing of many of the firms in the industry. Furthermore, nominal rates of return on equity and debt were industry specific. However, it is by no means certain that these are the actual rates that firms face, particularly at the margin (one might expect that as a firm's debt load increases, it faces a higher required rate of return on further borrowing). Thus what the applied researcher desires is a measure of the marginal real cost of finance that is specific to the firm. Similar problems occur when computing the tax savings due to depreciation allowances. Tax credit figures were based on the average eligibility of assets by industry a. Gross investment figures were computed using industrial asset weights

5.6.4 Structural Stability of the Model and the Lucas Critique

As was noted in section 5.2, one of the assumptions that was made in estimating the model is that coefficients remain constant over time for the various cross-sectional units. However, as Robert Lucas (1976) has pointed out, in a rational expectations framework this need not be the case. Under the rational expectations hypothesis, agents will incorporate systematic policy rules into their decision making rules. If tax policy is used as a stabilization tool by policy-makers and agents know this, they will incorporate this knowledge in their expectations of future tax parameters. Agents will adopt different decision rules under different policy regimes, which may result in different regression models being appropriate for each policy regime. Coefficient values may change from regime to regime and it may be the case that variables that were relevant to decision making under one policy regime are of no importance under another. It can be argued that the 1987 tax reform was meant to be a lasting reform and also possibly a move away from an interventionist tax policy, which suggests that indeed there is the possibility that agents behaved differently after the reform. The Chow test that was performed with the instrumental variables approach suggested that there was indeed a structural break in the data set. However, it was not possible to attribute this to the tax reform. If in fact there was a structural break with the tax reform, the forecasting methodology of Auerbach and Hassett may be providing an estimate that has no economic meaning, since it effectively combines a pre-reform estimate of β with a post-reform estimate of γ.

5.6.5 Endogeneity of Variables

As was noted in section 2, the neoclassical model is a model of optimal capital stock, derived under the assumption that firms are price takers. In a general equilibrium setting, however, prices will ultimately be determined in the market and supply considerations will then be relevant as well. In a model in which the dependent variable was a measure of aggregate or even industry-wide investment, price of capital goods would be determined simultaneously with the equilibrium quantity of capital goods purchased in a given period. In this case, including price as a regressor would be a mistake, as price is an endogenous variable. In this case, estimates of the model could be biased by the endogeneity of this variable. Other variables have the potential to be endogenous as well. In a full model, the market for outputs, the labour market, and the financial markets would all be included[4], with prices across markets being simultaneously being determined. If government then used tax policy to target levels of investment, tax parameters could also be endogenous. By using firm level data instead of industrial level data, the problem of endogeneity is to some extent reduced, as individual firms can be treated as price-takers. A greater degree of variability will also occur at such a level of disaggregation.

5.6.6 Aggregation

As was noted at the beginning of the chapter, by using the level of asset aggregation that is present in the Compustat data, one is making some strong assumptions about the way assets are combined in production. In particular, it is assumed that the various assets (buildings, equipment and machinery, and land) are always purchased according to a particular ratio. Yet as the figures in Chapter one shows, for businesses overall, the ratio

[4] In a small open economy like Canada, interest rates can be taken as exogenously determined by international financial interactions.

of investment in equipment and machinery to GDP have increased over time, while the ratio of investment in buildings to GDP has fallen over time. Economic theory suggests that there may be a substitution across assets as relative prices or tax treatments change. By using aggregated capital stocks and weighted prices, such substitution is masked. It is then not clear whether a model using data at the level of aggregation has any real economic meaning.

5.6.7 Tax Losses - Limitations of the Neoclassical Treatment of Taxation

In reality, the tax system tends to be quite complex, and as such it is only imperfectly reflected by the simple mathematical formulation of the neoclassical model. In particular, it may be that due to low profits in a given year, a firm may not have enough taxable income against which to declare all of its write-off allowances. Provisions exist by which firms can charge depreciation allowances from a past year in which they were not needed to a future year when they are needed. In this case, inflation will result in a further discounting of the value of these allowances which is not reflected in the neoclassical model. It may be the case that a firm never achieves the necessary cash flow to use all its depreciation allowances. In this case, tax savings due to investment incentives can no longer be treated as a riskfree cash flow.

Table 5.1: First Stage Regression Results (Forecasts Using 1989 Data Only)

	Model Specification						
	1	2	3	4	5	6	7
Outliers	Yes	No	No	No	No	No	No
# of Lags	1	1	1	2	2	3	3
Trend	No	No	Yes	No	Yes	No	Yes
Communications							
Number of firms	6	5	5	5	5	5	5
Investment error	.114	.024	.057	.022	.036	.066	.066
	(.281)	(.092)	(.093)	(.092)	(.092)	(.092)	(.092)
User cost error	.019	.019	.018	.0156	.016	.013	.0064
	(.0003)	(.0002)	(.001)	(.0005)	(.001)	(.001)	(.0003)
$\bar{R}^2$(investment)	.08	.49	.56	.48	.60	.64	.63.
$\bar{R}^2$(user cost)	.67	.65	.65	.67	.67	.70	.82
Construction							
Number of firms	3	0	0	0	0	0	0
Investment error	-.238	n/a	n/a	n/a	n/a	n/a	n/a
	(.642)						
User cost error	.030	n/a	n/a	n/a	n/a	n/a	n/a
	(.0003)						
$\bar{R}^2$(investment)	.22	n/a	n/a	n/a	n/a	n/a	n/a
$\bar{R}^2$(user cost)	.74	n/a	n/a	n/a	n/a	n/a	n/a
Manufacturing							
Number of firms	69	48	48	48	48	48	48
Investment error	.124	.044	.007	.011	.0022	-.0155	-.0167
	(1.39)	(.185)	(.184)	(.185)	(.184)	(.184)	(.184)
User cost error	.0051	.0055	.025	-.007	.0041	.0197	.0123
	(.0012)	(.0020)	(.001)	(.002)	(.0005)	(.0006)	(.0004)
$\bar{R}^2$(investment)	.04	.13	.13	.13	.13	.13	.13
$\bar{R}^2$(user cost)	.41	.41	.59	.45	.93	.91	.96
Public Utilities							
Number of firms	4	2	2	2	2	2	2
Investment error	.65	-.020	-.139	-.070	-.118	-.099	.051
	(.12)	(.092)	(.105)	(.093)	(.108)	(.099)	(.084)
User cost error	.037	.040	.047	.040	.044	.045	.037
	(.001)	(.005)	(.006)	(.005)	(.007)	(.006)	(.006)
$\bar{R}^2$(investment)	.01	.31	.36	.28	.33	.24	.46
$\bar{R}^2$(user cost)	.72	.71	.74	.69	.76	.71	.79

Table 5.1 (con't)

	Model Specification						
	1	2	3	4	5	6	7
Retail Trade							
Number of firms	14	11	11	11	11	11	11
Investment error	.148	.066	-.068	-.043	-.071	-.097	-.050
	(152)	(.138)	(.138)	(.138)	(.138)	(.0138)	(.138)
User cost error	.0063	.0062	.0013	-.0015	-.0016	-.0054	-.0126
	(.0001)	(.0001)	(.0003)	(.0002)	(.0002)	(.0003)	(.0004)
$\bar{R}^2$(investment)	.01	.04	.11	.07	.10	.09	.10
$\bar{R}^2$(user cost)	.40	.39	.45	.52	.51	.59	.84
Service							
Number of firms	3	2	2	2	2	2	2
Investment error	-.138	-.389	-.494	.-.581	-.578	-.595	-.669
	(.025)	(.006)	(.006)	(.005)	(.005)	(.005)	(.003)
User cost error	.009	.0083	.0076	.0006	.002	.0026	-.0046
	(.001)	(.0003)	(.0003)	(.0003)	(.0002)	(.0003)	(.0001)
$\bar{R}^2$(investment)	.05	.14	.11	.14	.09	.09	.04
$\bar{R}^2$(user cost)	.55	.58	.55	.67	.73	.67	.80
Transportation and Storage							
Number of firms	5	4	4	4	4	4	4
Investment error	.037	.195	.225	.263	.259	.244	.226
	(.089)	(.225)	(.225)	(.224)	(.225)	(.225)	(.225)
User cost error	-.0063	-.0060	-.0024	-.0218	-.0164	-.0111	-.0172
	(.0002)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
$\bar{R}^2$(investment)	.03	.27	.25	.27	.25	.25	.24
$\bar{R}^2$(user cost)	.24	.22	.22	.48	.91	.80	.91
Wholesale Trade							
Number of firms	11	8	8	8	8	8	8
Investment error	-.178	.022	.0499	.004	.022	.056	.071
	(.166)	(.171)	(.171)	(.171)	(.171)	(.171)	(.171)
User cost error	.0095	.0098	.0169	.0044	.0085	.0128	.0067
	(.0008)	(.0006)	(.0004)	(.0007)	(.0001)	(0004)	(.0001)
$\bar{R}^2$(investment)	-.02	.14	.14	.13	.13	.14	.13
$\bar{R}^2$(user cost)	.60	.59	.65	.63	.91	.82	.92

Note: Figures in parentheses indicate the standard deviation of the forecast errors.

Table 5.2: First Stage Regression Results (Forecasts Using 1989-90 Data)

	Model Specification						
	1	2	3	4	5	6	7
Outliers	Yes	No	No	No	No	No	No
# of Lags	1	1	1	2	2	3	3
Trend	No	No	Yes	No	Yes	No	Yes
Communications							
Number of firms	6	5	5	5	5	5	5
Investment error	.114	.0182	.054	.016	.039	.054	.054
	(.298)	(.068)	(.066)	(.068)	(.067)	(.068)	(.068
User cost error	.017	.0174	.0155	.014	.014	.012	.0095
	(.002)	(.002)	(.003)	(.002)	(.002)	(.002)	(.0035)
$\overline{R}^2$(investment)	.08	.49	.55	.48	.60	.64	.63
$\overline{R}^2$(user cost)	.67	.65	.65	.67	.71	.70	.82
Construction							
Number of firms	3	0	0	0	0	0	0
Investment error	-.197	n/a	n/a	n/a	n/a	n/a	n/a
	(.452)						
User cost error	.011	n/a	n/a	n/a	n/a	n/a	n/a
	(.051)						
$\overline{R}^2$(investment)	.22	n/a	n/a	n/a	n/a	n/a	n/a
$\overline{R}^2$(user cost)	.74	n/a	n/a	n/a	n/a	n/a	n/a
Manufacturing							
Number of firms	69	48	48	48	48	48	48
Investment error	-.046	.008	-.028	-.024	-.032	-.046	-.047
	(1.03)	(.200)	(.199)	(.199)	(.199)	(.199)	(.198)
User cost error	.017	.018	.037	.006	.0184	.030	.025
	(.012)	(.012)	(.012)	(.015)	(.014)	(.010)	(.012)
$\overline{R}^2$(investment)	.04	.13.	.13	.13	.13	.13	.13
$\overline{R}^2$(user cost)	.41	.41	.59	.45	.93	.91	.96
Public Utilities							
Number of firms	4	2	2	2	2	2	2
Investment error	.688	.148	.032	.105	.048	.082	.13
	(.185)	(.268)	(.27)	(.272)	(.26)	(.277)	(20)
User cost error	.035	.035	.042	.035	.040	.039	.037
	(.002)	(.006)	(.007)	(.006)	(.006)	(.007)	(.0038)
$\overline{R}^2$(investment)	.01	.31	.36	.28	.33	.24	.46
$\overline{R}^2$(user cost)	.72	.71	.74	.69	.84	.71	.79

Table 5.2 (con't)

	Model Specification						
	1	2	3	4	5	6	7
Retail Trade							
Number of firms	14	11	11	11	11	11	11
Investment error	.132	.0163	-.12	-.082	-.127	-.13	-.12
	(.205)	(.202)	(.20)	(.200)	(.204)	(.20)	(.21)
User cost error	.001	.0055	.0003	-.0016	-.0017	-.005	.007
	(.40)	(.0008)	(.0011)	(.0001)	(.0002)	(.0005)	(.006)
$\overline{R}^2$(investment)	.01	.04	.11	.07	.10	.09	.10
$\overline{R}^2$(user cost)	.40	.39	.45	.52	.52	.59	.84
Service							
Number of firms	3	2	2	2	2	2	2
Investment error	..158	.14	.033	-.036	-.030	-.048	-.083
	(.937)	(1.16)	(1.16)	(1.17)	(1.17)	(1.17)	(1.20)
User cost error	.009	.009	.009	.0021	.0044	.0040	.0006
	(.001)	(.001)	(.001)	(.0017)	(.0026)	(.0016)	(.0059)
$\overline{R}^2$(investment)	.05	.14	.11	.14	.09	.09	.04
$\overline{R}^2$(user cost)	.55	.58	.55	.67	.73	.67	.80
Transportation and Storage							
Number of firms	5	4	4	4	4	4	4
Investment error	-.023	.095	.126	.16	.15	.14	.13
	(.158)	(.19)	(.193)	(.20)	(.20)	(.20)	(.19)
User cost error	-.002	-.0013	.0024	-.015	-.007	-.006	-.008
	(.005)	(.005)	(.0052)	(.007)	(.009)	(.005)	(.010)
$\overline{R}^2$(investment)	.03	.27	.25	.27	.25	.25	.24
$\overline{R}^2$(user cost)	.24	.22	.22	.48	.91	.80	.91
Wholesale Trade							
Number of firms	11	8	8	8	8	8	8
Investment error	-.182	.-.016	.0134	-.032	-.064	.013	.018
	(.144)	(.13)	(.134)	(.13)	(.13)	(.14)	(.14)
User cost error	.012	.012	.0196	-.007	.014	.015	.013
	(.003)	(.0025)	(.0028)	(.003)	(.005)	(.002)	(.006)
$\overline{R}^2$(investment)	-.02	.14	.14	.13	.13	.14	.14
$\overline{R}^2$(user cost)	.60	.13	.65	.63	.92	.82	.92

Note: Figures in parentheses indicate the standard deviations of the forecast errors.

Table 5.3: Second Stage Regression Results (1989 Forecasts Only)

	Model Specification						
	1	2	3	4	5	6	7
Outliers	Yes	No	No	No	No	No	No
Trend	No	No	Yes	No	Yes	No	Yes
Lags	1	1	1	2	2	3	3
Manufacturing							
User cost Coefficient	87.3	-33.85*	-82.28	-28.07*	-140.9*	-95.4*	-158.8*
	(.64)	(-2.68)	(-1.751)	(-2.72)	(-2.66)	(-2.32)	(-2.41)
Constant	-.32	.231*	2.039	-.17*	.575*	1.86*	1.93*
	(-.45)	(3.12)	(1.757)	(-2.40)	(2.65)	(2.31)	(2.39)
d.f.	67	46	46	46	46	46	46
$\overline{R}^2$	-.01	.12	.04	.12	.11	-.01	.09
Reset (2)	.89	1.18	2.22	.84	.84	1.91	1.67
Reset (3)	.59	.67	1.12	.45	.45	1.08	.96
Reset (4)	.68	1.23	1.37	1.08	1.07	1.31	1.29
Non-manufacturing							
User cost Coefficient	8.32*	-4.20	-1.67	-4.11	3.52	-.705	1.10
	(2.09)	(-1.34)	(-.54)	(-1.47)	(-1.21)	(-.23)	(.35)
Constant	-.044	.072	.0043	-.0075	-.0076	-.018	.0024
	(-.68)	(1.61)	(.050)	(-.19)	(.0042)	(.044)	(.056)
d.f.	44	30	30	30	30	30	30
$\overline{R}^2$	.07	.03	-.0233	.04	.01	-.03	-.03
Reset (2)	6.83*	1.38	.12	3.16	1.39	.004	.289
Reset (3)	6.73*	1.25	4.85*	3.77*	5.21*	7.45*	7.98*
Reset (4)	4.89*	.85	8.09*	2.44	3.61*	7.64*	7.28*
All							
User cost Coefficient	6.28	-5.51	-.392	-4.76*	-3.83	-.42	.105
	(.49)	(-1.92)	(-.191)	(-2.18)	(-1.48)	(-.21)	(.050)
Constant	.0473	.079	.007	-.015	.0082	-.012	-.011
	(.33)	(.029)	(.143)	(-.64)	(.33)	(-.34)	(-.39)
d.f.	113	78	78	78	78	78	78
$\overline{R}^2$	-.01	.03	-.01	.05	.02	-.01	-.01
Reset (2)	.195	2.98	.55	5.75*	1.15	.019	.56
Reset (3)	.399	1.71	2.46	4.29*	3.43*	3.46*	3.28*
Reset (4)	.336	1.86	4.53*	3.64*	2.58	4.98*	4.10*
Chow test	.69	3.46*	2.29	2.92	3.74*	2.83	3.13*

t-statistics in brackets * Indicates estimate is significant at .05 level.

Table 5.4: Second Stage Regression Results (1989-90 Forecasts)

	Model Specification						
	1	2	3	4	5	6	7
Outliers	Yes	No	No	No	No	No	No
Trend	No	No	Yes	No	Yes	No	Yes
Lags	1	1	1	2	2	3	3
Manufacturing							
User cost Coefficient	-12.49	-3.61*	-3.16	-3.21*	-2.51	-3.30	-2.52
	(-1.73)	(-2.19)	(-1.81)	(-2.13)	(-1.80)	(-1.64)	(-1.56)
Constant	.167	.072*	.088	-.002	.014	.052	.016
	(.150)	(2.04)	(1.313)	(.09)	(.43)	(.825)	(.348)
d.f.	136	94	94	94	94	94	94
$\overline{R}^2$	.01	.04	.02	.04	.02	.02	.01
Reset (2)	.159	.46	.76	.37	.60	.68	.69
Reset (3)	.69	3.79*	1.52	3.80*	3.93*	2.94	3.08
Reset (4)	2.17	2.50	1.05	2.51	2.59	1.97	2.06
Non-manufacturing							
User cost Coeff.	1.56	-.115	2.59	.25	.74	2.63	2.61
	(.63)	(-.027)	(.78)	(.10)	(.23)	(.84)	(.89)
Constant	.038	.036	-.039	-.012	-.024	-.028	-.017
	(.80)	(.611)	(-.74)	(-.29)	(-.53)	(-.648)	(-.40)
d.f.	90	62	62	62	62	62	62
$\overline{R}^2$	-.01	-.02	-.006	-.02	-.02	-.005	-.003
Reset (2)	5.33*	.57	.78	.035	.53	.055	.604
Reset (3)	6.66*	.95	.53	.58	2.55	1.81	1.22
Reset (4)	6.78*	.72	.35	1.98	1.82	1.46	2.81*
All							
User cost Coeff.	-5.41	-2.78	-.716	-1.64	-1.37	-.829	-.87
	(-1.40)	(-1.651)	(-.623)	(-1.17)	(-1.02)	(-.671)	(-.72)
Constant	.074	.06	-.0023	-.01	-.008	-.016	-.017
	(.94)	(1.90)	(-.064)	(-.48)	(-.297)	(-.51)	(-.60)
d.f.	228	158	158	158	158	158	158
$\overline{R}^2$	.004	.01	-.004	.002	.0003	-.004	-.003
Reset (2)	.081	.78	3.60	.052	.14	1.65	.33
Reset (3)	1.15	.79	1.79	1.55	1.34	1.86	2.13
Reset (4)	2.48	.52	1.20	2.48	2.34	1.85	3.69*
Chow Test	2.81	.54	1.93	1.04	.77	2.03	2.17

t-statistics in brackets. * Indicates estimate significant at .05 level.

Table 5.5: Estimation Results Using Instrumental Variables Approach

	Model Specification						
	1	2	3	4	5	6	7
Outliers		No	No	No	No	No	No
# of Lags		1	1	2	2	2	2
Trend		No	Yes	No	Yes	No	Yes
Coefficient Estimates							
Constant		.124 (.856)	-23.99 (-1.43)	.127 (.87)	47.20 (1.25)	.059 (.37)	72.78 (1.76)
User cost		-.622 (-1.44)	-.309 (-.64)	-.90* (-2.00)	-1.82* (-2.11)	-.383 (-.51)	-1.30 (-1.43)
Lag Cash		.123* (4.89)	.121* (4.79)	.117* (4.49)	.117* (4.47)	.115* (4.31)	.114* (4.28)
Price		.194 (1.44)	.84 (1.79)	.308 (2.16)	-.85 (-.91)	.28 (1.83)	-1.55 (-1.47)
Oil Pr.		-.079 (-1.56)	-.10 (-1.95)	-.148* (-2.51)	-.17* (-2.77)	-.133* (-2.25)	-.164* (-2.65)
Int. Rate		.0002 (.587)	.003 (.73)	.006 (1.51)	.009 (1.91)	.004 (.89)	.006 (1.29)
Trend		n/a	.012 (1.44)	n/a	-.023 (-1.25)	n/a	-.036 (-1.75)
Inv (-1)		.225* (6.02)	.220* (5.87)	.216* (5.49)	.216* (5.52)	.206* (5.10)	.206* (5.12)
Inv (-2)		n/a	n/a	-.042 (-1.05)	-.043 (-1.07)	-.034 (-.80)	-.035 (-.83)
Inv (-3)		n/a	n/a	n/a	n/a	-.063 (-1.48)	-.066 (-1.55)
$\overline{R}^2$		.087	.089	.090	.091	.094	.097
Chow Test		2.71	4.52	2.72	3.20	2.85	3.20

* Statistically significant at the .05 level.

CHAPTER 6: SUMMARY AND CONCLUSIONS

6.1 A Review

The purpose of this thesis is to empirically investigate the impact of corporate taxes on real business investment. Towards this end, an investment model based upon the work of Auerbach and Hassett (1991) and Cummins and Hassett (1992) is estimated using Canadian data. This model is based on the neoclassical theory of investment which relates the optimal amount of investment to the user cost of capital adjusted for taxes.

The Auerbach/Hassett/Cummins (AHC) methodology involves a two-step procedure designed to address the problems that the econometrician faces in measuring the user cost of capital perceived by firms due to uncertainty regarding future tax parameters. To overcome this problem, AHC take advantage of a "natural experiment" offered up by the 1986 TRA in the U.S., after which, they argue, the user cost of capital is measurable to the econometrician due to the "permanent" nature of the tax reform and the accompanying stability of the tax parameters. Canada underwent a similar tax reform in 1987, suggesting that a similar empirical approach may be used to assess the impact of taxation on investment in a Canadian setting.

As indicated, the estimation consisted of two stages. Before the 1987 tax reform, firm expectations of the present value of depreciation allowances could not be measured correctly, due to uncertainties about future tax parameters. As a consequence, *ex post* values of the user cost term will contain measurement errors and if they are used to estimate the tax coefficient, then the resultant coefficient estimate will be inconsistent. In the first stage, then, the investment equation is estimated without the unobservable user cost variable, which, provided the model is otherwise correctly specified, results in an estimate of the remaining coefficient β that is biased in a known way. The bias depends on the extent to which the (actual) user cost term can be represented by a linear combination of the remaining regressors. The first stage also consists of regressing the *ex post* values of the user cost on the remaining variables to find an estimate of the coefficient π that results from the auxiliary regression of the actual user cost on the remaining independent variables. If one had the actual values for π and γ (the coefficient of the user cost term in the investment function) one could then use this information along with the biased estimate to recover an unbiased estimate of β.

In essence, the first-stage regression recovers an estimate of β, excluding the information contained in the user cost coefficient. One can then use cross-sectional data after the reform, for which the user cost is measured without error, to estimate only γ, leading to a more precise estimate of this coefficient. The second-stage of the estimation process involves using the first-stage regressions and the post-reform data to forecast values of investment and the user cost. Forecast errors are then the difference between actual and forecast values of the variables. The user cost coefficient is estimated by regressing investment forecast errors on the user cost forecast errors.

The two-step technique was used to estimate investment functions for Canadian firms. The data used in this paper was at a higher level of aggregation than that used by Cummins and Hassett, and included land, equipment and machinery, and buildings. A variety of specifications were used in the first stage. Estimates of the user cost coefficient tended to be statistically insignificant for most of the data set, regardless of the model specification used in the first stage. Statistically significant estimates of the user cost were found for some first-stage specifications when estimates were confined to a pool of manufacturing firms. These estimates implied an elasticity at the mean of investment with respect to the user cost that was three or more times greater than those values found by Cummins and Hassett. Such high values seem implausible.

The Ramsey Reset test was applied to the second-stage regression for each of the various model specifications. When only 1989 data was used in the second stage, the test failed for numerous first-stage specifications, particularly when only non-manufacturing was used to estimate the model. Once outliers were removed and post-reform data for both 1989 and 1990 were used, most specifications passed. Chow tests suggest that once data is pooled for all industries and both post-reform years, there is no difference between the user cost coefficient for manufacturing and non-manufacturing firms.

Using the *ex post* user cost as an instrumental variable for the expected user cost, the model was re-estimated in a single step regression for the pool of manufacturing firms. Estimates of the user cost coefficient were significant for several model specifications and tended to be more in line with the values found by Cummins and Hassett. However, this result is consistent with a measurement error in the pre-reform user cost variable, since such a measurement error results in attenuation of the estimate. Chow tests provided indications of a structural break somewhere in the data set, although this could not be attributed to the 1987 tax reform.

There are a number of possible reasons why the results of this paper differ from those of Cummins and Hassett. One obvious reason may be the difference in the level of aggregation of the data used in the two studies. The data set that Cummins and Hassett used allows for investment in buildings and in equipment and machinery to move in opposite directions and allows for substitution effects. If the two are "forced" to move together, as they are here due to data restrictions, it is not clear what is being measured by the tax coefficient if in fact investment in one asset is increasing while that in the other asset is declining.

Several possible problems with the methodology were pointed out as well. It is by no means clear that the two-step process that Auerbach and Hassett developed actually does eliminate the measurement errors resulting from using *ex post* values of the user cost in the auxiliary regression. If errors are not removed, this method will result in inconsistent estimates. It was also noted that by using the kind of financial data that was used here and by Cummins and Hassett, one produces a measure of the capital stock that is inconsistent with economic notions of the capital stock. It fact, measurements produced with such data are not even comparable across firms, and their use in estimating an investment function is suspect.

6.2 Suggestions for Further Research

Based on insights gained through the research that lead to this work, a number of suggestions can be made about possible directions that future investment research can take. The next few subsections mention briefly some possible approaches that could be undertaken if sufficient time and resources were available.

6.2.1 Construction of a Meaningful Measure of Capital

As noted in chapter 5, capital stock estimates based on historical costs are not consistent with notions of capital used in economic modeling. In principle, an estimate of capital stock that was consistent with economic notions could be constructed if one had access to a firm's books. As long as one had price indicies for capital and an estimate of depreciation, one could use annual investment figures and the perpetual inventory method described in section 3.6 to build a meaningful measure of capital for each firm. Of course even if one could gain access to the books of various firms such an exercise would likely be time consuming. It might nonetheless be possible then to build capital stock estimates at a lower level of aggregation than the values that appear here, with distinctions made between assets at a level that was at least as fine as that available to Cummins and Hassett (i.e. buildings vs. equipment and machinery).

Even if one was unable to build such a data set, a number of possibilities exist for producing a data set which allows for the possibility that the ratio of goods purchased varied over time. Here, it was assumed that the ratios of different type of assets remained fixed over the entire sample period and as a consequence investment bundles consisted of the same blend of assets in each period. Whether or not this is true for particular industries or firms, it most certainly is not true for the economy as a whole. As a percentage of GDP, business investment on buildings in Canada has trended downwards (from 7% of GDP in 1982 to 5% in 1990) while investment in equipment and machinery has increased (from 5% in 1977 to 9% in 1990). Even if year by year estimates of the breakdown of investment by asset type, one might be able to improve measures by using asset ratios for two years (one near the beginning of the data set and one near the end) and using interpolative methods to fill in the gaps.

6.2.2 Firm-specific Cost of Finance

Although it was not done here, it would be possible to use firm level data to produce debt to equity ratios for individual firms. In this case, a cost of finance figure may be estimated for each individual firm. Although this may be an improvement over using industry averages, it will likely still not measure the cost of finance that is applicable to the marginal investment. Marginal investment may be financed by a single type of financing (debt or equity) at a rate of return that differs signficantly from the average cost of finance. In this case, firm specific average costs of finance still will not measure the cost of finance applicable to the last unit of investment.

6.2.3 Irreversibility of Investment

If investment is not fully irreversible, then the appropriate user cost term will not be the term that follows from the Jorgensonian formulation of the neoclassical model. Use of the this term will then underestimate the true user cost firms face. Further research could incorporate this possible irreversibility of investment. Abdelgawad and Rhee (1994) have estimated a model with U.S. data in which complete irreversibility of investment is assumed. Although they found weak evidence for irreversibility, room for future research remains. Moreover, they did not explicitly account for tax effects.

APPENDIX A: ESTIMATION OF A MODEL WITH A MISSING REGRESSOR

Let I is a function of the variables X,c and a stochastic term ε:

$$I = X\beta + c\gamma + \varepsilon \tag{A.1}$$

Now suppose that one were instead to estimate the model:

$$I = Xb + \nu \tag{A.2}$$

In this case, if one were to use an OLS estimator, one would get

$$\hat{b} = (X^T X)^{-1} X^T I \tag{A.3}$$

which is a biased estimate of β. To see this, substitute (A.1) into (A.3) to get

$$\hat{b} = (X^T X)^{-1} X^T (X\beta + c\gamma + \varepsilon) \tag{A.4}$$

and then apply the expectations operator to both sides. The result is

$$E(\hat{b}) = \beta + (X^T X)^{-1} X^T c\gamma \tag{A.5}$$

But $(X^T X)^{-1} X^T c$ is just the coefficient resulting from the auxiliary regression of c on X

$$c = X\pi + e \tag{A.6}$$

and so (A.5) may be rewritten as

$$E(\hat{b}) = \beta + \pi\gamma \tag{A.7}$$

It should be noted that (A.6) does not imply that c is a function of X. Rather (A.7) is a mathematical artifact by which the vector c is decomposed into the portion $X\pi$ that projects onto the space spanned by X and the portion e that is orthogonal to the space spanned by X.

BIBLIOGRAPHY

Akerlof, George. "The Market for 'Lemons': Quality, Uncertainty and the Market Mechanisms." Quarterly Journal of Economics 84: 488-500.

Auerbach, Alan J. "Taxation, Corporate Financial Policy and the Cost of Capital." Journal of Economic Literature 21 (1983): 905-940.

Auerbach, Alan J., and Kevin Hassett. "Recent U.S. investment behaviour and the tax reform of 1986: A disaggregate view." Carnegie-Rochester Conference Series on Public Policy 35 (1991): 185-216.

---. "Tax Policy and Business Fixed Investment in the United States." Journal of Public Economics 47 (1992): 141-170.

Auerbach, Alan J., and James R. Hines, Jr. "Investment Tax Incentives and Frequent Tax Reforms." American Economic Review. 78 (1988): 211-216.

Berndt, Ernst R. "Explaining and Forecasting Aggregate Investment Expenditures: Distributed Lags and Autocorrelation." The Practice of Econometrics: Classic and Contemporary. Reading, Mass.: Addison-Wesley, 1991. 224-305.

Bertola, Giuseppe, and Ricardo J. Caballero. "Irreversibility and Aggregate Investment." National Bureaus of Economic Research, U.S.A., W.P. 3865, 1991.

Boadway, Robin W. "The Theory and Measurement of Effective Tax Rates." The Impact of Taxation on Business Activity. ed. J.M. Mintz and D.D. Purvis. Kingston, Ontario: John Deutsh Institute, 1987. 60-98.

Chirinko, Robert S. "Business Fixed Investment Spending: Modeling Strategies, Empirical Results, and Policy Implications." Journal of Economic Literature 31 (1993): 1875-1911.

Cummins, Jason G., and Kevin A. Hassett. "The Effects of Taxation on Investment: New Evidence From Firm Level Panel Data." National Tax Journal 45 (1992): 243-251.

Eisner, Robert and Robert H. Strotz. "Determinants of Business Investment." Impacts of Monetary Policy. Commission on Money and Credit. Englewood Cliffs, NJ: Prentice-Hall, 1963. 59-233.

Hall, Robert E. and Dale W. Jorgenson. "Application of the Theory of Optimum Capital Accumulation." Tax Incentives and Capital Spending. ed. Gary Fromm. D.C. Brookings Institution, 1971. 9-60.

Jog, V. and J.M. Mintz. "Corporate Tax Reform and its Economic Impact: An Evaluation of the Phase I Proposals." Economic Impact of Tax Reform. Canadian Tax Paper No.84. ed. J.M. Mintz and J. Whalley. Toronto: Canadian Tax Foundation, 1989.

Jorgenson , Dale. "Capital Theory and Investment Behaviour." American Economic Review 53 (1963): 247-259.

Jung, Jack. "The Calculation of Marginal Effective Corporate Tax Rates in The 1987 White Paper on Tax Reform." Tax Policy and Legislation Branch, Department of Finance, Canada, W.P. 89-6, 1989.

McKenzie, Kenneth J. "The Implications of Risk and Irreversibility for the Measurement of Marginal Effect Tax Rates on Capital." Canadian Journal of Economics 27 (1994): 604-619.

Scarth, William M. "Rational Expectations and the Lucas Critique." Macroeconomics: An Introduction to Advanced Methods. Toronto: Harcourt Brace Jovanovich, 1988. 65-79.

Solow, Robert M. "A Contribution to the Theory of Economic Growth." Quarterly Journal of Economics (February 1956): 65-94.

Watt, P.A. "Econometric Testing of the Displacement Effect: A Note." Finanzarchiv 36 (1978): 445-448.

---. "Tests of Equality between Sets of Coefficients in Two Linear Regressions when Disturbance Variances are Unequal: Some Small Sample Properties." The Manchester School 47 (1979): 391-396.