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CAPITAL INVESTMENT DECISIONS OF LARGE INDUSTRIAL FIRMS IN MAJOR EUROPEAN COUNTRIES

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**CAPITAL INVESTMENT DECISIONS OF LARGE INDUSTRIAL
FIRMS IN MAJOR EUROPEAN COUNTRIES**

by

FATIH YILMAZ

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for the degree of

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Abstract

Using large-company panel data, this thesis empirically analyses investment decisions in major European countries. We particularly concentrate on three issues: the taxation of capital in the EU, the role of agency costs of debt on investment decisions, and the empirical analyses of the investment-uncertainty relationship. First, based on a dynamic system in capital and Tobin's q ratio, some simplified analytical results are derived to simulate various tax policy effects on investment. Also, for a single investment project, a model is developed to consider jointly the role of uncertainty and irreversibility in the taxation of capital. The simulation results cast doubt on the tax competition view for the domestic investment case. Second, using a Euler equation approach, an investment equation is derived to test the possible effects of agency/financial distress costs of debt on investment for UK, German and French firms. The results reveal that the agency/financial distress cost of debt does matter for the highly leveraged firms. Further, an alternative model is derived in a q theory framework to test this negative effect. The model is tested for the UK firms, and similar results are obtained. Third, by considering the product structure of firms, the firm-level investment-uncertainty relationship is tested for UK firms. Unlike previous empirical findings, the results support the two opposing views in this field. Additionally, using vector autoregression analysis, a statistical account of the aggregate investment-uncertainty relation is given for the UK. An important observation is that although the exchange rate uncertainty has negative effects on machinery and equipment investment, it has no effect on construction investment.

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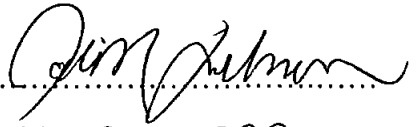
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Author's Declaration

This study was financed with the aid of a scholarship from the University of Plymouth Business School. At no time during the registration for the degree of Doctor of Philosophy have I been registered for any other University award. I certify that all material in this thesis which is not my own work has been identified and that no material is included for which a degree has previously been conferred upon me. The following papers are based on the work presented in this thesis :

Yilmaz, F. 1998, 'METR and Tax Asymmetries in the EU Under Uncertainty and Irreversibility', *Plymouth Business School Discussion Paper*, No:178 (based on chapter 3).

Yilmaz, F. 1998, 'The Sign of the Investment-Uncertainty Relationship: A UK Panel Study', *Plymouth Business School Discussion Paper*, No:179 (based on chapter 6).

Signed.....
Date.....16-2-1999.....

INTRODUCTION

This thesis empirically studies various aspects of incremental capital investment decisions from a firm's perspective. Capital investment involves formation of tangible capital assets such as machinery, equipment or buildings. Investment decisions are crucial for firms because capital investments affect future profits and cash flows both as sources and uses. The durability of capital affects the health and environment of a firm for the remainder of the asset's life. For the economy, aggregate investment determines aggregate demand and the level of employment. In the longer-term it determines production capacity and growth of living standards. Moreover, the volatility of investment greatly affects economic cycles. Therefore, it is important to understand the investment decisions and the implications of various policies for it.

Studying incremental investment decisions from a firm's perspective requires analysing complex decision processes. One has to consider many things including profit expectations, cost of funds, availability of funds, various forms of uncertainty, irreversibility of investment decisions, corporate and personal taxation, inflation, interactions with financial capital structure decisions and dividend decisions, employment of working capital and intangible assets, the structure of factor and product markets and industry, managerial problems, etc. In a modelling process, one has to consider the durability of capital and the forward-looking nature of investment decisions. Also, immediate completion of an

investment project takes time or becomes costly. Thus, an explicit adjustment mechanism becomes an integral part of a formulation. Moreover, since firms make investment decisions according to their future expectations, these expectations should be properly treated. The first chapter of this study gives a review of the theory of investment at both theoretical and empirical levels. The first two sections present the modern literature on investment: the neo-classical theory originated by Dale Jorgenson, and the q theory developed by James Tobin. Later sections of this chapter present the theoretical and empirical studies relevant to taxation, financing conditions and uncertainty and irreversibility.

The motivation behind this empirical study is to concentrate on some of the topics that exhibit controversy and to make a contribution to the empirical literature on these topics. Particularly, the focus is on three issues: the taxation of capital in the European Union (EU) and harmonisation of corporate tax rules, the role of incentive problems and agency/financial distress costs of debt on investment decisions, and the empirical analyses of the investment-uncertainty relationship.

Many studies investigating various aspects of capital investment decisions include large numbers of small firms in their samples. Although including all available individual data results in a better approximation of aggregate data and reduces selection biases and increases degrees of freedom, in some cases it might be misleading. For instance, if a study is testing the effects of financing constraints on investment decisions of firms, a significant result for small firms

may not have very important implications for the whole economy since it will be the larger firms that constitute a very large fraction of aggregate investment. In this thesis we study the investment behaviour of large industrial firms. Thus, the empirical results obtained are not subject to the above-mentioned small firm biases. This is certainly the case throughout chapters 4-6 in which we analyse the effects of financing conditions and firm-level uncertainty.

On the other hand, using only large-company data greatly reduces the available number of observations. Moreover, firm-level data is generally available on a yearly basis. Considering these restrictions, we employ firm-level panel data throughout chapters 2-6. Employing panel data increases the degrees of freedom and gives more information, increasing the efficiency of estimates and easing making inferences. Moreover, it has the certain advantage of allowing for heterogeneity either through time or across firms that could not be modelled using cross-section and time-series data. It also has the advantage of reducing collinearity since the cross-section dimension adds a lot of variability. Throughout the chapters, we give explanations about the econometric methodology employed.

The data are collected for the companies that are gathered under the general industries classification of Datastream. The general industries classification includes engineering, chemicals, electronic and electrical equipment, engineering vehicle components, house building and other construction, building materials and

merchants, diversified industries, paper printing and packaging, and textiles, clothing and footwear as sub-industries.

Chapters 2 and 3 analyse the impacts of the harmonisation of basic corporate tax rules in Europe. The analyses concentrate on the UK, France, Germany and the Netherlands. Harmonisation of tax rules in the EU has been an important argument. Some studies argued in favour of independent tax systems for demand management and economic stabilisation and adjustment. On the other hand, some argued in favour of harmonisation to prevent discrimination and distortion in investment decisions which will result in inefficient location decisions. Based on the q theory of investment, chapter 2 simulates the effects of various tax policy shocks in a dynamic partial equilibrium framework. Instead of measuring the tax burden as in a static case, the dynamic analysis tells us the effects of various policy changes on investment decisions. We admit the results will be limited to the extent that the q theory explains the investment behaviour. However, it has the advantage of treating expectations. Simulation results reveal that tax policies can be used to affect investment decisions. It is found that investment is more sensitive to investment tax credit changes relative to other policy effects. Substantial differences are observed for the tax policy effects on investment between the UK and France, Germany, and the Netherlands as a group, and also differences within this group in terms of different policy effects. Among the countries, investment is found least sensitive to all policy shock effects in the UK.

More importantly, the harmonisation of the corporate tax rules reduces the observed asymmetry only by a limited amount.

Many studies investigating the effects of taxation on capital investment apply effective tax rates. Effective tax rates are commonly employed to reveal the role of a tax system on investment decisions. However, the traditional measures assume a perfectly certain environment and ignore the irreversibility risk governing investment decisions. In chapter 3, a model is constructed to include the joint effects of income uncertainty and irreversibility risk into the domestic marginal effective tax rate measures. Considering a zero loss offset income tax case, it is shown that this joint effect greatly increases the tax distortion measures. Also, the effects of harmonising the corporate tax rules are analysed. When the joint risk is incorporated, the reduction in the observed asymmetry is far less than the reduction in the case of certainty and reversibility. Within the context of the models employed in chapters 2 and 3, we conclude that the obtained results cast doubt on the tax competition view in the EU for the domestic investment case. Thus, harmonising corporate tax rules may mean the loss of a fiscal tool which can be used for adjustments of asymmetric shocks or for national demand management and economic stabilisation of the member economies.

In the literature, many studies proposed that information and incentive problems may create frictions in financial capital markets. The imperfect substitution between internally generated and externally raised funds due to imperfect

information and incentive problems can create an external financing premium. Moreover, some firms might be under financial distress, or even credit rationed. Thus, financing conditions may have important implications for investment decisions. Studies testing the possible relations between investment and financing decisions mostly documented cash flow and liquidity effects. However, existing empirical studies about the effects of incentive problems on investment decisions are not numerous and find controversial results, showing that more empirical investigations of these effects are required.

Thus, in chapter 4, using a Euler equation approach and based on the agency/financial distress costs of debt, an investment equation is derived to test the role of debt financing conditions on investment decisions. In the model, we also consider the possible beneficiary role of working capital on the asset side of the balance sheet to smooth these costs and pressures. The study covers large UK, German and French firms. The estimation results reveal that the perfect financial capital markets hypotheses are not acceptable. According to the developed model, the agency/financial distress costs of debt are important so that debt financing has a significant role in management's investment decisions. However, to some extent, firms have the ability to smooth these costs and alleviate pressures through their working capital policy on the asset side of their balance sheets. Further analyses reveal that the agency/financial distress cost of debt does matter for the high-leverage groups, whereas it is not significant for the low-leverage groups.

The findings of this chapter imply important effects for the three economies as the increments in corporate leverage may increase the economy-wide costs and risk.

In chapter 5, we derive an alternative model in a q theory framework to test the role of agency/financial distress costs of debt on investment. In this formulation, the investment equation includes the debt-capital ratio under the hypothesis of incentive problems of debt and capital market imperfections. We test this alternative model for the UK firms. Similar to the findings in chapter 4, the estimation results reveal that the agency/financial distress costs of debt have a significant negative role in investment decisions of highly leveraged firms. To some extent, those firms have the ability to smooth these costs through their working capital policy.

Chapter 6 empirically examines the sign of the short-run investment-uncertainty relationship for large UK industrial companies. At a firm level analysis, the theoretical work on the investment-uncertainty relationship suggests that the direction of this sign depends on the degree of competition faced by a firm and/or the assumption about the technology that the firm adapts. A small number of studies examined the sign of the investment-uncertainty relationship at the firm level and found mostly negative effects. We particularly consider the product market structure while studying this relation via the product specialisation criteria. The chapter does not attempt to develop a fully specified structural model, however, to test the robustness of the findings, two different models and two different measures

of uncertainty are employed. The findings reveal that consideration of the product market structure confirms the predictions of both theoretical works, and this result is robust under different model specifications. Moreover, it is observed that one should be careful about the employed uncertainty measure before reaching a conclusion about the nature of this relationship.

Finally, using impulse response functions and forecast error variance decomposition analyses of the vector autoregression methodology, chapter 7 gives a statistical account of the aggregate investment-uncertainty relation in the UK. We analyse the effects of interest rate uncertainty, exchange rate uncertainty and inflation uncertainty. Although they are not large, negative effects of exchange rate and inflation uncertainty are observed on the total investment. Further analyses reveal stronger negative effects of exchange rate uncertainty on the machinery and equipment investment. However, it has no effect on the construction investment.

CHAPTER 1

A REVIEW OF THE THEORY OF INVESTMENT

Section 1.1 Introduction

Because of its importance, there have been many studies to understand the investment behaviour and the factors determining it. For instance, in an early study Clark (1917) models net investment as a proportional change in desired capital stock. The model is known as the accelerator model in which the desired capital is proportional to output. As an alternative to the accelerator model, Tinbergen (1939) proposes a model in which the investment decision depends on the level of profit which is developed later by Klein (1951). In the model, the investment decision is governed by expected profits and realised profits are used as a measure of expected profits. Later, the unitary adjustment coefficient of the simple accelerator model was rejected by many empirical studies. To model the adjustment mechanism, Chenery (1952) and Koyck (1954) introduce the flexible accelerator model. In this model, attention is focused on the time structure of the investment process, and the desired capital stock is determined by long-run considerations. Instead of an adjustment coefficient with unity, the changes in the desired capital are transformed into actual investment expenditures by a geometric distributed lag function. In another study, Meyer and Kuh (1957) stress the importance of the availability of sources to finance the investment, and they consider the effects of liquidity and internal funds to

determine investment behaviour. Eisner and Strotz (1963), Bischoff (1971) and Jorgenson (1971) give extensive surveys of these early models.

Besides the studies mentioned above, the modern literature on investment stems primarily from two equivalent sources: the neo-classical theory originated by Dale Jorgenson, and the q theory developed by James Tobin. The starting point in the earlier neo-classical approach developed by Jorgenson (1963) is the firm's optimisation behaviour. The objective of the firm is to maximise the present discounted value of net cash flows subject to technological constraints summarised by the production function. In the model, the desired capital is determined by the equality between the marginal revenue product of capital and the user cost of capital. In the other formulation suggested by Tobin (1969), investment is a function of q , which is the ratio of the capitalised value of the marginal investment to its replacement cost. According to this model, net investment would be undertaken by the firm and the capital stock would be increased if the q ratio is greater than unity, otherwise the reverse would apply.

In the following section of this chapter the neo-classical model is presented in detail and its empirical drawbacks are discussed. In section 1.3 the adjustment cost literature is summarised which rationalises the theoretical shortcomings of the neo-classical model. Later, the q theory of investment is derived from this augmented neo-classical theory of investment to present that in fact the two theories are equivalent. Sections 1.2 and 1.3 present the investment models in a tax-free world

under certainty and reversibility assumptions without attention to financing decisions. Considering the enormous literature written on the topic, in the rest of the chapter the aim is to summarise and give the basic intuition behind the important studies relevant to taxation, financing conditions, and uncertainty and irreversibility issues. In section 1.4 the effects of corporate taxes are presented, discussing the effects of the corporate tax rate, depreciation deductions and investment tax credit. Also, personal taxation and the effects of inflation via depreciation deductions are considered. Section 1.5 first discusses the theoretical literature about the effects of financing constraints due to credit rationing or more expensive external funding on investment decisions which might occur because of informational and incentive problems. After that, empirical evidence about these effects on investment behaviour is presented. Section 1.6 releases the certainty and reversibility assumptions and discusses the important theoretical and empirical literature for investment behaviour under uncertainty and irreversibility assumptions. Section 1.7 presents the final concluding remarks.

Section 1.2 The Neo-classical Model

... it is impossible to reconcile the theory of econometric literature on investment with the neo-classical theory of optimal capital accumulation. The central feature of the neo-classical theory is the response of the demand for capital to changes in relative factor prices or the ratio of factor prices to the price of output. This feature is entirely absent from the econometric literature on investment.

(D. Jorgenson 1963 , p. 247)

In the well-known accelerator theory of investment, capital is tied to output in a fixed ratio. However, in the neo-classical theory of investment, substitution between the inputs of production the function is allowed, and this is the most important difference between the two theories. In the above quotation, Jorgenson is stressing the missing feature of the neo-classical investment theory and arguing that there is ignorance of the substitution parameters in the econometric literature.

To overcome the above mentioned problem, Jorgenson (1963) develops a model. Generally, his model can be viewed as a demand-side oriented model in which the aim is to determine the desired capital stock position and then to identify the adjustment mechanism from the current capital stock position to the desired position. The desired capital stock is determined from the profit maximisation behaviour of the firm. The short-run determination of investment behaviour depends on the time form of lagged response to changes in the demand for capital and the form of lagged response is assumed to be fixed

Maximising Behaviour and the Desired Capital Stock

In the model, the demand for capital stock is determined so as to maximise the net worth of the firm, and the net worth is the discounted sum of net revenues. The net revenue can be simply defined as the current revenue less the current and capital account expenditures. Assuming labour and capital as the two factors of production, the net revenue for each point in time by excluding the taxes can be written as

$$R = pF(K, L) - wL - p^I I \quad (1)$$

where p , F , w , K , L , p^I and I represent the price of output, quantity of output, wage of labour, capital stock, quantity of labour, price of the investment good and fixed investment, respectively. The constant returns-to-scale production function $F(K, L)$ is assumed to be twice differentiable and accompanied by the assumption of diminishing marginal products.

Under the assumptions of certainty, costless reversibility, and perfect capital, output and factor markets, the objective of the competitive firm, maximising the present value of the net worth, can be written in continuous time t as

$$NW = \max \int_0^{\infty} \exp(-rt) R(t) dt . \quad (2)$$

The firm faces two constraints in the maximisation process. First, the capital stock identity, which is equal to investment less depreciation, where the replacement is assumed to be proportional to capital stock. This can be written as

$$\dot{K} = I - \delta K \quad (3)$$

where the dot denotes the time derivative, and the term δ represents the economic depreciation rate. Stated another way, investment can be decomposed as the investment for capital expansion and the investment for replacement. The second constraint that the firm faces is the technological constraint, summarised by the production function.

Obviously, in this dynamic optimisation problem, the aim is to find the optimal time paths of the state variables capital and labour which will maximise the present value of the net worth. The optimal paths of K and L give the desired K^* and L^* , hence, the desired investment path can be derived from the desired capital path. From the fundamental lemma of calculus of variations, the necessary Euler equations for capital and labour satisfy the maximisation of the objective functional. Considering the equality constraint for investment in equation (3) and inserting it into the integrand directly, instead of using the Lagrange form, the objective functional can be expressed as

$$NW = \max \int_0^{\infty} \exp(-rt) [pF(K, L) - wL - p'(\dot{K} + \delta K)] dt. \quad (4)$$

Hence, the necessary Euler equation for labour will be

$$\exp(-rt) [p \partial F(K, L) / \partial L - w] = 0 \quad (5)$$

and from here

$$\partial F(K, L) / \partial L = w / p \quad (6)$$

which means that the firm will hire labour at each point of time up to where the marginal product of labour is equal to the real wage rate.

The Euler equation for capital can be derived as

$$\exp(-rt) [p \partial F(K, L) / \partial K - \delta p' - r p' + \dot{p}'] = 0 \quad (7)$$

and rearranging the above equation gives

$$\frac{\partial F(K, L)}{\partial K} = \frac{p'(r + \delta - \dot{p}' / p')}{p} = \frac{c}{p} \quad (8)$$

which means, similarly, that the capital will be employed at each point of time up to where the marginal product of capital equals the cost of capital. The right-hand side of equation (8) is the user cost of capital that Jorgenson defines in his original model. Since p' is the flow price of capital for each time period, $p'r$ and $p'\delta$ would be the interest charge on the price of capital and the depreciation charge on a unit of capital in each period, respectively. The last term (\dot{p}' / p') can be interpreted as the reduction in the cost of capital due to increase in the price of a unit of capital, meaning a capital gain for the firm.

Although the aim in this dynamic optimisation problem is to find the optimum paths for the state variables, the Euler equations just lead through the marginal productivity conditions of these variables. In that case, it is interesting that the optimisation problem loses its dynamic nature and collapses to a static case, except that the marginal productivity conditions which are determined by the Euler equations are supposed to hold at every point in time. Normally, in mathematical terms, the Euler equations can also be expressed in the form of differential equations and the solutions of these equations give the necessary optimal paths for the state variables. However, respectively, the linear character and the absence of the first derivatives of the capital and labour variables in the integrand in equation (4) do not permit the Euler equations to be in differential forms and reduces the problem into a static context.

Adjustment Mechanism

Having determined the output and the desired level of labour and capital from the hypothesised production function and the marginal productivity conditions, if there is no lag in the completion of investment projects, the level of investment can easily be found from the constraint defined in equation (3). However, as implied earlier, an instantaneous adjustment mechanism is not realistic, and identification of it complements the other part of the problem.

For the adjustment mechanism, Jorgenson introduces the delivery lags. He divides the investment process into several stages and derives the actual investment expenditure for capital expansion as a distributed lag function of the change in desired capital stock. To grasp that mechanism, two things need to be understood. The first one is the distributed lag relationship between investment expenditures and the new investment projects, and the second one is the intuition behind the initiation of new projects.

For the first issue, let IE and IN represent the investment expenditures in new projects and the level of starts of new projects. Since the completion of new projects takes time, by assuming that the distribution of completion of new projects is fixed, Jorgenson defines the investment for capital expansion for each time as a weighted average of the level of projects initiated in all previous periods. This can be presented in the lag operator as

$$IE(t) = W(S)IN(t) = W(0)IN(t) + W(1)IN(t-1) + \dots \quad (9)$$

Here, $W(0)$, $W(1)$, $W(2)$, . . . is a power series which represents the distribution of completion over time. It is also assumed to be a sequence of nonnegative numbers adding up to unity.

For the second issue, in each period the firm will be stimulated to initialise new projects until the backlog of uncompleted projects at the beginning of the period is equal to the difference between desired and actual capital stock. Assuming that the firm initiates the necessary new project at time $t-1$ to satisfy the level of desired capital stock at time $t-1$, new project initiations at the current period can also be presented as the difference between the current and previous levels of the desired capital stock:

$$IN(t) = K^*(t) - K^*(t-1). \quad (10)$$

Using equations (9) and (10), and assuming that the replacement investment is proportional to capital stock, investment expenditure can be expressed as

$$IE(t) = W(S)(K^*(t) - K^*(t-1)) + \delta K_{t-1}. \quad (11)$$

Empirical Issues and Critics

To implement the theory, two issues should be identified. The former is the technology, or more precisely, the type of production function to determine the level

of the desired capital stock, and the latter is the distributed lag function in equation (11) for the adjustment mechanism.

For the type of the technology, Jorgenson chooses a Cobb-Douglas production function $(F(K,L) = AK^\alpha L^\beta)$ where the elasticity of substitution between capital and labour is unity. If α shows the elasticity of output with respect to capital, the marginal productivity condition for capital can be written as

$$\frac{\partial F(K,L)}{\partial K} = \alpha \frac{F(K,L)}{K}. \quad (12)$$

Then, by utilising the marginal productivity condition of capital in equation (8), equation (12) can be rearranged for the level of desired capital stock as

$$K^* = \alpha \frac{pF}{c}. \quad (13)$$

Clearly, this exposition serves Jorgenson's aim, which is mentioned earlier, since the level of desired capital stock includes the relative price of output and capital within itself.

For the adjustment mechanism, Jorgenson applies a rational distributed lag function as described in Jorgenson (1966). Assuming that the $W(k)$ of coefficients has a rational generating function, the rational distributed lag function for any arbitrary distributed lag function $Y(t) = W(0)X(t) + W(1)X(t-1) + W(2)X(t-2) + \dots$ is expressed as

$$Y(t) = \frac{g(S)}{h(S)} X(t) \quad (14)$$

where $g(S)$ and $h(S)$ are polynomials in S

$$g(S) = g_0 + g_1 S + g_2 S^2 + \dots + g_m S^m$$

$$h(S) = h_0 + h_1 S + h_2 S^2 + \dots + h_n S^n$$

in which the terms g_0 and h_0 are normalised to unity. This general function, respectively, for $g(S) = (1-\lambda)$, $h(S) = (1-\lambda S)$ and for $g(S) = (1-\lambda)^r$, $h(S) = (1-\lambda S)^r$, also covers the geometric distributed lag function $(1-\lambda S)Y(t) = (1-\lambda)X(t)$ of Koyck (1954) and the Pascal lag distribution $(1-\lambda S)^r Y(t) = (1-\lambda)^r X(t)$ of Solow (1960) as special cases.

Hence, from equations (13) and (14), equation (11) can be rewritten as

$$I(t) = \frac{g(S)}{h(S)} \left[\alpha \frac{p(t)F(t)}{c(t)} - \alpha \frac{p(t-1)F(t-1)}{c(t-1)} \right] + \delta K(t-1) \quad (15)$$

which is the final form that Jorgenson and his associates use in their empirical applications. Using the above equation, Jorgenson (1963, 1965) and Jorgenson and Stephenson (1967) study the investment behaviour for the United States economy. They propose that the neo-classical theory provides a highly satisfactory explanation of investment behaviour, and they find substantial short-run responses of investment with respect to the price of output, price of capital, interest rate and various tax effects.

However, Eisner and Nadiri (1968) test the theory and reject their findings. The important point in their criticism is the unitary elasticity of capital with respect to

output and relative prices, which is implicitly assumed in the model by using a Cobb-Douglas production function. They suggest that, if these elasticity are different from one, constraining the response of investment to different effects to be of equal magnitude via equation (15) would be misleading. For that purpose, with the same data, Eisner and Nadiri estimate equation (15) by shifting it to a logarithmic form to measure the output and relative price elasticity of capital separately. They find that these two elasticity measures are far less than unity, and they also report contra-evidence for the constraints which are imposed upon the lag distribution.

To understand the main point in these criticisms, take the general production function of Arrow, Chenery, Minhas and Solow (1961). The constant elasticity of substitution production function, which permits the elasticity of substitution to take any positive value for the constant returns-to-scale case is

$$F(K, L) = \gamma [\xi K^{-\varphi} + (1 - \xi)L^{-\varphi}]^{-\frac{1}{\varphi}} \quad (16)$$

where $\gamma > 0$, $0 < \xi < 1$ and $\varphi > 1$. In this function, γ denotes the efficiency parameter that shifts the whole production function, ξ is a distribution parameter that permits the relative importance of labour and capital to vary, and φ is the substitution parameter. From equation (16), by taking the partial derivative of output with respect to capital, the marginal productivity condition for capital can be expressed as

$$\frac{\partial F(K, L)}{\partial K} = \xi \gamma^{-\varphi} F^{(1+\varphi)} K^{-(1+\varphi)}. \quad (17)$$

Using the marginal productivity condition found in equation (8), equation (17) can be rearranged for the desired level of capital stock as

$$K^* = (\xi \gamma^{-\varphi})^\sigma [F(p/c)^\sigma] \quad (18)$$

where σ denotes the elasticity of substitution, which is equal to $(1+\varphi)^{-1}$ for the constant returns-to-scale case for that general production function. For the Cobb-Douglas production function, taking the elasticity of substitution parameter σ as one, the equation (18) simply reduces to equation (13). However, if the elasticity of substitution is less than unity, the effect of the relative price ratio as well as the interest rate and various tax effects via the user cost of capital will be miscalculated because of the imposed restriction.

Section 1.3 Adjustment Costs and Tobin's q

Jorgenson's model can be viewed as a successful step towards a theory of investment, because it considers the durability of capital explicitly with its forward-looking nature, even if it is under static expectations of the firm. Also, the structural form of the model provides a suitable base to study various policy analyses. However, in addition to the empirical criticisms stated in section 1.2, the model has some important theoretical shortcomings. In this stock-oriented model, the desired capital stock is derived from the comparative static profit maximisation considerations which is then used together with a distributed lag function to determine the investment. Actually, the model cannot determine the rate of investment by itself because it relies on an ad hoc stock adjustment mechanism by

which the adjustment costs are introduced implicitly. Moreover, the desired capital stock is derived without regard to this auxiliary adjustment mechanism. The investment path is actually a decision that affects variables like sales or profit, which in turn play an important role in determining the level of desired capital stock.

From a theoretical perspective (e.g. as in Keynes 1936, p.136) the marginal efficiency of capital slopes downwards as a function of the rate of investment because of the rising supply price of capital goods. Since the marginal efficiency of capital is supposed to equal the interest rate, investment will be a decreasing function of the interest rate. In his model, Jorgenson ignores the role of this rising supply curve of new capital goods in determining the rate of investment.

Adjustment Costs and the Modified Neo-classical Theory

Later on, to justify the stock adjustment mechanism defined by Jorgenson, various studies apply a particular dynamic adjustment mechanism by introducing the concept of the adjustment costs in the criterion functional. This can be thought of as a formal counterpart to the rising supply curve of capital goods. In this augmented approach, the firm faces adjustment costs as an increasing convex function of the investment rate when it is altering its investment. This new formulation provides a rationale for the lags in the adjustment of capital.

Two types of adjustment costs have been identified for the theory of investment: internal adjustment costs such as in Eisner and Strotz (1963), Lucas (1967) and Gould (1968) that arise from the internal activities of the firm, and external adjustment costs as in Witte (1963) and Foley and Sidrauski (1970) which occur because of market forces external to the firm. Internal adjustment costs can be thought of as a loss in output or in revenue of the firm when it diverts its resources from production to investment, occurring from planning or installation costs. This happens because new investment plans require new administrative activities, new research and development, or new capital installations need to train some human power or alter production activities. External adjustment costs can be viewed as firm-specific costs or a kind of premium that the firm has to pay in the form of higher prices when its investment rate is larger in any period of time. So, the more capital the firm demands, the higher prices it pays, creating a rising supply price of capital goods. Clearly, external adjustment costs are more in line with Keynesian short-run analysis; however, internal adjustment costs are more common in the literature. As Mussa (1977) shows, these two approaches are not alternatives, but they each form an important part of the theory of investment function.

The neo-classical model of Jorgenson has a static nature, the production factors are perfectly variable, and the dynamics are implicit. Obviously, adjustment costs help to introduce the dynamic elements explicitly into the theory and to give the capital a quasi-fixed character. This provides a rigorous basis for the optimal rate of capital accumulation and rationalises the flexible accelerator models of investment

behaviour. However, as Rothschild (1971) points out, in many cases the weak theoretical foundations of the convexity assumptions may cause difficulties. The convexity assumption forces the firm to look ahead to the future because if the firm accumulates slowly it may lose profit. On the other hand, rapid accumulation costs more. Alternatively, if the firm faces concave or linear adjustment costs, it can immediately close the necessary gap between the actual and the desired capital stock. This implies that at this point the investment will be undefined and the lagged adjustment will disappear. In addition to this criticism, a more crucial frailty of the model is the treatment of expectations. The neo-classical model augmented by the idea of adjustment costs assumes that firms have perfect foresight so the decisions are based on the explicit inter-temporal optimisation. With static expectations as in Gould (1968), the model reduces to a simple case where there is nothing left to be estimated.

Tobin's q Theory : An Equivalent Approach

But the daily revaluations of the Stock Exchange, though they are primarily made to facilitate transfers of old investments between one individual and another, inevitably exert a decisive influence on the rate of current investment. For there is no sense in building up a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased; whilst there is an inducement to spend on a new project what may seem an extravagant sum, if it can be floated off on the Stock Exchange at an immediate profit.

(J. M. Keynes 1936, p.151)

James Tobin (1969) illustrates a very general and flexible basic framework for monetary analysis. In his framework, it is possible to realise the spirit of Keynes (see especially Keynes 1936, chapter 12), which can be illustrated via the above quoted passage. According to his approach, the aggregate demand is affected by various policies and events principally by changing the valuations of physical assets relative to their replacement costs. He defines a key variable q within this framework, which is the ratio of the market value of installed capital to its replacement cost. In general equilibrium, where IS and LM curves cut each other, the q ratio is equal to one. More importantly, investment is an increasing function of the q ratio. If an additional unit of installed capital would raise the market value of the firm by more than the cost of replacing the capital, the firm proceeds with this new investment, which happens when q is greater than one. So, the greater the difference between q and one, the greater is the incentive to invest. Alternatively, if q is less than one, then the gain that the firm would make is less than the replacement value of capital, in which case the firm does not make the investment. The most important advantage of Tobin's q approach over the neo-classical model is the treatment of expectations. The model is actually free of expectation problems because it relies on well-functioning asset markets. Since the numerator of the q ratio includes the market value, all relevant information and expectations about the future will be directly captured in this approach. However, the market value approach loses its ability to examine the policy effects through a structural model. Also, as Hayashi (1982) argues, some sort of ad hoc adjustment costs lie behind the theory, and moreover, the role of the production function is not clear.

Although the neo-classical model modified with adjustment costs and Tobin's q model look different, actually they constitute the demand and supply side of the same theory. This point was recognised in Lucas and Prescott (1971) and in Mussa (1977), and it was formally presented under the Cobb-Douglas technology by Abel (1979). The neo-classical model looks at the factors behind the market value by analysing the net revenue of the firm, whereas the q approach directly uses the market value in determining the optimal investment. The link between these two models can be presented by deriving the q approach from the neo-classical model starting with a firm's value maximisation problem. For simplicity, the economy will again be assumed tax-free.

Let the net revenue of the firm be

$$R = pF(K, L) - wL - p^I I - pA(I, K). \quad (19)$$

Here, $pF(K, L)$ represents gross sales, where wL and $p^I I$ are the cost of labour and the cost of investment goods to the firm. The last term on the right-hand side of equation (19) is the internal adjustment cost, which is supposed to be a loss in the firm's revenue function. Because the instalment costs depend on the size of investment relative to capital, the installation function A depends on capital as well as investment. This function is twice differentiable and an increasing convex function of investment, making the instalment cost per unit of investment greater, the greater the rate of investment for any given level of capital. Thus, $(\partial A / \partial I) > 0$ and $(\partial^2 A / \partial I^2) > 0$.

The firm is considered as if it is trying to maximise the present value of its future net revenues:

$$V(0) = \max \int_0^{\infty} \exp(-rt) R dt \quad (20)$$

where r is the discount factor that discounts the net revenues at date t back to the current date. By using the equation of motion for the state variable capital stock

$$\dot{K} = I - \delta K \quad (21)$$

as a dynamic constraint in the maximising problem, the current value Hamiltonian can be written as

$$H = pF(K, L) - wL - p^I I - pA(I, K) + \lambda(I - \delta K) \quad (22)$$

where λ is the current-value shadow price of capital. Applying the Pontryagin's maximum principle to this control problem, the first order conditions for the control variables labour and investment can be written as

$$\frac{\partial F(K, L)}{\partial L} = \frac{w}{p} \quad (23)$$

and

$$\lambda = p \frac{\partial A(I, K)}{\partial I} + p^I. \quad (24)$$

Equation (23) is simply the marginal productivity condition of labour as in equation (6), and equation (24) states that the firm chooses the rate of investment so as to equate the value of an additional unit of newly installed capital to its purchase price plus the marginal adjustment cost. From the control theory, the equation of

motion for the costate variable should also satisfy $\dot{\lambda} - r\lambda = -\partial H / \partial K$. From equation (22) this result can be presented as

$$\dot{\lambda} = (r + \delta)\lambda - p \frac{\partial F(K, L)}{\partial K} + p \frac{\partial A(I, K)}{\partial K}. \quad (25)$$

Equation (25) is a differential equation which shows the optimality condition for the motion of the costate variable, or in economic terms, for the motion of shadow price of capital. Solving this differential equation yields

$$\lambda = \int_0^{\infty} \exp(-(r + \delta)t) [p \partial F(K, L) / \partial K - p \partial A(I, K) / \partial K] dt \quad (26)$$

which shows the equality between the present discounted value of the marginal revenue attributable to a unit of installed capital and the shadow price of capital. The first term in the integral is simply the additional revenue which comes from the additional unit of capital. As mentioned earlier, the instalment costs depend on the size of investment relative to capital, thus the second term denotes the savings in the adjustment costs as the effect of an additional unit of installed capital. The discount factor also includes the depreciation rate δ since the capital stock depreciates at this rate.

Ignoring the adjustment costs from equation (24) for a moment makes the shadow value of capital $\lambda = p^I$. Inserting this result in equation (25) and rearranging gives

$$\frac{\partial F(K, L)}{\partial K} = \frac{p^I (r + \delta - \dot{p}^I / p^I)}{p} = \frac{c}{p} \quad (27)$$

which is Jorgenson's user cost of capital that is defined earlier in equation (8). The difference is the additional internal adjustment costs, which is the result of the augmented neo-classical model. Actually, this is the same condition derived under the control theory approach instead of using the classical calculus of variations as in Jorgenson's model. So, naturally we get the same results.

However, the important point is that equation (24) can be manipulated as

$$p \frac{\partial A}{\partial I} = \left(\frac{\lambda}{p^I} - 1 \right) p^I. \quad (28)$$

By defining a certain quadratic adjustment cost function such as

$$A(I, K) = \frac{\beta}{2} \left(\frac{I}{K} - \alpha \right)^2 K \quad (29)$$

where β is the adjustment cost parameter and α is the normal rate of investment.

Using equation (29), equation (28) can be rewritten as

$$\frac{I}{K} = \alpha + \frac{1}{\beta} \left(\frac{\lambda}{p^I} - 1 \right) \frac{p^I}{p}. \quad (30)$$

Since λ represents the shadow value of capital, the term (λ / p^I) can be defined as the marginal q , which is the ratio of the marginal value of an additional unit of installed capital to its purchase price p^I . From here, equation (30) can be rewritten as

$$\frac{I}{K} = \alpha + \frac{1}{\beta} (q - 1) \frac{p^I}{p}. \quad (31)$$

Equation (31) is clearly the desired result, which shows that Tobin's q theory approach and the augmented neo-classical model are equivalent.

However, one important problem with the above exposition is the inequality of marginal q and average Q , because, in equation (31) investment is a function of marginal q , but in reality what one can observe is the average Q ratio, which is the ratio of the average market value of a unit of capital to its replacement cost. Fortunately, Hayashi (1982) shows that under the assumption of both a linearly homogenous production function and an adjustment cost function, marginal q would be equal to average Q . He also extends this important result for imperfect competition. In the case of imperfect competition, the Q ratio also includes the present value of expected revenues due to market power as an additional term. In the limiting case, the firm faces a flat demand curve and the additional term disappears, corresponding to the perfect competition case.

Although the q model of investment is theoretically very appealing, empirically it has performed less successfully. Early applications of the model were carried out by von Furstenberg (1977), Abel (1980), Summers (1981), Blanchard and Wyplosz (1981) and Hayashi (1982). As also pointed out in an extensive survey by Chirinko (1993), three persistent empirical problems appear with the q models of investment. First, according to equation (31), no other variables should have a systematic relation with investment. This is because the market value in the numerator of the q ratio is already assumed to capture all relevant information. However, variables like output, profit, and liquidity frequently enter in the investment equation significantly, and the restricted form results in low R -square measures. Second, estimated adjustment cost parameters are unreasonably large which implies large adjustment

costs and very slow adjustments. Finally, specification tests indicate the presence of serial correlation in residuals, and lagged values of the q ratio and the investment-capital ratio appear to be significant.

In an extensive study, by using the US data and vector autoregression (VAR) analysis, Abel and Blanchard (1986) carefully construct a series for marginal q to observe whether the divergence between marginal q and observed average Q is responsible for the poor empirical performance of the q models of investment. They find that the results are not improved and also report that the variations in their constructed series are due more to variations in the discount factor than to the variations in marginal profit. Poret and Torres (1989) compare the performance of the Q model with the flexible accelerator and profitability models for the US, Japan, Germany, France and Italy for aggregate-level investment. They conclude that in none of the five countries does the Q ratio explain the investment behaviour better than the two traditional models do. Blanchard, Rhee and Summers (1993) analyse the effect of the Q ratio on US aggregate investment from 1900 to 1990. They conclude that, after controlling the profit rates, the Q ratio appears to play a limited role in affecting investment decisions. In two other aggregate-level studies, Kopcke (1985, 1993) compares the performance of the neo-classical and the Q model of investment with the accelerator, the cash flow, and the autoregressive models for the US capital investment series. In many cases, the simple traditional models perform as well as and/or outperform the other two models.

Unlike the aggregate data, studies using panel data mostly estimate less serial correlation, or find robust results for common factor restriction such as in a UK panel study by Blundell et al. (1992). Using US firm-level panel data, Schaller (1990) also shows evidence that aggregation is responsible for upward bias in estimated adjustment costs as well as for observed serial correlation. By employing aggregate UK data, but based on imperfect competition, Schiantarelli and Georgoutsos (1987) obtain better empirical results. Generally, although employing panel data improves the performance of the Q model of investment and reduces the observed autocorrelation and the adjustment costs, empirically, the results are still at unsatisfactory levels.

Section 1.4 Taxes and Inflation

The investment models were derived under the assumption of a tax-free world in the previous sections. However, in reality the incentive to invest is influenced by tax codes, and the role of the tax environment has been an important research area. Generally, corporate taxes have been the major issues. The three popular aspects of the corporate tax code that have been investigated are the corporate tax rate, the investment tax credit and the depreciation allowance. Additionally, the effects of personal taxation and inflation have also been considered.

Investment and Corporate Taxation

In its simplest form, investment tax credit and the depreciation allowance are positively related to investment decisions since they reduce the price of investment goods. On the other hand, the corporate tax rate is negatively related to investment because it reduces after-tax profit. However, it does also have a positive relation to investment since it increases the present value of tax savings due to depreciation deductions, and the overall effect of it depends on the tax codes and the magnitudes of the related variables.

For the neo-classical model, considering the tax factors, the revenue function given in equation (1) can be rewritten as

$$R = (1 - u)pF(K, L) - wL - (1 - k - uz)p^I I. \quad (32)$$

From the profit maximisation problem in equation (4), considering these corporate tax factors and taking the first-order condition for capital, the user cost of capital derived in equation (8) can be altered as

$$\frac{c}{p} = \frac{p^I (r + \delta - \dot{p}^I / p^I) (1 - k - uz)}{p (1 - u)}. \quad (33)$$

Here, u , k and z , respectively, represent the corporate tax rate, investment tax credit and the present value of the depreciation deductions. As can be seen from equation (33), if $k + uz = u$, then the tax effects would be neutral. The numerator of the additional tax factor comes from the reduction of the price of investment goods and the denominator denotes the taxation of profits. Hall and Jorgenson (1967), based

on the neo-classical theory of investment and by employing US aggregate data, investigate the effects of various tax codes for the postwar period, and they report an important relationship between the tax policy and investment expenditures.

For the q theory of investment derived in the previous section, after incorporating the corporate tax factors, the first-order condition for capital which is derived in equation (24) can be presented as

$$\lambda = (1 - u)p \frac{\partial A}{\partial I} + (1 - k - uz)p^I. \quad (34)$$

From here, by also considering the tax factors, the investment equation derived in equation (31) can be written as a function of the observable q ratio as

$$\frac{I}{K} = \alpha + \frac{1}{\beta} \left(\frac{V - G}{(1 - k - uz)p^I K} - 1 \right) \left(\frac{(1 - k - uz)p^I}{(1 - u)p} \right). \quad (35)$$

Here, the ratio in the first parenthesis denotes the average Q ratio. In the numerator of this ratio, G represents the tax savings due to depreciation deductions on existing capital which is subtracted from the market value since it does not have anything to do with new investment decisions. In the denominator of the average Q ratio, the replacement cost of capital is simply adjusted for the tax factors that reduce the price of the investment good. These factors are, respectively, the investment tax credit and the tax savings due to depreciation deductions on the installed capital. The second parenthesis denotes the additional tax factors and the relative price effect. Summer (1981) estimates the investment equation for US annual data which is based on the q theory of investment both with and without tax effects. He shows econometric

evidence that the inclusion of tax factors greatly improves the empirical performance of the investment equation. Based on the tax adjusted q theory of investment, Salinger and Summers (1983) examine the impacts of alternative tax reforms on the investment decisions of individual manufacturing firms for the United States. They report that the empirical results are promising. Using UK firm-level panel data for manufacturing companies for the period 1968-1986, Blundell et al. (1992) report that although it is small, the tax-adjusted observable Q ratio has a statistically significant effect on the investment decisions of the firms under investigation.

By employing three different models of investment based on the real net rate of return, the rate of return over cost and the flexible capital stock adjustment, Feldstein (1982) presents econometric evidence on the effect of tax incentives in the US for the period 1953-1978. He concludes that the interaction of existing tax rules and inflation has contributed substantially to the decline of business investment after the late 1960s. In a survey study, Morgan (1992) examines the effects of the 1984 tax reform on the investment decisions of large UK firms. The main changes in the UK corporate tax system for the period 1984-1987 were the reduction of the corporate tax rate from 50% to 35%, and the abolishment of 100% and 75% first year allowance, respectively, for investment in plant and machinery, and industrial buildings. The survey results reveal that the level of the investment of most firms would be insensitive to tax policy changes. However, of the tax regime sensitive cases, more firms would have cut back their investment than would have increased.

In another study, based on the Euler equation that they derive, Auerbach and Hassett (1992) report that taxes have played an independent role in affecting US investment behaviour of the postwar period (1954-1988), particularly for investment in machinery and equipment. Unlike the other models based on the optimising behaviour of rational agents, their model provides direct estimates of the effects of tax policy variables on investment and permits a structural interpretation.

Because of the explicit inter-temporal nature of the q theory of investment, there have also been various studies about the dynamic effects of tax policies on investment decisions by employing q models. In a partial equilibrium framework, using the q theory approach, Abel (1982) analyses the dynamic effects of permanent and temporary tax policies on investment by graphical analysis. A partial equilibrium system consisting of two differential equations in capital and marginal q can be constructed from the inter-temporal optimising firms including the convex costs of adjustment. Abel shows that a temporary investment tax credit need not be more expansionary than a permanent investment tax credit. By using numerical methods, Summers (1981) simulates the dynamic effects of changes in inflation, investment tax credit, corporate tax rate and personal taxation on investment for the US economy. Similarly, Dinenis (1989) analyses the dynamic effects of various tax policies for the UK economy by using numerical methods.

In a general equilibrium context, Judd (1985) examines the short-run dynamic impacts of current and future changes in fiscal policies on investment for the US

economy by applying analytical techniques. Although in a partial equilibrium framework, again by using analytical techniques, Auerbach (1989) simulates the effects of various tax reforms introduced in the US. Auerbach's model also includes the adjustment costs and has a richer tax characterisation than Judd (1985).

Effects of Personal Taxation and Inflation

Besides the corporate tax effects, personal taxes can also affect the investment behaviour of firms. Under the classical system, shareholders are subject to double taxation. This is because, the company pays the corporate tax for its profits, and the shareholders pay the personal tax for the distributed profits. Under the imputation system, the shareholders receive credit for the corporate tax paid by the company on distributed profits. Personal taxation can be summarised by the ratio

$$P = \frac{(1 - d) / (1 - m)}{(1 - g)} \quad (36)$$

where d , g , and m denote the personal tax rate on dividend, tax rate on capital gains, and the imputation rate. Under the classical system, m is equal to zero. This ratio determines the relative tax advantage of dividends against retained earnings. If $P = 1$, then investors will receive the same after-tax return from the distributions and retained earnings. If $P > 1$, the after-tax value of dividends become greater than the after-tax capital gain. In this case the shareholders should prefer dividends. In a dynamic setting, King (1974) analyses the effect of personal taxation together with corporate taxation on both the firm's choice of financial policy and investment

decisions. He shows that the optimal financial policy of firms will be influenced by personal taxation. This in turn alters the Jorgenson's cost of capital, hence the firm's investment decision.

When a firm or a project is financed by a mixture of debt and equity, the valuation formula or the cost of capital measure should consider both corporate and personal taxation. For instance, Ashton (1989) analyses the cost of capital under an imputations tax system in a mean-variance equilibrium framework. Taggart (1991) gives cost of capital measures under personal and corporate taxation. O'Brien (1991) analyses the constant growth model with personal taxation for a one-year shareholding period. Recently, Pointon (1996) extends his model to include an imputation system, more than a year shareholding period, and indexation for inflation. For empirical findings about the effects of personal taxation on the valuation of dividends, see Poterba and Summers (1984), Chui et al. (1992) and the studies cited there, for instance.

Because effective tax rates on corporate distributions vary substantially in the postwar period for the UK, the UK data offer more potential for the examination of tax effects on investment decisions. Using UK aggregate data for the period 1950-1980, Poterba and Summers (1983) test the effect personal taxation has on investment behaviour in a q theory framework. Their results reject the hypothesis that by raising the cost of paying out funds to shareholders, dividend taxes encourage investment through retentions. Their findings support that dividend taxes

discourage corporate investment. The main reason for this finding is that corporations act as if marginal investment is financed through new equity issues. Thus, changes in dividend taxation alter the cost of capital and effect the investment behaviour. They argue that their findings suggest the importance of including variables reflecting personal taxes in investment specifications.

Together with tax effects, the effect of inflation on investment behaviour has also been considered in the literature. For instance, from the neo-classical theory, if the depreciation allowances are based on the nominal historical cost of a piece of capital rather than on its replacement cost, an increase in inflation will reduce the present value of real depreciation deductions. Obviously, as can be seen from equation (33), this would cause an increase in the user cost of capital and, by that way, a reduction in the investment. For a discussion of this effect, see Shoven and Blow (1975) for instance.

Additionally, because different capital categories have different durability, in the presence of historical cost depreciation, inflation may distort the choice between different types of capital. Using a general equilibrium model, Auerbach (1979) analyses the effect of inflation on the choice of asset durability. In his model, consumption is determined by a proportional savings function. His simulation results reveal that higher inflation leads firms to choose more durable capital. However, Abel (1981) modifies Auerbach's model by incorporating adjustment costs into the model and also by making consumption decisions based

on inter-temporal utility maximisation. Abel generalises Auerbach's findings, and he shows that depending on the depreciation rate and on the nominal interest rate, an increase in the rate of inflation can either decrease or increase the degree of durability of capital chosen by firms.

Depending on the tax codes, inflation may also have some other effects. For instance, the taxation of nominal rather than real capital gains can increase the cost of equity capital, and the cost of debt may increase or decrease depending on whether the loss from paying taxes on the inflation premium at the personal level exceeds the gain from its deductibility at the corporate level. For a discussion of these and some other points, see Feldstein (1976), Auerbach (1983), and Coulthurst (1986) for instance.

Section 1.5 The Effects of Financing Conditions

In the previous sections it was implicitly assumed that financing and investment decisions of firms were independent, which is also in line with Modigliani and Miller (1958). Modigliani and Miller propose that in the absence of taxes and under the assumptions of competitive markets and perfect information, real economic decisions would depend on factors such as consumer tastes, input and technology, but not on how the ownership claims to the firm happen to be labelled. Later, Modigliani and Miller (1963) suggest that there will be a corporate tax advantage to debt financing, but this will also increase the probability of bankruptcy. In

another study, Stiglitz (1972) argues that firms will choose an optimal debt policy trading off the tax benefits of issuing debt with the related bankruptcy costs. Bankruptcy costs include costs such as legal fees and lost profits during reorganisation or liquidation. Nevertheless, Miller (1977) argues that the bankruptcy costs are trivial, and the corporate tax advantage will be offset by the personal tax disadvantage. In another study, for firms facing future return uncertainty, DeAngelo and Masulis (1980) consider the tax loss effect and show that the optimum leverage can exist since the firm will be trading off the tax deductibility benefits with the cost of losing tax write-offs if it is in a no tax paying situation. With regard to the bankruptcy argument, Webb (1983) shows that one can restore the Modigliani-Miller argument by allowing for personal bankruptcy costs that offset the bankruptcy costs at the corporate level. However, apart from the arbitrage and trade off arguments, as discussed in Myers (1984), the capital structure decisions of firms can also depend on the ranking of the cost of funds, resulting from informational and incentive problems. For more discussion and empirical tests of capital structure decisions, see Mackie-Mason (1990), Harris and Raviv (1991) and Bennett and Donnelly (1993) for instance.

As implied by the pecking order argument of Myers (1984), the investment decisions of firms might well be affected by the availability of funds to finance their investments. Some firms might be credit rationed. This happens if they cannot obtain external funding while apparently identical ones can, although they are willing to pay exactly the same rate. Additionally, firms might be subject to an

external financing premium which is the cost between external and internal financing. As Gertler (1988) points out in an excellent survey, although there are various studies about the effects of financial factors on real economic activity in the early literature such as Fisher (1933), Gurley and Shaw (1955), and Kuh and Meyer (1957), they are mostly overshadowed by influential studies like the irrelevance result of Modigliani and Miller (1958), and the monetarist views of Friedman and Schwartz (1963). However in the 1970s, the effects of financial factors on real economic decisions comes back to the agenda with some path breaking studies, especially in the field of information economics and corporate finance.

Incentive and Informational Problems

In an important theoretical study, Jensen and Meckling (1976) argue that the result of Modigliani and Miller will disappear under imperfect information. Unlike Modigliani-Miller's irrelevance result, according to Jensen and Meckling, different ownership of capital in a firm will create different problems and additional costs. For instance, suppose that agents, or in other terms insiders or managers and directors, own a small percentage of equity. If the firm is highly leveraged, and if the bankruptcy penalties are not too discouraging, then the agents may take excessively risky actions or undertake risky investment to increase their part from the retention of profits. In the case of a failure, most of the burden will be on debt holders. Alternatively, if the firm is mostly equity financed, then assuming that the principals, or in other terms outside shareholders, cannot monitor their actions

effectively, agents may also have less incentive to achieve better since their portion of profit will be quite low.

Jensen and Meckling point out that under imperfect information, both the external debt and external equity finance would create inevitable agency costs for firms. Agency costs, which may occur because of incentive problems due to external finance, will create an additional financing premium. Hence, in terms of investment, from the firms which operate with identical opportunities, the ones with more internal finance funding facilities may be more willing to undertake investments. In another influential study, Myers (1977) shows that a high level of indebtedness can even restrict a value maximising firm to raise funds for financing positive net present value projects, since the return from such an investment project will be distributed to debt holders.

In a seminal paper, Akerlof (1970) discusses the consequences of asymmetric information in a used car market. In his example, in a typical situation the seller knows more about the car that is being sold than the potential buyer does. Akerlof argues that in a market like that, even if the price falls, the demand might not increase because with existing prices the owners of the good quality cars will not be willing to sell their cars. In that case, buyers may realise that the lower the prevailing prices, only the owners of the bad quality cars, in other terms the owners of 'lemons', will be willing to sell their cars. Moreover, in the extreme case the market collapses.

Similar to Akerlof's basic idea that the lemons problem might distort economic behaviour, Jaffee and Russell (1976) explain how unobserved differences in the quality of loan demanders can induce credit rationing in their analyses of the economics of bank lending to consumers. Also, Stiglitz and Weiss (1981) explicitly show that informational asymmetries in loan markets may create credit rationing where the market denies funding borrowers with characteristics identical to the firms that receive loans. In their model, the borrower knows the expected return and risk of his project, whereas the lender knows only the expected return and risk of the average project in the economy. If the lender raises the interest rate, his revenue does not necessarily increase since the probability of default may also rise with rising interest rates. Thus, the lender may find it in his interest to lower the interest rate to the point where his receipts are maximised, and this may not be the market clearing rate. In this case, demand for credit would exceed the supply and credit rationing will occur. There are two basic reasons why the relationship between the interest rate and the expected receipts of the lender may not be monotonic. First, as the interest rate increases, debt may increase the risk-taking of borrowers, which is known as the adverse incentive effect. Second, as the interest rate rises it will affect safer borrowers who anticipate they will always repay the loan more than it does the riskier borrowers. Hence, safer borrowers may even drop out of the market and this is known as the adverse selection effect.

The idea of asymmetric information was also applied to the problem of equity finance by Myers and Majluf (1984). In their model, external investors cannot

distinguish the differences between good and bad firms because of informational problems. Thus, they demand a premium to purchase the shares of relatively good firms to offset the losses that will arise from funding the lemons. This, in turn, will raise the cost of equity finance and increase the importance of internal funding as a determinant of investment. Also, in his pecking order theory, Myers (1984) discusses that firms will first prefer cheaper internally generated funds, and then debt, and finally equity financing.

Under different financial regimes, Hayashi (1985) theoretically analyses a value maximising firm in which the financial and investment decisions are determined simultaneously. He shows that if the profit-investment ratio is small, the firm chooses to finance a constant fraction of new investment by debt and the rest by retention. Alternatively, if the profit-investment ratio is large, then the firm finances a constant fraction of new investment by debt and the rest from new equity issues. In the model, only in these two regimes a relation between the Q ratio and investment can be derived, and in any other regime the relation disappears.

Monetary Transmission Mechanism and Aggregate Investment

As discussed earlier, the neo-classical theory of investment relies on an ad hoc adjustment mechanism. Although the model considers the durability of capital, it suffers from the expectations problem. Thus, it is difficult to interpret the estimated coefficients since the distributed lags might be representing either the

expectations or the delivery lags. On the other hand, as discussed in section 1.3, although the q model is theoretically consistent, empirically it has performed less successfully. Moreover, the traditional models easily outperform these two structural models. Many economists started to question the smoothly functioning financial system presumption and to reconsider the possible links between the financial system and real activity. The idea of capital market friction also became an important issue in the analysis of transmission of monetary policy. The external financing premium, the difference in cost between internally generated and externally raised funds and/or credit rationing, could help to explain the weak cost of capital and Q ratio effects on aggregate investment behaviour. However, this was not an alternative to the classical monetary transmission mechanism, but an enhancement channel.

Two aspects have received extensive attention, namely, the borrowers' balance-sheet channel and the bank lending channel. The balance-sheet channel argues that the external financing premium depends on the quality of borrowers' balance-sheets which can affect their investment behaviour. The balance-sheet channel arises because monetary policy changes affect not only the interest rates but also the borrowers' financial positions. For example, an increase in interest rates will increase the interest expenses, reduce the net cash flows, and weaken the financial condition of a firm. Moreover, it will also cause a reduction in the asset prices and shrink the value of the firm's collateral. In the literature, this phenomenon has been called the financial accelerator which can amplify and propagate business

cycles. For instance, Bernanke and Gertler (1989) develop a simple neo-classical model in which business downturns weaken borrowers' net worth, increase the agency costs of financing real capital investments, and amplify downturns.

The bank lending channel focuses on the effects of monetary policy changes on the supply of loans by depository institutions. According to this view, if the loans and non-bank sources are imperfect substitutes for firms on the liability side of their balance-sheets, and if the monetary authorities can affect the supply of intermediated loans by the banking system, then a lending channel which enhances the role of the conventional money channel can exist. Thus, the price of the loans and the quantity of the loans can change, and affect the investment behaviour. For instance, Kashyap, Stein and Wilcox (1993) suggest that tighter monetary policy can reduce loan supply which leads to a shift in firms' mix of external financing, and affect investment spending. For an extensive review of the channels of monetary transmission mechanism, see for instance, Bernanke (1993), Bernanke and Gertler (1995), and Bernanke, Gertler and Gilchrist (1996).

Financing Conditions and Empirical Evidence

To test the significance of incentive and informational problems, most studies incorporate the cash flow or the financial leverage ratios into the standard Q model or the Euler equation version with adjustment cost. As Schiantarelli (1996) points out in an extensive survey, the basic strategy in these studies is to test the

importance of these imperfections for different groups of firms based on criteria such as size, age, dividend behaviour, ownership structure and association with banks.

For instance, to test whether financial constraints and cash flow conditions affect investment behaviour, Fazzari, Hubbard and Petersen (1988) split US manufacturing firms according to their dividend behaviour. They estimate investment functions based on the Q theory approach as depicted in equation (31) by also using the cash flow-capital ratio as an additional variable. They report that financial effects are generally important for investment in all firms. However, their findings consistently indicate a substantially greater sensitivity of investment to cash flow and liquidity in firms that have low-dividend payout ratios, which are generally smaller, younger and faster growing ones. They also report that the statistically and economically significant difference between the groups is robust to a wide variety of model specification and estimation techniques. The firms that pay lower dividends represent the group of firms that exhaust nearly all of their cheaper internal funds and show more sensitivity to fluctuations in their cash flow than the firms that pay high dividends. Also, liquidity has a greater effect on investment for low-dividend ones.

In a study of Japanese firms, Hoshi, Kashyap and Scharfstein (1991) investigate the effects of informational problems on investment behaviour. In Japan, many firms are affiliated with industry groups, and firms within a particular group also

benefit from the close relationship of the group's main bank which may help to overcome informational problems. Using manufacturing firms listed on the Tokyo Stock Exchange over the period 1965-1986, Hoshi et al. perform regressions in a Q model framework. Their results indicate that investment spending of independent firms are more sensitive to changes in internal cash flow and liquidity compared to the group members that have easier access to external funds. In another study, Himmelberg and Petersen (1994) use US panel data to examine the role of cash flow by controlling the investment decisions by average Q and sales ratios. Their results confirm the role of internal finance for the research and development expenditures of small firms in high-tech industries. Using Canadian firm-level panel data, Chirinko and Schaller (1995) test the significance of liquidity effects in a Q theory framework. They sort the sample according to maturity, managerial ownership structure and group membership criteria. Their results indicate significant informational problems for firms belonging to young, less concentrated ownership and independent groups.

For US manufacturing sector panel data, Whited (1992) uses the Euler equation method, and based on the test of over-identifying restrictions, shows that the liquidity constraint appears to be stronger for highly leveraged firms as well as for firms that do not participate in the corporate bond markets. The Euler equation method is based on the elimination of the shadow value of capital by substitution in the discrete version of the value maximisation problem in which the Q ratio disappears. The borrowing condition can be incorporated into the Euler equation

as an exogenous constraint. Then, after parameterising the constraint by using the appropriate cash flow or liquidity instruments, the validity of the constraint can be tested by the orthogonality condition of the instruments and the error terms of the econometric equation. Using the Euler equation method, for US panel data, Hubbard, Kashyap and Whited (1995) produce similar results for low-dividend payout firms.

Similarly, based on the Euler equation method, Bond and Meghir (1994) empirically investigate the effect of financial policy on the investment behaviour for UK manufacturing sector panel data over the period 1974-1986, also employing the hierarchy of finance approach. Their results suggest that there are significant differences in the investment behaviour of subsamples of firms allocated according to their financial policies. Exclusion of firms with low-dividend payments significantly reduces the sensitivity of investment to cash flow and other financial variables.

Although a strong relation between investment spending and cash flow does exist, it is actually difficult to establish the causal connection between them since shocks to profitability affect both cash flow and investment. For instance, a survey by Pike (1983) covering large UK companies reveals that many firms impose internal constraints due to lower profitability prospects and uncertainty. To overcome such a criticism, Calomiris and Hubbard (1993) use the tax policy changes in the US in 1936-1937 as a natural experiment. More specifically, they analyse how firm-level

investment reacted to changes in the taxation of undistributed profits relative to dividends. Holding constant investment opportunities, if external and internal funds are perfect substitutes, investment should not react to tax changes. However, they find that the investment of high surtax-margin firms was sensitive to shifts in cash flow. To investigate the effect of internal finance on investment behaviour in a more evident circumstance, Lamont (1997) focuses on the 1986 oil price shock and the effects of it on the non-oil investment of oil companies for US data. By concentrating on segments of the firms, Lamont shows the importance of oil cash flows for non-oil investment spending.

Based on informational problems, cash flow and liquidity effects are well documented. On the other hand, as explained above, the theoretical developments in the corporate finance side concentrate on incentive problems and possible relations between financial capital structure and investment decisions. However, unlike the empirical evidence for cash flow and liquidity variables, the empirical studies for the leverage effects are not numerous, and they find controversial results.

For instance, by employing US firm-level panel data for the period 1968-1987, Cantor (1990) investigates the effect of leverage on investment and employment patterns of firms with different levels of leverage ratios. The motivation behind the study is that a highly leveraged firm with a small average cash flow will cut its investment sharply when it suffers from lack of internal funds. On the other hand, it

will be more apt to increase investment when its revenues and internal funds improve. Therefore, the highly leveraged firm is likely to exhibit greater variability in its investment over time. Confirming his argument, Cantor's results show a significant positive relation between the leverage and volatility of investment and employment of highly leveraged firms. Using a Q model, a Euler equation model and an unrestricted investment model, Galeotti, Schiantarelli and Jaramillo (1994) test possible effects of agency costs of debt on investment decisions for Italian panel data. Their results provide support for a significant departure from the hypothesis of perfect substitutability between internal and external sources.

On the other side, in another US panel data study, Oliner and Rudebusch (1992) investigate the sources of financing hierarchy for investment. They test the effect of asymmetric information, agency costs, and transaction costs. For that purpose, they run reduced-form regressions including the Q ratio, sales ratio, and cash flow ratio. For the asymmetric information effect, they split the sample according to maturity and insider trading criteria. For the transaction cost effect they use the size variable. To capture the agency cost of equity effect, they use information about the outstanding common stock controlled by the firm's board of directors. They find significant effects of asymmetric information and insignificant results for the agency costs and transaction costs effects. Using US firm-level data and after performing reduced-form regressions, Kopcke and Howrey (1994) report that their findings do not support the view that companies with more debt invest less than their sales and cash flows would warrant. In another study, using US firm-

level panel data and after performing reduced-form regressions, Lang et al. (1996) find that financial leverage negatively affects growth of the firms. However, this result only holds for the firms with low Tobin's Q ratio. Optimal capital structure theories based on managerial discretion as in Jensen (1986) and Stulz (1990) show that leverage reduces the agency costs of managerial discretion by reason of the control role of debt. Thus, Lang et al. argue that the negative relation between leverage and investment could be due to the restrictive role of debt on managers of firms with poor investment opportunities.

Also, studies employing aggregate data have conflicting results. For instance, Chirinko (1987) incorporates the equation of motion of debt as a constraint into the maximisation problem to derive a relation between investment and Q ratio in the presence of an endogenous financial policy. Chirinko shows that the relation between the average Q and the marginal q would be different under the endogenous financial policy case, and he translates his theoretical model into an econometric equation to estimate the structural parameters. He uses US aggregate data for the period 1950-1981 to test the model. However, he reports that problems such as high adjustment cost, serially correlated residuals and low explanatory power still remain. On the other hand, using an error correction model and cointegration technique, Cuthbertson and Gasparro (1995) obtain satisfactory results for UK aggregate data when they include the capital gearing ratio in their investment model in a Q theory framework.

Section 1.6 Uncertainty and Irreversibility

In sections 1.2 and 1.3, the models were developed under the certainty assumption, and the investment was implicitly supposed to be reversible. Of course, one cannot expect a firm's investment behaviour to be the same in a certain and uncertain environment, or for a reversible and irreversible investment decision. There are two dimensions of the uncertainty effect on investment at a firm-level analysis. The first one is based on the capital asset pricing model (CAPM) which compares a firm with the other firms and emphasises covariances in the returns between the investment projects. According to the CAPM, risk and return are positively related, and the risk of an investment project is measured by the covariance of the return of this project with the market as a whole. As the covariance increases, the required rate of return increases, creating a negative investment-uncertainty relationship. Along this argument, Craine (1989) shows this negative relation in a general equilibrium where an increase in exogenous risk reallocates resources towards less risky business.

The second line of argument looks at the firm in isolation from the other firms and concentrates on the variances while studying the uncertainty effect on investment decisions. For the variance effect argument, there are mainly two opposing theoretical views. The former view hypothesises a positive relation, whereas the other considers the irreversibility of investment decisions and predicts a negative effect. This section will concentrate on the second line of argument, and the

neglected role of uncertainty and irreversibility on investment decisions will be considered. The two opposing views will be discussed and contrasted theoretically. Empirical studies will also be presented, including the aggregate-level ones.

Theoretical Aspects

In a theoretical study, Hartman (1972) studies the effect of increased uncertainty in future output prices, wage rates, and investment costs on the quantity of investment undertaken by a risk-neutral competitive firm. In his model, the firm maximises the expected value of the sum of discounted cash flows independently of its financial activities under increasing marginal costs of investment and produces under the Cobb-Douglas technology. Hartman concludes that current investment does not decrease with increased uncertainty in future output prices and wage rates, and it is invariant to increased uncertainty in future investment costs.

For a risk-neutral value maximising competitive firm, Abel (1983) explicitly shows that increased uncertainty in the price of output causes an increase in the investment undertaken by the firm, which also verifies Hartman's earlier conclusion. In Abel's model, the price of the output p follows a random walk as

$$dp_t = p_t \sigma dz \quad (37)$$

where, σ is the variance parameter and dz is a Wiener process with zero mean and unit variance. The firm produces under Cobb-Douglas technology as

$$F(K_t, L_t) = CL_t^\alpha K_t^{(1-\alpha)} \quad (38)$$

and F , L , K and α denote the output, labour, capital stock and the labour elasticity of output. The term C denotes the scale parameter, and for simplicity it will be assumed one. When the firm undertakes investment, it incurs convex costs of adjustment. The firm's revenue and the cost of investment at time t can be written as

$$\pi(K_t, L_t) = p_t L_t^\alpha K_t^{(1-\alpha)} - w_t L_t \quad (39)$$

$$A(I_t) = \gamma I_t^\beta \quad (40)$$

where w is the wage rate, γ is a positive coefficient and $\beta > 1$. For simplicity, the price of capital is assumed one. The firm maximises its value at time t as

$$V(K_t, p_t) = \max E_t \int_t^\infty [\pi(K_u, L_u) - \gamma I_u^\beta] \exp(-r(u-t)) du \quad (41)$$

subject to the usual capital accumulation equation

$$dK_t = (I_t - \delta K_t) dt \quad (42)$$

where r and δ represent the constant required rate of return and the economic depreciation rate. From the no-arbitrage condition, the total return expected by the owners of the firm can be written as

$$rV(K_t, p_t) dt = \max[\pi(K_t, L_t) - \gamma I_t^\beta] dt + E_t(dV) \quad (43)$$

which consists of the cash flow and the expected capital gain. Using Ito's Lemma and equations (37) and (42), the expected capital gain can be expressed as

$$E_t(dV) = [(I_t - \delta K_t)(\partial V / \partial K) + 0.5 p_t^2 \sigma_t^2 (\partial^2 V / \partial p^2)] dt. \quad (44)$$

Note that, while deriving equation (44) we make use of $E(dz)=(dt)^2=(dz)(dt)=0$.

Hence, the optimality condition in equation (43) can be rearranged by substituting the result in equations (44) as

$$rV(K_t, p_t) = \max_{L_t} [\pi(K_t, L_t) - \mathcal{M}_t^\beta + (I_t - \delta K_t)(\partial V / \partial K) + 0.5 p_t^2 \sigma_t^2 (\partial^2 V / \partial p^2)]. \quad (45)$$

From here, the optimal rate of investment can be obtained as

$$(\partial V / \partial K) = \gamma \beta I_t^{\beta-1} \quad (46)$$

which says that the marginal cost of investment equals the marginal value. Under the model assumptions, also by using the optimality condition for labour, the marginal revenue product of capital equals the average revenue product of capital:

$$\partial \pi(K, L) / \partial K = \pi(K, L) / K. \quad (47)$$

Finally, by using equations (46) and (47), equation (45) can be rewritten as

$$rV(K_t, p_t) = (\partial \pi / \partial K) K_t + (\beta - 1) \mathcal{M}_t^\beta - \delta K_t (\partial V / \partial K) + 0.5 p_t^2 \sigma_t^2 (\partial^2 V / \partial p^2). \quad (48)$$

Equations (46) and (48) can be expressed as a non-linear second-order partial differential equation. In Abel (1983), the explicit solution to this problem is given as

$$I_t = (x / \beta \gamma)^{1/(\beta-1)} \quad (49)$$

where

$$x = \frac{\partial \pi / \partial K}{r + \delta - 0.5 \alpha \sigma^2 / (1 - \alpha)^2}.$$

The marginal revenue product of capital can be expressed as

$$\partial \pi / \partial K = (1 - \alpha) p L^\alpha K^{-\alpha}. \quad (50)$$

Moreover, using the optimality condition of labour from equation (45) and the production function given in equation (38), the labour can be expressed as

$$L = (w / p\alpha)^{1/(\alpha-1)} K. \quad (51)$$

Using equation (51), equation (50) can be rewritten as

$$\partial\pi / \partial K = (1 - \alpha)(\alpha / w)^{\alpha/(1-\alpha)} p^{1/(1-\alpha)}. \quad (52)$$

The important thing in equation (52) is that the marginal revenue product of capital becomes a convex function of the output price. Moreover, it is also independent of the capital stock. Observe from equation (49) that this makes x and also the investment decision at time t independent of the capital stock. Abel also shows that the expected marginal revenue product of capital can be written as

$$(1 - \alpha)(\alpha / w)^{\alpha/(1-\alpha)} E_t[p_u^{1/(1-\alpha)}] = (1 - \alpha)(\alpha / w)^{\alpha/(1-\alpha)} p_t^{1/(1-\alpha)} \exp(0.5\alpha\sigma^2(u-t)/(1-\alpha)^2). \quad (53)$$

Considering that the capital depreciates, using the result in equation (53), the expected present value of marginal revenue products of capital can be expressed as

$$\begin{aligned} \int_t^{\infty} E_t(\partial\pi / \partial K)_u \exp(-(r + \delta)(u - t)) du &= \int_t^{\infty} (1 - \alpha)(\alpha / w)^{\alpha/(1-\alpha)} p_t^{1/(1-\alpha)} \\ &\exp[-(r + \delta)(u - t) + 0.5\alpha\sigma^2(u - t)/(1 - \alpha)^2] du \end{aligned} \quad (54)$$

which is obviously equal to the term x given in equation (49). Thus, investment becomes the function of the present value of expected marginal revenue products of capital. As can be seen, when the marginal revenue product of capital is a strictly convex function of the price of output, increased uncertainty about the future price of output increases the expected future marginal revenue product of capital, and hence the term x and investment.

For the uncertainty effects of the output price and the input costs, the results of both Hartman and Abel depend on the assumption that the marginal revenue product of

capital is a convex function of the price of output and the input costs. This is because, an increase in the variances of the output price and costs also implies an increase in the expected present value of marginal revenue product of capital, which in turn implies an increase in the optimal rate of investment. Abel (1984, 1985) also extends the effects of uncertainty in a stochastic q theory of investment framework.

In an early study, Arrow (1968) discusses the implications of irreversibility in a certain environment. Irreversibility usually arises if the capital employed by a firm is industry-specific and/or firm-specific. If a firm can not disinvest, the investment decision would be irreversible and the investment expenditures would be sunk costs. Unlike a reversible investment decision, the firm should consider the value of not undertaking the project. Thus, for an irreversible investment decision, in an uncertain environment, the value maximising firm should consider the value in waiting since the investment expenditures could be treated as sunk costs once the investment is undertaken. McDonald and Siegel (1986) analyse the optimal timing of investment in an irreversible single project in which both the benefits and costs of the project are assumed to follow a geometric Brownian motion. Because the future values of the benefits of the investment are unknown, there is an opportunity cost of investing today. In their analysis, McDonald and Siegel explore the importance of the value in waiting to invest. Based on their numerical simulations, they conclude that timing considerations are quantitatively important. Instead of a discrete project as in McDonald and Siegel, Pindyck (1988) analyses the effect of irreversibility together with uncertainty for incremental investment. In his model, unlike Abel and

Hartman, Pindyck ignores the adjustment costs and studies the effects of demand uncertainty on investment decisions. In the model, the firm tries to maximise its value and faces a stochastically shifting downward sloping demand curve. Investment expenditure involves exercising of an option which represents the resources that can be productively invested at any time in the future. The model accounts for the value of the lost option as an additional cost of the new investment, and uncertainty affects investment decisions through the options that the firm holds. Pindyck's results suggest that firms should hold less capacity in markets with volatile and unpredictable demand than they would if future demands were predictable or investments were reversible. For irreversible investment decisions under uncertainty, Dixit and Pindyck (1994) demonstrate how to obtain the optimal investment rules for a variety of models including discrete and incremental investment decisions by using dynamic programming techniques and contingent claim analyses.

In his model, Pindyck shows that increases in uncertainty will lower the investment whereas Hartman and Abel conclude the opposite. In Abel and Hartman, investment is reversible and the adjustment costs are symmetric. This means that the opportunity cost of investing is zero in terms of Pindyck's model. On the other hand, the irreversible investment model of Pindyck implies a kind of asymmetric adjustment costs case when compared to the models of Abel and Hartman since the investment expenditures would be sunk costs. To investigate the opposite findings of the cited studies and some others about the sign of the investment-uncertainty

relationship, Caballero (1991) develops a model with a cost of adjustment mechanism general enough to consider both the symmetric-convexity and the irreversibility as special cases. However, he also points out the hidden role of the assumptions about the markets and the production functions in these studies. Abel and Hartman mainly assume perfect competition and a constant returns-to-scale type of production function, whereas the irreversibility literature assumes either imperfect competition or decreasing returns-to-scale, or both. In Caballero's general model, risk-neutrality is assumed and the firm's technology is described by a homogenous Cobb-Douglas production function as

$$F(K, L) = (CL^\alpha K^{(1-\alpha)})^\varphi \quad (55)$$

where φ represents the returns-to-scale parameter. Equation (55) reduces to the constant returns-to-scale case as in equation (38) when φ is one. The firms faces a general demand function as

$$p_t = F_t^{(1-\psi)/\psi} Z_t \quad (56)$$

where Z is a stochastic term described by a lognormal random-walk process as

$$Z_t = Z_{t-1} \exp(\varepsilon_t) \quad (57)$$

and ε is normally distributed with variance σ^2 and mean $-0.5\sigma^2$. In equation (56), the term ψ represents the markup coefficient which is greater than or equal to one. Note that for a perfectly competitive firm, since the elasticity of demand is infinite, the markup coefficient will take the value of 1. Thus, the price process described by equations (56) and (57) reduces to a similar case given in equation (37). When ψ is 1, the firms faces a flat demand curve which corresponds to the perfectly

competitive firm case as in Abel and Hartman. On the other hand, the bigger the markup coefficient, the smaller the elasticity of demand will be, which will increase the degree of imperfect competition and will create a stochastically shifting downward sloping demand function as in Pindyck (1988). Under these conditions, the profit function can be written as

$$\pi(K_t, Z_t) = h Z_t^\eta K_t^\mu \quad (58)$$

where

$$h = (1 - \alpha\varphi / \psi) C^{(\varphi/\psi)/(1-\alpha\varphi/\psi)} (\alpha\varphi / w\psi)^{(\alpha\varphi/\psi)/(1-\alpha\varphi/\psi)}$$

and

$$\eta \equiv \frac{1}{1 - (\alpha\varphi / \psi)} > 1, \text{ and } \mu \equiv \frac{(1 - \alpha)\varphi / \psi}{1 - (\alpha\varphi / \psi)} \leq 1.$$

Observe that, under the assumptions of perfect competition, the constant returns-to-scale case and $C = 1$, the terms $\eta = 1/(1-\alpha)$ and $\mu = 1$, thus the profit function given in equation (58) will be exactly the same as in Abel (1983) which can be confirmed from the marginal revenue product of capital given in equation (52). Otherwise it corresponds to a similar case described in Pindyck (1988). Finally, the cost of investment is given by the general function

$$A(I) = I + [I > 0]\gamma_1 I^\beta + [I < 0]\gamma_2 |I|^\beta \quad (59)$$

where γ_1 and γ_2 are two nonnegative parameters and $\beta \geq 1$, and price of capital is assumed as unity. This general case corresponds to the symmetric-convex adjustment cost case of Abel (1983) when $\beta > 1$ and the two parameters γ_1 and γ_2

are positive. On the other hand, when $\beta=1$, $\gamma_1=0$ and $\gamma_2=\infty$, the irreversibility case of Pindyck (1988) is obtained.

For the perfect competition case under constant returns-to-scale type of technology, Caballero derives the investment equation at time $t = 1$ considering a two-period optimisation problem as

$$I_1 = \left(\frac{X-1}{\gamma_1 \beta} \right)^{1/(\beta-1)} \text{ for } I_1 > 0, \text{ and } I_1 = \left(\frac{1-X}{\gamma_2 \beta} \right)^{1/(\beta-1)} \text{ for } I_1 < 0 \quad (60)$$

where

$$X = hZ_1^\eta (1 + \exp(0.5\eta(\eta-1)\sigma^2)).$$

Clearly, investment is independent of the capital stock, and the positive investment-uncertainty relationship is obtained as in Abel and Hartman. However, as can be seen from equation (60), the asymmetry of the adjustment costs has nothing to do with the sign of the response of investment to increases in uncertainty. The results of Abel and Hartman continue to hold in the presence of asymmetric adjustment costs which typically correspond to the effect of the irreversibility argument in the literature. When there is imperfect competition, there is no closed-form solution for the investment function. Thus, Caballero (1991) makes some numerical simulations for the imperfect competition case. Retaining the symmetric adjustment costs but varying the degree of imperfect competition via the markup parameter creates a negative investment-uncertainty relationship. Also, once the degree of competition is significantly imperfect, the investment-uncertainty relationship becomes more negative as the asymmetry of the adjustment costs, in other words the irreversibility

effect, becomes larger. Moreover, creating decreasing returns-to-scale by altering the returns-to-scale parameter φ makes a negative investment-uncertainty relationship more likely.

Overall, the results of Caballero (1991) show the importance of the effects of the assumptions of the two theoretical views on the sign of the investment-uncertainty relationship. Despite the ineffectiveness of asymmetric adjustment costs, or in other words the irreversibility for the results of Abel and Hartman, the imperfect competition and the decreasing returns-to-scale assumptions tend to change the sign of the investment uncertainty relationship towards negativity.

For a risk-neutral competitive value maximising firm under the constant returns-to-scale assumption, Abel and Eberly (1994) show the effect of price uncertainty on investment decisions in a q theory framework also considering the potential irreversibility of investment. They define an augmented adjustment cost function which includes the traditional convex adjustment costs as well as the possibility of fixed costs and the possibility that the resale price of capital goods is below their purchase price, and may even be zero. According to their model, investment is a non-decreasing function of the variance of the price for a given price level, which is consistent with the line of argument in Caballero (1991). Moreover, Abel and Eberly (1997) present a parametric example of a competitive firm with a constant returns-to-scale production function facing convex costs of adjustment and

irreversibility and provide closed-form solutions for the investment and the value of the firm in a q theory framework.

When uncertainty increases, better and worse news become more likely. However, it is optimal to increase the protection from costly irreversibility by investing less since the resale price of capital is likely to be less than the current acquisition price. When the firm invests, it loses the option to invest in the future which increases the cost of investment and reduces the firm's incentive to invest. On the other hand, the firm can continue to invest later, but the future acquisition price of the capital may be higher than its current acquisition price, making expandability costly. In other words, waiting to invest will have an additional cost if the price of capital is expected to increase. Thus, the two options will have opposite effects on the investment decision of the firm. In a theoretical work, Abel, Dixit, Eberly and Pindyck (1996) study the interactions of these two options to determine the net effect of expandability and reversibility and the net effect of uncertainty on the optimal capital stock in a q theory framework. Since the values of both options increase with uncertainty and the two options have opposing effects on the incentive to invest, they conclude that the net effect of uncertainty will be ambiguous.

Empirical Studies

In the literature, only recently have various studies examined uncertainty and irreversibility effects on investment decisions empirically. Given the difficulty of

obtaining an estimable structural model, most of these studies incorporate some form of proxy measures for uncertainty into the traditional investment models, and many of them examine the investment-uncertainty relationship at an aggregate level. In an early study, Brainard, Shoven and Weiss (1980) investigate the relation between investment and uncertainty. They employ firm-level US data for 187 firms and assess the effects of CAPM-based risk measures on investment via average Q . They perform cross-section regressions and report both positive and negative effects, only some of which are significant. In a more recent study, using US large-company panel data, Driver et al. (1996) examine the effect of demand uncertainty on company investment decisions. They use market share turbulence as a measure of demand uncertainty where turbulence is measured as the dispersion in movement between a firm's and its two main competitors' market shares. They incorporate demand uncertainty into a standard investment equation. Although weak, their estimation results show evidence that increased demand uncertainty may reduce the incentive to invest. Moreover, this negative relationship appears to be more significant in highly-integrated plants where firms have better protection from competition.

Leahy and Whited (1996) examine both the covariance and variance effects using q models of investment for US firm-level panel data. To construct the measures of uncertainty, they employ share price returns. Moreover, to examine the two opposing theoretical views for the variance effect, they split the sample according to the substitutability of labour for capital and the magnitude of the labour-capital ratio

because the ability to substitute labour for capital increases the convexity of the marginal product of capital, making the positive investment-uncertainty relationship more likely. Also, the higher is the labour's share, the greater is the convexity in returns induced by varying the firm's labour input. They also split their sample according to the low-beta and high-beta firms for the covariance effect because the greater the covariance, the greater the beta becomes, making uncertainty less desirable since the sensitivity of a firm's investment depends on its beta coefficient via the required return. Their results indicate that an increase in uncertainty decreases investment primarily through its effect on average Q . Moreover, they find no evidence for the covariance effect or for the positive effect by the channel of the convexity of the marginal product of capital.

Using the model developed in Abel and Eberly (1994), Eberly (1997) presents a q model of investment considering the irreversibility of investment decisions. In the traditional q model, investment becomes a linear function of the q ratio because of the symmetric convexity assumption. In this model, fixed, linear and convex (not necessarily quadratic) adjustment costs are considered, and investment becomes a non-linear function of the q ratio. Using firm-level panel data for 11 countries, Eberly (1997) presents evidence that a non-linear form of investment equations performs better when compared to the linear case.

Using aggregate-level data, Caballero and Pindyck (1992) investigate the effect of uncertainty on irreversible investment decisions for 20 US manufacturing industries.

In the case of a single firm, while analysing the irreversibility effect, the opportunity to wait and its value do not depend on the firm's competitors. However, in the case of an industry-wide analysis one needs to consider the possible entry of new competitors and/or possible expansion of existing ones. The price cannot be taken as exogenous since it becomes an endogenous variable of the industry equilibrium. Moreover, the sources of uncertainty at aggregate-level and firm-level should be distinguished and the ways they effect investment should be identified. In a competitive industry with free entry and constant returns-to-scale technology, Caballero and Pindyck (1992) derive an expression for the required return to trigger irreversible investment. In the model, although the distribution of the future marginal profitability of capital for any single firm is independent of its current investment, this distribution depends on industry-wide investment. Idiosyncratic shocks affect only an individual firm and do not induce entry and/or expansion. On the other hand, positive industry-wide shocks are accompanied by the entry of new firms and/or expansion of existing ones placing a limit on the price, whereas negative aggregate shocks reduce the market price. Since negative shocks reduce profits more than positive shocks increase them, this asymmetry causes a reduction in irreversible investment. To test the model, Caballero and Pindyck use the extreme values of the marginal profitability of capital as a proxy for the trigger point (required return). They present evidence for the positive dependence of these proxy measures on the volatility of the marginal profitability of capital, implying an indirect negative investment-uncertainty relationship analysed at industry-level.

Pindyck and Solimano (1993) employ a similar version of the model developed in Caballero and Pindyck (1992). They examine the relationship between aggregate investment and volatility across three decades. Their panel regressions for 29 countries indicate a negative relationship which is in greater magnitude for developing countries. Note that in Caballero and Pindyck (1992), as the competitiveness of the industry increases, the negative effect of aggregate uncertainty also increases on the industry-wide investment level since the entry and expansion becomes easier, increasing the asymmetry. To test their hypothesis, Ghosal and Loungani (1996) employ data for US manufacturing industries. To control the extent of the product market competition, they partition their sample according to the seller concentration ratio. In their reduced-form panel regressions, they find that the effect of price uncertainty is negative and statistically significant for the highly competitive firms. On the other hand, the results for the industries with high levels of seller concentration appear to be small and not significantly different from zero.

Using US aggregate data, Ferderer (1993) explores the empirical relationship between uncertainty and aggregate investment spending. Unlike other studies, he uses the risk premium embedded in the term structure of interest rates to measure the uncertainty about interest rates and other macroeconomic variables. He concludes that uncertainty has a negative and statistically significant effect on investment decisions which is also larger in impact when compared to the cost of capital and average Q ratios. In another aggregate-level study, Bell and Campa

(1997) investigate the effects of three different sources of volatility on irreversible investment decisions of the chemical industries in the United States and Europe. They report a significant negative effect of exchange rate volatility in Europe, but they find that input prices and product demand volatility do not appear to have a significant effect in any of the regions.

Section 1.7 Concluding Remarks

The early investment models rely purely on reduced form relations and ad hoc adjustment mechanisms. With its forward-looking nature, the neo-classical model takes a structural approach to consider the durability of capital and derives the long-run desired level of capital from the value maximisation problem. However, it still relies on an ad hoc stock adjustment mechanism by which the adjustment costs (and by implication, the investment rate) are introduced implicitly. Moreover, the desired capital stock is derived without regard to this auxiliary adjustment mechanism. From an empirical perspective, it is difficult to interpret the estimated coefficients since the distributed lags might be representing either the expectations or the delivery lags. To justify the adjustment mechanism of the neo-classical model, various studies apply a particular dynamic adjustment mechanism by introducing the concept of adjustment costs in the criterion functional. Although this new formulation provides a rigorous basis for the optimal rate of capital accumulation and rationalises the flexible accelerator models of investment behaviour, the measurement of expectations still has important problems. More recent

contributions point out the equivalence between the neo-classical model and the q theory of investment. In fact, the neo-classical model and the q model constitute the demand and supply side of the same theory, respectively. The neo-classical model looks at the factors behind the market value by analysing the net revenue of the firm, whereas the q approach uses the market value directly in determining the optimal investment. Moreover, the q theory is in principle free of the expectations problem since the market value purports to summarise all the relevant information and expectations. Although the q model of investment is theoretically very appealing, empirically it has performed less successfully. Moreover, the traditional models easily outperform these two structural models.

The more general the investment models, the less realistic they become. It is difficult to construct and estimate consistent structural models, but, the structural approach is to be preferred over the ad hoc models. To make the structural investment models more realistic and to improve their empirical performance, the theoretical literature considers the other determinants of investment such as taxation, financing conditions and uncertainty and irreversibility. It is also widely recognised that the differences between groups of firms require different modeling requirements. On the empirical side, with the growing availability of data, more studies employ panel data to consider the heterogeneity of firms and to overcome aggregation problems.

The tax environment is one of the most important aspects influencing the incentive to invest. Empirical studies show strong evidence that taxes, both at the corporate and personal levels, play a significant role in determining investment decisions. Apart from the effects of actual rates of taxes themselves, the structure of corporate and personal taxation has complex effects on investment through the other determinants of investment, such as cost of capital and inflation. Future studies should give more emphasis to these complex effects through factors such as uncertainty, irreversibility, capital structure and incentive and informational problems: indeed cost of capital, capital structure, uncertainty and irreversibility issues are addressed in chapters 2 and 3.

Both the neo-classical and q models of investment assume perfect capital markets and rely on the irrelevance result of Modigliani and Miller. However, many theoretical studies posit that informational and incentive problems may create frictions in financial capital markets. The imperfect substitution between internally generated and externally raised funds owing to imperfect information and incentive problems can create an external financing premium. Moreover, some firms might be under financial distress, or even credit rationed. Thus, financing conditions may have important implications for investment decisions and proxies for this factor may also improve the empirical performance of the employed models. Studies testing the possible relationship between investment and financing decisions document cash flow and liquidity effects. However, existing empirical studies about the effects of incentive problems on investment

decisions are not numerous and produce controversial results. Given the inconclusive nature of the empirical studies and their contradictory results, the role of incentive problems certainly deserves further investigation and more empirical studies. These issues are addressed in chapters 4 and 5.

Theoretical studies incorporated the effect of uncertainty into the standard neo-classical and q models of investment. However, two opposing theoretical views exist as to the effect of uncertainty. The first view hypothesises a positive relation, whereas the other considers the irreversibility of investment decisions and predicts a negative effect. Extended theoretical works suggest that the sign of the investment-uncertainty relationship depends on the degree of competition faced by a firm and/or the assumption about the technology that the firm adopts. The technology to estimate stochastic structural models which treat time and uncertainty explicitly is developing. However, computational requirements still remain formidable. Given the problems of estimating stochastic structural models, empirical studies use reduced form investment equations and incorporate proxy measures of uncertainty in an ad hoc way. However, the existing empirical studies are limited in number and none of them consider the joint impacts of market structure while investigating the sign of this relationship. Thus, further empirical studies are required in this field to consider the role of the market structure and other assumptions embedded in the models. In chapter 6, we make an in depth investigation of these issues by using the UK firm-level panel data,

In the rest of the thesis, using large-company panel data for the major European countries, we study the effects of corporate taxation, financing conditions, and uncertainty on investment decisions, and aim to make a contribution to the literature on the topics that exhibit controversy. In chapters 2 and 3, while studying the corporate tax effects on investment behaviour, we analyse particularly the possible consequences of the harmonisation of corporate tax rules in Europe. In the literature there have been arguments over this issue. Some authors argue in favour of harmonised tax rules mainly to prevent discrimination and distortion in investment decisions. On the other hand, some authors defend independent tax systems for national demand management and stabilisation. The ultimate aim in chapters 2 and 3 is to study whether the asymmetric effects of corporate taxes on investment decisions can be eliminated by harmonising the corporate tax rules.

Empirical studies employ static measures such as effective tax rates and cost of capital to compare the effects of the tax systems. In chapter 2, instead of employing such a methodology, we conduct a dynamic tax simulation analysis based on the q theory approach. This study is the first of its type applied in this context. Instead of revealing the existing tax burden as in static measures case, the dynamic analysis has the advantage of studying the responses of investment to tax policy changes. We derive some original formulae so as to decompose the asymmetric tax policy responses of investment owing to corporate tax rules and other variables related to investment decisions. This approach lets us measure the true effects of the differences in the corporate tax systems on the observed asymmetries. In the

modeling process, for simplicity, we assume quadratic adjustment costs, perfect certainty, costless reversibility and perfect financial and output markets. Even though analysing the tax effects quantitatively will be limited by the model assumptions and the explanatory power of the model, the analytical derivations and the resulting simulations allow us to make qualitative inferences concerning the tax harmonisation issues. For quantitatively more realistic results, the model assumptions can be relaxed and the empirical fit of the investment model can be improved.

To complement the tax analysis of chapter 2, we conduct another tax study in chapter 3 by employing domestic effective tax rates. Previous studies employing effective tax rates and cost of capital measures for corporate tax analyses ignore the irreversibility of investment decisions. Using real option pricing techniques, we take a more realistic approach and develop an original model to incorporate the income uncertainty and irreversibility risk jointly into the traditional effective tax rate measures. As in chapter 2, we analyse the consequences of harmonising the tax rules and compare the observed asymmetries both for the certainty/uncertainty and irreversibility cases. In the modeling process, for ease of analysis, we assume a fully irreversible case, consider only the income uncertainty, and ignore the possible tax carry-forwards and carry-backs of losses. For a more realistic case, the model can be altered to overcome some of these restrictive assumptions.

In chapter 4, based on the Euler equation approach, a model is developed to test the possible effects of agency/financial distress costs of debt by incorporating an external financing premium via the debt-capital ratio. Unlike cash flow and liquidity effects, this explicit incorporation provides a sharper test of the hypothesised relationship. Additionally, the model also considers the possible role of working capital as a source of finance to smooth the agency/financial distress costs of debt. The Euler equation approach adapted in chapter 4 eliminates the unobservable shadow value of capital via substitution. In chapter 5, we extend the analysis in a q theory framework and derive an original alternative model in which the unobservable shadow value of capital is converted to an observable one, again by considering the possible agency/financial distress costs of debt. For simplicity, the models employed in chapters 4 and 5 assume a tax-free world and costless reversibility. To analyse the effects of financing conditions on investment together with tax effects and irreversibility, the tax parameters can be incorporated into the models and linear costs can be introduced to capture the irreversibility effect.

In chapter 6, we examine the sign of the short-run investment-uncertainty relationship for large UK industrial companies. Unlike previous empirical studies, we consider the market structure via product specialisation criteria. Given the difficulty of obtaining an estimable structural model, the uncertainty effect is incorporated into the investment equations in an ad hoc fashion. However, to test the robustness of the obtained results, two different investment models and two different measures of uncertainty are employed. As an extension to this study,

other reduced form models, uncertainty measures and splitting criteria can be considered. In the final chapter, the effects of inflation uncertainty, exchange rate uncertainty and interest rate uncertainty on aggregate investment are investigated in a vector autoregressive framework. Using impulse response functions and variance decomposition techniques we try to measure the sign and magnitude of these relationships in a reduced form model. We also investigate the uncertainty effects separately on different categories of investment which the previous literature has not considered before. This aggregate-level study can be further applied at the industry level to understand the role of different industry structures for the observed relationships.

CHAPTER 2

A DYNAMIC TAX SIMULATION ANALYSIS

Section 2.1 Introduction

There have been many studies about the effects of corporate taxation on investment decisions in the literature both at theoretical and empirical levels. Generally, as a corporate tax policy, a government alters the corporate tax rate, changes the depreciation rules for capital allowances, and gives or cancels investment tax credits. Obviously, the structure of the tax system is only one of the determinants of capital formation, but it is an important fiscal tool held by a government which may well have distortionary effects on investment behaviour, since an increase in the tax burden will lower the available resources to a firm and also increase the costs. Conversely, corporate tax policy may induce investment.

Many studies investigating the effects of taxation on capital investment apply static measures like effective tax rates or an implied cost of capital to observe the existing tax burden. This will be addressed in the next chapter. As a first aim, this chapter will deal with the measurement of the dynamic effects of various permanent corporate tax policy changes. The analyses will concentrate on three major European countries in Europe: the United Kingdom, France and Germany. Additionally, the Netherlands will be included in the analyses for comparative

purposes. We will try to address questions like: how permanent changes in corporate tax rules affect the investment behaviour in a dynamic equilibrium; whether these tax effects are important or negligible; whether corporate tax policy changes the investment behaviour; which policy is more important for which country. For the theoretical framework, based on the q theory, a partial equilibrium model is derived. Partial equilibrium means that the multiplier effects of increased investment as well as the interest rate effects of variations in the government deficit are ignored. Although the q theory approach will limit the analyses to the extent that it explains the investment behaviour, it considers the role of expectations via the market value approach. Also, dynamic policy effects can be studied when the q theory is linked to the augmented neo-classical model. While doing so, a simplified numerical procedure is applied to study the effects of permanent changes in three corporate tax rules, namely the corporate tax rate, the depreciation rules and the investment tax credit.

As a second aim, particular attention will be given to the tax competition argument via inter-country comparisons. This has important implications for the European Union because centralisation of fiscal policies, including the harmonisation of tax systems in Europe, has been an important argument. Moving towards a more united Europe, especially with the introduction of a Monetary Union and a European Central Bank, monetary authority will be abandoned at the national level. Hence, the use of domestic monetary policy and exchange rate adjustments for the purpose of national demand management and economic

stabilisation will be lost. Of course, the cost of forsaking monetary independence in a monetary union will depend on how much the monetary policy is capable of facilitating adjustments, and whether the shocks to the member economies are symmetric or asymmetric. If the monetary policy is effective for adjusting macroeconomic imbalances, and if the member economies are giving asymmetric responses to shocks, then the costs will be greater. For instance, in their study, Cohen and Wyplosz (1989) find that symmetric shocks are larger than asymmetric shocks in Europe. However, Bayoumi and Eichengreen (1992) show that, unlike demand shocks, asymmetry in the supply side shocks may be highly pervasive in Europe. When the monetary policy is lost, factor mobility and price flexibility are vital mechanisms for adjustments in a monetary union. However, it is often discussed that the adjustments will probably be more difficult with limited factor mobility and price rigidity in Europe when compared to the United States. This implies that fiscal policies may need to work harder and more effectively to cover the effects of possible asymmetric shocks and for economic adjustments. For that reason, some authors such as Masson and Melitz (1990) and Hughes-Hallet and Scott (1993) argue in favour of fiscal autonomy and independent tax systems, or some in favour of fiscal coinsurance. On the other hand, some authors such as Emerson (1990) and Goodhart (1992, 1994) argue in favour of a fiscal co-ordination. Mainly, two reasons can be cited for this view. The first and more important one is the international spill-over effects. Since one country's fiscal policies can affect the output and employment in other member countries, the co-ordination of fiscal policies can eliminate these spill-over effects. The second one

is that the differences in tax systems can cause discrimination and distortion in investment decisions which will also result in inefficient location decisions. For an extensive review of the fiscal implications of the European Monetary Union in conjunction with other issues, see for instance, Eichengreen (1993), Kenen (1995) and Obstfeld(1997).

Table 2.1 Corporate Tax Rules (%)

	UK	FR	BD	NL
Corporate Tax Rates	33	33.33	45	35
Plant & Machinery	25(RB)	20(SL)	30(RB)	12.5(SL)
Industrial Buildings	4(SL)	5(SL)	4(SL)	2.5(SL)
Commercial Buildings	-	4(SL)	4(SL)	2.5(SL)

Source: Yearly corporate tax guides of Price Waterhouse and Ernst & Young.

1. RB stands for the reducing-balance method and SL represents the straight-line method.
2. In Germany, companies also pay municipal tax on top of the 45%, which is deductible from the corporate tax rate. This rate varies approximately between 10%-20%, and with an average of 15% it increases the tax rate to 53.25%.
3. In France and the Netherlands, the reducing-balance method is also allowed for plant and machinery. In table 2.1, 20% is the generally accepted rate for France, and, 12.5% is the average of 5-10 years for the Netherlands. Also, straight-line method is allowed for plant and machinery in Germany.
4. For France, 4% for commercial buildings, and for the Netherlands, 2.5% for industrial and commercial buildings are the average rates for typical ranges.

To reveal the burden and the diversities of the corporate tax systems, table 2.1 presents the corporate tax rules for the period 1995-1996 for four European countries: the UK, France, Germany and the Netherlands. As can be seen, there is a considerable difference between the corporate tax rate in Germany and the other three countries as well as differences between the countries for the treatment of the depreciation allowances, especially for the plant and machinery. Although the

tax rules for the depreciation allowances vary, the values in table 2.1 represent the most commonly used average values.

Ruding (1992), the report by the European Community (EC) committee of independent experts, investigates the harmonisation of business taxation within the EC. The committee reports that there are important differences in the corporate tax systems and bases as well as in tax rates. However, there is also evidence of tax convergence through a general trend of a statutory tax rate cut. Among the findings of the committee is that the tax differences between the member states seriously affect locational decisions and also that withholding taxes causes bias against inward and outward investment. On the other hand, Devereux and Pearson (1995), for instance, analyse the impact of potential harmonisation of the taxation of income from capital on production efficiency in the EU. The production efficiency holds if total output cannot be reallocated across projects in such a way as to reduce total cost. Their simulation results suggest that, although there are important differences between the tax systems, neither harmonising all the corporate tax rates nor harmonising all the tax bases in the EU would lead to a significant convergence of costs of capital for transnational investment. Hence, there would only be a small gain in terms of production efficiency.

As mentioned above, as a second aim, this chapter will deal with the tax competition argument side of the fiscal implications of the EMU for the domestic

investment case. However, instead of comparing static measures such as the cost of capital or some sort of effective tax rates, we will make comparisons between the dynamic responses of different economies to various tax policy changes. By that way, instead of a simple measure, the responses of investment decisions can be measured. Furthermore, the nature of the model also requires econometric estimation of the investment equations. We will address issues like: whether the economies are responding to policy shocks in very different ways; whether there is a wide dispersion; if there is, then whether the asymmetry can be reduced by harmonising the tax rules; and whether the overall asymmetry is due to factors other than the corporate tax rules.

Starting from neo-classical intertemporal optimisation, and augmented with the external adjustment costs of capital, the next section of this chapter presents the basic investment behaviour of the firm. Section 2.3 converts the results of section 2.2 to a partial equilibrium system in capital and marginal q . Also, the resulting system and the beneficial tax policy effects are analysed graphically for qualitative demonstration purposes. Section 2.4 converts the unobservable marginal q to an observable variable for the estimation of the required adjustment cost parameters and for the simulations. Section 2.5 derives the permanent tax policy effects to make the desired simulations. Section 2.6 describes the data and the econometric methodology. Section 2.7 presents the estimation and the simulation results, and the final section concludes.

Section 2.2 The Basic Model

In the model, the behaviour of all firms will be represented by a single representative firm. The representative firm will be a competitive one that seeks to maximise the market value of its equity. For simplicity, personal taxation will be ignored. Also, irreversibility and issues like capital market imperfections are not dealt with in the model. Hence, by solving the value of the firm forward, the objective of the firm can be written in continuous time as

$$V(0) = \max \int_0^{\infty} e^{-rt} [Div(t) - NE(t)] dt \quad (1)$$

where the terms r , Div , and NE denote the after-tax nominal discount factor, the dividend and the new share issue, respectively. The firm maximises its market value under two constraints. The first one is the motion of capital stock as

$$\dot{K} = I - \delta K \quad (2)$$

where K , I and δ represent the capital stock, the investment and the depreciation rate, respectively. Throughout the chapter, the dot on the variables will denote the time derivative. Also, the time subscript will be suppressed for notational purposes. The factors of production are assumed perfectly variable except the capital stock; the firm will incur adjustment costs when it is changing its capital stock.

The second constraint is for the definition of dividend which also includes the adjustment costs of capital. The profit function is defined as

$$\pi(K, N) = pF(K, N) - wN$$

and the dividend as

$$Div = [(1 - c)\pi(K, N) - (1 - k - \beta)p^I(I + A(I, K)) - INT + B + NE + \tilde{G}]. \quad (3)$$

Here, $\pi(K, N)$ represents the profit function, $F(K, N)$ the linearly homogenous production function, $A(I, K)$ the strictly convex external adjustment cost function, p the price of good, N the variable input vector, w the nominal price of variable input vector, c the corporate tax rate, k the investment tax credit, β the present value of tax savings due to depreciation deductions for a unit of investment, INT the after-tax nominal interest payments on existing debt, B the net borrowings, p^I the price of investment good. The final term \tilde{G} represents the value of writing down allowances on past investments that can be claimed in the present period. In equation (3), net changes in working capital and intangible assets are ignored for simplicity, however, they will be considered later.

By ignoring the linear term, the quadratic external adjustment cost function can be introduced as

$$A(I, K) = \frac{\Phi}{2} \left(\frac{I}{K} - \alpha \right)^2 K \quad (4)$$

where Φ is the adjustment cost parameter and α is the normal rate of investment. As the firm increases its investment, it has to pay additional adjustment costs. The function is assumed to be twice differentiable where first-order and second-order partial derivatives of function A with respect to investment are both greater than zero.

Letting λ be the Lagrange multiplier associated with the first constraint, and after inserting equation (3) into equation (1), the firm's maximisation problem can be rewritten as

$$V(0) = \max \int_0^{\infty} e^{-rt} [(1-c)\pi(K, N) - (1-k-\beta)p^I(I + A(I, K)) - INT + B + \lambda(I - \delta K - \dot{K})] dt + G(0). \quad (5)$$

In equation (5), the final term $G(0)$ denotes the present value of writing down allowances on past investments that can be claimed in the present and future periods. The first-order conditions for investment and capital yield

$$\lambda = (1-k-\beta)p^I + (1-k-\beta)p^I \frac{\partial A}{\partial I} \quad (6)$$

and

$$\dot{\lambda} = (r + \delta)\lambda - (1-c) \frac{\partial \pi}{\partial K} + (1-k-\beta)p^I \frac{\partial A}{\partial K}. \quad (7)$$

Equation (6) simply shows that the shadow value of capital will be equal to the tax adjusted price of investment good plus the additional adjustment cost. Equation (7) is the equation of motion of the constraint which describes the evolution of the shadow price of capital. For ease of interpretation, solving this differential equation yields

$$\lambda = \int_0^{\infty} [(1-c) \partial \pi / \partial K - (1-k-\beta)p^I \partial A / \partial K] e^{-(r+\delta)t} dt. \quad (8)$$

This shows the equality between the present discounted value of the marginal revenue attributable to a unit of installed capital and the shadow price of capital. The first term in the integral is the additional revenue which comes from the

additional unit of capital. Since the adjustment costs depend on the size of investment to capital, the second term denotes the savings in the adjustment costs as the effect of an additional unit of installed capital.

Section 2.3 The K-q Plane

For a more fruitful analysis, the shadow value of capital can be eliminated and the above results can be transformed into a system of differential equations in capital and marginal q . First of all, the first-order condition for investment in equation (6) can be rearranged as

$$\frac{\partial A}{\partial I} = \frac{\lambda}{(1-k-\beta)p^I} - 1. \quad (9)$$

If the firm's investment-capital ratio does not exceed the normal rate of investment, then in equilibrium, the shadow value of capital equals the cost. As can be seen from equation (8), the shadow value of capital would be the sum of expected marginal profitability of newly installed capital which is discounted by the cost of capital. From here, marginal q can be defined as

$$\frac{\lambda}{(1-k-\beta)p^I} = q. \quad (10)$$

For simplicity, assuming that the normal rate of investment equals the depreciation rate, the marginality conditions of investment and capital for the adjustment cost function can be written as

$$\frac{\partial A}{\partial \mathcal{A}} = \Phi \left(\frac{\dot{K}}{K} \right) \quad (11)$$

$$\frac{\partial A}{\partial K} = -\frac{\Phi}{2} \left(\left(\frac{\dot{K}}{K} + \delta \right)^2 - \delta^2 \right). \quad (12)$$

By using equations (10) and (11), equation (9) can be modified as

$$\dot{K} = \frac{1}{\Phi} K(q - 1). \quad (13)$$

Also from equation (10):

$$\lambda = qp^I (1 - k - \beta). \quad (14)$$

and

$$\dot{\lambda} = \dot{q}p^I (1 - k - \beta) + q\dot{p}^I (1 - k - \beta) - qp^I (\dot{k} + \dot{\beta}). \quad (15)$$

Hence, by using equations (14) and (15), and after making the necessary adjustments, the first-order condition for capital in equation (7) can be rewritten as

$$\dot{q} = (r + \delta)q - \frac{(1 - c)}{(1 - k - \beta)p^I} \frac{\partial \pi}{\partial K} + \frac{\partial A}{\partial K} - q \frac{\dot{p}^I}{p^I} + q \frac{(\dot{k} + \dot{\beta})}{(1 - k - \beta)}. \quad (16)$$

Equations (13) and (16), which are the modified versions of equations (6) and (7), describe the equations of motions for the capital and the marginal q , and they also form a non-linear system of differential equations. By inserting equation (13) into equation (12), and that result into equation (16), the system can be rewritten more explicitly and in a compact form as

$$\dot{K} = K(q-1)\frac{1}{\Phi} \quad (17)$$

$$\dot{q} = -\frac{1}{2\Phi}(q-1)^2 + \left(r - \frac{\dot{p}'}{p'} + \frac{(\dot{k} + \dot{\beta})}{(1-k-\beta)} \right) q - \frac{(1-c)}{(1-k-\beta)p'} \frac{\partial \pi}{\partial K} + \delta. \quad (18)$$

At the steady-state, since $\dot{K} = \dot{q} = \dot{p}' = \dot{k} = \dot{\beta} = 0$, and $q = 1$, equation (17) indicates that the only investment is to recover the depreciation, and equation (18) shows the equality between the marginal product of capital and the cost of capital in equilibrium. Because of non-linearity, the equations of motion cannot be solved explicitly. However this partial equilibrium model can be linearised around its steady-state to investigate the local behaviour of K and marginal q close to that fixed point. By using the first-order Taylor expansion, the linearised system can be written in the matrix form as

$$\begin{bmatrix} \dot{K} \\ \dot{q} \end{bmatrix} = \begin{bmatrix} \frac{1}{\Phi}(q_{ss}-1) & \frac{1}{\Phi}K_{ss} \\ \frac{-(1-c)\partial^2 \pi}{(1-k-\beta)p'^2 \partial K_{ss}^2} & -\frac{1}{\Phi}(q_{ss}-1) + r - \frac{\dot{p}'}{p'} + \frac{\dot{k} + \dot{\beta}}{(1-k-\beta)} \end{bmatrix} * \begin{bmatrix} K - K_{ss} \\ q - q_{ss} \end{bmatrix}$$

If the terms \dot{p}' , \dot{k} and $\dot{\beta}$ are ignored, the system reduces to an autonomous form and the eigenvalues of the system will be

$$\Psi_{1,2} = r \mp \sqrt{r^2 - 4 \frac{\partial^2 \pi}{\partial K_{ss}^2} \frac{K_{ss}(1-c)}{\Phi(1-k-\beta)p'}}. \quad (19)$$

If we assume that $\frac{\partial^2 \pi}{\partial K_{ss}^2} < 0$, then there will be two real distinct eigenvalues as

($\Psi_1 < 0 < \Psi_2$). This, in turn, implies that the fixed point is a saddle point and there

Figure 2.1 The Phase Diagram

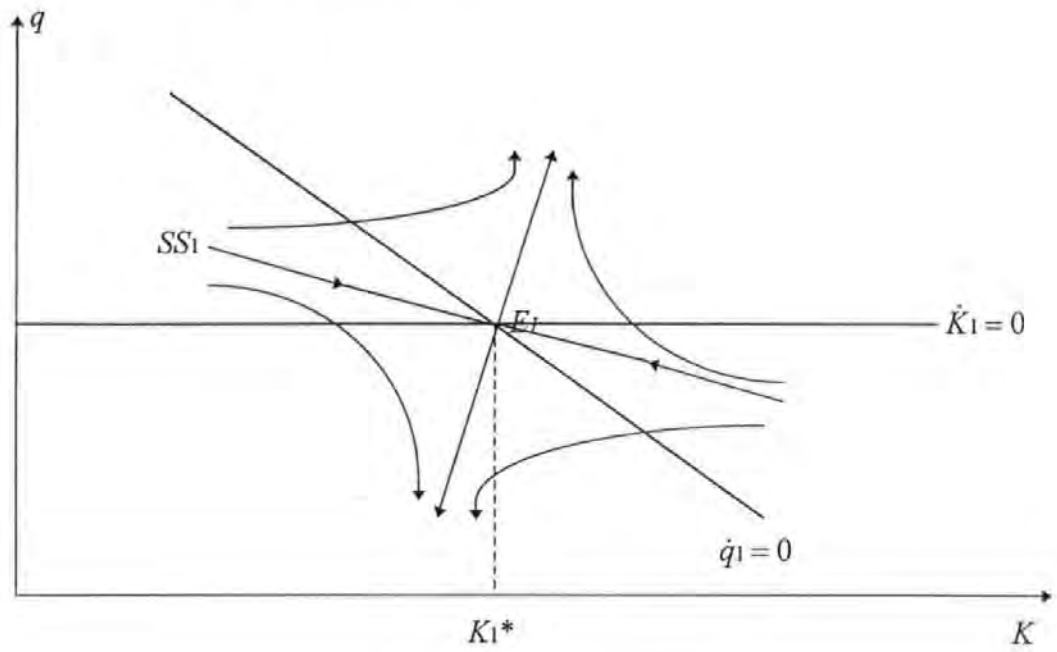
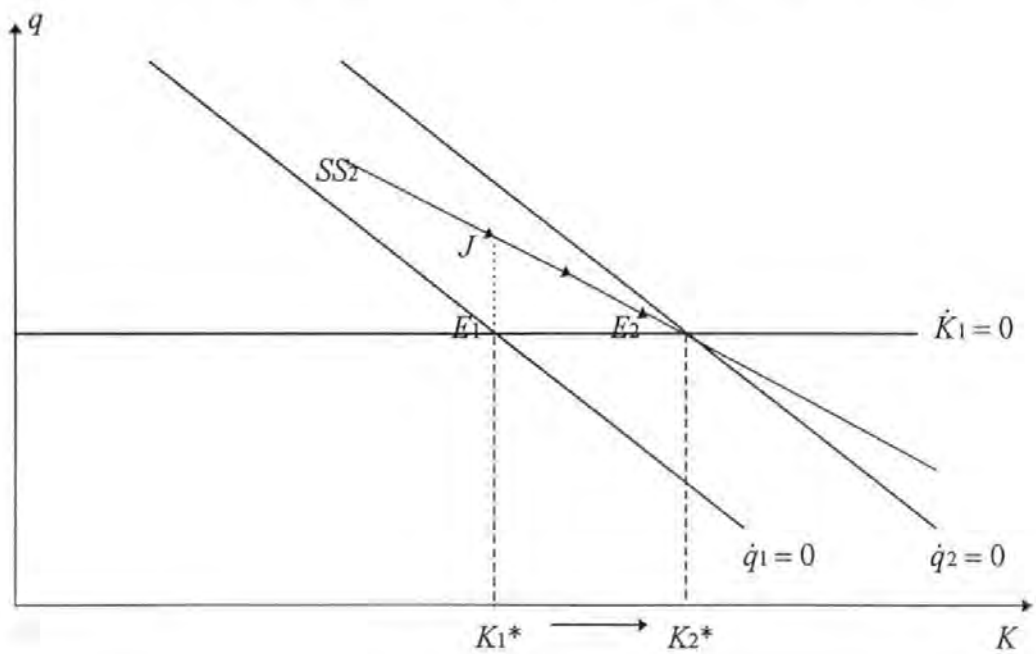


Figure 2.2 Permanent Unanticipated Beneficial Tax Policy Effects



is a unique equilibrium path which converges towards the equilibrium point in the $K-q$ plane. Figure 2.1 shows the phase diagram of the system, and the demarcation curves illustrate the subset of points in the $K-q$ plane where the capital and the marginal q are stationary. The unique equilibrium path SS_1 converges towards the equilibrium point E_1 which represents the steady state of the entire system. Because the fixed point is a saddle point, all other paths diverge from the equilibrium point.

Figure 2.2 illustrates the effects of permanent unanticipated beneficial tax policy effects on the steady-state capital stock. As can be seen from equations (17) and (18), when the system is in equilibrium, a beneficial tax policy such as reducing the corporate tax rate or giving an investment tax credit does not affect the locus of the $\dot{K}_1 = 0$. However, it causes a shift in the $\dot{q}_1 = 0$ locus to the right. The steady state of the system moves from the equilibrium point E_1 to the new equilibrium point E_2 . The new equilibrium path is denoted by SS_2 . The path of the adjustment towards the new steady state is composed of an initial jump from E_1 to the point J , and a movement from J to the new equilibrium point E_2 over time. With the permanent beneficial tax policy shock, the initial intertemporal equilibrium capital stock K_1^* increases to the new steady-state level K_2^* . Similarly, adverse shocks would create a reduction in the steady-state level of the capital stock.

To obtain quantitative measures for the tax policy effects, the system described by equations (17) and (18) can be linearised around certain tax policy variables and then solved to derive exact analytical results as in Auerbach (1989). However, this approach requires actual parameter values for the production function. Alternatively, numerical simulation methods can be applied, as in Summers (1981) and Dinenis (1989), to analyse various policy effects. Numerically, to simulate various tax policy effects on investment, the entire system should be estimated simultaneously since the paths of the variables will be affected by these policy effects. First of all, one needs to assume that the system is already at a steady state at the current time and then reaches another one after making perturbations in certain policy parameters. For a proper calculation, the system can be solved as a two-point boundary problem by a shooting algorithm such as the one developed in Lipton et al. (1982). By this way, the adjustment paths of the variables can be traced between the two steady states.

However, as Summers and Salinger (1983) show, since the response of investment to changes in q is not large, one can also directly calculate the policy effects on q and then on investment, where the approximation error involved in this procedure would be very small. In terms of figure 2.2, instead of calculating the policy shock effect with a movement over time towards the new equilibrium, we will be calculating the initial change in q and then the response in K to this change. Following Summer and Salinger, this simplified numerical procedure will be employed, and some easily interpretable analytical results will be derived

which will also include fundamental variables such as the profitability of capital and the capital structure together with the tax parameters. This derivation will enable us to analyse the policy effects from the firm's point of view. More importantly, while comparing asymmetries due to shocks in tax policy variables between different major countries of Europe, we will be able to decompose the effects of shocks on investment into tax effects and other related variables. This will enable us to analyse the importance of the differences in corporate tax systems on the effects of these shocks. However, first we need to set up the relation between investment and the fundamental variables, in other words, set up the relation between marginal q and average Q which will also be employed to estimate the required adjustment cost parameters.

Section 2.4 Marginal q and Average Q

Following Hayashi (1982), and assuming in a restrictive way that both the production function and the adjustment cost function are linearly homogenous in their related variables, the external adjustment cost function can be expressed by the Euler's theorem as

$$A(I, K) = \frac{\partial A}{\partial I} I + \frac{\partial A}{\partial K} K. \quad (20)$$

The perfect competition and the linearly homogenous production function assumptions also allow the marginal net revenue product of capital to be written as the average net revenue product of capital:

$$\frac{\partial \pi}{\partial K} = \frac{\pi}{K}. \quad (21)$$

Next, the time derivative of the term $\lambda K e^{-rt}$ can be written as

$$\frac{d}{dt}(\lambda K e^{-rt}) = (\dot{\lambda} K + \lambda \dot{K} - r \lambda K) e^{-rt} \quad (22)$$

From equations (2), (6) and (7) we have

$$\dot{K} = I - \delta K \quad (23)$$

$$\lambda = (1 + \frac{\partial A}{\partial I})(1 - k - \beta) p^I \quad (24)$$

$$\dot{\lambda} = (r + \delta) \lambda - (1 - c) \frac{\partial \pi}{\partial K} + (1 - k - \beta) p^I \frac{\partial A}{\partial K}. \quad (25)$$

Inserting (20), (21), (23), (24) and (25) into the right-hand side of (22) and making the necessary adjustments gives

$$\frac{d}{dt}(\lambda K e^{-rt}) = -[(1 - c) \pi(K, N) - (1 - k - \beta) p^I (I + A(I, K))] e^{-rt}. \quad (26)$$

Integrating both sides of (26) from zero to infinity and adjusting yields

$$\lambda(0) K(0) = \int_0^{\infty} [e^{-rt} (1 - c) \pi(K, N) - (1 - k - \beta) p^I (I + A(I, K))] dt. \quad (27)$$

While obtaining equation (27), the transversality condition $\lim_{t \rightarrow \infty} \lambda K e^{-rt} = 0$ is

imposed. From equation (5), we have

$$\begin{aligned} V(0) &= \int_0^{\infty} e^{-rt} [(1 - c) \pi(K, N) - (1 - k - \beta) p^I (I + A(I, K))] dt \\ &\quad + \int_0^{\infty} e^{-rt} [-INT + B] dt + G(0). \end{aligned} \quad (28)$$

The right-hand side of equation (27) can be expressed in terms of equation (28) as

$$V(0) - G(0) + \int_0^{\infty} e^{-rt} [INT - B] dt. \quad (29)$$

Also, it is possible to proxy the last term in equation (29) by the stock of debt at the beginning of the period as

$$D(0) = \int_0^{\infty} e^{-rt} [INT - B] dt \quad (30)$$

where D denotes the stock of debt. With these in hand, multiplying equation (27) by $1/(1-k-\beta)p^I K(0)$ yields

$$\frac{\lambda(0)}{(1-k-\beta)p^I} = \frac{V(0) + D(0) - G(0)}{(1-k-\beta)p^I K(0)}. \quad (31)$$

Equation (31) shows the equality of marginal q defined in equation (10) and the average Q . Addition of the stock of debt D in the numerator of the Q ratio arises because, together with the equity capital, it is the stock of debt that is used to finance the asset side. However, note that the market value of equity and debt does not only reflect the value of capital, but the value of all assets. To consider the role of the other assets, one can add their replacement value to the denominator or simply subtract them from the numerator. The present value of writing down allowances on past investments is not related to the new capital, and the subtraction of the term $G(0)$ in the numerator reflects this fact. Finally, by using equations (4) and (9), and the result derived in equation (31), the relation between investment and the observable average Q can also be expressed as

$$\frac{I}{K} = \alpha + \frac{1}{\Phi} \left(\frac{V(0) + D(0) - G(0)}{(1 - k - \beta)p^I K(0)} - 1 \right). \quad (32)$$

The simplicity of the investment function comes from the assumption that the average Q is assumed to capture all the information relevant to investment decisions via the market value. Moreover, the model is not subject to a direct rational expectation criticism since the model parameters α and Φ are technological parameters.

Section 2.5 Tax Policy Effects

In the previous section, the equality of marginal q and average Q was derived under some assumptions. As can be seen from equation (31), the problem of calculating the tax effects comes from the difficulty of calculating the policy effects on the market value. For this purpose, it will be assumed that the expected future growth of the firm will not be affected by policy changes and variables such as the discount rate and prices remain stable.

Hence, using equations (28), (29) and (30), Q can also be written in terms of the model variables as

$$Q = \frac{\int_0^{\infty} e^{-rt} [(1 - c)\pi(K, N) - (1 - k - \beta)p^I (I + A(I, K))] dt}{(1 - k - \beta)p^I K(0)}. \quad (33)$$

To ensure that the role of the tax deductibility of interest payments is not overweighted, by ignoring the personal taxation and introducing an exogenous risk premium, we express the discount factor r as

$$r = (1 - c)(1 - w)r_D + wr_E \quad (34)$$

where w , r_D , r_E , respectively, represent the ratio of equity in the composition of finance, the cost of debt and the cost of equity. Also the present value of tax savings for depreciation deductions for a unit of investment can be rewritten in a separate form as $\beta = c\theta$, where θ represents the present value of depreciation deductions for a unit of investment. More formally, θ can be presented as

$$\theta = \int_0^{\infty} C(x)e^{-nx} dx \quad (35)$$

where $C(x)$ denotes the depreciation deduction for an asset of age x , and n denotes the risk-free discount rate. In equation (35), it is implicitly assumed that there are no tax losses and there is a sufficiency of profits in the future against which to offset the tax depreciation amounts.

As an exogenous tax policy, we assume that the government alters the corporate tax rate, changes depreciation rules for capital allowances and gives or cancels investment tax credits. For instance, as can be easily seen from equation (33), the effect of a corporate tax cut on Q comes from four different sources. The first one is a positive effect which increases the after-tax profits, but the other three sources have negative effects. Firstly, the cut of the corporate tax rate reduces the market value because of the reduction in the tax savings due to depreciation deductions of

new investments. It also causes a reduction in the market value via the increment in the cost of capital since the interest payments are tax deductible. The final negative effect comes from the replacement cost of capital, again because of the reduction in tax savings of depreciation deductions as can be seen from the denominator in equation (33). The adjustment cost function can simply be ignored by assuming that the investment-capital ratio equals the normal rate of investment at the steady state. Hence, denoting the constant expected future growth rate as g , the effect of a corporate tax rate cut of Δc on Q can be written as

$$\Delta Q_{\Delta c} = \frac{\frac{(1-c+\Delta c)\pi - (1-k-c\theta+\Delta c\theta)p^I I}{(1-c+\Delta c)(1-w)r_D + w r_E - g}}{(1-k-c\theta+\Delta c\theta)p^I K} - \frac{\frac{(1-c)\pi - (1-k-c\theta)p^I I}{(1-c)(1-w)r_D + w r_E - g}}{(1-k-c\theta)p^I K}. \quad (36)$$

Doing the necessary adjustments, the overall impact of the effect of a corporate tax rate reduction on investment can be presented in a compact form as

$$\Delta\left(\frac{I}{K}\right)_{\Delta c} = \frac{p^I I \Delta c (1-w)r_D + \pi \left(\frac{(1-c+\Delta c)}{(1-k-c\theta+\Delta c\theta)} (\tilde{r} - g) - \frac{(1-c)}{(1-k-c\theta)} (r - g) \right)}{\hat{\Phi}(\tilde{r} - g)(r - g)p^I K} \quad (37)$$

where $\tilde{r} = (1-c+\Delta c)(1-w)r_D + w r_E$. The right-hand side of equation (37) reveals that the overall impact on investment of a reduction in the corporate tax rate depends on the magnitude of the change of the corporate tax rate, the level of the corporate tax rate, the composition of the cost of capital, depreciation rules, growth rate, investment tax credit, existing depreciation rules, cost of debt and equity, investment capital ratio, profit capital ratio, and the magnitude of the adjustment cost parameter which smoothes the response of the investment to this policy effect.

Unlike the corporate tax rate cut, the effect of increasing the present value of depreciation deductions and the effect of increasing the investment tax credit has two positive effects on Q , as can be seen from equation (33). The first effect comes from the reduction of the cost of new investment goods, which increases the market value. The second effect is the reduction in the replacement value of the capital. In a similar fashion, the effects of increasing the present value of depreciation deductions and giving investment tax credits on Q and on investment can respectively be written as

$$\Delta Q_{\Delta\theta} = \frac{\frac{(1-c)\pi - (1-k-c\theta-c\Delta\theta)p^I I}{(1-c)(1-w)r_D + w r_E - g}}{(1-k-c\theta-c\Delta\theta)p^I K} - \frac{\frac{(1-c)\pi - (1-k-c\theta)p^I I}{(1-c)(1-w)r_D + w r_E - g}}{(1-k-c\theta)p^I K} \quad (38)$$

$$\Delta\left(\frac{I}{K}\right)_{\Delta\theta} = \frac{\pi(1-c)c\Delta\theta}{\hat{\Phi}p^I K((1-c)(1-w)r_D + w r_E - g)(1-k-c\theta)(1-k-c\theta-c\Delta\theta)} \quad (39)$$

and

$$\Delta Q_{\Delta k} = \frac{\frac{(1-c)\pi - (1-k-\Delta k-c\theta)p^I I}{(1-c)(1-w)r_D + w r_E - g}}{(1-k-\Delta k-c\theta)p^I K} - \frac{\frac{(1-c)\pi - (1-k-c\theta)p^I I}{(1-c)(1-w)r_D + w r_E - g}}{(1-k-c\theta)p^I K} \quad (40)$$

$$\Delta\left(\frac{I}{K}\right)_{\Delta k} = \frac{\pi(1-c)\Delta k}{\hat{\Phi}p^I K((1-c)(1-w)r_D + w r_E - g)(1-k-c\theta)(1-k-\Delta k-c\theta)} \quad (41)$$

which will be used for simulation purposes. Equations (39) and (41) reveal that the overall impacts of these policies on investment depend on the size of the policy changes, the average profitability of capital, the magnitude of the adjustment cost parameter, capital structure, cost of debt and equity, growth rate, level of existing corporate tax rate, depreciation rules and investment tax credit.

Section 2.6 Data and Econometric Issues

To simulate the tax policy effects on investment via equations (37), (39) and (41), one must estimate the industry-wide adjustment cost parameters (Φ) and growth rates (g) and determine the industry-wide present value of depreciation deductions for a unit of investment (θ), the weights of debt ($1-w$) and equity (w) in the cost of finance, cost of debt (rd) and cost of equity (re), investment-capital (I/K) and profit-capital ($\pi/p^I K$) ratios, and the necessary tax parameters. Panel data were collected for the companies that are gathered under the "general industries" classification of Datastream for the period 1991-1995, which constitute the majority of the largest industrial companies traded in the stock markets. General industries include as sub-industrial sectors: house building and other construction; building materials and other merchants; chemicals; diversified industries; electronic and electrical equipment; engineering; engineering vehicle components; paper, printing and packaging; and textiles, clothing and footwear. Although the companies are not numerous, they are sufficiently large to represent the aggregate levels of the necessary variables, with sales and market values ranging from hundreds of millions of pounds to billions of pounds. The number of the companies are 82, 38, 76 and 19, respectively, for the UK, France, Germany and the Netherlands. Datastream was also the basic data source for the other macro variables such as the stock market indices, interest rates and prices of investment goods. The corporate tax rules were obtained from the yearly corporate tax guides

of Price Waterhouse and Ernst & Young. Below, the construction of the variables is described together with Datastream codes in brackets.

To obtain the required adjustment cost parameters, one must estimate the investment equation given in (32) in section 2.4. For that purpose, investment-capital and Q ratios were calculated for the firm-level panel data.

Calculation of I/K Ratios

Investment ($p^I I$) is the total new fixed assets [1024 for the UK and 435 for France, Germany and the Netherlands]. The replacement cost of capital figures ($p^K K$) were not available. Thus, by assuming that the historic cost valuations [330 for the UK, France and the Netherlands, and 2005 for Germany] equals the replacement cost for the first year, they were calculated from the perpetual inventory formula as

$$p^I(t+1)K(t+1) = p^I(t+1)I(t+1) + (p^I(t+1)/p^I(t))(1-\delta)p^I(t)K(t). \quad (42)$$

The price index (p^I) is the implicit price deflator of fixed investment, respectively, [UKIPDMNIF], [FRIPDCFME], [BDIPDCAPE] and [NLIPDINV] for the UK, France, Germany and the Netherlands. However, the economic depreciation rates (δ) are not necessarily equal to the accounting depreciation rates. Thus, they were estimated for a unit of investment, without splitting the data for plant and machinery and buildings, to employ in equation (42) by solving the system

$$\begin{bmatrix} K(t+2) \\ K(t+3) \\ K(t+4) \\ K(t+5) \end{bmatrix} = \begin{bmatrix} (1-\delta) & 0 & 0 & 0 \\ (1-\delta)^2 & (1-\delta) & 0 & 0 \\ (1-\delta)^3 & (1-\delta)^2 & (1-\delta) & 0 \\ (1-\delta)^4 & (1-\delta)^3 & (1-\delta)^2 & (1-\delta) \end{bmatrix} \begin{bmatrix} K(t+1) \\ I(t+2) \\ I(t+3) \\ I(t+4) \end{bmatrix} + \begin{bmatrix} I(t+2) \\ I(t+3) \\ I(t+4) \\ I(t+5) \end{bmatrix} \quad (43)$$

for five years for the firm-level data via Newton-Raphson algorithm through a non-linear iterative procedure. The results obtained as percentages with heteroscedasticity and first-order autocorrelation robust *t*-statistics for the four countries are

Parameter	UK	FR	BD	NL
δ	4.67%	4.66%	5.98%	6.34%
	(17.671)	(15.470)	(16.047)	(20.613)

Calculation of *Q* ratios

To obtain the denominator of the *Q* ratios for each firm in each year, tax-adjusted replacement value of capital $(1-c\theta)p^I K$ figures are required. The replacement value figures were calculated as described above. To calculate $(1-c\theta)$ figures for each firm in each year, the present value of tax savings due to depreciation deductions ($c\theta$) are required. Furthermore, to calculate $(c\theta)$ figures, the split of investment figures by asset type are required. However, these items were not available. Therefore, to obtain investment figures in plant and machinery ($p^I I_{PM}$) and buildings ($p^I I_{BL}$) separately, gross historic values of capital in plant and machinery [328], and gross historic values of capital in buildings [327] were differenced. However, for Germany, Datastream also did not have the split in gross fixed assets. For this purpose, the company reports were obtained for 32

companies from Germany by request, and the remainder was proxied by the average of this sample for each year. Hence, after assuming that the corporate tax rate (c) is equal to the statutory tax rate, and by dropping the time subscripts for the variables c , n , and d , the present value of tax savings for the reducing-balance method was calculated as

$$c\theta_{RB} = \sum_{j=1}^{\infty} [cd \prod_{i=1}^j (1+n)^{-1} \prod_{i=1}^{j-1} (1-d)]. \quad (44)$$

Here, RB stands for the reducing-balance method, d denotes the accounting depreciation rate and n represents the discount factor employed, which is the long-term government bond yield in each country. Datastream codes for the bond yields are [UKMGLTB], [FRNGLTB], [GRMGLTB] and [HOLGLTB], respectively, for the UK, France, Germany and the Netherlands. In equation (44), $\prod_{i=1}^0 (1-d)$ was taken as unity. Similarly, the present value of tax saving for the straight-line method was calculated by employing

$$c\theta_{SL} = \sum_{j=1}^{(1/d)} [cd \prod_{i=1}^j (1+n)^{-1}] \quad (45)$$

where SL represents the straight-line method. Consequently, the present value of tax savings due to depreciation deductions in each year for each firm was calculated from

$$c\theta = c[\theta_L \psi + \theta_L (1-\psi)\zeta] \quad (46)$$

where, L denotes RB or SL , and

$$\psi = \frac{p^I I_{PM}}{p^I I_{PM} + p^I I_{BL}}.$$

Here, ψ represents the ratio of investment in plant and machinery to the total fixed investment for each firm in each year. In the UK, investments in commercial buildings receive no tax allowances, therefore they should be omitted. The term ζ in equation (46) serves this purpose and denotes the ratio of investment in industrial buildings to investment in total buildings, which was assumed 0.65. This ratio was taken from Blundell et al. (1992). For other countries, this parameter was taken as one, because both commercial and industrial buildings attract similar tax treatments.

As mentioned earlier, the market value of equity and debt reflects not only the value of fixed capital, but all assets. To consider this, total current assets [376], total intangibles [344], total investments including associates [356] and other assets [359] were also added to the denominator of the Q ratios.

For the numerator of the Q ratios, in each year for each firm, the market value (V) is the market value of total equity at the end of the preceding accounting year [MV]. Total debt (D) was constructed by adding total current liabilities [389], total loan capital [321], minority interests [315], total long-term provisions excluding deferred tax [313], and total deferred tax [312]. The present value of writing down allowances on past investments that can be claimed at the present and future periods (G) also needed to be calculated separately for investment in

plant and machinery machinery ($p^I I_{PM}$), and for investment in buildings ($p^I I_{BL}$). By denoting the sample starting date as s and dropping the time subscripts for c , n and d for ease of exposition, the present value of tax savings on investment made before date t for the reducing-balance method for each firm in each year was calculated as

$$G_{RB,t}^m = cp_s^I I_s^m (1+n)^{-(t-s)} d(1-d)^{(t-s-1)} + cp_{s+1}^I I_{s+1}^m (1+n)^{-(t-s-1)} d(1-d)^{(t-s-2)} + \dots$$

$$\dots + cp_{t-2}^I I_{t-2}^m (1+n)^{-2} d(1-d) + cp_{t-1}^I I_{t-1}^m (1+n)^{-1} d \quad (47)$$

where m represents the type of asset. The straight-line method was calculated in a similar fashion as

$$G_{SL,t}^m = cp_s^I I_s^m (1+n)^{-(t-s)} d + cp_{s+1}^I I_{s+1}^m (1+n)^{-(t-s-1)} d + \dots + cp_{t-1}^I I_{t-1}^m (1+n)^{-1} d. \quad (48)$$

Hence, the present value of tax allowances on investment made before date t in each year for each firm was calculated as

$$G_t = G_{PM,t} + G_{BL,t} \quad (49)$$

where the commercial buildings were again excluded from the calculations for the UK companies. Table 2.2 gives summary statistics for the calculated I/K and Q ratios for the period 1991-1995 for the UK, France, Germany and the Netherlands.

Calculation of Other Required Variables

The industry-wide weights of debt ($1-w$) in the cost of finance were constructed by averaging the gearing ratios [731] for the firm-level data from 1991 to 1996 for each country. They were found to be 27.88%, 40.48%, 27.3% and 33.55%,

Table 2.2 Summary Statistics of I/K and Q Ratios

UK-82 Firms	Mean	Stdev.	Min.	Max.
<i>I/K</i>	0.1089	0.0873	0.0136	0.9429
<i>Q</i>	1.3518	0.5306	0.3970	4.3678
FR-38 Firms	Mean	Stdev.	Min.	Max.
<i>I/K</i>	0.1013	0.0471	0.0089	0.301
<i>Q</i>	0.9398	0.2395	0.5534	2.4805
BD-76 Firms	Mean	Stdev.	Min.	Max.
<i>I/K</i>	0.1016	0.0779	0.0000	0.9584
<i>Q</i>	0.8316	0.3529	0.2995	2.6409
NL-19 Firms	Mean	Stdev.	Min.	Max.
<i>I/K</i>	0.1211	0.0918	0.0160	0.5869
<i>Q</i>	0.8463	0.2697	0.4245	1.9542

respectively, for the UK, France, Germany and the Netherlands. To obtain the industry-wide θ figures, different tax codes of the countries described in table 2.1 were used. However, the calculation of θ for a unit of investment again required the ratios for the split of investment by asset type, which were not available. Thus, using the panel data, the ψ figures as described in equation (46) were employed. By averaging the five years' firm-level data for the countries, the ratios of investment in plant and machinery to total investment were found as 70.7%, 60.3%, 64.5% and 62.4%, respectively. Hence, the industry-wide θ figures were calculated by using these ratios and the formulas presented in equations (44), (45) and (46). They were obtained as 61.5%, 70.4%, 68.1% and 62.4%, respectively.

Cost of debt (rd) for each country was proxied by the monthly averages of the long-term government bond rates for the period 1991-1995. The results obtained were 8.02%, 7.11%, 6.59% and 6.662%, respectively, for the UK, France,

Germany and the Netherlands. Because the stock market returns fluctuate excessively in many periods, a unique risk premium was constructed to calculate the cost of equity (r_E) for each country. For that purpose, monthly total market returns were calculated for the four countries by using Datastream total market indices from 1991 to 1996. Then, taking the monthly government long-term bond rates as risk-free rates, monthly excess returns were calculated and averaged for the four countries to obtain a unique value. The unique risk premia of 4.23% was obtained and added to the cost of debt to calculate the cost of equity for each country.

The necessary growth rates were estimated by using the pre-tax profits at the firm-level data to proxy the necessary growth rates. For that purpose, for each country, the system

$$\begin{bmatrix} \pi(t+1) \\ \pi(t+2) \\ \pi(t+3) \\ \pi(t+4) \end{bmatrix} = \begin{bmatrix} \pi(t)(1+g) \\ \pi(t)(1+g)^2 \\ \pi(t)(1+g)^3 \\ \pi(t)(1+g)^4 \end{bmatrix} \quad (50)$$

was solved through a non-linear iterative procedure for the period 1991-1995, where π and g represent the pre-tax profits [154] and the growth rate. Finally, the industry-wide investment-capital (I/K) and profit-capital (π/p^1K) ratios were obtained by the arithmetic averages of the firm-level panel data for each country. The obtained I/K ratios were 10.89%, 10.13%, 10.16% and 12.11%. Similarly, the obtained profit-capital ratios were 11.09%, 11.46%, 12.22% and 10.21%, respectively.

Table 2.3 Other Variables Required for Simulation (%)

	UK	FR	BD	NL
I/K	10.89	10.13	10.16	12.11
$\pi p^I K$	11.09	11.46	12.22	10.21
w	72.12	59.52	72.70	66.45
r_D	8.02	7.11	6.59	6.62
r_E	12.25	11.34	10.82	10.85
θ	61.5	70.4	68.1	62.4
g	2.97	4.47	2.77	3.54
	(2.564)	(3.147)	(4.834)	(3.994)

1. The I/K , $\pi p^I K$ and w figures were based on the arithmetic average of the entire sample for each country. The present value of depreciation deductions were calculated according to the depreciation rules described in table 2.1, and by using the necessary ratios for investment types given above.
2. Cost of debt was proxied by the monthly average of the long-term government bond rates of the countries for the period 1991-1995.
3. For the cost of equity, a unique risk premia of 4.23% was added to the cost of debt for all countries.
4. The parentheses show the heteroscedasticity and first-order autocorrelation robust t -statistics for the growth rates g , and they were estimated as described above.

Table 2.3 presents the required variables other than the tax and adjustment cost parameters to simulate the tax policy effects. The next section presents the estimation results of the adjustment cost parameters for each country by using the calculated investment-capital and Q ratios for panel data. Below, the employed basic econometric methodology for data is described.

Econometric estimation of panel data requires special treatment as it differs from time-series and cross-section regressions. For the purpose of estimation, a general linear single equation regression can be presented as

$$y_{it} = \omega + X'_{it}\beta + u_{it} \quad (51)$$

where $i=1,2,\dots,N$ and $t=1,2,\dots,T$. Here i denotes the cross-section dimension and t denotes the time-series dimension. X , y and u represent the K -regressors, the regressand and the disturbance term, respectively. The parameters (ω, β) can be estimated by ordinary least square (OLS) method. However, estimation by OLS simply ignores the unobservable individual specific effects. OLS can only be consistent and efficient if the individual effects are the same across units. For a proper treatment of individual effects, by ignoring time effects for simplicity, equation (51) can be rewritten as

$$y_{it} = \omega + X'_{it}\beta + \eta_i + \xi_{it} \quad (52)$$

where, η_i represents unobservable individual specific effects and ξ_{it} denotes the remainder disturbance. One way to estimate equation (52) is by treating individual effects as fixed parameters. Equation (52) can be presented in the vector form as

$$y = \omega \iota_{NT} + X\beta + F_\eta \eta + \xi \quad (53)$$

where, y is $NT \times 1$, X is $NT \times K$ and ι_{NT} is a vector of ones of dimension NT . F_η is a matrix of individual dummies to estimate the individual effects. More formally $F_\eta = I_N \otimes \iota_T$, where I_N is an identity matrix of dimension N , ι_T is a vector of ones of dimension T and the term \otimes denotes the Kronecker product. One can perform OLS on equation (53) to get estimates of (ω, β, η) which is known as the least square dummy variable (LSDV) estimation. However, because the F_η matrix has a dimension of $NT \times N$, estimation would require inversion of a large matrix. Instead one can transform equation (53) and then carry out the estimation. For the transformation, equation (53) can be pre-multiplied by matrix D which obtains the

deviations from individual means. Formally, $D = I_{NT} - A$ and the matrix A averages the observation across time for each individual, which is $A = I_N \otimes \bar{C}_T$. Here $\bar{C}_T = C_T / T$ and C_T is a matrix of ones of dimension T . Both matrices A and D are symmetric idempotent matrices. Hence, pre-multiplying equation (53) by matrix D yields

$$Dy = DX\beta + D\xi \quad (54)$$

since $DF_\eta = DI_{NT} = 0$. Matrix D simply wipes out the individual effects while transforming the other variables, known as the Within Groups estimation. From here, after performing OLS, the resulting estimator would be $\hat{\beta}_{Within} = (X'DX)^{-1} X'Dy$ with variance $\text{var}(\hat{\beta}_{Within}) = \sigma_\xi^2 (X'DX)^{-1}$. Simply, this transformation can be presented as

$$y_{it} - \bar{y}_i = \beta(x_{it} - \bar{x}_i) + (\xi_{it} - \bar{\xi}_i). \quad (55)$$

Despite its easy implementation, the Within Groups estimation method suffers from a large degrees of freedom loss, and because that it sweeps away the fixed effects, it cannot estimate any time-invariant variable effect.

Alternatively, one can also treat the individual effects in equation (52) as random. By this way, the degrees of freedom loss can be recovered and constant term can be retained. In this case, η_i and ξ_{it} are distributed identically and independently with zero means and variances of σ_η^2 and σ_ξ^2 , respectively. From equation (53), the covariance matrix can be written as

$$\Omega = F_{\eta} E(\eta\eta') F_{\eta}' + E(\xi\xi') \quad (56)$$

which reduces to

$$\Omega = \sigma_{\eta}^2 (I_N \otimes C_T) + \sigma_{\xi}^2 (I_N \otimes I_T). \quad (57)$$

For the elements of the covariance matrix, for $i=j, t=s$, the covariance(u_{it}, u_{js}) would be $(\sigma_{\eta}^2 + \sigma_{\xi}^2)$, and for $i=j, t \neq s$, covariance(u_{it}, u_{js}) would be σ_{η}^2 . As can be seen, the estimation is a generalised least square (GLS) estimation. However, it is difficult to invert the covariance matrix Ω with $NT \times NT$ dimension. As shown in Baltagi (1995), replacing C_T by $\overline{C_T}$ and I_T by $(H_T + \overline{C_T})$, where H_T is $(I_T - \overline{C_T})$ by definition, and after adjusting, equation (57) can be rewritten as

$$\Omega = (T\sigma_{\eta}^2 + \sigma_{\xi}^2)(I_N \otimes \overline{C_T}) + \sigma_{\xi}^2(I_N \otimes H_T) = (T\sigma_{\eta}^2 + \sigma_{\xi}^2)A + \sigma_{\xi}^2 D. \quad (58)$$

From the properties of matrix A and D , the general case

$$\Omega^n = (T\sigma_{\eta}^2 + \sigma_{\xi}^2)^n A + (\sigma_{\xi}^2)^n D \quad (59)$$

can be derived. Equation (53) can be pre-multiplied by the term $(\sigma_{\xi}^2 \Omega^{-1/2})$. From equation (59), this term would be $(D + (\sigma_{\xi}^2 / (T\sigma_{\eta}^2 + \sigma_{\xi}^2)^{1/2})A)$, and then OLS can be performed on the resulting transformed regression to obtain the GLS estimate of the desired parameters. Hence, the transformed y and x can be presented as

$$\tilde{y}_{it} = \sigma_{\xi}^2 \Omega^{-1/2} y_{it} = y_{it} - \overline{\varphi y}_{it} \quad (60)$$

and

$$\tilde{x}_{it} = \sigma_{\xi}^2 \Omega^{-1/2} x_{it} = x_{it} - \overline{\varphi x}_{it} \quad (61)$$

where $\varphi = 1 - (\sigma_{\xi}^2 / (T\sigma_{\eta}^2 + \sigma_{\xi}^2))^{1/2}$. To carry out the GLS estimation, one requires the estimates of the variance components. Balestra (1973) gives the best quadratic unbiased estimates as

$$\hat{\sigma}_{\xi}^2 = \frac{\sum_{i=1}^N \sum_{t=1}^T (u_{it} - \bar{u}_i)^2}{N(T-1)}, \text{ and } (T\hat{\sigma}_{\eta}^2 + \hat{\sigma}_{\xi}^2) = T \sum_{i=1}^N \bar{u}_i^2 / N. \quad (62)$$

Although equation (62) gives the estimates of variance components to carry out the GLS estimates of the desired parameters, one cannot actually observe the true disturbances u_{it} . For that purpose, Wallace and Hussain (1969) suggest substituting the OLS residuals, whereas Amemiya (1971) shows that using the LSDV residuals would result in estimates of variance components that have the same asymptotic distribution as that in which the true disturbance is known.

For the GLS estimation, an important assumption is that the explanatory variables X_{it} and the individual effects η_i are not correlated. If this occurs, then the estimated parameters would be biased. In the Within Groups estimation, this problem disappears since this method wipes the individual effects. Hausman (1978) suggests comparing the GLS and Within Groups estimates of the parameters. Under the null hypothesis, the two estimates should not differ systematically. Thus, the Hausman specification test is based on the difference of the two estimates, and the test statistic can be given by

$$\hat{s}'[\text{var}(\hat{s})]^{-1}\hat{s} \xrightarrow{d} \chi_K^2 \quad (63)$$

where $\hat{s} = \hat{\beta}_{\text{GLS}} - \hat{\beta}_{\text{Within}}$. Here, \hat{s} represents the estimated difference vector and $\text{var}(\hat{s})$ denotes the estimated variance of the difference vector. The test statistic is asymptotically distributed as χ_K^2 under the H_0 and K denotes the dimension of the slope vector β . If the test statistic fails to reject the H_0 hypothesis that the two estimates do not differ systematically, then the random effects are not significantly correlated with the explanatory variables for the GLS estimation. However, rejection of the H_0 hypothesis would mean the GLS estimates are inconsistent. In this case, one can progress with an instrumental variable estimation.

Section 2.7 Estimation and Simulation Results

For the estimation purpose, the investment equation in (32) can be presented as

$$\left(\frac{I}{K}\right)_{it} = \alpha + \frac{1}{\Phi}(Q_{it} - 1) + \eta_i + \xi_{it}. \quad (64)$$

As mentioned in the previous section, here, η_i denotes the firm-specific effects and ξ_{it} denotes the remainder disturbance as an idiosyncratic shock to adjustment costs. Table 2.4 gives the results for OLS, Within Groups and GLS estimations. First of all, for all countries, the estimation results reveal that investment is significantly related to the Q ratio according to all three estimation methods. Looking at the OLS estimation of the constant parameters, which represents the normal rate of investment according to the theory, it is possible to say that they are all at reasonable levels for the manufacturing industries of the four countries. The estimated normal rates of investment are 8.10%, 10.63%, 11.43% and 14.12%,

Table 2.4 Estimation of $(I/K)_{it} = \alpha + (1/\Phi)(Q_{it}-1) + \eta_i + \xi_{it}$

United Kingdom (82 Firms, 1991-1995)			
	OLS	Within Groups	GLS
α	0.0810 (0.0031)	-	0.0829 (0.0048)
$1/\Phi$	0.0478 (0.0086)	0.0377 (0.0079)	0.0420 (0.0093)
DW	0.926	2.200	1.773
\bar{R}^2	0.1976	0.0950	0.1281
Hausman $\chi^2(1)$	-	-	(0.3793)
France (38 Firms, 1991-1995)			
	OLS	Within Groups	GLS
α	0.1063 (0.0038)	-	0.1059 (0.0052)
$1/\Phi$	0.0830 (0.0164)	0.0611 (0.0437)	0.0761 (0.0166)
DW	1.268	1.961	1.641
\bar{R}^2	0.1729	0.0466	0.1059
Hausman $\chi^2(1)$	-	-	(0.7107)
Germany (76 Firms, 1991-1995)			
	OLS	Within Groups	GLS
α	0.1143 (0.0062)	-	0.1141 (0.0077)
$1/\Phi$	0.0753 (0.0157)	0.0708 (0.0370)	0.0745 (0.0193)
DW	1.325	2.227	1.710
\bar{R}^2	0.1132	0.0291	0.0745
Hausman $\chi^2(1)$	-	-	(0.9077)
Netherlands (19 Firms, 1991-1995)			
	OLS	Within Groups	GLS
α	0.1412 (0.0118)	-	0.1405 (0.0139)
$1/\Phi$	0.1309 (0.0287)	0.0778 (0.0522)	0.1258 (0.0313)
DW	1.947	2.280	2.089
\bar{R}^2	0.1388	0.0133	0.0972
Hausman $\chi^2(1)$	-	-	(0.2505)

1. Standard errors in parentheses are corrected for heteroscedasticity.
2. Degrees of freedom correction is made for the Within Groups estimation.
3. Parentheses show the significance levels for the Hausman Specification tests.

respectively, for the UK, France, Germany and the Netherlands. Although the estimated adjustment cost parameters imply slow adjustment and high adjustment costs, they are smaller and economically more meaningful compared to most of the previous studies. For a comparison, see Schaller (1990), for instance. This is most likely due to the fact that large companies were employed in the estimation process which might increase the efficiency. Also, the effect of using panel data instead of aggregate data should be considered.

For all countries, the significance levels of Hausman test statistics fail to reject the null hypothesis that the firm effects are not correlated with Q_{it} , making GLS preferable over Within Groups estimation. The GLS estimates reveal that the adjustment cost parameters are 23.81, 13.14, 13.43 and 7.95 for the UK, France, Germany and the Netherlands, respectively. As Bhargava et al. (1982) report, Durbin-Watson (DW) statistics are tighter for panel data than for time-series data. Although the estimation results reveal that serial correlation remains a problem for some countries according to some of the estimation techniques, for others it is not very disturbing.

Using the tax parameters in table 2.1, the other variables in table 2.3 and the GLS estimates of the adjustment cost parameters from table 2.4, simulation results are presented in table 2.5 to approximate the three different tax policy effects on fixed investment for the four countries. To make a comparison, effects of a 10% reduction in corporate tax rates, a 10% increase in the present value of

depreciation deductions which will result from changing depreciation rules, and a 5% increase in investment tax credits are simulated by using equations (37), (39) and (41) given in section 2.5. To measure the asymmetry between the countries as a result of the tax policy shocks, two measures of dispersion are calculated. They are the standard deviation and the mean absolute deviation. For that purpose, the same shocks are applied to calculate the average reaction by using the average tax rules described in table 2.1, the average variables given table 2.3 and the average GLS results of the estimated adjustment cost parameters in table 2.4. The standard

deviation for policy effect j is calculated as $SDV_j = \sqrt{\frac{\sum_i^N (PSE_{ij} - AVER_j)^2}{N}}$

where N is the number of countries, PSE is the policy shock effect and $AVER$ is the average. The mean absolute deviation for policy j is calculated as

$$MAD_j = \frac{\sum_i^N |PSE_{ij} - AVER_j|}{N}$$

The results in table 2.5 reveal that a permanent

unanticipated 10% reduction of corporate tax rate causes a 5.38% increase in the investment-capital ratio between the two steady states for the Netherlands. Similarly, a permanent unanticipated 10% increase in the present value of depreciation deductions and a 5% increase of investment tax credit cause the largest effect of 6.68% increase in the investment-capital ratio in Germany and 12.66% in France, respectively. Among all, the investment-capital ratio is the least

Table 2.5 Tax Policy Effects (%)

	UK	FR	BD	NL	AVER.	SDV	MAD
Δc	1.12	3.38	4.47	5.38	6.74	3.502	3.135
$\Delta \theta$	1.28	5.73	6.68	4.96	3.97	2.160	2.039
Δk	3.27	12.66	9.42	11.78	8.67	3.718	3.331

1. The values of the variables and the parameters employed for calculating the effects of policy shocks on the average given in column 5 are, (I/K) : 10.8225%, $(\pi/p' K)$: 11.245% , w : 67.6975%, r_D : 7.085%, r_E : 11.315%, g : 3.4375%, $(1/\Phi)$: 0.0796, $c(\text{AVER.})$: 38.645%, $\theta(\text{AVER.})$: 65.6%, $k(\text{AVER.})$: 0.0%.
2. The magnitudes of the shocks are, $\Delta c(\text{UK})$: 3.3%, $\Delta c(\text{FR})$: 3.33%, $\Delta c(\text{BD})$: 3.825%, $\Delta c(\text{NL})$: 3.5%, $\Delta c(\text{AVER.})$: 3.4895%, $\Delta \theta(\text{UK})$: 6.15%, $\Delta \theta(\text{FR})$: 7.04%, $\Delta \theta(\text{BD})$: 6.81%, $\Delta \theta(\text{NL})$: 6.24%, $\Delta \theta(\text{AVER.})$: 6.56%, and for all countries Δk : 5%.
3. For the calculation of $\Delta c(\text{BD})$: 3.825%, $c(\text{AVER.})$: 38.645, and $\Delta c(\text{AVER.})$: 3.4895% , the effect of municipal tax which is deductible from corporate tax is considered for German companies.

sensitive one to all policy effects in the United Kingdom. For instance, a 10% reduction in the corporate tax rate induces investment capital ratio to raise 1.12% in the long-run.

Comparing the adjustment cost parameters and the differences in responses from table 2.4 and table 2.5 reveals that this result is due not only to the differences in the magnitudes of adjustment cost parameters, which is estimated as the smallest for the UK, but also to the differences in the magnitudes of other variables. Simulation results reveal that the Netherlands gives the largest response to a shock in corporate tax rate, whereas Germany and France are the most sensitive to changes in depreciation rules and investment tax credits, respectively. As can be seen from column 5, permanently reducing the average corporate tax rate from 38.645% to 35.1555% causes a 6.74% increase in the average investment-capital ratio. Similarly, increasing the present value of depreciation deductions 10% and

giving a 5% investment tax credit increases the average investment-capital ratio 3.97% and 8.67%, respectively.

Overall, the simulation results reveal that tax policies can be used to affect investment decisions. From the results in table 2.5, it can be inferred that fixed investment is more sensitive to investment tax credit relative to other policy effects because of its direct effects which should be considered by policy makers. On the other hand, there are substantial differences for tax policy effects on investment between the UK and France, Germany and the Netherlands as a group. There are also differences within this group in terms of different policy effects. The standard deviations and the mean absolute deviations calculated in columns 6 and 7 reveal that the degree of asymmetry is the highest for investment tax credit shocks. This is followed by shocks in the corporate tax rate and depreciation rules.

An important issue is how much of these asymmetries actually occur because of the differences in the treatment of investment by the tax systems of the countries. How much of these asymmetries can be eliminated by harmonising the tax systems? To answer these questions, another simulation study is conducted by again using the equations (37) (39) and (41), but this time the tax rules are harmonised to the average rates for the four countries under investigation. As given in the first note of table 2.5, the harmonised corporate tax rate, the present value of the depreciation deductions and the investment tax credit are, respectively, 38.645%, 65.6%, and 0.0%. To make comparisons between the

degree of the asymmetries, again the effects of a permanent 10% reduction in the corporate tax rate, a permanent 10% increase in the present value of depreciation deductions and giving a permanent 5% investment tax credit are simulated. The results are presented in table 2.6.

Table 2.6 Tax Policy Effects: Tax Rules Harmonised (%)

	UK	FR	BD	NL	AVER.	SDV	MAD
Δc	2.37	13.24	5.42	10.82	6.74	4.465	4.069
$\Delta \theta$	1.60	5.74	3.90	5.69	3.97	1.714	1.484
Δk	3.49	12.55	8.53	12.44	8.67	3.747	3.244

1. The values of the variables and the parameters employed for calculating the effects of policy shocks on the average given in column 5 are, (I/K) : 10.8225%, $(\pi p' K)$: 11.245% , w : 67.6975%, r_D : 7.085%, r_E : 11.315%, g : 3.4375%, $(1/\Phi)$: 0.0796, $c(\text{AVER.})$: 38.645%, $\theta(\text{AVER.})$: 65.6%, $k(\text{AVER.})$: 0.0%.
2. The magnitudes of the shocks are the same for all countries. They are Δc : 3.4895%, $\Delta \theta$: 6.56%, and Δk : 5%, respectively.

The results in table 2.6 reveal that in the case of harmonised tax systems, the ranking of the responses to tax policy shocks also changes. In this case, France gives the highest response to all policy shocks, whereas the UK again gives the least response. Respectively, the Netherlands and Germany give the second and third highest responses to all of these permanent shocks. As can be seen from the standard and mean absolute deviations in columns 6 and 7 of table 2.6, harmonising the corporate tax rates actually increases the asymmetry in the responses to this shock to a higher level. Because the levels of investment tax credits were zero in the four countries, the degree of asymmetry stays at around the same level. Only in the case of depreciation rules does harmonising the tax rules reduce the asymmetry in the responses to this shock. The results found here

rule out the tax competition view for the domestic investment case. Expecting symmetric responses to tax policy shocks in the case of harmonised corporate tax rules will certainly be misleading.

The simulations can be carried one step further by analysing the policy shock effects in the case of leaving the tax rules unchanged but harmonising the other variables to see their role in asymmetric behaviour. The values for the harmonised variables and parameters are the same as they were taken for the average case, except for the tax rules which are given in the first note of table 2.7.

Table 2.7 Tax Policy Effects: Other Variables Harmonised (%)

	UK	FR	BD	NL	AVER.	SDV	MAD
Δc	6.16	5.81	9.09	6.34	6.74	1.315	1.069
$\Delta \theta$	2.99	3.73	6.17	3.27	3.97	1.257	1.026
Δk	8.08	8.76	9.76	8.23	8.67	0.657	0.551

1. The values of the variables and the parameters employed for calculating the effects of policy shocks on the average given in column 5 are, (I/K) : 10.8225%, $(\pi/p^I K)$: 11.245% , w : 67.6975%, r_D : 7.085%, r_E : 11.315%, g : 3.4375%, $(1/\Phi)$: 0.0796, $c(\text{AVER.})$: 38.645%, $\alpha(\text{AVER.})$: 65.6%, $k(\text{AVER.})$: 0.0%.
2. The magnitudes of the shocks are, $\Delta c(\text{UK})$: 3.3%, $\Delta c(\text{FR})$: 3.33%, $\Delta c(\text{BD})$: 3.825%, $\Delta c(\text{NL})$: 3.5%, $\Delta c(\text{AVER.})$: 3.4895%, $\Delta \theta(\text{UK})$: 6.15%, $\Delta \theta(\text{FR})$: 7.04%, $\Delta \theta(\text{BD})$: 6.81%, $\Delta \theta(\text{NL})$: 6.24%, $\Delta \theta(\text{AVER.})$: 6.56%, and for all countries Δk : 5%.

Actually, this final simulation decomposes the true effects of the differences in tax systems. Alternatively, it reveals the importance of the other variables rather than the tax rules for the asymmetric behaviour. As can be clearly seen from table 2.7, although the UK again gives the least and Germany gives the highest responses to all policy shocks, the differences between the countries are not too much in this

case. As expected, the standard deviations and mean absolute deviations reduce to very low levels compared to the two other cases. Especially in the case of the investment tax credit shocks, the measures of asymmetry reduce almost to 0.5%. This reveals the fact that to reduce the observed asymmetry, rather than convergence in the domestic tax rules, convergence in the fundamental variables such as expected profitability of capital, capital structure, cost of finance and adjustment costs is more important.

Section 2.8 Concluding Remarks

In this chapter, a dynamic tax simulation analysis was conducted to understand the role of corporate tax policy changes on investment decisions. The analyses were oriented on four major European countries: the United Kingdom, France, Germany and the Netherlands. First, we aimed to measure the dynamic effects of various corporate tax policy changes to see whether the effects are important, and which policy affects which country more. As a second aim, the policy effects were contrasted between the countries which has important implications for the tax harmonisation issue in the EU. To do so, starting from the neo-classical model augmented with the external adjustment costs of capital, a partial dynamic equilibrium model in capital and marginal q was derived. Simulations also required the adjustment cost parameters. To estimate these and to obtain some of the other industry-wide variables, panel data were collected for the period 1991-1995. Although the companies were not numerous, they were sufficiently big to

proxy the general industries of the analysed countries. Econometric estimation of the investment equations revealed that high adjustment costs, low R-squares, and to some extent, serial correlation remained as empirical problems. Nevertheless, investment-capital ratios were found to be very significantly related to the observable Q ratios, which also capture the role of the expectations via the market values. In fact, this implies that managers significantly consider stock market behaviour and value maximisation when they are making fixed capital investment decisions. It also reveals, how importantly real and financial markets are integrated with each other.

To measure the permanent policy shock effects quantitatively a simplified numerical procedure was followed. This approach enabled us to derive some easily interpretable analytical results, including the firm's fundamental variables, and to analyse the tax policy effects from the firm's point of view. Moreover, while making the inter-country comparisons, we could decompose the effects of shocks on investment into tax effects and other related variables which served for our second aim. The effects of three different permanent tax policy changes on investment were considered. To enable comparison, effects of a 10% reduction in corporate tax rates, a 10% increase in the present value of depreciation deductions which will result from changing depreciation rules, and a 5% increase in investment tax credits were simulated. For the first issue, simulation results revealed that that tax policies can be used to affect investment decisions. It was found that fixed investment was more sensitive to investment tax credit changes

relative to other policy effects because of its direct effects. Moreover, substantial differences were observed for the tax policy effects on investment between the UK and France, Germany, and the Netherlands as a group, and also differences within this group in terms of different policy effects. The Netherlands gave the largest response to a shock in the corporate tax rate, whereas Germany and France were the most sensitive ones to changes in the depreciation rules and the investment tax credits, respectively. Among all, the investment-capital ratio was the least sensitive one to all policy shock effects in the United Kingdom.

To see how much of these asymmetries can be eliminated by harmonising the tax rules, the same shocks were applied while the corporate tax rules were harmonised to the average values of the four countries. It was observed that the ranking of the responses to the tax policy shocks changed. In this case, France gave the highest response to all policy shocks whereas the UK again gave the least response. Respectively, the Netherlands and Germany gave the second and third highest responses to all of these permanent shocks. Harmonising the corporate tax rates actually increased the asymmetry in the responses to this shock to a higher level. Only in the case of depreciation rules, harmonising the tax rules reduced the asymmetry a limited amount in the responses to this shock. Within the context of the employed model, the obtained results rule out the tax competition view for the domestic investment case. As discussed in the introduction, in terms of the EU, harmonising corporate tax rules may mean the loss of a fiscal tool which could be

used for adjustments of asymmetric shocks or for national demand management and economic stabilisation of the member economies.

CHAPTER 3

TAXATION OF IRREVERSIBLE PROJECTS

UNDER UNCERTAINTY

Section 3.1 Introduction

In the previous chapter, a dynamic tax simulation study was conducted to observe the effect of changes in corporate tax rules on investment behaviour, and to investigate tax harmonisation issues in the EU. While studying the effects of a corporate tax system on investment, one approach commonly employed is to calculate the marginal effective tax rates. The marginal effective tax rate measures the difference between the pre-tax rate of return on investment and the post-tax rate of return on the capital used to finance the project. This difference is known as the tax wedge and reveals the role of a tax system in the incentives or disincentives to invest given to firms. Pioneered by King and Fullerton (1984), effective tax rates are commonly used for inter-country comparisons. In that study, they make comparisons between the effects of the tax systems of the UK, Sweden, West Germany and the US on incentives to invest. Recently, Chennells and Griffith (1997) analyse for ten countries how the corporate income taxes have affected the incentives for both domestic and international investment.

As discussed in chapter 2, taxation and its implications for investment decisions are also very important issues for the EU. Comparative studies often employ effective tax rates or implied cost of capital measures. For instance, to make comparisons between the member countries of the EU, Ruding (1992) uses the implied tax-adjusted cost of capital measures. Similarly, using effective tax rates, Devereux and Pearson (1995) analyse the impact on production efficiency of potential harmonisation of the taxation of income from capital in the EU.

When using the effective tax rates, the studies cited above and many others assume a deterministic environment and also ignore the role of irreversibility risk for the investment decisions. Mintz (1996) stresses that taxes may interact with different kinds of risk such as income risk, irreversibility risk, capital risk, financial risk, inflation risk, and political risk. The effects of taxation in an uncertain world has a long tradition which goes back to Domar and Musgrave (1944) and Stiglitz (1969). Their analysis was put in a general equilibrium framework by Gordon (1985) indicating that by taxing a risky stream of income, the government will also absorb a fraction of the risk. Under loss offsetting, while the investors receive a lower expected return, they also bear less risk, and these two effects largely offset each other. To understand this argument, assume an economy such that the return from a risk-free project is 4.5%. Assuming that the corporate tax rate is 35%, the after-tax return of this project would be 2.925%. Suppose that a risky project earns either 18% or -6% with equal chances. Thus, the standard deviation of this project would be 12%.

Hence, assuming the unit price of risk 0.125%, the pre-tax risk-adjusted return of the project would be 4.5%. Now suppose that the government fully refunds its share of losses, which is $(0.35 \times 6) = 2.1\%$ in this case. The after-tax return and risk on this project would be, respectively, 3.9% and 7.8%. Thus, the after-tax risk-adjusted return on the project would $(3.9 - 0.125 \times 7.8)$ be 2.925%. As can be seen, both the return and risk of the risky project reduces by 35%, and the after-tax risk-adjusted return from the risky project is equal to the after-tax return from the risk-free project. With full refundability, the tax system treats both projects equally.

However, in an influential paper, Bulow and Summers (1984) introduce capital risk, fluctuations in tangible asset prices, and argue that most of the risk borne by investors pertains to changes in relative asset prices rather than income risk, meaning that the government takes a much larger fraction of the return than it takes of the risk. They argue that, if economic depreciation is more costly than expected, the capital allowances will be less. Thus, the tax system can discourage risky investment. In another study, using the models developed in Pindyck (1988) and Bertola and Caballero (1994) for the incremental irreversible investment decisions under uncertainty, McKenzie (1994) shows that the tax distortion measures increase for various sectors in the Canadian economy.

This chapter has two objectives. First, it will analyse how the tax distortions, measured by the effective marginal tax rates, will be affected for the risky investment by also considering the irreversibility of the investment decisions. The

analysis will be limited to the domestic effective marginal tax rate measure, and only income uncertainty will be taken into account. Second, using actual values, an application will again be carried out for the four major European countries, the United Kingdom, France, Germany and the Netherlands, to see how the observed tax distortions will be affected under the new measure. More importantly, the effects of harmonising the corporate tax rules and the asymmetries in the tax distortion measures will be investigated.

Although employing an incremental investment decision approach as in McKenzie (1994) would give more valuable insights, this would also require actual parameter values for production and demand functions. To make the simulations feasible, the approach taken here is limited to a single project decision such as the one developed in McDonald and Siegel (1986). In the next section, a model which considers the effects of the income risk and the irreversibility of the undertaken project is developed. Section 3.3 presents the data and the simulation results, and the final section concludes.

Section 3.2 The Model

Consider a representative hypothetical investment project with a unit cost. The cost of the project net of the present value of any depreciation allowances can be written as

$$C = (1 - c\theta) \quad (1)$$

where c is the corporate tax rate and θ is the present value of the depreciation allowances which depends on the tax rules. Assuming that the inflation rate, the tax rules and the economic depreciation rate are constant over time, under perfect certainty, the value of this project can be written as

$$V = \int_0^{\infty} [(1 - c)P \exp - (\beta + \delta(1 + \pi))t] dt \quad (2)$$

where P , δ and π represent the pre-tax nominal rate of return, the real economic depreciation rate and the inflation rate, respectively. The term β denotes the appropriate nominal discount factor, and it implicitly includes the effect of the source of finance. Assuming that a typical saver in the economy does not pay any personal or wealth tax, the after-tax real rate of return to the saver will simply be

$$S = \frac{1 + i}{1 + \pi} - 1 \quad (3)$$

where i is the nominal interest rate prevailing in the economy. Therefore, considering the tax deductibility of the interest payments, the endogenous nominal discount factor without personal taxes can be written as

$$\beta = (1 - c)(1 - w)i + wi \quad (4)$$

where the term w represents the weight of the equity capital in the source of finance. Under the assumption of no personal taxation, since the cost of the retained earnings and the new equity issues would be the same, they are simply gathered under the source of equity finance. It is assumed that the decision maker

will be willing to maximise the net present discounted value of the project. By assuming that nominal profits grow with the inflation rate, the value maximisation condition can be stated as

$$W = \max \left\{ \Phi - \frac{(1 - c\theta)}{(1 - c)(1 + \pi)} (\beta + (1 + \pi)\delta - \pi), 0 \right\} \quad (5)$$

where Φ represents the pre-tax real rate of return. The equilibrium condition can be rewritten as

$$R = \frac{(1 - c\theta)}{(1 - c)(1 + \pi)} ((1 - c)(1 - w)i + wi + (1 + \pi)\delta - \pi) - \delta. \quad (6)$$

Here, R denotes the pre-tax real rate of return net of the real economic depreciation rate. Obviously, if there are no taxes, the equilibrium pre-tax real rate of return net of the real depreciation rate will be equal to the after-tax real rate of return stated in equation (3). In other words, the tax wedge will be zero. However, with corporate tax rules, since $0 < \theta < 1$, the firm has to cover the relative tax disadvantage effect $[(1 - c\theta)/(1 - c)]$ for the return to the saver and for the additional depreciation rate, except that it will benefit from the tax deductibility of the interest payments. Hence, the familiar form of the tax-inclusive domestic effective marginal tax rate under perfect certainty and reversibility assumptions can be expressed as

$$DEMTR = \frac{\frac{(1 - c\theta)}{(1 - c)(1 + \pi)} ((1 - c)(1 - w)i + wi + (1 + \pi)\delta - \pi) - \delta - \frac{1 + i}{1 + \pi} + 1}{\frac{(1 - c\theta)}{(1 - c)(1 + \pi)} ((1 - c)(1 - w)i + wi + (1 + \pi)\delta - \pi) - \delta} \quad (7)$$

which summarises the impact of the corporate tax system on the hypothetical investment project in the economy.

Now suppose that the pre-tax real rate of return (Φ) follows a stochastic process and that the investment decision is irreversible, which is a more realistic assumption for a real-world situation compared to the certainty and reversibility case. In this case, a rational decision maker should look ahead and compare the outcomes of investing immediately and waiting and investing at a future time. Since Φ evolves stochastically now, the equilibrium condition in equation (6), and the *DEMTR* in equation (7) will no longer hold. Thus, we need to find another critical value (Φ^*) at which it will be rational to invest when the pre-tax real rate of return is equal to, or greater than this critical value.

Given the uncertainty about the state variable Φ and the option to wait for undertaking the project, the problem in hand can be viewed as an infinite horizon optimal stopping problem, which can be solved via dynamic programming. Assuming that Φ follows a geometric Brownian motion, the stochastic motion of Φ can be presented as

$$d\Phi = \sigma\Phi dx \quad (8)$$

where σ is the variance parameter, and $dx = e(dt)^{1/2}$. Here, x is a Weiner process and $e \sim N(0, 1)$. In order to make a comparison with the deterministic case, we keep assuming that the nominal profits grow with the inflation rate. Thus, the drift

rate of the process is assumed zero, which will also be considered later.

Therefore, the maximisation problem in equation (5) can be rewritten as

$$W^*(\Phi_t) = \max \left\{ \Phi_t - \left(\frac{(1-c\theta)}{(1-c)(1+\pi)} (\beta^* + (1+\pi)\delta - \pi) \right), \frac{1}{(1+\beta^* + (1+\pi)\delta - \pi)} E_t[W(\Phi_{t+1})] \right\} \quad (9)$$

where E represents the expectation operator. The first term in the right-hand side of equation (9) is the stopping value, the value that the firm gets when it makes the investment immediately, just as in equation (5). The extra term represents the continuation value, the value of waiting and making the investment in the next period. The continuation value is based on the firm's current time expectations about the future, and it is discounted to the current time with the appropriate discount factor.

Since there is uncertainty now, the saver should receive a premium for bearing the risk. Considering this, from the CAPM, the after-tax real rate of return in equation (3) can be altered as

$$S^* = \frac{(1-w)(1+i) + w(1+i + \rho\sigma\lambda(1+\pi))}{1+\pi} - 1. \quad (10)$$

Here, ρ denotes the correlation of the pre-tax real rate of return of the hypothetical project and the pre-tax real rate of return of the market portfolio of projects in the economy, and λ is the exogenously given expected real market price of risk. From here, the endogenous nominal discount factor given in equation (4) can be altered to include the effect of uncertainty as

$$\beta^* = (1-c)(1-w)i + w(i + \rho\sigma\lambda(1+\pi)). \quad (11)$$

Looking at equations (10) and (11), it can be inferred that although the government taxes the risk premium, it does not absorb the risk. Thus, the expected return to the saver does not change, and this can be taken as a no-refundability case for any losses that the firm incurs.

From equation (9), the Bellman equation in the continuation region can be written for continuous time case as

$$((1-c)(1-w)i + w(i + \rho\sigma\lambda(1+\pi)) + (1+\pi)\delta - \pi)Wdt = E(dW). \quad (12)$$

As can be seen from equation (9), we need to calculate $E(dW)$. Using Ito's Lemma, the total differentiation dW can be expressed as

$$dW(\Phi) = \sigma^2 \Phi^2 \frac{1}{2} \frac{d^2 W(\Phi)}{d\Phi^2} dt + \sigma \Phi \frac{dW(\Phi)}{d\Phi} dx \quad (13)$$

and from here,

$$E[dW(\Phi)] = \sigma^2 \Phi^2 \frac{1}{2} \frac{d^2 W(\Phi)}{d\Phi^2} dt. \quad (14)$$

Using the result in equation (14), the Bellman equation in (12) can be rearranged as

$$\frac{1}{2} \sigma^2 \Phi^2 \frac{d^2 W(\Phi)}{d\Phi^2} - ((1-c)(1-w)i + w(i + \rho\sigma\lambda(1+\pi)) + (1+\pi)\delta - \pi)W = 0. \quad (15)$$

As explained in Dixit (1993), the solution $W(\Phi)$ should satisfy the three boundary conditions,

$$W(0) = 0 \quad (16)$$

$$W'(\Phi) = \Phi - \frac{(1-c\theta)}{(1-c)(1+\pi)} (\beta^* + (1+\pi)\delta - \pi) \quad (17)$$

$$\frac{dW(\Phi^*)}{d\Phi} = \frac{d\left(\Phi^* - \frac{(1-c\theta)}{(1-c)(1+\pi)}(\beta^* + (1+\pi)\delta - \pi)\right)}{d\Phi} = 1. \quad (18)$$

Since when $\Phi=0$, the value of the option to invest will also be worthless, and the first boundary condition reflects this fact. Equations (17) and (18) are, respectively, the value-matching and the smooth-pasting conditions. The value-matching condition shows the value that the firm gets when it invests. The smooth-pasting condition implies that $W(\Phi)$ should be smooth and continuous at the optimal point. Otherwise, Φ^* would not be the optimal value. Normally, the Bellman equation appears in the form of a partial differential equation which usually makes analytical solution difficult, or sometimes impossible. However, due to the infinite horizon nature of the problem, the value function is independent of time, reducing the equation to a second-order differential equation. The differential equation in (15) has a solution as

$$W(\Phi) = g\Phi^r \quad (19)$$

and inserting this function into equation (15) gives

$$\frac{1}{2}\sigma^2\Phi^2r(r-1)g\Phi^{r-2} - (\beta^* + (1+\pi)\delta - \pi)g\Phi^r = 0. \quad (20)$$

Dividing through $g\Phi^r$, equation (20) reduces to

$$\frac{1}{2}\sigma^2r^2 - \frac{1}{2}\sigma^2r - (\beta^* + (1+\pi)\delta - \pi) = 0 \quad (21)$$

and the two solutions to equation (21) can be written as

$$r_{1,2} = \frac{\frac{1}{2}\sigma^2 \pm \sqrt{\frac{\sigma^4}{4} + 2\sigma^2(\beta^* + (1+\pi)\delta - \pi)}}{\sigma^2} \quad (22)$$

where $r_2 < 0$, $r_1 > 1$. The general solution given in equation (19) can be expressed as a linear combination of two independent solutions; however, the first boundary condition rules out the negative root. This reduces the solution to

$$W(\Phi) = g_1 \Phi^{r_1} \quad (23)$$

Inserting this solution into equations (17) and (18), two equations can be obtained to solve the two unknowns, g_1 and Φ^* , representing the constant and the critical value of the pre-tax real rate of return. The system of two equations will be

$$g_1 \Phi^{r_1} - \Phi = -\frac{(1-c\theta)}{(1-c)(1+\pi)}(\beta^* + (1+\pi)\delta - \pi) \quad (24)$$

$$r_1 g_1 \Phi^{r_1-1} = 1 \quad (25)$$

Hence, using equations (21), (22), (24) and (25), equation (6) can be altered as

$$R^* = \frac{(1-c\theta)}{(1-c)(1+\pi)}(\beta^* + (1+\pi)\delta - \pi + F^*) - \delta \quad (26)$$

and finally, the new condition for the domestic effective marginal tax rate in equation (7) can be rearranged as

$$DEMIR^* = \frac{\frac{(1-c\theta)}{(1-c)(1+\pi)}(\beta^* + (1+\pi)\delta - \pi + F^*) - \delta - \frac{(1-w)(1+i) + w(1+i + \rho\pi(1+\pi))}{1+\pi} + 1}{\frac{(1-c\theta)}{(1-c)(1+\pi)}(\beta^* + (1+\pi)\delta - \pi + F^*) - \delta} \quad (27)$$

where

$$F^* = \frac{\sigma^2}{4} + \sqrt{\frac{\sigma^4}{16} + \frac{\sigma^2(\beta^* + (1 + \pi)\delta - \pi)}{2}}.$$

The term F^* denotes the irreversibility effect which derives an additional wedge between the pre-tax return and the post-tax return. As the variance parameter σ approaches zero, the new equilibrium value derived in equation (26) for the pre-tax real rate of return net of real depreciation rate and the new domestic marginal effective tax rate in equation (27) approach the conditions derived in equations (6) and (7) under perfect certainty and reversibility.

To see how uncertainty affects the domestic effective marginal tax rate considering irreversibility, we can take the partial derivative of $DEMTR^*$ with respect to the uncertainty parameter σ . Doing the necessary calculations by assuming that all parameters are independent of each others gives

$$\frac{\partial DEMTR^*}{\partial \sigma} = \frac{\frac{w\rho\lambda(1+\pi)^2\delta(1-c)c(1-\theta)}{(1-c\theta)^2}(Z-1)}{\left(i(1-c(1-w)) + (1+\pi)\left(w\rho\sigma\lambda + \frac{\delta c(1-\theta)}{(1-c\theta)}\right) + F^* - \pi\right)^2} \quad (28)$$

where

$$Z = \frac{(1-c\theta)\left(ic(1-w) + \frac{(\sigma+G)(i-\pi)}{2w\rho\lambda(1+\pi)} + M\right)}{\delta(1+\pi)c(1-\theta)}$$

and

$$G \equiv \frac{\frac{\sigma^3}{4} + \frac{3\sigma^2 w \rho \lambda (1 + \pi)}{2} + \sigma(i(1 - c(1 - w)) + (1 + \pi)\delta - \pi)}{\sqrt{\frac{\sigma^4}{16} + \frac{\sigma^2(i(1 - c(1 - w)) + (1 + \pi)(\delta + w \rho \sigma \lambda) - \pi)}{2}}} > 0$$

and

$$M \equiv \frac{\sigma^2}{4} + \frac{\frac{\sigma^4}{16} + \frac{\sigma^3}{4} w \rho \lambda (1 + \pi)}{\sqrt{\frac{\sigma^4}{16} + \frac{\sigma^2(i(1 - c(1 - w)) + (1 + \pi)(\delta + w \rho \sigma \lambda) - \pi)}{2}}} > 0.$$

The denominator of equation (28) will be positive. Since $0 < \theta < 1$ and other parameters are positive, the first term in the numerator of equation (28) will also be positive. Thus, the effect of uncertainty for irreversible investment on the domestic marginal effective tax rate will depend on whether Z is greater than, equal to, or smaller than one. To understand how the effect of uncertainty works on the domestic effective marginal tax rate, we can multiply $(Z-1)$ with the term $\left(\frac{\delta(1 + \pi)c(1 - \theta)}{(1 - c\theta)} \right)$ in the numerator of equation (28), converting it to

$$Z^* = ic(1 - w) + \left(\frac{(\sigma + G)(i - \pi)}{2w\rho\lambda(1 + \pi)} + M \right) - \frac{\delta(1 + \pi)c(1 - \theta)}{(1 - c\theta)}. \quad (29)$$

These three terms summarise the effect of the uncertainty parameter σ on the $DEMTR^*$ which can be interpreted through equations (10), (11), (26) and (27). As the level of uncertainty increases, the required return to the saver (S^*) also increases. This also increases the cost of equity in the nominal discount factor given in equation (11). However, the tax advantage of debt finance relatively reduces compared to the previous level of uncertainty, increasing the $DEMTR^*$

due to the relatively higher level of the tax burden. The first term $ic(1-w)$ in equation (29) denotes this positive effect. The third term in equation (29) shows the only negative effect due to the relative reduction in the tax burden, occurring because of the depreciation rate that the firm has to cover. As can be seen from equation (27), the reason for this negative effect is the decrease in the relative importance of this tax burden due to the increase in the cost of equity finance. These two terms summarise the sign of the effect of σ on the $DEMTR^*$ in the case of reversibility. Only if these two terms exactly offset each other, regardless of the level of uncertainty, the $DEMTR$ given in equation (7) and $DEMTR^*$ in equation (27) will be exactly the same under the reversibility assumption ($F^*=0$).

Finally, as the uncertainty increases, the irreversibility effect summarised by the term F^* also increases. This happens because as σ increases, the time value of waiting increases. In other words, the price of the real option that the firm kills when it undertakes the project will increase. The increase in this additional cost will not affect the after-tax real rate of return to the saver in equation (10), but will increase the pre-tax real rate of return in equation (26). Thus, the second term in equation (29) shows this final positive effect. If the two positive effects in equation (29) are larger than the negative effect, then Z will be greater than one, and this will make the uncertainty effect positive on $DEMTR^*$ in equation (28). Otherwise, the effect will be negative or zero. However, a negative or neutral effect requires excessive or impossible values for some of the parameters, such as

very high depreciation rates or negative real interest rates. As will be demonstrated in the next section, for reasonable values the effect will be positive.

In equation (8), in order to make a comparison with the deterministic case, the drift rate of the stochastic process followed by the pre-tax real rate of return was assumed zero. For a more realistic case, equation (8) can be altered as

$$d\Phi = \alpha\Phi dt + \sigma\Phi dx \quad (8a)$$

Here, α denotes the expected growth rate of the pre-tax real rate of return, σ is the variance parameter, and dx is the increment of a Weiner process. Equations (26) and (27) can be altered to include the drift parameter α as

$$R^{**} = \frac{(1-c\theta)}{(1-c)(1+\pi)} (\beta^* + (1+\pi)\delta - \pi + F^{**}) - \delta \quad (26a)$$

$$DEMTR^{**} = \frac{\frac{(1-c\theta)}{(1-c)(1+\pi)} (\beta^* + (1+\pi)\delta - \pi + F^{**}) - \delta - \frac{(1-w)(1+i) + w(1+i + \rho\alpha(1+\pi))}{1+\pi} + 1}{\frac{(1-c\theta)}{(1-c)(1+\pi)} (\beta^* + (1+\pi)\delta - \pi + F^{**}) - \delta} \quad (27a)$$

where

$$F^{**} = \frac{\sigma^2}{4} - \frac{\alpha}{2} + \sqrt{\left(\frac{\alpha}{2} - \frac{\sigma^2}{4}\right)^2 + \frac{\sigma^2 (\beta^* + (1+\pi)\delta - \pi)}{2}}$$

To see how the expected growth rate α affects $DEMTR^{**}$, we can take the partial derivative of F^{**} with respect to α . This will be

$$\frac{\partial F^{**}}{\partial \alpha} \equiv \frac{1}{2} \left(\frac{\left(\frac{\alpha}{2} - \frac{\sigma^2}{4} \right)}{\sqrt{\left(\frac{\alpha}{2} - \frac{\sigma^2}{4} \right)^2 + \frac{\sigma^2(\beta^* + (1+\pi)\delta - \pi)}{2}}} - 1 \right) < 0. \quad (30)$$

Equation (30) shows that as the drift term increases, the term F^{**} decreases. This happens because as α increases, the value in waiting to undertake the project decreases. This implies that $DEMTR^{**} < DEMTR^*$ if we replace the stochastic process followed by Φ in equation (8) with the process described in equation (8a).

Section 3.3 Data Description

In this section, we present the data necessary to make the simulations. The analysis will be carried out for the UK, France, Germany and the Netherlands. For the calculation of the weight of debt ($1-w$) and the weight (w) of equity in the cost of finance and for the nominal economic depreciation rate ($\delta(1+\pi)$), the same set of panel data was employed for each country as in chapter 2. The necessary interest rates, prices, and stock market indices were also obtained from Datastream. The codes in brackets denote the associated Datastream codes. The corporate tax rules were obtained from the yearly corporate tax guides of Price Waterhouse and Ernst & Young, and table 3.1 describes the corporate tax rules for the year 1995.

Table 3.1 Corporate Tax Rules (%)

	UK	FR	BD	NL
Corporate Tax Rates	33	33.33	45	35
Plant & Machinery	25(RB)	20(SL)	30(RB)	12.5(SL)
Industrial Buildings	4(SL)	5(SL)	4(SL)	2.5(SL)
Commercial Buildings	-	4(SL)	4(SL)	2.5(SL)

1. See the notes in table 2.1.

Industry-wide weight parameters (w) and the present value of depreciation deductions (θ) were calculated as explained in section 2.6. The economic depreciation rates are not necessarily equal to the accounting depreciation rates, therefore they have to be estimated. The nominal depreciation rates were proxied by those previously estimated in section 2.6. The obtained results were 4.67%, 4.66%, 5.98% and 6.34%, respectively, for the UK, France, Germany and the Netherlands.

For the inflation rates (π), the monthly averages of annualised inflation rates were used from the beginning of 1991 to the end of 1995 for each country, and they were calculated by using the monthly consumer price indices. Datastream codes for the price indices are [UKRP....F], [FRCP....F], [BDCP....F], and [NLCP....F], respectively, for the UK, France, Germany and the Netherlands. The nominal interest rates (i) were the monthly averages of the annualised long-term government bond yields for 1991-1995 for each country. Datastream codes for the bond yields are [UKMGLTB], [FRNGLTB], [GRMGLTB], and [HOLGLTB], respectively. Table 3.2 describes the whole necessary data set for the simulation,

and the final column shows the average values of the four countries under investigation.

Table 3.2 The Data Required for Simulation

	UK	FR	BD	NL	MEAN
i	0.0802	0.0711	0.0659	0.0662	0.07085
π	0.0286	0.0203	0.0335	0.0258	0.02705
w	0.7212	0.5952	0.7270	0.6645	0.67698
c	0.3300	0.3333	0.5325	0.3500	0.38645
θ	0.6150	0.7040	0.6810	0.6240	0.65600
ρ	0.9292	0.9289	0.9774	0.9243	0.93995
σ	0.1428	0.2266	0.2119	0.2928	0.21850
λ	0.1954	0.1750	0.1221	0.1744	0.16673
α	0.0428	0.0795	0.0630	0.0765	0.06545
$\delta(1+\pi)$	0.0467	0.0466	0.0598	0.0634	0.05413

1. For the calculation of w , θ , and $\delta(1+\pi)$ figures, see section 2.6.
2. The corporate tax rate c in Germany includes the local tax rate.
3. Mean represents the arithmetic average of the values for the four countries.

To calculate the σ , α , λ and ρ figures, Datastream general industry sector indices and the total stock market indices were used. Datastream codes for the general industry sector indices are [GENINUK], [GENINFR], [GENINBD], and [GENINNLL], and the total stock market indices are [TOTMKUK], [TOTMKFR], [TOTMKBD], and [TOTMKNL]. For the calculations, annual data were used by going back to the year 1982. The α and σ figures were proxied by the means and standard deviations of the annual real returns on the general industry sector indices of the countries for the period 1982-1995. The real returns for the general industry sectors were calculated by adjusting the yearly nominal returns with the annualised inflation rates. The annualised inflation rates were calculated by using

the yearly consumer price indices for each country. The real expected market prices of risk (λ) were calculated by dividing the average excess annual real returns on the total market indices by the annual standard deviation of the real total market returns. The yearly average excess real total market returns were calculated by using the total market indices, the nominal long-term government bond yields as the nominal risk-free rates and the inflation rates. Finally, the correlation coefficients ρ are those between the yearly real general industry sector returns and the yearly real total market returns for the period 1982-1995.

Section 3.4 Simulation Results

In section 3.2, it was shown analytically that including income uncertainty and irreversibility risk into the traditional domestic effective marginal tax rate measures may have positive, neutral or negative additional effects for the tax distortions imposed by a corporate tax system upon investment decisions. In this section, the effect of this alteration will be measured and contrasted with the traditional deterministic case by using actual values for the UK, France, Germany and the Netherlands. Later, the effects of the new measure on the results of harmonising the corporate tax rules will be discussed, as they have important implications for the EU.

Using the required values from table 3.2 and equations (3), (6), (7), (10), (26), (27), (26a) and (27a) derived in section 3.2, the simulation results are presented in

table 3.3, table 3.4 and table 3.5. To measure the asymmetry between the countries, two measures of dispersion were calculated: the standard deviation, and the mean absolute deviation. For that purpose, average measures were calculated by using the mean values from table 3.2. The standard deviation was calculated as

$$SDV = \sqrt{\frac{\sum_i^N (Y_i - \text{Mean})^2}{N}} \quad \text{where } N \text{ is the number of countries, and } Y \text{ is the}$$

measure under consideration. The mean absolute deviation was calculated as

$$MAD = \frac{\sum_i^N |Y_i - \text{Mean}|}{N}.$$

Table 3.3 Simulation Results for S, S*, R, R* and R (%)**

	UK	FR	BD	NL	AVER.	SDV	MAD
<i>S</i>	5.02	4.98	3.14	3.94	4.27	0.78	0.73
<i>S*</i>	6.89	7.17	4.97	7.08	6.58	0.90	0.75
<i>R</i>	5.98	5.31	5.11	5.08	5.28	0.37	0.28
<i>R*</i>	12.71	15.43	15.57	20.41	15.83	2.78	2.09
<i>R**</i>	10.63	11.51	11.79	15.79	12.27	1.99	1.60

As can be seen from table 3.3, with the incorporation of uncertainty, the post-tax real rate of return (*S*) increases due to the risk premium required by the saver. Obviously, the net pre-tax real rate of return (*R*) also increases due to the effects of income uncertainty and irreversibility risk, which are associated with higher measures of asymmetry. Comparing the results of the changes in the after-tax real rate of return and the net pre-tax real rate of return reveals that it is the irreversibility effect which accounts, for the most part, for the increments in net

pre-tax real rate of returns. Both for the pre-tax real rate of return net of real depreciation rate and for the post-tax real rate of return, the highest differences occur in the case of the NL, whereas the lowest impacts are for the UK.

Table 3.4 Domestic Effective Marginal Tax Rates (%)

	UK	FR	BD	NL	AVER.	SDV	MAD
DEMTR	16.05	6.28	38.68	22.41	19.30	11.89	9.69
DEMTR*	45.82	53.52	68.06	65.33	58.42	8.99	8.51
DEMTR**	35.18	37.68	57.82	55.19	46.34	10.12	10.03

Table 3.4 presents the domestic effective marginal tax rates for the deterministic and reversibility case and for the uncertainty and irreversibility case with and without the drift parameter α . The drift parameter α denotes the expected growth rate of the pre-tax real returns. Comparing the results of the first row with the second and third rows shows that there is a very large difference between the measures of tax distortions. Considering income uncertainty under irreversibility increases the effective tax rate measures to almost two-three times higher levels. The most dramatic increase happens for France, for which the *DEMTR* increases from 6.28% to 37.68% when the drift rate is considered, and to 53.52% when it is ignored. As discussed before, the results verify the argument about Z^* from equation (29), indicating that the positive effects of income uncertainty under irreversibility are well above the negative effect on the domestic effective marginal tax rates. Additionally, the results show that *DEMTR*** measures are below the *DEMTR** measures, confirming the exposition in equation (30) about the effect of the drift rate. Because the levels of the measures are closer than those

in the certainty and reversibility case, *SDV* and *MAD* are also lower for *DEMTR** and *DEMTR***. As explained in section 3.3, uncertainty measures were calculated by using stock market data. This was based on the assumption that fluctuations in firm values reflect changes in the profits. In reality, however, the volatility of the stock market data will be much higher than the volatility of income, implying that the results in table 3.4 and table 3.5 for the uncertainty and irreversibility case will be biased upward. Nevertheless, the results indicate that commonly applied classical effective tax rate measures, especially those which ignore the role of irreversibility risk, will underestimate the role of tax distortions on investment decisions.

Important issues for the case of the European Union are: how much of the tax asymmetries actually occur because of the differences in the treatment of investment by the tax systems of the countries and to what extent can these asymmetries be eliminated by harmonising the tax systems? Moreover, what will be the effects of the commonly ignored irreversibility risk and income risk in reducing these asymmetries? To answer these questions, another simulation was conducted by again using equations (7), (27) and (27a), but this time the tax rules were harmonised to the average rates for the four countries under investigation. As given in the last column of table 3.2, the harmonised corporate tax rate and the present value of the depreciation deductions are, respectively, 38.645% and 65.6%. To make comparisons between the degree of the asymmetries, the *SDV* and *MAD* measures were again used.

Table 3.5 Effect of Harmonising Tax Rules (%)

	UK	FR	BD	NL	AVER.	SDV	MAD
DEMTR	17.29	12.97	26.23	22.97	19.30	5.14	4.74
DEMTR*	46.74	56.27	63.58	65.65	58.42	7.41	6.55
DEMTR**	36.24	41.45	51.60	55.57	46.34	7.73	7.37

The results in table 3.5 reveal that in the case of harmonised tax systems, the asymmetry in the domestic effective marginal tax rates reduces for the three methods. The answers to the above questions can be best given by comparing the calculated standard and mean absolute deviations in columns 6 and 7 of table 3.4 and table 3.5. As can be seen, for the certainty and reversibility case, harmonising the corporate tax rules reduces half of the observed asymmetry; however, almost half of the asymmetry still remains because of the differences in other values. More importantly, including uncertainty and irreversibility reduces the observed asymmetry for harmonising the tax rules far less than the certainty and reversibility case. For instance, the *SDV* of *DEMTR*** reduces from 10.12% to 7.73%, and the *SDV* of *DEMTR** reduces from 8.99% to only 7.41%. To a large extent, the results found here rule out the tax competition view for the domestic investment case. As found in chapter 2, expecting similar effective tax rate measures in the case of harmonised corporate tax rules will certainly be misleading, especially when the irreversibility risk and income risk are considered. This reveals the fact that, for the effects of taxation on investment decisions, it is not only the corporate tax rules that matter, but also their interactions with the relevant variables. Although convergence in interest rates and inflation rates would alleviate the observed asymmetry, convergence is also

required in the other structural variables like the expected growth rates and the uncertainties governing the profitability of capital, the financial capital structures and the economic depreciation rates.

Section 3.5 Concluding Remarks

Effective tax rates are commonly employed to reveal the role of a tax system in the incentives or disincentives to invest given to firms. However, for simplicity, many studies using these measures ignore the role of uncertainty and irreversibility risks. As an extension of the previous chapter, this chapter analysed the joint effects of income uncertainty and irreversibility of investment decisions on the domestic effective marginal tax rates. In the second section of the chapter, it was shown analytically that, although the joint effect might be neutral or might have negative effects on the measure of tax distortion, for reasonable values it would have positive effects. The third section presented evidence by using actual data for the UK, France, Germany and the Netherlands that the joint effect of uncertainty and irreversibility will increase the commonly used marginal effective tax rates measures to much higher levels.

As a second objective, the effects of including uncertainty and irreversibility were analysed in the case of harmonisation of the corporate tax rules towards the average values by considering only the four countries under investigation. The results suggested that, when the joint risk was incorporated, the reduction in the

observed asymmetry was far less than the reduction in the asymmetry in the case of certainty and reversibility. Similar to the findings in chapter 2 for the dynamic effects of tax policy changes, the results found in this chapter have important implications for the EU since it contradicts the tax competition view for the domestic investment case.

CHAPTER 4

INVESTMENT AND AGENCY/FINANCIAL DISTRESS COSTS

OF DEBT: A EULER EQUATION APPROACH

Section 4.1 Introduction

Although the neo-classical and Q models of investment are theoretically appealing, empirically they have performed less successfully. Both approaches assume perfect capital markets and rely on the irrelevance result of Modigliani and Miller (1958). In their path-breaking paper, Modigliani and Miller propose that capital structure decisions will be irrelevant to a firm's value. They argue that internal and external funds will be perfect substitutes and that financing and investment decisions will be independent. Also, Miller (1991) argues that increased leveraging by corporations does not imply increased risk for the whole economy, and that financial distress of highly leveraged firms does involve mainly private costs.

On the other hand, for instance, informational problems as discussed in Akerlof (1970), Stiglitz and Weiss (1981), and Myers and Majluf (1984), and/or incentive problems as in Jensen and Meckling (1976) and Myers (1977), rule out the irrelevance result of Modigliani and Miller. Although there is a growing empirical literature about the interactions of financing and investment decisions, most of

these studies concentrate on cash flow and liquidity effects such as in Fazzari et al. (1988), Hoshi et al. (1991), Whited (1992), Calomiris and Hubbard (1993), Fazzari and Peterson (1993), Himmelberg and Peterson (1994), Bond and Meghir (1994), Hubbard et al. (1995), Chirinko and Schaller (1995) and Lamont (1997).

Based on informational problems, cash flow and liquidity effects are well documented. On the other hand, as explained in section 1.5, the theoretical developments in the corporate finance side concentrate on incentive problems and possible relations between financial capital structure and real investment decisions. However, unlike the empirical evidence for the cash flow and liquidity variables, the empirical studies for the effects of incentive problems are not numerous, and they find controversial results. For instance, Cantor (1990), Galeotti et al. (1994), Cuthbertson and Gasparro (1995) and Lang et al. (1996) find support for incentive problems, whereas the results of Chirinko (1987), Oliner and Rudebusch (1992) and Kopcke and Howrey (1994) reveal opposite findings.

The controversial empirical results about the effects of incentive problems on investment decisions imply that more empirical investigations into these effects are required. Therefore, this chapter aims to make a contribution to the empirical literature on this issue. For that purpose, based on the Euler equation approach, a model is developed to test the role of financing conditions on investment decisions. The model considers the possible effects of agency/financial distress

costs of debt by incorporating an external financing premium via the debt-capital ratio. As discussed in Schiantarelli (1996), unlike cash flow and liquidity effects, this explicit incorporation provides a sharper test of the hypothesised relationship. Fazzari and Peterson (1993) point out the neglected role of working capital as a source of finance. Firms might be smoothing agency/financial distress costs of debt in the short-run with their working capital policies. Thus, the model also considers possible beneficiary roles of working capital. Most of the studies that investigate financial factors' effect on investment decisions include large numbers of small firms in their samples. Unlike these, using firm-level panel data for the UK, Germany and France, in this study only large firms are investigated, and the findings make more sense for the overall economies. Moreover, the model is tested for firms with different levels of indebtedness, since it is more likely that this relation will hold more significantly for highly leveraged firms.

In the next section, the basic model is developed to investigate the potential links between investment and agency/financial distress costs of debt. The third section describes the econometric methodology. The fourth section presents the data and the estimation results of the model. In the fifth section, the results of the model are investigated further for firms with different levels of indebtedness, and concluding remarks are presented in the final section.

Section 4.2 The Model

In the model, it is assumed that managers aim to maximise the wealth of shareholders. For simplicity, a tax-free world is presumed. The return to the shareholders of firm i at time t comprises dividends and capital appreciation net of new equity issues as

$$\rho_{it} = \frac{E_t(V_{i,t+1} - NE_{i,t+1}) - V_{it} + E_t Div_{i,t+1}}{V_{it}}. \quad (1)$$

Here, E_t stands for the expectations at time t , and ρ_{it} denotes the equilibrium required return by the shareholders of the firm i at time t , which follows from the usual capital market arbitrage condition. The terms V , Div , and NE represent the market value of equity, dividends and new equity issues. Hence, by ruling out any bubbles and solving equation (1) forward, the firm's market value at time zero can be expressed as

$$V_{i0} = E_0 \sum_{t=1}^{\infty} \left[\left(\prod_{j=0}^{t-1} \beta_{ij} \right) (Div_{it} - NE_{it}) \right] \quad (2)$$

where $\beta_{it} = (1 + \rho_{it})^{-1}$.

The firm maximises its market value under two constraints. The first constraint is the motion of capital stock which can be given in the discrete time as

$$K_{it} - K_{i,t-1} = I_{it} - \delta K_{i,t-1} \quad (3)$$

where K , I , and δ represent the capital stock, the fixed investment and the economic depreciation rate, respectively.

In the model, for the sake of simplicity and also because of their negligible quantitative relevance, the firm's policy about the net additions to equity capital is taken as exogenous. To make the debt policy endogenous, it will be assumed that the presence of debt may create agency/financial distress costs. Agency costs of debt may arise because of imperfections in the financial capital markets. For instance, if the lenders cannot perfectly observe the acts of managers or the quality of the projects that the firm is undertaking, they may charge additional agency costs as an insurance premium which may have negative effects on the managers' real investment decisions. Additionally, higher levels of debt may create financial distress costs and may also increase the likelihood of bankruptcy. Thus, the firm may not be able to borrow further to undertake profitable investment opportunities. However, the firm may smooth the agency/financial distress costs of debt through its working capital, since the firm may partially replicate the financing role of debt or alleviate the above mentioned pressures by its working capital policy. For instance, working capital policies may include using cash and liquid assets, and altering debt and stock policies. Thus, it is postulated that the agency/financial distress cost function depends positively on debt and negatively on working capital. Further, the usual external adjustment costs of capital investment are also considered.

The profits of the firm i at time t are defined as

$$\pi(K_{it}, N_{it}) = p_{it}F(K_{it}, N_{it}) - w_{it}N_{it} \quad (4)$$

where $F(K_{it}, N_{it})$ is the linearly homogenous production function, and p , w and N denote the price of the good sold, price of variable inputs, and the variable inputs employed in the production process. The second constraint is for the definition of the dividend as

$$\begin{aligned} Div_{it} = & p_{it}F(K_{it}, N_{it}) - w_{it}N_{it} - p_{it}^I(I_{it} + A(I_{it}, K_{it})) + NE_{it} - r_{i,t-1}D_{i,t-1} \\ & + (D_{it} - D_{i,t-1}) + m_{i,t-1}WC_{i,t-1} - (WC_{it} - WC_{i,t-1}) - X(D_{it}, WC_{it}, K_{it}). \end{aligned} \quad (5)$$

where $A(I, K)$ is the strictly convex external adjustment cost function, p^I the price of the investment good, r the nominal interest rate on debt, D the stock of debt, m the return on employed working capital, WC the working capital. The final term $X(D, WC, K)$ represents the agency/financial distress costs as a function of debt, working capital and capital stock.

Using the two constraints in equation (3) and equation (5) for the maximisation problem stated in equation (2), the optimality conditions for N , D , WC , I and K can be written as

$$p_{it}F_N(K_{it}, N_{it}) - w_{it} = 0 \quad (6)$$

$$1 - X_D(D_{it}, WC_{it}, K_{it}) - E_t\beta_{it}(1 + r_{it}) = 0 \quad (7)$$

$$E_t\beta_{it}(1 + m_{it}) - 1 - X_{WC}(D_{it}, WC_{it}, K_{it}) = 0 \quad (8)$$

$$\lambda_{it} - p_{it}^I(1 + A_I(I_{it}, K_{it})) = 0 \quad (9)$$

$$p_{it}F_K(K_{it}, N_{it}) - p_{it}^IA_K(I_{it}, K_{it}) - \lambda_{it} - X_K(D_{it}, WC_{it}, K_{it}) + E_t\beta_{it}(1 - \delta)\lambda_{i,t+1} = 0. \quad (10)$$

Equation (6) denotes the usual marginal productivity condition for the variable input vector. Equation (7) states that the marginal benefit of an additional unit of

debt should be equal to the discounted cost of this debt plus the associated agency/financial distress costs. Also, equation (7) can be arranged as

$$\beta_{it} = \frac{1 - X_D(D_{it}, WC_{it}, K_{it})}{1 + r_{it}} \quad (7a)$$

implying that the firm should conduct its debt policy so as to equate the marginal cost of debt and equity along the optimal path. Similarly, the optimality condition for WC in equation (8) states that the marginal cost of an additional unit of working capital should equate the discounted return on working capital plus the associated marginal smoothing benefits of this additional unit of working capital.

Equation (9) denotes that the firm chooses its investment rate so as to equate the value of an additional unit of newly installed capital to its purchase price plus the marginal external adjustment cost. Solving the optimality condition forward for capital in equation (10) yields

$$\lambda_{it} = E_t \sum_{s=t}^{\infty} \left[\left(\prod_{j=t}^{s-1} \beta_{ij} (1 - \delta) \right) \left(p_{is} F_K(K_{is}, N_{is}) - p'_{is} A_K(I_{is}, K_{is}) - X_K(D_{is}, WC_{is}, K_{is}) \right) \right] \quad (10a)$$

showing the equality between the present discounted value of the marginal revenue attributable to a unit of installed capital net of associated adjustment and agency/ financial distress costs, and the shadow price of capital. As usual, the discount factor also includes the economic depreciation rate δ , since capital depreciates at this rate.

To obtain a feasible investment equation, the shadow value of capital λ derived in equation (9) can be substituted into the optimality condition of capital stated in equation (10) as

$$p_{it} F_K(K_{it}, N_{it}) - p_{it}^I A_K(I_{it}, K_{it}) - p_{it}^I (1 + A_I(I_{it}, K_{it})) - X_K(D_{it}, WC_{it}, K_{it}) + E_t \beta_{it} (1 - \delta) p_{i,t+1}^I (1 + A_I(I_{i,t+1}, K_{i,t+1})) = 0. \quad (11)$$

By this way, the unobservable shadow value of capital is eliminated. Also, note that the linearly homogenous assumption about the adjustment cost function $A(I, K)$ is not necessary, since the market value approach is not adapted. The production function was presumed linearly homogenous. Using the Euler's theorem, it can be rewritten as

$$F(K_{it}, N_{it}) = F_K(K_{it}, N_{it}) K_{it} + F_N(K_{it}, N_{it}) N_{it}. \quad (12)$$

Using equation (12), the definition in equation (4) and the optimality condition for N in equation (6), the marginal productivity of capital can be transformed to an observable variable as

$$F_K(K_{it}, N_{it}) = \frac{\pi(K_{it}, N_{it})}{p_{it}^I K_{it}}. \quad (13)$$

Hence, using equation (13) and dividing through p_{it}^I , equation (11) can be rewritten as

$$\begin{aligned} \frac{\pi(K_{it}, N_{it})}{p_{it}^I K_{it}} - A_K(I_{it}, K_{it}) - (1 + A_I(I_{it}, K_{it})) - \frac{1}{p_{it}^I} X_K(D_{it}, WC_{it}, K_{it}) \\ + E_t \beta_{it} (1 - \delta) \frac{p_{i,t+1}^I}{p_{it}^I} (1 + A_I(I_{i,t+1}, K_{i,t+1})) = 0. \end{aligned} \quad (11a)$$

To make the model operational, the external adjustment cost function can be presented as

$$A(I_u, K_u) = \frac{\Phi}{2} \left(\frac{I_u}{K_u} - \alpha \right) I_u \quad (14)$$

where Φ and α denote the adjustment cost parameter and the normal rate of investment. In equation (14), as the investment-capital ratio exceeds the normal rate of investment, the firm incurs external adjustment costs as a fraction of the undertaken investment. From here, the marginal adjustment costs for investment and capital can be derived as

$$A_I(I_u, K_u) = \Phi \left(\frac{I_u}{K_u} - \frac{\alpha}{2} \right) \quad (15)$$

and

$$A_K(I_u, K_u) = -\frac{\Phi}{2} \left(\frac{I_u}{K_u} \right)^2. \quad (16)$$

Finally, the agency/financial distress cost function is given as

$$X(D_u, WC_u, K_u) = h_1 \left(\frac{D_u}{p_u^I K_u} \right) D_u - h_2 \left(\frac{WC_u}{p_u^I K_u} \right) WC_u \quad (17)$$

where h_1 and h_2 are parameters to be estimated. The function is dependent positively on the debt-capital ratio, and negatively on the working capital-capital ratio. The debt-capital ratio is multiplied by the stock of debt and weighted with the parameter h_1 . This can be viewed as an additional cost on top of the interest paid for debt. The working capital-capital ratio is multiplied by the working capital and weighted with the parameter h_2 . Similarly, this can be viewed as an

additional return on top of the income obtained from working capital. Using equation (17), the necessary marginality condition for capital can be derived as

$$X_K(D_u, WC_u, K_u) = -h_1 \left(\frac{D_u}{p_u^I K_u^2} \right) D_u + h_2 \left(\frac{WC_u}{p_u^I K_u^2} \right) WC_u \quad (18)$$

which shows that as the capital stock increases, the agency/financial distress costs of debt decreases, but also that the smoothing benefits of working capital diminishes.

Using equations (15), (16) and (18) and rearranging equation (11a) gives an estimable investment equation via the Euler equation for capital

$$\begin{aligned} \left(\frac{I_u}{K_u} \right) - \frac{1}{2} \left(\frac{I_u}{K_u} \right)^2 &= \left(\frac{\alpha}{2} - \frac{1}{\Phi} \right) + \frac{1}{\Phi} \left(\frac{\pi_u(K_u, N_u)}{p_u^I K_u} \right) + E_t \beta_u (1 - \delta) \left(\frac{p_{i,t+1}^I I_{i,t+1}}{p_u^I K_{i,t+1}} \right) \\ &+ \left(\frac{1}{\Phi} - \frac{\alpha}{2} \right) E_t \beta_u (1 - \delta) \left(\frac{p_{i,t+1}^I}{p_u^I} \right) + \frac{h_1}{\Phi} \left(\frac{D_u}{p_u^I K_u} \right)^2 - \frac{h_2}{\Phi} \left(\frac{WC_u}{p_u^I K_u} \right)^2. \end{aligned} \quad (19)$$

In the estimations, the discount factor β_u is treated as a parameter and also the industry wide prices (p_t^I) are employed. Hence, by assuming that the expectations are rational and allowing for a forecast error ε_u , equation (19) can be transformed to a stochastic Euler equation as

$$\begin{aligned} \left(\frac{I_u}{K_u} \right) - \frac{1}{2} \left(\frac{I_u}{K_u} \right)^2 &= \left(\frac{\alpha}{2} - \frac{1}{\Phi} \right) + \frac{1}{\Phi} \left(\frac{\pi_u(K_u, N_u)}{p_u^I K_u} \right) + \beta(1 - \delta) \left(\frac{p_{t+1}^I I_{t+1}}{p_t^I K_{t+1}} \right) \\ &+ \left(\frac{1}{\Phi} - \frac{\alpha}{2} \right) \beta(1 - \delta) \left(\frac{p_{t+1}^I}{p_t^I} \right) + \frac{h_1}{\Phi} \left(\frac{D_u}{p_u^I K_u} \right)^2 - \frac{h_2}{\Phi} \left(\frac{WC_u}{p_u^I K_u} \right)^2 + \varepsilon_u \end{aligned} \quad (19a)$$

where $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$. In equation (19a), the first three variables (the profit-capital ratio, the expected investment-capital ratio and the expected price ratio) control the current investment ratio which is net of savings in the adjustment costs due to changes in the capital stock. Under the assumption of perfect capital markets, the agency/financial distress cost function $X(D_{it}, WC_{it}, K_{it})$ should not enter in the maximisation problem, hence the optimality condition for capital and investment. Thus, in this case, the final two terms, especially the squared debt-capital ratio, should not matter. However, if the agency/financial distress costs are binding, then the squared debt-capital ratio should be significant. Also, the squared working capital-capital ratio should be significant if the firms are using working capital policies to assist their investment decisions.

Section 4.3 Econometric Issues

For estimation purposes, by also considering the firm-specific effects, the investment equation in (19a) can be rewritten as

$$\begin{aligned}
 Y_{it} = & \Psi_0 + \Psi_1 \left(\frac{\pi_{it}}{p_{it}^I K_{it}} \right) + \Psi_2 \left(\frac{p_{t+1}^I I_{t,t+1}}{p_t^I K_{t,t+1}} \right) + \Psi_3 \left(\frac{p_{t+1}^I}{p_t^I} \right) \\
 & + \Psi_4 \left(\frac{D_{it}}{p_{it}^I K_{it}} \right)^2 + \Psi_5 \left(\frac{WC_{it}}{p_{it}^I K_{it}} \right)^2 + \eta_i + v_{it}
 \end{aligned} \tag{20}$$

where $Y_{it} = \left(\frac{I_{it}}{K_{it}} \right) - \frac{1}{2} \left(\frac{I_{it}}{K_{it}} \right)^2$, η_i denotes the firm-specific effects and $\eta_i + v_{it} = \varepsilon_{it}$, $\Psi_0 = \left(\frac{\alpha}{2} - \frac{1}{\Phi} \right)$, $\Psi_1 = \frac{1}{\Phi}$, $\Psi_2 = \beta(1 - \delta)$, $\Psi_3 = \left(\frac{1}{\Phi} - \frac{\alpha}{2} \right) \beta(1 - \delta)$, $\Psi_4 = \frac{h_1}{\Phi}$ and $\Psi_5 = -\frac{h_2}{\Phi}$. The coefficient Ψ_0 is the constant. Ψ_1 is the inverse of the adjustment cost parameter, and it should be positive. Ψ_2 denotes the discount factor including the economic depreciation rate, and it should be positive. Ψ_3 represents the coefficient for the expected price ratio, and its sign depends on the magnitudes of Φ and α . Ψ_4 is the coefficient on the squared debt-capital ratio, and it is expected to have a positive sign if agency costs of debt are binding. Ψ_5 represents the coefficient on the squared working capital-capital ratio, and it is expected to have a negative sign if working capital is employed as a source of finance.

As can be seen from equation (20), there is an obvious simultaneity problem because of the one-period ahead values of the investment-capital ratio. The simultaneity can also occur because of the debt/capital and working capital-capital ratios. Since debt and working capital decisions are not necessarily exogenous, they may well depend on management's knowledge of investment opportunities. When the error terms and explanatory variables are correlated, estimated parameters will be biased. Thus, the estimation of equation (20) requires to employ some sort of instrumental variables which will be orthogonal to the error

terms. Observe from equation (20) that removing the means to eliminate the firm-specific effects may violate the orthogonality conditions and thereby cause estimation bias. Therefore, instead of estimating the model in levels, the first-difference of the model was employed as suggested by Anderson and Hisao (1982). This eliminates the firm-specific effects as

$$\begin{aligned}\Delta Y_{it} = & \Psi_1 \Delta \left(\frac{\pi_{it}}{p_{it}^I K_{it}} \right) + \Psi_2 \Delta \left(\frac{p_{t+1}^I I_{i,t+1}}{p_t^I K_{i,t+1}} \right) + \Psi_3 \Delta \left(\frac{p_{t+1}^I}{p_t^I} \right) \\ & + \Psi_4 \Delta \left(\frac{D_{it}}{p_{it}^I K_{it}} \right)^2 + \Psi_5 \Delta \left(\frac{WC_{it}}{p_{it}^I K_{it}} \right)^2 + \Delta v_{it}.\end{aligned}\quad (21)$$

where Δ denotes the first-difference operator. For the estimation of equation (21), the generalised method of moments (GMM) technique outlined in Hansen (1982) was used. Hansen and Singleton (1982) describe how the GMM technique can be used for estimating the parameters of dynamic objective functions of decision makers without solving for the stochastic equilibrium, with an application for an intertemporal asset pricing model. Arellano (1989) shows that the estimator that uses the levels instead of differences as instruments has much smaller variances. Following his suggestion, for the estimation of equation (21), time $t-2$ and $t-3$ instruments in levels were employed, which will still be orthogonal to the moving-average error that is caused by the first-difference of the model. However, time $t-2$ values of the one-period ahead investment-capital ratio would be time $t-1$ values, thus violating the orthogonality conditions. In addition, the difference between Y_{it} and the investment-capital ratio is only the squared investment-capital

ratio, making them almost the same. Considering this, the employed instrument set S can be presented as

$$S = \left\{ Y_{i,t-2}, Y_{i,t-3}, \frac{\pi_{i,t-2}}{p_{i,t-2}^I K_{i,t-2}}, \frac{\pi_{i,t-3}}{p_{i,t-3}^I K_{i,t-3}}, \frac{p_{i,t-2}^I}{p_{i,t-3}^I}, \frac{p_{i,t-3}^I}{p_{i,t-4}^I}, \left(\frac{D_{i,t-2}}{p_{i,t-2}^I K_{i,t-2}} \right)^2, \right. \\ \left. \left(\frac{D_{i,t-3}}{p_{i,t-3}^I K_{i,t-3}} \right)^2, \left(\frac{WC_{i,t-2}}{p_{i,t-2}^I K_{i,t-2}} \right)^2, \left(\frac{WC_{i,t-3}}{p_{i,t-3}^I K_{i,t-3}} \right)^2 \right\}. \quad (22)$$

To estimate the necessary parameters, first a preliminary two-stage least square (2SLS) estimation was carried out to construct the required optimal weighting matrix. The first-step 2SLS estimation of the parameters can be written as

$$\hat{\Psi} = (\Delta X'Z(Z'Z)^{-1}Z'\Delta X)^{-1}\Delta X'Z(Z'Z)^{-1}Z'\Delta Y \quad (23)$$

where ΔY is $NT \times 1$ stacked vector of observations on ΔY_{it} , ΔX is a $NT \times K$ matrix and each column of it represents the stacked observations on the right-hand side variables, and Z is a $NT \times J$ matrix and each column of it represents the stacked observations on the employed instruments. Here, NT , K , and J denote the total sample size, the number of the right-hand side variables, and the number of the instruments, respectively. The variance-covariance matrix of the estimated parameters will be

$$\text{var}(\hat{\Psi}) = \sigma_{\Delta y}^2 (\Delta X'Z(Z'Z)^{-1}Z'\Delta X)^{-1}. \quad (24)$$

Then, using the estimated residuals of the first-step estimator, the optimal weighting matrix can be constructed as

$$W_M = (Z'\hat{\Delta}\hat{\Delta}'Z) \quad (25)$$

where $\Delta\hat{v}$ is the $NT \times 1$ vector of residuals from the first-step estimation. As a second-step, by using this optimal weighting matrix, the GMM estimation can be carried out as

$$\hat{\Psi} = (\Delta X'Z(W_M)^{-1}Z'\Delta X)^{-1}\Delta X'Z(W_M)^{-1}Z'\Delta Y \quad (23a)$$

where

$$\text{var}(\hat{\Psi}) = \sigma_{\Delta v}^2 (\Delta X'Z(W_M)^{-1}Z'\Delta X)^{-1}. \quad (24a)$$

The weighting matrix given above does not account for possible heteroscedasticity or autocorrelation. For a more efficient estimation, the weighting matrix was altered by employing the method presented in Newey and West (1987) to obtain a heteroscedasticity and first-order autocorrelation consistent covariance matrix. The GMM estimation is based on the moment conditions between the instruments and the error terms. Thus, the minimum distance estimator will be $\hat{\Psi}$ that minimises

$$\Delta v'ZW_M^{-1}Z'\Delta v. \quad (26)$$

As suggested by Hansen (1982), to test the orthogonality conditions between the error terms and the instruments, one can test whether the minimum distance criteria is significantly different than zero. The test statistic is given as

$$\Delta v'ZW_M^{-1}Z'\Delta v \xrightarrow{d} \chi_{(J-K)}^2 \quad (27)$$

where J denotes the number of instruments employed, and K represents the number of parameters in the model. Actually the test is an extension of an earlier test proposed by Sargan (1958). The H_0 hypothesis claims that the imposed moment conditions will be zero, and the alternative H_1 hypothesis says that it will

be significantly different from zero. If $J \leq K$, the model will be under-identified or exactly identified, and there will be nothing to test. Therefore, to be able to test the validity of the moment conditions, or in other terms, the validity of the employed instruments, one must over-identify the model by setting $J > K$.

The resulting GMM estimator described above does not cover all the available moment conditions between the error terms and the instruments. For instance, Arellano and Bond (1991) suggest using additional available instruments. Baltagi (1995) chapter 8 covers a survey on this topic. However, although in a single linear static equation context, Biørn and Klette (1998) show that only a small fraction of the potential orthogonality conditions are essential, namely those based on one-period and two-period differences.

Section 4.4 Data and Estimation Results

The estimations were carried out for the UK, Germany and France. Panel data was collected from Datastream for the firms which are gathered under the general industries classification. As in chapter 2, these companies constitute many of the largest industrial companies in the UK, Germany and France. Most of the studies that investigate financial factors' effect on investment decisions include large numbers of small firms in their samples. Unlike these, in this study only large firms were investigated, and the findings make more sense in terms of the whole economy since these firms form a very large fraction of the total investment.

Table 4.1 gives information about the size of the companies employed by using the average values of the market value of equity from 1992 to 1996 in terms of each countries' currency. Figures ranging from hundred of millions to billion pounds, marks and francs show that the firms are notably large.

Table 4.1 Size Information About the Firms

UK-76 Firms				
'000,000	Mean	Median	Stdev.	No. of Firms
0-250	172.35	180.33	38.87	20
250-500	377.61	370.87	84.90	18
500-1000	714.64	706.99	116.34	15
1000-2000	1,373.63	1,324.23	297.89	12
2000 and Over	3,897.70	2,309.00	2,832.47	11

Germany-38 Firms				
'000,000	Mean	Median	Stdev.	No. of Firms
0-250	245.01	245.01	-	1
250-500	423.45	473.04	84.18	5
500-1000	714.02	710.59	137.41	9
1000-2000	1,406.64	1,413.20	41.87	5
2000 and Over	10,231.63	4,932.70	10,385.23	18

France-26 Firms				
'000,000	Mean	Median	Stdev.	No. of Firms
0-250	-	-	-	-
250-500	-	-	-	-
500-1000	780.87	792.21	148.97	4
1000-2000	1,544.51	1,634.40	338.17	5
2000 and Over	13,945.65	7,210.00	15,285.35	17

Because the model includes squared variables, to reduce the measurement errors the companies with very excessive values were excluded from the samples. For the UK panel data was collected for 76 companies for the period 1982-1996 for

Table 4.2 Summary Statistics of the Model Variables

United Kingdom	Nobs.	Mean	Stdev.	Min.	Max.
ΔY_{it}	836	-0.0038	0.0684	-0.3363	0.3019
$\Delta(\pi_{it} / p_{it}^I K_{it})$	836	-0.0010	0.0824	-0.8897	0.7890
$\Delta(p_{i,t+1}^I I_{i,t+1} / p_t^I K_{i,t+1})$	836	-0.0055	0.0923	-0.5723	0.5051
$\Delta(p_{i,t+1}^I / p_t^I)$	836	-0.0039	0.0322	-0.0573	0.0564
$\Delta(D_{it} / p_{it}^I K_{it})^2$	836	-0.0041	0.2941	-4.2337	4.5909
$\Delta(WC_{it} / p_{it}^I K_{it})^2$	836	-0.0727	1.0476	-7.6021	13.0540
Germany	Nobs.	Mean	Stdev.	Min.	Max.
ΔY_{it}	190	-0.0066	0.0266	-0.0863	0.0694
$\Delta(\pi_{it} / p_{it}^I K_{it})$	190	-0.0086	0.0406	-0.2371	0.1259
$\Delta(p_{i,t+1}^I I_{i,t+1} / p_t^I K_{i,t+1})$	190	-0.0114	0.0292	-0.1058	0.0813
$\Delta(p_{i,t+1}^I / p_t^I)$	190	-0.0102	0.0068	-0.0174*	-0.0002
$\Delta(D_{it} / p_{it}^I K_{it})^2$	190	-0.0017	0.0382	-0.1618	0.2937
$\Delta(WC_{it} / p_{it}^I K_{it})^2$	190	-0.0632	0.2338	-1.2628	1.3433
France	Nobs.	Mean	Stdev.	Min.	Max.
ΔY_{it}	130	-0.0070	0.0291	-0.0961	0.1051
$\Delta(\pi_{it} / p_{it}^I K_{it})$	130	-0.0074	0.0521	-0.1667	0.1798
$\Delta(p_{i,t+1}^I I_{i,t+1} / p_t^I K_{i,t+1})$	130	-0.0078	0.0324	-0.1185	0.1008
$\Delta(p_{i,t+1}^I / p_t^I)$	130	-0.0064	0.0112	-0.0269	0.0039
$\Delta(D_{it} / p_{it}^I K_{it})^2$	130	-0.0280	0.1091	-0.5587	0.4761
$\Delta(WC_{it} / p_{it}^I K_{it})^2$	130	-0.0891	0.3290	-1.6827	1.0969

fifteen years. For Germany and France, the available number of companies that had the whole necessary data set dropped significantly over the period of 1982-1996. Thus, the time dimension was constrained for the period 1988-1996 for nine

years. For Germany, data for 38 companies, and for France, data for 26 companies were obtained. First-differencing the data, and also using time $t-2$ and $t-3$ values in levels as instruments, gave a total sample size of 836 for the UK, 190 for Germany, and 130 for France. Table 4.2 gives the summary statistics for the model variables over the estimation period.

The construction of the necessary variables and related Datastream codes are as follows. To calculate the replacement values of capital ($p'K$), the unobservable economic depreciation rates (δ) were required. Thus, as in section 2.6, the equation of motion for the capital described in equation (3) was solved as a non-linear system by employing firm-level panel data. The system contains 14 equations for the UK, and 8 equations for Germany and France. The obtained results were as

Parameter	UK	Germany	France
δ	0.0616 (0.0017)	0.0833 (0.0049)	0.0454 (0.0054)

where the standard errors of the estimated parameters are reported in parentheses.

As in section 2.6, by using the estimated economic depreciation rates, the necessary replacement values for the capital figures were calculated from the perpetual inventory formula by employing the total new fixed asset figures [435 for Germany and France, and 435 and 1024 for the UK], and the historical values of capital [330 for the UK and France, and 2005 for Germany]. The price index (p') is the implicit price deflator of gross fixed capital formation, which is

Table 4.3 GMM Estimation of the Euler Equations: All Firms

UNITED KINGDOM - (76 Firms, 11 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.4847	0.2005	2.4177	0.0156
Ψ_2	0.2858	0.2222	1.2860	0.1985
Ψ_3	0.4018	0.2252	1.7839	0.0744
Ψ_4	0.1045	0.0719	1.4544	0.1458
Ψ_5	-0.0262	0.0124	-2.1108	0.0348
Test Result			Significance	
Hansen $\chi^2(6)$	9.5342		0.1457	
GERMANY - (38 Firms, 5 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.3308	0.2065	1.6012	0.1092
Ψ_2	0.6299	0.2923	2.1551	0.0312
Ψ_3	0.5227	0.2615	2.0758	0.0379
Ψ_4	0.5395	0.2799	1.9269	0.0540
Ψ_5	-0.1667	0.0580	-2.8737	0.0041
Test Result			Significance	
Hansen $\chi^2(6)$	4.8445		0.5639	
FRANCE - (26 Firms, 5 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.4441	0.1036	4.2854	0.0000
Ψ_2	0.4275	0.2879	1.4847	0.1376
Ψ_3	-0.1117	0.4697	-0.2379	0.8120
Ψ_4	0.1010	0.0349	2.8940	0.0038
Ψ_5	-0.0292	0.0257	-1.1360	0.2560
Test Result			Significance	
Hansen $\chi^2(6)$	10.8027		0.0947	

[UKIPDMNIF] for the UK, [BDIPDCAPE] for Germany and [FRIPDCFME] for France. For the profit, debt and working capital figures, respectively, pre-tax profits [154], total debt [309+321], and total working capital [376] figures were employed.

To test whether the agency/financial distress costs of debt are important for investment decisions, the first-difference of the stochastic Euler equation for capital given in equation (21) was estimated using the GMM technique as described in the previous section. For possible time effects, the inclusion of time dummies were considered via the residual sum of squares criteria. The Euler equations were estimated both with and without time dummies. In all cases, the inclusion of time dummies increased the value of the residual sum of squares. Thus, the reported results do not include time dummies. As can be seen from table 4.3, the results of the over-identifying restriction (Hansen) tests indicate that the instruments are orthogonal to the error terms for the three panels, validating the imposed moment conditions and the instruments employed in the estimations. Note that the H_0 hypothesis claims that the error terms and the instruments are not correlated. Thus, the higher the p -value of the test, the less the probability of making a mistake in accepting the H_0 hypothesis. The standard errors and the t -tests in table 4.3 are robust to general heteroscedasticity and first-order autocorrelation, where the correction was made via the Newey-West procedure.

The estimation results for Ψ_1 parameters are very significant, and they all have positive signs as expected. They are, respectively, 0.48, 0.33 and 0.44 for the UK, Germany and France with t -statistics of 2.42, 1.60 and 4.29. These are the coefficients on the profit-capital ratios, and they are the inverse of the adjustment cost parameters Φ . The results are at quite reasonable levels compared to the adjustment cost parameters estimated in section 2.7. Obviously this result is due

to the elimination of the shadow value of capital, and employment of the Euler equation method for estimating the investment-capital ratios. The Ψ_2 parameters imply the inverse cost of capital values, and they all appear with positive signs as in equation (21). Although the estimated coefficients are unreasonably high, observe from equation (7a) that this is qualitatively consistent with the model assumptions, since the cost of debt also includes the associated agency/financial distress costs of debt as an additional premium. The signs of the price coefficients Ψ_3 depend on the magnitudes of the adjustment cost parameters and the normal rate of investment parameters for each country. They appear significant with positive signs for the UK and Germany, and negative and insignificant for France.

More importantly, observe from equation (17) that the agency/financial distress cost of debt was given as a function of debt, working capital, and capital. It was hypothesised that if the agency/financial distress costs of debt are important, then there should be a positive relation between the investment-capital ratio and the squared debt-capital ratio. On the other hand, it was also discussed that firms might smooth these pressures and costs via their working capital policy. In this case, it was hypothesised that there should be a negative relation between investment-capital and squared working capital-capital ratios. Estimation results reveal that the Ψ_4 coefficients are all positive. Although the corresponding t -ratio is only 1.45 for UK firms, it is significant at 6% level for German firms and 1% level for French firms. Also, as expected according to the model

assumptions, the Ψ_5 coefficients appear with negative signs for the UK, Germany and France with t -ratios of -2.11, -2.87 and -1.14, respectively.

Obviously, the results indicate that the agency/financial distress costs are binding so that debt financing matters, playing a significant role in management's investment decisions. However, to some extent, firms have the ability to smooth these pressures and alleviate the costs by the way of their working capital policy. As proposed earlier, a possible explanation for this result is that when lenders cannot perfectly observe the acts of managers or the quality of the projects that the firm is undertaking, they may charge additional agency costs as an insurance premium. For instance, as in Smith and Warner (1979), to protect themselves, debt holders may demand covenants that restrict management behaviour in various ways. From the firm's point of view, this would create an additional external financing premium in addition to the interest rate on debt, which may have negative effects on the managers' real investment decisions. With higher levels of debt, it is likely that the value of tax savings due to additional borrowings may disappear because of the additional financial distress costs. Further, higher levels of debt may also increase the likelihood of bankruptcy and the firms may not be able borrow further.

Section 4.5 Splitting The Sample

In section 4.2, it was argued that if there are imperfections in the credit markets, possible agency/financial distress costs of debt may affect the investment decisions in negative ways. Considering the possible smoothing effects of the working capital policies, evidence was given of the above-mentioned hypothesis for the firms under study. However, it is likely that the firms with higher leverage ratios will face more significant costs and pressures of debt. In this section, to measure these possibilities, the model presented in equation (21) is tested for firms with different levels of indebtedness for the three countries. Thus, the three samples for the UK, Germany and France were split into two subsamples according to their book leverage ratios.

Table 4.4 gives the summary statistics for the leverage ratios of the low-leverage and high-leverage groups for the three countries. The sample split criterion is the arithmetic average of the mean and the median of each sample. The split criterion is 28.86% for the UK firms, 19.05% for the German firms and 42.46% for the French firms. The number of firms in the low-leverage group is 34 out of 76 firms for the UK, 21 out of 38 firms for Germany, and 14 out of 26 firms for France. Among the three countries, the French firms under investigation appear with the highest average leverage ratio of 43.35%, whereas the German firms appear with the lowest average leverage ratio of 20.24%.

Table 4.4 Summary Statistics of Leverage Ratios

UK-LEVERAGE (%), 1983-1996						
	Mean	Median	Stdev.	Min.	Max.	Number
All Firms	28.2129	29.5136	9.1669	7.2621	53.9236	76
Low-Leverage	20.1695	21.3054	5.6454	7.2621	28.5700	34
High-Leverage	34.7243	33.4057	5.5664	29.0343	53.9236	42

GERMANY-LEVERAGE (%), 1989-1996						
	Mean	Median	Stdev.	Min.	Max.	Number
All Firms	20.2431	17.8638	12.4678	2.4888	54.1363	38
Low-Leverage	11.3909	11.6300	5.3453	2.4888	19.0263	21
High-Leverage	31.1782	27.5325	9.6877	19.3650	54.1363	17

FRANCE-LEVERAGE (%), 1989-1996						
	Mean	Median	Stdev.	Min.	Max.	Number
All Firms	43.3457	41.5825	17.8422	15.5750	88.7388	26
Low-Leverage	30.4703	31.6969	8.4249	15.5750	41.6475	14
High-Leverage	58.3669	59.3531	13.5088	42.8783	88.7388	12

Using the subsamples described above, estimations were carried out first for the low-leverage group, and then for highly leveraged firms. Table 4.5 gives the GMM estimation results for the low-leverage groups for the three countries. The results are robust to general heteroscedasticity and first-order autocorrelation. The over-identifying restriction tests indicate that the employed instruments are valid for the three countries. The estimated Ψ_1 , Ψ_2 and Ψ_3 parameters all appear with the expected positive signs. However, some of the parameters are not very significant, especially the Ψ_1 parameter for Germany. Interestingly, the Ψ_4 parameters appear to be insignificant for all countries. It comes with a positive sign, but it has a t -ratio of 1.33 for the UK. Although it is positive for France, it comes with a very insignificant t -ratio. For German firms, it comes with

Table 4.5 GMM Estimation of the Euler Equations: Low-Leverage Group

UNITED KINGDOM - (34 Firms, 11 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.5978	0.2648	2.2573	0.0240
Ψ_2	0.3055	0.2611	1.1702	0.2419
Ψ_3	0.5415	0.3720	1.4555	0.1455
Ψ_4	0.1977	0.1492	1.3250	0.1852
Ψ_5	-0.0418	0.0232	-1.8068	0.0708
Test Result			Significance Level	
Hansen $\chi^2(6)$	8.3220		0.2155	
GERMANY - (21 Firms, 5 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.1311	0.1671	0.7845	0.4327
Ψ_2	0.3771	0.3076	1.2261	0.2202
Ψ_3	0.6180	0.3093	1.9979	0.0572
Ψ_4	-0.3866	0.6445	-0.5999	0.5486
Ψ_5	-0.0421	0.0375	-1.1247	0.2607
Test Result			Significance Level	
Hansen $\chi^2(6)$	9.0255		0.1722	
FRANCE - (14 Firms, 5 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.3758	0.2298	1.6355	0.1020
Ψ_2	0.4763	0.3088	1.5423	0.1230
Ψ_3	0.6483	0.5576	1.1626	0.2450
Ψ_4	0.0121	0.0890	0.1361	0.8917
Ψ_5	-0.0455	0.0291	-1.5664	0.1173
Test Result			Significance Level	
Hansen $\chi^2(6)$	5.7188		0.4554	

a negative and very insignificant sign. On the other hand, the Ψ_5 parameters appear with the expected negative signs for the three countries. The t -ratios for these parameters are -1.81 for UK firms, -1.12 for German firms and -1.57 for

Table 4.6 GMM Estimation of the Euler Equations: High-Leverage Group

UNITED KINGDOM - (42 Firms, 11 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.5860	0.2532	2.3301	0.0198
Ψ_2	0.0301	0.0310	0.0970	0.9227
Ψ_3	0.2607	0.2598	1.0033	0.3157
Ψ_4	0.0633	0.0338	1.8724	0.0611
Ψ_5	-0.0192	0.0086	-2.2308	0.0198
Test Result			Significance Level	
Hansen $\chi^2(6)$	6.5594		0.3635	
GERMANY - (17 Firms, 5 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.2920	0.1528	1.9107	0.0560
Ψ_2	0.2615	0.2023	1.2926	0.1962
Ψ_3	0.3134	0.3974	0.7887	0.4303
Ψ_4	0.3080	0.1558	1.9765	0.0481
Ψ_5	-0.0583	0.0322	-1.8132	0.0698
Test Result			Significance Level	
Hansen $\chi^2(6)$	10.8577		0.0929	
FRANCE - (12 Firms, 5 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.2365	0.0778	3.0393	0.0024
Ψ_2	0.1902	0.2104	0.9039	0.3660
Ψ_3	-0.3448	0.4963	-0.6948	0.4872
Ψ_4	0.0626	0.0273	2.2946	0.0218
Ψ_5	0.0109	0.0157	0.6955	0.4868
Test Result			Significance Level	
Hansen $\gamma^2(6)$	7.7999		0.2531	

French firms. Not surprisingly, the results suggest that the low-leverage groups do not face significant agency/financial distress costs of debt. In other words, the hypothesised costs and pressures do not bind the investment decisions of these firms, and debt policy does not matter for their investment decisions. In addition,

the results reveal that, although not significantly, these firms use their working capital policies to assist their investment activities.

Table 4.6 presents the results for the high-leverage groups. The over-identifying restriction tests verify the imposed moment conditions and the employed instruments. The Ψ_1 parameters on the profit-capital ratios all appear with positive significant signs. The Ψ_2 and Ψ_3 coefficients appear to be very insignificant. Moreover, the Ψ_2 coefficients come with very small values, implying unjustifiable cost of capital measures. However, as mentioned earlier, this observation is qualitatively inline with the agency/financial distress costs of debt argument.

As expected, the Ψ_4 parameters all appear with positive and significant signs. The related t -ratios are 1.87 for the UK, 1.98 for Germany and 2.29 for France, implying significant agency/financial distress costs of debt. Although the Ψ_5 parameter appears with an opposite and very insignificant t -ratio for French firms, the results suggest that UK and German firms significantly use their working capital policies to smooth these costs and pressures. Overall, the findings show that the agency/financial distress costs of debt matter for the high-leverage groups, implying important interactions between financing and investment decisions.

Section 4.6 Concluding Remarks

Both the Q theory and neo-classical theory of investment draw on the proposition of Modigliani and Miller, assuming perfectly operating financial markets and exogenous financing decisions. However, information and incentive problems may create frictions in financial capital markets and undermine the MM theory's applicability which assumes perfect capital markets. The imperfect substitution between internally generated and externally raised funds due to imperfect information and incentive problems can create an external financing premium. Moreover, some firms might be under financial distress, or even credit rationed. Thus, unlike Modigliani and Miller's irrelevance result, financing conditions may have important implications on investment decisions.

Studies testing the possible relations between investment and financing decisions mostly documented cash flow and liquidity effects. However, existing empirical studies about the effects of incentive problems on investment decisions reveal a controversy while at the same time showing that empirical investigations into these effects are important. Thus, in this chapter, using the Euler equation approach and based on the agency/financial distress costs of debt, an investment equation was derived to test the role of debt financing conditions on investment decisions. In the model, we also considered the possible beneficiary role of working capital on the asset side of the balance sheet to smooth these costs.

Using panel data, the analyses were carried out for the UK, Germany and France. In the model, it was hypothesised that if the agency/financial distress costs of debt were binding, then the squared debt-capital ratio in the investment equation should appear with a significant positive coefficient. Similarly, if the firms were using their working capital policy to smooth these costs, the squared working capital-capital ratio should have a significant negative coefficient. The estimation results revealed that the perfect financial capital markets hypotheses were not acceptable. According to the developed model, the agency/financial distress costs of debt were important so that debt financing had a significant role in management's investment decisions. However, to some extent, firms had the ability to smooth these costs and alleviate pressures through their working capital policy on the asset side of their balance sheets.

It was argued that, more likely, the firms with higher leverage ratios would face more significant costs and pressures of debt. To measure these possibilities, the model was tested for firms with different levels of indebtedness for the three countries. Thus, the samples were split into two subsamples according to their book leverage ratios. Not surprisingly, the results revealed that the agency/financial distress costs of debt did matter for the high-leverage groups, whereas it was not significant for the low-leverage groups.

Overall, the results show that imperfections in the markets exist, financing and investment decisions interact, and the financing conditions have important

implications for investment decisions. Naturally, these effects are in different magnitudes and combinations in different countries. However, it is for the high-leverage group of all three countries that these hypothesised costs and pressures of debt matter. The agency costs of debt might occur when lenders cannot perfectly observe the acts of managers or the quality of the projects that the firm is undertaking. They may charge additional agency costs as an insurance premium to protect themselves and/or restrict management behaviour in various ways. Higher levels of debt may create additional financial distress costs, increase the likelihood of bankruptcy, and restrict the firms to borrow further. Moreover, as discussed in Myers (1977), in the case of a highly leveraged firm, since most of the return from a positive net present value project will be distributed to debt holders, the managers may not be willing to exploit all the available growth opportunities if they are acting in the shareholders' interests.

The findings of this study imply important effects for the three economies, since it was conducted by using only large industrial firms which constitute a very large fraction of the total investment in the UK, German and French economies. Thus, contrary to Miller's argument, leverage increases by corporations may increase the economy-wide costs, risk and financial distress.

CHAPTER 5

CAPITAL MARKET IMPERFECTIONS, THE Q RATIO AND INVESTMENT: THE UK CASE

Section 5.1 Introduction

In the previous chapter, based on the stochastic Euler equation for capital, an investment equation was derived to test the possible relationships between investment decisions and balance sheet variables. In this approach the unobservable shadow value of capital was eliminated via substitution. In this chapter, an alternative model will be derived in which the unobservable shadow value of capital will be converted to an observable one, again by considering the possible agency/financial distress costs of debt. The possible smoothing benefits of the working capital will also be taken into account. An application will be carried out for UK firms to test this alternative representation.

The approach is an extended version of the standard Q model of investment which considers the possible imperfections in the capital markets and the interactions between financing and investment decisions. The next section presents the model developed in a continuous time framework and a tax-free world. It starts from the usual value maximisation objective. In this structural model, investment becomes a function of marginal q . Section 5.3 converts the unobservable marginal q to an

observable one under the model assumptions. Section 5.4 presents the data and the estimation results. The final section concludes.

Section 5.2 The Model

In the model, for simplicity, we assume a tax-free world. As in chapter 4, the net equity issue policy is taken as exogenous. By ruling out any bubbles, the usual continuous time value maximisation objective can be presented as

$$V(0) = \max \int_0^{\infty} e^{-\rho t} [Div(0) - NE(0)] dt \quad (1)$$

where the terms ρ , NE and Div denote the required nominal rate of return, the new equity issue and the dividend, respectively. For ease of exposition, both the firm and the time notations will be suppressed. Four constraints are introduced into the maximisation problem. The first one is the motion of capital stock

$$\frac{dK}{dt} = I - \delta K \quad (2)$$

where K , I and δ represent the capital stock, the investment and the depreciation rate. The second and the third constraints are the motion of debt and working capital as

$$\frac{dD}{dt} = B \quad (3)$$

$$\frac{dWC}{dt} = L \quad (4)$$

where D and B denote the stock of debt and net borrowing, and WC and L denote the working capital and the net change in the working capital. It is assumed that the agency/financial distress costs of debt depend on the level of the stock of debt and on net borrowing. Additionally, the possible smoothing role of working capital is considered. It is assumed that this smoothing function depends on the net change in working capital and on the level of working capital stock. Also, the usual external adjustment costs of investment are considered. Hence, the final constraint is for the definition of dividend which includes the adjustment costs of capital, the possible agency/financial distress costs of debt, and the smoothing benefits of the working capital as

$$Div = [pF(K, N) - wN - p^I(I + A(I, K)) + NE - r(D + X(B, D)) + B + m(WC + S(L, WC)) - L] \quad (5)$$

where $F(K, N)$ is the production function, $A(I, K)$ the strictly convex external adjustment cost function, $X(B, D)$ the agency/financial distress cost function, $S(L, WC)$ the smoothing benefit function, p the price of output, N the variable input vector, w the nominal price vector of the variable input vector, p^I the price of investment good, r the nominal interest rate on debt, m the nominal rate of return on working capital.

The functional relationships $F(K, N)$, $A(I, K)$, $X(B, D)$ and $S(L, WC)$ are all assumed to be linearly homogenous in their arguments. Further, it is postulated that the agency/financial distress costs of debt are positively dependent on net borrowing and stock of debt, and priced in terms of the nominal interest rate on debt. Similarly the smoothing benefits are positively dependent on net change in

working capital and stock of working capital and priced in terms of the nominal rate of return on working capital. By ignoring the linear term, the quadratic external adjustment cost function is introduced as

$$A(I, K) = \frac{1}{\Phi} \left(\frac{I}{K} - \alpha \right)^2 K \quad (6)$$

where, Φ is the adjustment cost parameter and α is the normal rate of investment.

Using the four constraints, the maximisation problem in equation (1) can be rewritten as

$$V = \max \int_0^{\infty} e^{-\rho t} [pF(K, N) - wN - p^I (I + A(I, K)) + B - r(D + X(B, D)) - L \\ + m(WC + S(L, WC)) + \lambda(I - \delta K - dK/dt) + \Gamma(B - dD/dt) + H(L - dWC/dt)] dt \quad (7)$$

where the symbols λ , Γ and H represent the related Lagrange multipliers.

Respectively, the first-order conditions for N , K , I , D , B , WC and L will be

$$p \frac{\partial F(K, N)}{\partial N} = w \quad (8)$$

$$\frac{d\lambda}{dt} = (\rho + \delta)\lambda - p \frac{\partial F(K, N)}{\partial K} + p^I \frac{\partial A(I, K)}{\partial K} \quad (9)$$

$$\lambda = \int_t^{\infty} e^{-(\rho+\delta)s} [p \frac{\partial F(K, N)}{\partial K} - p^I \frac{\partial A(I, K)}{\partial K}] ds \quad (9a)$$

$$\lambda = p^I + p^I \frac{\partial A(I, K)}{\partial I} \quad (10)$$

$$\frac{d\Gamma}{dt} = \rho\Gamma + r + r \frac{\partial X(B, D)}{\partial D} \quad (11)$$

$$-\Gamma = \int_t^{\infty} e^{-\rho s} [r + r \partial X(B, D) / \partial D] ds \quad (11a)$$

$$-\Gamma = 1 - r \frac{\partial X(B, D)}{\partial B} \quad (12)$$

$$\frac{dH}{dt} = \rho H - m - m \frac{\partial S(L, WC)}{\partial WC} \quad (13)$$

$$H = \int_t^{\infty} e^{-\rho s} [m + m \partial S(L, WC) / \partial WC] ds \quad (13a)$$

$$H = 1 - m \frac{\partial S(L, WC)}{\partial L} \quad (14)$$

Equation (8) denotes the usual marginal productivity condition for the variable input vector. Solving the optimality condition for capital in equation (9) yields equation (9a), showing the equality between the present discounted value of the marginal revenue attributable to a unit of installed capital and the shadow price of capital. The optimality condition for I in equation (10) states that the firm chooses the rate of investment so as to equate the value of an additional unit of newly installed capital to its purchase price plus the marginal adjustment cost.

Equation (11) is the shadow value of debt, and solving this equation gives equation (11a). Equation (11a) states that the marginal cost of additional debt is the present value of the nominal interest rate on debt plus the associated marginal agency/financial distress costs. Since debt is a liability, the shadow value comes with a negative sign. Equation (12) shows that the marginal benefit of this additional debt equals the receipts minus the associated agency/financial distress

costs. At the steady state, by using the condition derived in equation (12), equation (11) also implies that the firm should conduct the debt policy so as to equate the marginal cost of debt and equity along the optimal path. Solving the optimality condition for working capital gives equation (13a), indicating that the marginal benefit of additional working capital is the present value of the nominal rate of return on working capital plus the associated marginal smoothing benefits. Finally, equation (14) states that the marginal cost of this additional working capital will be the unit of spending net of the associated smoothing benefits.

Next, using equation (6) and manipulating equation (10) yields an investment equation as

$$\frac{I}{K} = \alpha + \frac{1}{\Phi} \left(\frac{\lambda}{p^I} - 1 \right). \quad (15)$$

Since p^I and λ are, respectively, the unit purchase price and the shadow value of capital, the term (λ / p^I) can be defined as Tobin's marginal q . As usual, equation (15) implies that if marginal q is greater than one, then the marginal value of the project exceeds its replacement cost and the firm should undertake the project, or vice versa. However, in practice it is not possible to observe the marginal q , and for the purpose of estimation it should be converted to an observable variable.

Section 5.3 The Observable Q

In this section we derive an empirically feasible expression for the unobservable marginal q ratio under the imperfect financial capital markets considering the assumptions of the model.

Proposition: For the model which is described above, an observable relation such as

$$\frac{\lambda(0)}{p^I(0)} = \frac{V(0) + D(0) - WC(0) - (1 + \Gamma(0))D(0) + (1 - H(0))WC(0)}{p^I(0)K(0)} \quad (16)$$

holds along the optimal path, if and only if the functions $F(K, N)$, $A(I, K)$, $X(B, D)$ and $S(L, WC)$ are linearly homogeneous in their arguments.

Proof: Using the linearly homogeneous assumption for $F(K, N)$, $A(I, K)$, $X(B, D)$ and $S(L, WC)$, from the Euler's theorem

$$F(K, N) = \frac{\partial F(K, N)}{\partial K} K + \frac{\partial F(K, N)}{\partial N} N \quad (17)$$

$$A(I, K) = \frac{\partial A(I, K)}{\partial I} I + \frac{\partial A(I, K)}{\partial K} K \quad (18)$$

$$X(B, D) = \frac{\partial X(B, D)}{\partial B} B + \frac{\partial X(B, D)}{\partial D} D \quad (19)$$

$$S(L, WC) = \frac{\partial S(L, WC)}{\partial L} L + \frac{\partial S(L, WC)}{\partial WC} WC. \quad (20)$$

Using the conditions derived in equations (8) and (17), the marginal productivity condition of capital will be

$$\frac{\partial F(K, N)}{\partial K} = \frac{pF(K, N) - wN}{pK}. \quad (21)$$

Consider the term $[\lambda K + (1 + \Gamma)D - (1 - H)WC]e^{-\rho t}$. The time derivative of this term can be written as

$$\begin{aligned} \frac{d[\lambda K + (1 + \Gamma)D - (1 - H)WC]e^{-\rho t}}{dt} = & [(d\lambda/dt)K + \lambda(dK/dt) - \rho\lambda K + (d\Gamma/dt)D \\ & + \Gamma(dD/dt) - \rho\Gamma D + (dH/dt)WC + H(dWC/dt) - \rho HWC \\ & - (dWC/dt) + \rho WC]e^{-\rho t}. \end{aligned} \quad (22)$$

Using equations (2), (3), (4), (9), (11) and (13), the equality in equation (22) can be rewritten as

$$\begin{aligned} d[\lambda K + (1 + \Gamma)D - (1 - H)WC]e^{-\rho t} = & [((\rho + \delta)\lambda - p\partial F(K, N)/\partial K + p^I \partial A(I, K)/\partial K)K \\ & + \lambda(I - \delta K) - \rho\lambda K + (\rho\Gamma + r + r\partial X(B, D)/\partial D)D + \Gamma B - \rho\Gamma D + B - \rho D \\ & (\rho H - m - m\partial \mathcal{S}(L, WC)/\partial WC)WC + HL - \rho HWC - L + \rho WC]e^{-\rho t} dt. \end{aligned} \quad (23)$$

Adjusting equation (23) yields

$$\begin{aligned} d[\lambda K + (1 + \Gamma)D - (1 - H)WC]e^{-\rho t} = & [-p(\partial F(K, N)/\partial K)K + p^I(\partial A(I, K)/\partial K)K \\ & + \lambda I + rD + r(\partial X(B, D)/\partial D)D + \Gamma B + B - \rho D - mWC - m(\partial \mathcal{S}(L, WC)/\partial WC)WC \\ & + HL - L + \rho WC]e^{-\rho t} dt. \end{aligned} \quad (24)$$

Then, using equations (10), (12), (14) and (21), and adjusting equation (24) gives

$$\begin{aligned} d[\lambda K + (1 + \Gamma)D - (1 - H)WC]e^{-\rho t} = & [-pF(K, N) + wN + p^I(\partial A(I, K)/\partial K)K \\ & + p^I I + p^I(\partial A(I, K)/\partial I)I + rD + r(\partial X(B, D)/\partial D)D - B + r(\partial X(B, D)/\partial B)B \\ & + B - \rho D - mWC - m(\partial \mathcal{S}(L, WC)/\partial WC)WC + L - m(\partial \mathcal{S}(L, WC)/\partial L)L - L + \rho WC]e^{-\rho t} dt. \end{aligned} \quad (25)$$

Multiplying equation (25) by minus one, integrating from zero to infinity, and using equations (18), (19) and (20) yields

$$[\lambda(0)K(0) + (1 + \Gamma(0))D(0) - (1 - H(0))WC(0)] = \int_0^{\infty} pF(K, N) - wN - p^I(I + A(I, K)) + B - r(D + X(B, D)) + m(WC + S(L, WC)) - L]e^{-\rho t} dt + \int_0^{\infty} e^{-\rho t} [\rho D - B] dt - \int_0^{\infty} e^{-\rho t} [\rho WC - L] dt. \quad (26)$$

In deriving equation (26), note that we make use of

$$\lim_{t \rightarrow \infty} [\lambda K]e^{-\rho t} = \lim_{t \rightarrow \infty} [(1 + \Gamma)D]e^{-\rho t} = \lim_{t \rightarrow \infty} [(1 - H)WC]e^{-\rho t} = 0. \quad (26a)$$

At time zero, $(dD/dt) = B = (dWC/dt) = L = 0$, and the last two terms in equation (26) imply the stock of debt and working capital in the beginning of the period as

$$D(0) = \int_0^{\infty} e^{-\rho t} [\rho D - B] dt \quad (27)$$

and

$$WC(0) = \int_0^{\infty} e^{-\rho t} [\rho WC - L] dt. \quad (28)$$

Observe the similarity between the first integral in equation (26) and the right-hand side of equation (7). Using equations (7), (27) and (28), the equality in equation (26) can be rewritten as

$$[\lambda(0)K(0) + (1 + \Gamma(0))D(0) - (1 - H(0))WC(0)] = V(0) + D(0) - WC(0). \quad (29)$$

Finally, adjusting equation (29) and dividing through p^I gives equation (16), which completes the proof.

Section 5.4 Data and Estimation Results

Inserting equation (16) into equation (15) and partitioning gives an observable investment equation as

$$\frac{I}{K} = \alpha + \frac{1}{\Phi} \left(\frac{V + D - WC}{p^I K} - \frac{(1 + \Gamma)D}{p^I K} + \frac{(1 - H)WC}{p^I K} - 1 \right). \quad (30)$$

The first ratio on the right-hand side of equation (30) can be interpreted as the average Q ratio since it denotes the ratio of market value of equity and debt to the replacement value of capital. Note that the market value of liabilities not only includes the fixed capital, but also the working capital and intangible assets. The subtraction of the term WC in the numerator verifies this fact. Because the intangible assets were not explicitly included in the model, they do not exist here, but they will be considered in the estimation process.

Obviously, the second term $D/p^I K$ on the right-hand side of equation (30) denotes the effect of financing activities on investment decisions. Observe from equation (12) that if agency/financial distress costs do not exist, then $\Gamma = -1$, and the debt-capital ratio disappears. However, if these costs are binding, since $X_B(B, D)$ is assumed positive, then it is expected that the debt-capital ratio negatively affects the investment decisions. This can be seen from equations (12) and (30). The third term $WC/p^I K$ on the right-hand side of equation (30) denotes the effect of working capital policy on investment decisions. Again, observe from equation (14) that if the postulated smoothing benefits do not exist, then $H = 1$, and the working

capital-capital ratio disappears. However, if these benefits are important, since $S_L(L, WC)$ is assumed positive, then the working capital-capital ratio should enter the investment equation positively. This is evident from equations (14) and (30).

For the econometric estimation, equation (30) can be rewritten as

$$\left(\frac{I}{K}\right)_i = \Psi_0 + \Psi_1(Q_i - 1) + \Psi_2\left(\frac{D}{P^I K}\right)_i + \Psi_3\left(\frac{WC}{P^I K}\right)_i + \eta_i + v_i \quad (31)$$

where $\Psi_0 = \alpha$, $\Psi_1 = 1 / \Phi$, $\Psi_2 = -(1 + \Gamma) / \Phi$ and $\Psi_3 = (1 - H) / \Phi$. The term η_i represents the usual firm-specific effects. Also, note that the Lagrange multipliers Γ and H could be further extended by defining the functions $X(B, D)$ and $S(L, WC)$ explicitly; but for simplicity, they were left to be estimated as parameters in equation (31). Since the financing decisions are not necessarily exogenous and may well depend on the management's knowledge of investment opportunities, debt-capital ratios might be correlated with the disturbance terms. This can cause biases in the estimated coefficients. This may also happen because of the simultaneity between investment-capital and working-capital/capital ratios, and investment-capital and Q ratios. Thus, a consistent estimation requires the use of instrumental variables. For that purpose, equation (31) was first-differenced to eliminate the firm-specific effects η_i . Then, the GMM estimations were carried out and the optimal weighting matrix was constructed via the Newey-West procedure as in section 4.3. Time dummies were considered for the possible time effects, however, the residual sum of squares criteria rejected their inclusion. Also

twice-lagged instruments in levels were employed which would be orthogonal to the error terms.

The model was tested for the UK firms employed in the previous chapter. The necessary variables were constructed as follows. The replacement cost of capital was calculated as described in section 4.4. To calculate the numerator of the Q ratios, market value of equity [MV], total loan capital [321], total current liabilities [389], minority interests [315] and total long-term provisions excluding deferred tax [313] were added, and total current assets [376], total investments including associates [356] and total intangibles [344] were subtracted. For the numerator of the debt-capital ratios, total debt [1301] figures were employed, comprising total loan capital [321] and borrowings repayable in less than a year [309]. For the numerator of the working capital-capital ratios, total current assets [376] were employed, comprising total stock and work-in-process [364], total debtors and equivalents [370], and total cash and equivalents [374].

The instrument set includes twice-lagged values of the investment-capital ratios, Q ratios, debt-capital ratios and working capital-capital ratios. To over-identify the model, a constant and twice-lagged values of the squared investment-capital ratios, total sales [104]-capital ratios, depreciation [136]-capital ratios, total interest charges [153]-capital ratios, pre-tax profit [154]-capital ratios, adjusted total tax charges [172]-capital ratios and minority interests [315]-capital ratios were employed as additional instruments. All capital figures in the denominators

were the replacement cost of capital values used to normalise the extra instruments. Observe that the model will be over-identified with nine degrees of freedom, since the difference between the employed instruments and the estimated coefficients is nine.

Table 5.1 GMM Estimation of $\Delta(I/K)_{it} = \Psi_1\Delta(Q_{it}-1) + \Psi_2\Delta(D/p^1K)_{it} +$

$$\Psi_3\Delta(WC/p^1K)_{it} + \Delta v_{it}$$

FULL-SAMPLE PANEL, (76 Firms, 11 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.0499	0.0157	3.1858	0.0014
Ψ_2	-0.3202	0.1677	-1.9089	0.0563
Ψ_3	0.1190	0.0814	1.4611	0.1440
	Test Result		Significance	
Hansen $\chi^2(9)$	12.3160		0.1961	
LOW-LEVERAGE PANEL, (34 Firms, 11 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.0342	0.0170	2.0134	0.0441
Ψ_2	-0.0719	0.1256	-0.5725	0.5670
Ψ_3	0.0766	0.1192	0.6430	0.5202
	Test Result		Significance	
Hansen $\chi^2(9)$	15.0782		0.0888	
HIGH-LEVERAGE PANEL, (42 Firms, 11 Years)				
	Coefficient	Std. Error	T-Stat	Significance
Ψ_1	0.0538	0.0221	2.4348	0.0149
Ψ_2	-0.4020	0.2268	-1.7724	0.0763
Ψ_3	0.1426	0.0842	1.6935	0.0904
	Test Result		Significance	
Hansen $\chi^2(9)$	9.5388		0.3891	

Estimation results are given in table 5.1. The model was tested for all firms, and then the estimations were carried out separately for the low-leverage and high-

leverage groups. The two subsamples are as described in table 4.6. The results in table 5.1 indicate that for the full-sample panel, the moment conditions and the employed instruments are valid. The Q ratio appears to be quite significant, but the implied adjustment costs are unreasonably high, as found in section 2.7. Both the Ψ_2 and Ψ_3 parameters come with the expected signs. Although the debt-capital ratio is significant at 6% level, the working capital-capital ratio appears with t -ratio of 1.46, which is only significant at 15% level. Nevertheless, the overall results for the full-sample supports the model and the hypothesised agency/financial distress costs of debt, casting doubt for the independent financing and investment decisions argument. As can be seen, a 1% increase in the debt-capital ratio causes a 0.32% decrease in the investment-capital ratio. However, the results imply that this negative effect is alleviated around 0.12% by the interactions between investment and working capital policies.

Contrary to the results found for the full-sample, the results for the low-leverage panel supports neither the agency/financial distress costs of debt nor the smoothing benefits of working capital policies argument, as evident from the significance levels of the Ψ_2 and Ψ_3 parameters. Although these parameters appear with the expected signs, the t -ratios are only -0.5725 and 0.643, respectively. For the high-leverage panel, the Q ratio again appears to be quite significant for investment decisions. Both the Ψ_2 and Ψ_3 parameters come with the expected signs. Unlike the results for the low-leverage group, they are both significant at 10% level, implying significant agency/financial distress costs of

debt and smoothing benefits of working capital. For this group, a 1% increase in the debt-capital ratio causes a 0.40% decrease in the investment-capital ratio, and a 1% increase in the working capital-capital ratio implies a 0.14% increase in the investment-capital ratio. The overall results suggest that the agency/financial distress costs of debt does matter for the investment decisions of the highly leveraged firms, implying significant interactions between debt financing and capital investment decisions. Also the results reveal that the highly leveraged group use their working capital policies significantly to support their investment decisions.

Section 5.5 Concluding Remarks

In this chapter, considering the possible agency/financial distress costs of debt and the smoothing benefits of working capital, an investment equation was derived as a function of the observable Q ratio. In the model, the Q ratio was used to control the investment opportunity, the debt-capital ratio for the possible interactions between financing and investment decisions and the working capital-capital ratio as a measure of the working capital policy to assist the investment decisions. If the agency cost function is insignificant, the model satisfies the standard Q model of investment which draws on the MM proposition. It was hypothesised that if the agency/financial distress costs are binding, then the debt-capital ratio should have a significant negative coefficient. The model was tested using UK panel data for 76 large industrial firms over 11 years for two groups of firms with different

levels of indebtedness. The findings revealed that agency/financial distress costs of debt matters for the highly leveraged group, hence, affect their investment decisions negatively. However, the results also show that the firms use their working capital policy to smooth these costs and pressures to some extent. As mentioned in the previous chapter, the findings of this study imply important effects for the whole economy, since it was conducted by using only large industrial firms, constituting an important fraction of total investment in the UK economy.

CHAPTER 6
PRODUCT SPECIALISATION AND THE ROBUSTNESS
OF THE INVESTMENT-UNCERTAINTY
RELATIONSHIP: A UK PANEL STUDY

Section 6.1 Introduction

Apart from the negative relation between investment and uncertainty due the covariance effect of CAPM, economic theory has two opposing views about the variance effect at firm-level analysis. Assuming perfect competition and constant returns-to-scale technology, Hartman (1972) and Abel (1983) show that current investment does not decrease with increased uncertainty. In these models, the positive relation between investment and uncertainty depends entirely on the convex relation between the expected value of the marginal revenue product of capital and the price of output and/or input costs. As in Hartman (1972), a Jensen's inequality argument explains the positive relationship, since an increase in the variances of the output price and/or input costs will increase the marginal profitability of capital due to convexity, hence the current investment level.

On the other hand, the opposing view considers the irreversibility of investment decisions under uncertainty and assumes some degree of imperfect competition and/or decreasing returns-to-scale technology. Irreversibility usually arises if the

capital employed by a firm is industry- and/or firm-specific, making the return to investment asymmetric. Investment expenditure involves exercising an option which represents resources that can be productively invested at any time in the future. This lost option becomes an additional cost of the new investment, and uncertainty affects investment decisions through the options held by the firm. An increase in uncertainty makes better and worse news more likely, but it is optimal to increase the protection by investing less due to the irreversibility effect.

As Caballero (1991) shows, the results of Abel and Hartman continue to hold even in the case of irreversibility. Despite the ineffectiveness of the asymmetric adjustment costs for the results of Abel and Hartman, the assumptions of imperfect competition and decreasing returns-to-scale technology tend to change the sign of the investment-uncertainty relationship towards negativity. Thus, the product market structure and/or the production technology play the central role in the findings of these two opposing theoretical views.

A small number of studies examined the sign of the investment-uncertainty relationship at firm level and found mostly negative effects. For instance, using firm-level US data, Brainard et al. (1980) investigate the relation between investment and CAPM-based uncertainty. They report both positive and negative effects, only some of which are significant. In a more recent study, using US large-company panel data, Driver et al. (1996) report that increased demand uncertainty may reduce the incentive to invest. Moreover, this negative relationship appears to

be more significant in highly integrated plants where firms have better protection from competition. In a more comprehensive study, Leahy and Whited (1996) examine both the covariance and variance effects using Q models of investment for US firm-level panel data. Although they report negative effects of uncertainty, they find no evidence for the covariance effect or for the positive effect due to convexity.

Empirical studies are considerably behind the theoretical developments in the field of the investment-uncertainty relation. Most of the studies are at aggregate-level, and more firm-level studies are required. Another important issue in studying this relationship is the particular consideration of the market structure and/or the technology. Using UK panel data for 66 large industrial firms, this chapter examines the sign and significance of the investment-uncertainty relationship. Unlike previous empirical studies, particular emphasis is given to product specialisation criteria to consider the assumptions of the two opposing theoretical views. Moreover, to test the robustness of the observed relationship, two different models and two different measures of uncertainty are employed. The next section presents the relevant empirical issues and the employed investment models. The third section describes the data and gives the summary statistics. The fourth section presents the econometric evidence, and the final section concludes.

Section 6.2 The Empirical Issues

To test the sign of the investment-uncertainty relationship, two issues should be considered. The first one is the difficulty of constructing and estimating a structural model, since the resulting inferences will be sensitive to the assumptions used to derive the model. Thus, one-period ahead uncertainty forecasts will be incorporated into the investment equations in an ad hoc way in which any long-run, and any form of non-linear relations between investment decisions and expected uncertainty will be ignored. However, to consider the two opposing theoretical works, the sample will be split according to the product structure criteria embedded in the assumptions of the model.

For the purposes of estimation, two different models will be used. The first one incorporates the expected uncertainty measures into the static Q model in a linear fashion as

$$(I / K)_{it} = \Psi_0 + \Psi_1(Q_{it} - 1) + \Psi_2 E_{it}[\sigma_{i,t+1}^2] + \eta_i + \xi_{it}. \quad (1)$$

In this reduced-form model, the variables I , K , Q and σ^2 represent investment, capital stock, average Q ratio and uncertainty, and the terms E , η and ξ denote the expectations operator, the firm-specific effects and the remaining stochastic disturbance term. Since we are not analysing the long-run adjustments of investment to uncertainty shocks, one-period ahead forecasts of the uncertainty measures will be employed.

To observe the robustness of the results obtained from equation (1), another ad hoc linear dynamic investment equation will be employed as

$$(I / K)_{it} = \Psi_0 + \Psi_1(I / K)_{i,t-1} + \Psi_2 SG_{it} + \Psi_3 (CF / K)_{i,t-1} + \Psi_4 E_{it}[\sigma_{i,t+1}^2] + \eta_i + \xi_t \quad (2)$$

where the variables SG and CF denote the sales growth and the cash flow. In this model, the sales growth and the lagged investment-capital ratio control the investment opportunities and the lagged form of adjustment, and the cash flow-capital ratio controls the effect of the availability of funds to finance the investments.

The two theoretical works about the investment-uncertainty relationship predict opposite signs. The irreversibility argument predicts negative effect of uncertainty on investment decisions, and requires some degree of imperfect competition. On the other hand, assuming perfect competition, Abel and Hartman predict positive effect of uncertainty. To consider this difference in the assumptions of the two opposing views, in estimating the investment equations given in equations (1) and (2), the sample will be split according to the product specialisation criteria. For the sample split criteria, sales figures will be used to obtain the average critical ratio (CR). Firms produce and sell different kinds of products; some are specialised and some are more diversified in their products. If a firm's sales figures are concentrated in one product market, the irreversibility effect should be stronger for this firm. Moreover, if a firm is heavily specialised in one product, it might be expected to have more market power when compared to a less specialised firm, resulting in a higher degree of imperfect competition. On the

contrary, if a firm is less specialised in its products, it is likely to be more competitive and also less vulnerable to the irreversibility effect when compared to a heavily specialised firm. Thus, it will be classified in the positive effect group.

While investigating the sign of the investment-uncertainty relationship, the second problem would be to identify and measure the uncertainty because many variables affecting investment decisions will be a part of the relationship. For instance, uncertainty can be in the form technological uncertainty, output price uncertainty, wage uncertainty, demand uncertainty such as changes in consumer tastes, and/or in other forms. Moreover, uncertainty concerns possible outcomes of events but not actual outcomes. Thus, we can only obtain proxy measures of the expected uncertainty. Given the identification problem of the source of uncertainty, the movements in the share prices will be employed to obtain the measures of uncertainty for each firm. Although various forms of bubbles and noise traders would be incorporated into our proxy measure, this general measure can capture different forms of uncertainty relevant to a firm's investment decision, since it would reflect the market's expectations covering all aspects.

For the empirical implementation, two different uncertainty measures will be constructed. The first one is the CAPM-based risk measure. For each firm, based on conditional CAPM, ex-ante abnormal share return volatility will be calculated as a proxy for expected uncertainty. For the purposes of estimation, the conditional CAPM can be presented as

$$E[R_{it} - RF_t] = \alpha + \beta E[(RM_t - RF_t) \setminus \Omega_{t-m}] + \mu_{it} \quad (3)$$

where R , RM , RF , Ω , α , β and μ represent the share return, the stock market return, the risk-free rate, the conditioning information available to the investors before time t , the constant, the firm's beta and the idiosyncratic shock. The information set may include various variables such as long-term interest rates, term structure of interest rates, dividend yield, etc. However, a certain chosen set of information variables may not be a good proxy for some of the firms. For that purpose we will employ the lagged values of the excess market return in the information set. In the estimation process, monthly returns will be used, and the information set will be extended up to time $t-6$ values of the excess market return to include most of the relevant information. The conditional CAPM can be presented as

$$E[R_{it} - RF_t] = \alpha + \sum_{m=1}^6 \Phi_m (RM - RF)_{t-m} + \mu_{it} \quad (4)$$

where Φ represents the set of parameters on the information variables. For each firm, based on the recursively estimated α and the set of Φ parameters, out-of-sample forecasts will be carried out to obtain the ex-ante volatility measures. Hence, for each firm, the proxy measure of expected uncertainty can be presented as

$$E_{it} [\sigma_{1i,t+1}^2] = [(R_{i,t+1} - RF_{t+1}) - (\alpha_{it} + \sum_{m=1}^6 \Phi_{it,m} (RM - RF)_{t+1-m})]^2. \quad (5)$$

The investment models presented in equations (1) and (2) will be estimated on a yearly frequency basis. Although employing the 12-month moving-average of the

forecast squared errors may help to capture the overlapping effects from one period to another, this will also smooth the effects of the forecasts of expected uncertainty on investment decisions. Considering this, for each firm in each year one-period ahead uncertainty forecasts will be constructed by the arithmetic average of the 12-month uncertainty forecasts.

However, note that the CAPM-based uncertainty measures will reflect mostly the firm-specific uncertainty effects. Since the irreversibility argument considers primarily the firm-specific shocks, employing these measures may bias the estimation results of the investment-uncertainty relation towards negativity. Considering this possibility, and also to test the robustness of the estimations, another proxy measure will be constructed for the expected uncertainty. The second uncertainty will be based only on the ex-ante volatility measures of the share returns. By this way, not only the firm-specific uncertainty effects, but also the economy-wide shocks can be taken into account. For the second uncertainty measure, for each firm an AR(6) (autoregressive) process will be employed. This can be presented as

$$E[R_{it}] = \alpha + \sum_{m=1}^6 \Phi_m R_{i,t-m} + \mu_{it} \quad (6)$$

Again, by using equation (6), recursive estimations will be carried out for each firm. After obtaining the monthly recursive out-of-sample forecasts of the share returns, the second uncertainty measure will be calculated as

$$E_{it}[\sigma_{2it,t+1}^2] = [R_{i,t+1} - \alpha_{it} - \sum_{m=1}^6 \Phi_{it,m} R_{i,t+1-m}]^2. \quad (7)$$

Section 6.3 Data and Summary Statistics

This section describes the construction of the data and presents the related summary statistics. The study covers the UK consisting of 66 industrial firms for the period 1982-1996. The construction of the critical ratio (CR) to split the sample, the construction of the two measures of uncertainty forecasts and the other variables employed in the estimation of the investment equations are explained. The necessary variables were obtained from Datastream, and the associated Datastream codes are given in brackets..

Datastream gives the distribution of sales figures [190F] in percentages according to the three-digit standard industry classification codes. For each firm in each year, the highest percentage sales figures were taken for the period 1987-1996. Then, for each firm, the arithmetic averages of these highest figures were calculated over the ten-year period. Using this average figure for each firm, the arithmetic average and the median of 66 firms were calculated. They are given in table 6.1. Hence, the CR to split the sample was constructed as the arithmetic average of the mean and the median of the whole sample. This was found to be 61.38%.

Table 6.1 Sales Specialisation Figures (%)

<i>Highest Sales (1987-1996)</i>	All Firms	Firms<CR	Firms>CR
Mean	62.259	47.695	78.703
Median	60.5	51	75.556
Stdev.	19.306	9.333	13.491
Min.	28.333	28.333	63.111
Max.	100	61.111	100
No. of Firms	66	35	31

The number of firms belonging the subsample with sales specialisation figures lower than the CR is 35. As discussed in the previous section, these firms are assumed more competitive when compared to the firms in the other subsample. Thus, the positive effect of the expected uncertainty should be more significant for this subgroup. Conversely, for the firms with sales specialisation figures above the CR, the irreversibility effect of uncertainty should be significant. Thus, it is more likely that the expected uncertainty will have a negative effect for this subgroup. To observe this, estimations will be carried out separately for the two different subsamples.

To construct the proxy measures for the two uncertainty effects, the monthly share prices [P], and the monthly dividend yields [DY] were obtained from 1 January 1976 to 1 January 1998. For the dividend yields, Datastream gives the annualised figures in percentages. Thus, for each firm in each month, the share returns were calculated as

$$R_{it} = \frac{P_{it} + (P_{it} * DY_{it}) / 1200 - P_{i,t-1}}{P_{i,t-1}} \quad (8)$$

where P denotes the capitalisation issue-adjusted share prices. The stock market return was calculated by using the monthly stock market index [TOTMKUK], and for the risk-free rate, monthly yield on 1-month Treasury Bills [LDNTB1M] were employed. For each firm, starting from the period 1 January 1976-1 January 1982, equations (4) and (6) were estimated recursively. Then, forward forecasts were obtained by equations (5) and (7) to construct the ex-ante volatility measures. The procedure was applied up to 1 January 1998.

Table 6.2 Summary Statistics of the Uncertainty Measures

σ_1^2 (1982-1997)	All Firms	Firms<CR	Firms>CR
Mean	0.0087	0.0091	0.0083
Stdev.	0.0147	0.0185	0.0087
Min.	0.0005	0.0007	0.0005
Max.	0.4027	0.4027	0.0970
σ_2^2 (1982-1997)	All Firms	Firms<CR	Firms>CR
Mean	0.0096	0.0103	0.0089
Stdev.	0.0228	0.0298	0.0102
Min.	0.0007	0.0009	0.0007
Max.	0.5796	0.5796	0.1107

Table 6.2 gives the summary statistics for the one-year ahead uncertainty forecasts in monthly frequencies. The results are reported for the two measures and also for the two subgroups for the period 1982-1997. For the whole sample, the mean of the CAPM-based risk measure is 0.87 % and the mean of the return-based risk measure is 0.96 %. Both measures are slightly higher for the group of firms below the CR.

The investment-capital and Q ratios were calculated as in section 5.4. For some of the firms, the adjusted profit measures were missing. Thus, depreciation of fixed assets [136] was added to profits [154] as a proxy for the cash flow figures. For the denominator of the cash flow-capital ratios, previously constructed replacement value of capital figures were employed. Finally, sales [104] figures were used for the sales growth. Table 6.3 gives the summary statistics of these four variables for the whole sample and for the two subgroups. For the whole sample, the I/K ratio appears with a mean of 12.8%, the Q ratio

Table 6.3 Summary Statistics of the Model Variables

I/K (1982-1996)	All Firms	Firms<CR	Firms>CR
Mean	0.1280	0.1177	0.1396
Stdev.	0.0986	0.0913	0.1052
Min.	0.0000	0.0000	0.0088
Max.	0.9011	0.9011	0.8724
$Q-I$ (1983-1996)	All Firms	Firms<CR	Firms>CR
Mean	0.4082	0.2589	0.5767
Stdev.	1.1748	0.9922	1.3329
Min.	-1.3924	-1.3924	-1.2585
Max.	9.7242	8.9749	9.7242
CF/K (1982-1996)	All Firms	Firms<CR	Firms>CR
Mean	0.2372	0.2178	0.2592
Stdev.	0.1460	0.1378	0.1520
Min.	-0.2684	-0.2684	-0.0965
Max.	1.4857	1.4857	0.9927
SG (1983-1996)	All Firms	Firms<CR	Firms>CR
Mean	0.1512	0.1336	0.1712
Stdev.	0.4930	0.5988	0.3354
Min.	-0.3544	-0.3192	-0.3544
Max.	10.761	10.761	4.234

with 1.4082, the CF/K ratio with 23.72% and the sales growth with 15%. The mean of the I/K ratio for the group of firms > CR is 13.96% and it is higher than

the other subgroup. Consistent with that observation, the mean of the Q ratio and the sales growth are also higher for the group of firms above the CR.

Section 6.4 Estimation Results

For the estimation of models, first-difference of equations (1) and (2) were taken to eliminate the unobservable fixed effects. The new equations can be presented as

$$\Delta(I / K)_{it} = \Psi_1 \Delta(Q_{it} - 1) + \Psi_2 \Delta E_{it} [\sigma_{i,t+1}^2] + \Delta \xi_{it} \quad (9)$$

$$\Delta(I / K)_{it} = \Psi_1 \Delta(I / K)_{i,t-1} + \Psi_2 \Delta SG_{it} + \Psi_3 \Delta(CF / K)_{i,t-1} + \Psi_4 \Delta E_{it} [\sigma_{i,t+1}^2] + \Delta \xi_{it}. \quad (10)$$

To consider any possible simultaneity effects, the GMM estimation technique was employed as in section 4.3. To obtain heteroscedasticity and autocorrelation consistent optimal weighting matrix, the procedure of Newey and West (1987) was applied. The models were over-identified, and the Hansen tests were carried out for the imposed moment conditions. Also, time $t-2$ and $t-3$ level instruments were employed which would be orthogonal to the moving-average error caused by the first-difference of the data.

Equation (9) was estimated for the whole sample and for the two subsamples by employing the two uncertainty measures. The employed instrument set includes a constant, time $t-2$ and $t-3$ values of the investment-capital ratios, the Q ratios, the uncertainty measures, and the squares of these three variables. With 13

instruments, the first model is over-identified with 11 degrees of freedom. All estimations were carried out with and without time dummies. For the inclusion of the time dummies, the unrestricted residual sum of squares and the restricted residual sum of squares were compared. The estimation results are given in table 6.4 together with the t -ratios in parentheses. The results of the Hansen tests verify the validity of the employed instruments and moment conditions for all estimations. In all cases the inclusion of the time dummies reduces the residual sum of squares, thus the reported results include the time dummies. The first two columns of table 6.4 give the results for the whole sample. Estimation results reveal that the Q ratio is very significant. The uncertainty measures come with positive signs, however, neither the CAPM-based risk measure nor the return-based risk measure is significant.

Table 6.4 GMM Estimation of $\Delta(I/K)_{it} = \Psi_1 \Delta(Q_{it}-1) + \Psi_2 \Delta E_{it}[\sigma^2_{1,t+1}] + \Delta \xi_{it}$

	All Firms		Firms < CR		Firms > CR	
$\Delta(Q_{it}-1)$	0.0667 (5.416)	0.0566 (8.705)	0.0589 (4.605)	0.0390 (3.496)	0.0710 (2.865)	0.0831 (3.224)
$\Delta E_{it}[\sigma^2_{1,t+1}]$	0.0996 (0.730)	—	0.4039 (2.832)	—	-0.3497 (-2.207)	—
$\Delta E_{it}[\sigma^2_{2,t+1}]$	—	0.1118 (0.686)	—	0.4294 (2.620)	—	-0.2538 (-1.323)
Hansen $\chi^2(11)$	0.7003	0.5473	0.9231	0.6863	0.7565	0.7161
URRSS	5.8980	5.7238	2.3147	2.1564	3.2664	3.3600
RRSS	7.5883	9.2953	4.5452	4.2674	3.5005	3.4261

1. The t -ratios are given in parentheses which are corrected for heteroscedasticity and first-order autocorrelation.
2. Significance levels of the results of the Hansen tests are given.
3. URRSS denotes the unrestricted residual sum of squares for the estimations with the time dummies, and RRSS denotes the residual sum of squares for the estimations without the time dummies.

The firms<CR are less vulnerable to irreversibility effects and they are likely to be more competitive when compared to the other subgroup. Consistent with this argument, when the sample is split according to the CR of the sales specialisation figures, estimation results reveal that the one-period ahead uncertainty forecasts affect investment decisions in a positive and significant way for the firms<CR. This result holds regardless of the type of uncertainty measure employed. The return-based uncertainty measure comes with a slightly higher coefficient for this group, and the Q ratios have significant positive coefficients.

The second subgroup consists of firms which are more specialised in their products when compared to the firms<CR. Thus, this group may have more power in their product market, increasing the degree of the imperfect competition. Also, their exposure to irreversibility effects should be more. The estimation results for this subgroup indicate that the Q ratios have significant positive coefficients. As expected, the results for the firms>CR indicate that the CAPM-based risk measure appears with a negative and significant coefficient. Although the return-based risk measure appears with a negative sign, it is not as significant as the CAPM-based risk measure for this subgroup. However, these results are consistent with the argument that the CAPM-based risk measure is more likely to capture the irreversibility effect, since it is a measure of non-systematic risk.

In equation (9), while using the average Q ratio to control investment decision, perfect competition was assumed implicitly since the equality of marginal q and

average Q requires this. As discussed in section 1.3, the assumption of imperfect competition requires the inclusion of sales figures in the average Q ratio, and it should appear with a negative sign. For that purpose, the estimations were carried out by including the sales-capital ratios. The findings in table 6.4 were qualitatively robust to the inclusion of sales-capital ratios. Although insignificant, this ratio appeared with a positive sign for the firms<CR and with a negative sign for the firms>CR.

The results obtained imply the importance of considering the firms' heterogeneity and the differences in the assumptions of the two theoretical views while studying the investment-uncertainty relationship. As a second step, to test the robustness of the results obtained from equation (9), the investment model given in equation (10) was estimated. For this dynamic model, the instrument set employed includes a constant, time $t-3$ and $t-4$ values of the investment-capital and the cash flow-capital ratios, time $t-2$ and $t-3$ values of the sales growth, uncertainty measures, and the squared versions of all variables.

With 13 degrees of freedom, the results of the Hansen tests validate the instrument set employed and imposed moment conditions. The unrestricted residual sum of squares figures are smaller than the restricted residual sum of squares figures for all estimations. Therefore, the estimations include time dummies. For the whole sample, the lagged investment-capital appears with a negative and insignificant coefficient. Both the cash flow-capital ratio and the sales growth have

significant positive coefficients. Although negative, both measures of uncertainty appear with very insignificant *t*-ratios.

Table 6.5 GMM Estimation of $\Delta(I/K)_{it} = \Psi_1 \Delta(I/K)_{i,t-1} + \Delta \Psi_2 SG_{it} + \Psi_3 \Delta(CF/K)_{i,t-1} + \Psi_4 \Delta E_{it}[\sigma^2_{i,t+1}] + \Delta \xi_{it}$

	All Firms		Firms < CR		Firms > CR	
$\Delta(I/K)_{i,t-1}$	-0.0405 (-0.512)	0.0025 (0.028)	0.2698 (2.672)	0.2108 (2.004)	-0.4381 (-4.682)	-0.3999 (-3.316)
ΔSG_{it}	0.0563 (3.043)	0.0768 (6.444)	0.0677 (10.859)	0.0786 (9.048)	0.0858 (3.101)	0.0938 (3.398)
$\Delta(CF/K)_{i,t-1}$	0.3353 (6.374)	0.3447 (6.065)	0.3794 (5.068)	0.3143 (4.652)	0.7731 (4.078)	0.7432 (4.168)
$\Delta E_{it}[\sigma^2_{i,t+1}]$	-0.0787 (-0.624)	—	0.0808 (0.645)	—	-0.3260 (-2.502)	—
$\Delta E_{it}[\sigma^2_{2i,t+1}]$	—	-0.0250 (-0.171)	—	0.2199 (1.913)	—	-0.3009 (-1.928)
Hansen $\chi^2(13)$	0.4382	0.3598	0.8138	0.8522	0.4476	0.5331
URRSS	4.1698	4.3256	1.6121	1.5905	2.6690	2.5838
RRSS	5.0562	4.8390	1.7801	1.5965	2.8404	2.6615

1. See the notes in table 6.4.

The results for the group of firms < CR show that the lagged investment-capital ratio, the cash flow-capital ratio and the sales growth have significant coefficients. Although positive, the CAPM-based risk measure comes with an insignificant *t*-ratio of 0.645. On the other hand, the return-based uncertainty measure appears with a significant positive coefficient. As found in table 6.4, one-period ahead expected uncertainty seems to affect investment decisions in a positive way for this subgroup. Finally, all variables have significant coefficients for the group of firms > CR. As found before, both of the uncertainty variables appear with negative coefficients. Moreover, the CAPM-based risk measure again

has a more significant and slightly higher coefficient than the return-based risk measure for this subgroup.

Section 6.5 Concluding Remarks

In this chapter, we examined the sign of the short-run investment-uncertainty relationship for 66 large UK industrial companies. Theoretical work suggest that the sign of investment-uncertainty depends on the degree of competition faced by a firm and/or the assumption about the technology that the firm adapts. Considering this, the sample was split according to the product specialisation criteria. Although not a sufficient condition, one may expect that the firms which are highly specialised in their products will face less competition and may have more market power when compared to the firms which have diversified products. More importantly, the higher the degree of product specialisation, the more likely that a firm will suffer from irreversibility problems. Given the difficulty of obtaining an estimable structural model, the uncertainty effect was incorporated into the investment equations in ad hoc way. However, to test the robustness of the obtained results, two different models and two different measures of uncertainty were employed. The first uncertainty measure was based on conditional CAPM, and the second one was based directly on the conditional stock returns.

When the investment models were estimated for the whole sample, regardless of the uncertainty measures, the investment-uncertainty relationship appeared with both positive and negative insignificant coefficients. On the other hand, when the sample was split according to the product specialisation criteria, consistent with the theoretical argument, the sign of the investment-uncertainty relation was negative for the group of firms which are highly specialised in their products. Regardless of the different investment models employed, the negative sign consistently appeared for this subgroup. The negative effect of uncertainty seemed to be more significant in the case of the CAPM-based risk measure. However, this is consistent with the argument that the CAPM-based risk measure considers idiosyncratic uncertainty which can bias the results towards the irreversibility argument. Consistent with the convexity argument, the results generally appeared with positive significant coefficients for the firms < CR, which were considered to face more competition and less vulnerable to irreversibility effect. For this subgroup, the results are robust under different model specifications, and the positive effect of uncertainty is more significant in the case of the return-based risk measure.

Since both positive and negative effects appear significantly for different subgroups, the findings of this study are not consistent with the findings of the previous empirical studies. However, it is difficult to reach a conclusion about the short-run effect of the expected uncertainty at the aggregate-level. Even if there might be bias in the results due to the ad hoc nature of the models employed,

consistent with both of the theoretical views, disintegrating the firms according to the product market assumption resulted in strong figures about the sign of the investment-uncertainty relationship. This important result should be considered in future research. Another important result is that the uncertainty measure employed can affect the findings of a study. Thus, it is useful to employ different measures of uncertainty.

CHAPTER 7

A VAR ANALYSIS OF AGGREGATE UNCERTAINTY IN THE UK

Section 7.1 Introduction

In the literature, most of the aggregate-level studies examining the investment-uncertainty relationship report negative effects. For instance, using aggregate data for 20 US manufacturing industries, Caballero and Pindyck (1992) find a negative effect of uncertainty on irreversible investment decisions. Pindyck and Solimano (1993) employ a similar version of the model developed in Caballero and Pindyck (1992) for 29 countries. Their results also indicate a negative relationship that is in greater magnitude for developing countries. In a less ambitious reduced form model, using US aggregate-level data and the risk premium embedded in the term structure of interest rates to measure the uncertainty, Ferderer (1993) concludes that uncertainty has a negative and statistically significant effect on investment decisions. In another aggregate-level reduced form study, Bell and Campa (1997) report a significant negative effect of exchange rate volatility in Europe for chemical plant investments, but they find that input prices and product demand volatility do not appear to have a significant effect in either Europe or US.

This chapter investigates the effects of aggregate uncertainty on aggregate investment for the UK in a reduced-form relation. The employed methodology is VAR analysis and innovation decomposition techniques as developed in Sims (1980). The effects of long-term interest rate uncertainty, exchange rate uncertainty and inflation uncertainty on investment decisions will be investigated. Uncertainty estimations will be carried out by using the conditional volatility models developed in the financial econometrics literature. Moreover, uncertainty may have different impacts on different categories of investment. These effects will be considered separately on machinery and equipment investment and construction investment.

The next section explains the VAR analysis. The third section explains the estimations of conditional volatility. Section four presents the simulation results, and the final section concludes.

Section 7.2 VAR Analysis and Innovation Accounting

To investigate the investment-uncertainty relationship statistically, a VAR model will be employed and simulations will be carried out by giving shocks to the model. The relation between investment and uncertainty measures is described by a four dimensional linear dynamic stochastic system in the following form

$$\begin{aligned}
ULTI_t &= \sum_{l=0}^p \Psi_{11,l} INV_{t-l} + \sum_{l=0}^p \Psi_{12,l} UINF_{t-l} + \sum_{l=0}^p \Psi_{13,l} UFX_{t-l} + \sum_{l=1}^p \Psi_{14,l} ULTI_{t-l} + u_{1,t} \\
UFX_t &= \sum_{l=0}^p \Psi_{21,l} INV_{t-l} + \sum_{l=0}^p \Psi_{22,l} UINF_{t-l} + \sum_{l=1}^p \Psi_{23,l} UFX_{t-l} + \sum_{l=0}^p \Psi_{24,l} ULTI_{t-l} + u_{2,t} \\
UINF_t &= \sum_{l=0}^p \Psi_{31,l} INV_{t-l} + \sum_{l=1}^p \Psi_{32,l} UINF_{t-l} + \sum_{l=0}^p \Psi_{33,l} UFX_{t-l} + \sum_{l=0}^p \Psi_{34,l} ULTI_{t-l} + u_{3,t} \\
INV_t &= \sum_{l=1}^p \Psi_{41,l} INV_{t-l} + \sum_{l=0}^p \Psi_{42,l} UINF_{t-l} + \sum_{l=0}^p \Psi_{43,l} UFX_{t-l} + \sum_{l=0}^p \Psi_{44,l} ULTI_{t-l} + u_{4,t}
\end{aligned} \tag{1}$$

where INV , $UINF$, UFX and $ULTI$ denote the investment, the inflation uncertainty, the foreign exchange uncertainty and the long-term interest rate uncertainty, respectively. Thus, the investment equation employed takes the form of an autoregressive model, augmented with the uncertainty effects. The error terms u are assumed to be white noise disturbances which are uncorrelated with each other. For notational simplicity, the constant terms and other deterministic variables such as time dummies are not included in the system. The system links all variables since the contemporaneous values of the variables are allowed to affect each other. In addition to that, error terms will be pure innovations for each related variable but will have indirect contemporaneous effects on other variables through the right-hand side time t values.

The system given in (1) is a four dimensional p th-order VAR, and we can also write an N dimensional system in short-hand as

$$Y_t = H_0 Y_t + H_1 Y_{t-1} + H_2 Y_{t-2} + \dots + H_p Y_{t-p} + u_t \tag{2}$$

where each H represents $N \times N$ coefficients for the N dimensional system. The terms Y and u represent $N \times 1$ vector of variables and $N \times 1$ vector of uncorrelated

error terms with zero means and constant variances. Thus, the covariance matrix of the error term can be written as $E(u_t u_t') = I_N$, where I_N is an N dimensional diagonal matrix. Moreover, under the assumption of unit variance, it can also be taken as an N dimensional identity matrix. As in a univariate case, a VAR(p) process can be converted to a vector moving-average (VMA) form by iteration, and the variables can be expressed in terms of the values of innovations to trace the time paths of various shocks on the variables. As shown in Lütkepohl (1993), a VMA form can be also expressed in the lag operator notation as

$$Y_t = F(L)u_t. \quad (3)$$

where $F(L) = [I - H(L)]^{-1}$. The $F(L)$ matrix of coefficients on the structural error terms are called impulse response functions. They can be used to generate the effects of u_t shocks on the $N \times 1$ vector of Y variables. The elements of this matrix are known as impact multipliers at time zero and long-run multipliers for the accumulated effects of the impulses. Moreover, using the $F(L)$ matrix of coefficients, the forecast error variance of a variable can be decomposed to obtain the proportion of movements due to its own shocks versus shocks to other variables. Thus, one can quantify the proportions of the effects of shocks on each variable. As discussed in Sims (1980), impulse response functions, together with the forecast error variance decomposition, can be used as a very effective tool to investigate the effects and the interrelationships between variables within a VAR framework.

However, observe that the structural VAR(p) in equation (2) is not in the reduced form, and it cannot be estimated. For the purposes of estimation, a transformation is required, and the system in equation (2) can be rewritten in the reduced form as

$$Y_t = R_1 Y_{t-1} + R_2 Y_{t-2} + \dots + R_p Y_{t-p} + e_t \quad (4)$$

where $R_i = AH_i$ and $A = [I - H_0]^{-1}$ for $i = 1, 2, \dots, p$. This reduced form is known as the standard form, and it can be estimated by the OLS technique. OLS is consistent and asymptotically efficient since all the equations have the same predetermined regressors. The standard system is in an estimable form because the contemporaneous relations of the variables are now incorporated into the new error terms e_t by the term $[I - H_0]^{-1}$. This can be written in terms of the errors of the structural form as

$$e_t = Au_t \quad (5)$$

Thus, the error terms will include all the shocks, and they will be correlated with each other according to the contemporaneous relations in the system, reflecting the transformation of the structural form.

With the new transformation, the structural system in equation (2) will be under-identified. To recover all the information, we need to impose $N*(N-1)/2$ restrictions on the structural system for exact identification. The number of restrictions implies the difference between the contemporaneous effect matrix of the structural form and the additional covariance terms of the standard form. For instance, for the structural model given in equation (1), we will have 12

coefficients for the contemporaneous effects of the variables and 6 additional covariance terms in its standard form. Thus, 6 constraints must be imposed on the primitive system in equation (1) to recover all the information.

In practice, first, the standard VAR process given in equation (4) can be estimated by OLS to obtain the necessary coefficients and the symmetric covariance matrix of the cross-correlated error terms e_t . Then, the symmetric covariance matrix can be orthogonalised to obtain the diagonal covariance matrix of the structural form which will satisfy the desired properties. By that way, in the shock simulation process, the effects of the contemporaneous correlation can be eliminated and the forecast error variances can be decomposed into components attributable to each innovation. As can be seen from equation (5), for the orthogonalisation process, if we choose a matrix A such that:

$$A^{-1}E(e_t e_t')A'^{-1} = I_N \quad (6)$$

then $E(u_t u_t') = I_N$ will be also satisfied. Hence, by using equations (4) and (5), we can calculate

$$F(L) = [I - R(L)]^{-1} A \quad (7)$$

to obtain the impulse response functions and the forecast error variance decomposition of the variables. A convenient way of imposing the necessary $N(N-1)/2$ restrictions and obtaining the matrix A is to use the Cholesky decomposition technique. In this technique, the matrix A is assumed lower triangle, thus the structural system given in equation (2) reduces to a recursive system. In this semi-mechanical factorisation method, the ordering of the variables matters. For

instance, for the structural system given in equation (1), if the ordering is as $ULTI$, UFX , $UINF$, INV , then we will be restricting the contemporaneous effects of UFX , $UINF$ and INV on $ULTI$, the contemporaneous effects of $UINF$ and INV on UFX , and the contemporaneous effect of INV on the variable $UINF$. Exact identification will be achieved by imposing these 6 restrictions. However, one needs to be careful about the ordering, since the effect of it will increase as the correlation coefficients between the error terms of the standard form increase. One can decide the ordering according to the theory in hand and/or check the sensitivity of the impulse response functions and forecast error variance decomposition of the variables to various orderings.

Section 7.3 Volatility Estimates

Although one cannot observe uncertainty, or in other terms volatility, it can be estimated by the appropriate techniques. For instance, in early studies Officer (1973) estimates the volatility at each point in time by using a rolling standard deviation, achieved by moving the sub-sample period for the returns. More recent studies starting with Engle (1982) model time varying volatility by past forecast errors, known as autoregressive conditionally heteroscedastic (ARCH) processes. For financial series, large increases are often followed by larger increases, or large decreases are followed by larger decreases. Although it is difficult to observe significant behaviour in the first moments of these series, the volatility appears to be serially correlated. The basic idea in the ARCH techniques is to exploit this

correlation to model the changing volatility. Later, Bollerslev (1986) extends the ARCH process of Engle to a generalised autoregressive conditionally heteroscedastic (GARCH) process by including the past values of the estimated volatility. This can be viewed as an extension of an autoregressive process to an autoregressive moving-average process. In an ARCH process too many lagged values of the squared error terms are often included, and the stability criterion requires all roots to be positive. The GARCH process can mimic the long lags with the MA term. Engle, Lilien and Robins (1987) extend the GARCH model as GARCH-M (GARCH in mean) by making the conditional mean of the model linear in the conditional variance, implying a conditional mean-variance relationship.

There are also some other extensions offered in the literature. For instance, Nelson (1990) offers an exponential GARCH (EGARCH) model that does not require any parameter restrictions to ensure that the conditional volatility is always positive. Schwert (1989) estimates an absolute value ARCH model in which the conditional standard deviation becomes a linear function of the past standard deviations and the absolute values of the error terms. Hentschel (1995) gives a very general model which nests most of the models in the literature. In equation (9), a simplified version of this general model is presented which nests all the models described above.

Assume a stochastic functional relation between a variable y and a vector of independent variables x with a set of β parameters as

$$y_t = f(\beta, x_t) + u_t \quad (8)$$

where u represents the error term which is normally distributed with zero mean and σ^2 variance. Thus, assuming that e is normally distributed with zero mean and unit variance, we can also express the error term as $u_t = \sigma_t e_t$. A general model which nests the above-mentioned models can be given as

$$\frac{\sigma_t^\theta - 1}{\theta} = \omega + \delta \sigma_{t-1}^\theta [g(e_{t-1})]^\eta + \alpha \frac{\sigma_{t-1}^\theta - 1}{\theta} \quad (9)$$

where

$$g(e_{t-1}) = |e_{t-1}| - \varphi e_{t-1}$$

In equation (9), apart from σ and e , all other symbols represent constant parameters. If we assume $\theta = 2$, $\varphi = 0$, $\eta = 2$ and $\alpha = 0$, we obtain the ARCH(1) model. As an extension to the ARCH(1) model, the GARCH(1,1) model can be obtained by setting $\alpha \neq 0$. If we assume that variable x represents σ^2 in equation (8), then we can obtain the univariate ARCH-M and GARCH-M models. Moreover, by assuming $\theta = 1$, $\varphi = 0$ and $\eta = 1$, we can obtain the simplest version of the absolute value GARCH model, and setting $\theta = 0$, $\varphi \neq 0$ and $\eta = 1$ gives the EGARCH model. Also, all models can be extended for longer lags.

Before modelling volatility, we have to make the series stationary. A variable can be trend or difference stationary, or it can already be stationary. Thus, the augmented Dickey-Fuller tests for unit roots were carried out at 5% levels by also

considering the possibility of seasonal unit roots. The three series, the *LTl* (long-term interest rates), the logarithm of the *FX* (foreign exchange rate), and the logarithm of the *RPI* (seasonally unadjusted price index) were tested both with and without a trend variable as

$$\Delta \hat{y}_t = \gamma \hat{y}_{t-1} + \sum_{i=1}^N \beta_i \Delta \hat{y}_{t-i} + \varepsilon_t \quad (10)$$

where

$$\hat{y}_t = y_t - \alpha - \mu t - \sum_{i=1}^{11} \delta_i \text{Dummy}_i .$$

The results were contrasted with the required critical ratios which are higher than the standardised normal due to the spurious correlation. The long-term interest rate is the rate for 20-year UK government bonds, the exchange rate is the rate of the US dollar to the UK pound and the price index is the UK retail price index. Monthly data was obtained from 1972 to 1998 and the Datastream codes for the three series are, respectively, [UKOCLNG%], [UKOCEXCH] and [UKRP....F]. In equation (10), γ is the coefficient on the lagged value of \hat{y} , α is the constant and μ is the coefficient on the trend variable. \hat{y} was obtained by regressing the monthly levels of the variables on a constant, 11 dummy variables for each month and a trend variable. In the testing procedure, the idea is to test whether or not the coefficient γ is significantly different from zero. In equation (10), since the first difference of the variable \hat{y} is regressed on its own lagged-one level, the null hypothesis of a unit root should not be rejected if this coefficient is not significantly different than zero. The number of observations are more than 300,

and table 7.1 gives the obtained results for the three variables together with the 5% critical values of the t -ratios for a sample size of 500. If the null hypothesis of a unit root was not rejected, to determine whether too many deterministic variables were included, the significance of the γ coefficient was again tested by excluding the trend variable. For all variables, the null hypothesis of unit root was accepted. Thus, we concluded that three variables are difference stationary.

Table 7.1 Unit Root Test Results

$n=500$	<i>LTI</i>	<i>FX</i>	<i>RPI</i>	CV:5%
trend and constant included				
γ	-2.9747	-2.4838	-2.1397	[-3.42]
only constant included				
γ	-1.5926	-2.1773	-1.4276	[-2.87]

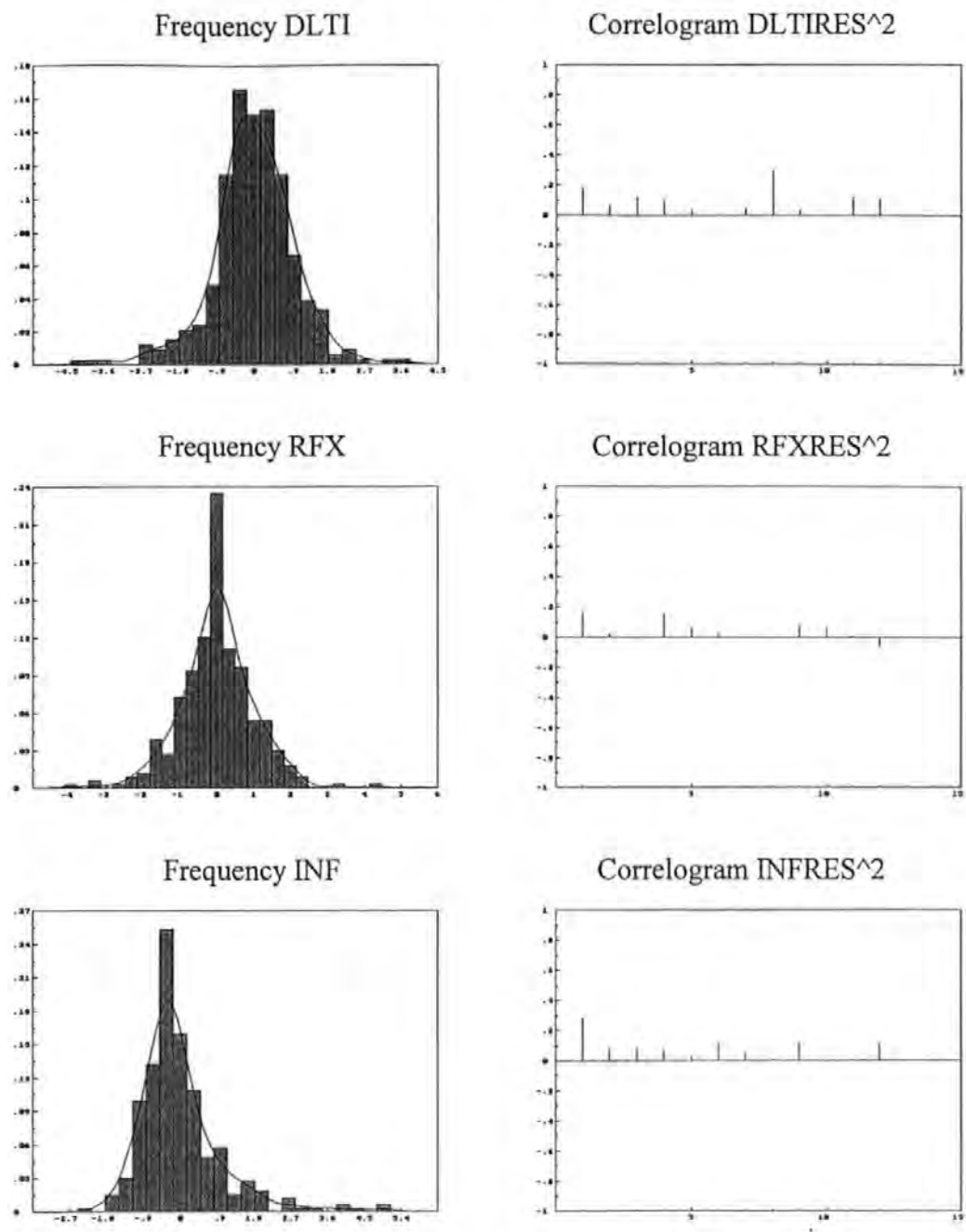
A general observation for financial time series is that ARCH effects are mostly present in high frequency data, such as daily and weekly data. Since we have monthly data, before trying to model the volatility for each series, it is helpful to test the normality and ARCH effects formally. In addition, it is useful to test the fourth moments of the variables because large variances increase the mass in the tails. Thus, if we have a leptokurtic (excess kurtosis) distribution, it is possible to estimate the volatility by generalised ARCH models. Moreover, one can also check the autocorrelation function of the squared residuals to obtain an additional information about the lag structure of the conditional volatility. Table 7.2 presents the skewness and excess kurtosis measures for the variables *DLTI*, *RFX* and *INF*. They represent the monthly changes in the long-term interest rate at annual rates,

annualised monthly holding returns of the foreign exchange rate and the monthly retail price inflation rate at annual rates, respectively. For normality and ARCH effects, the Bera-Jarque tests and the ARCH(1) and ARCH(4) tests are carried out. The Bera-Jarque test compares the excess kurtosis and skewness of a distribution with the null hypothesis of a normal, and it is distributed as a chi-squared with two degrees of freedom. In a normal distribution, both excess kurtosis and skewness are assumed to be zero. The test is carried out by computing $\chi^2 = T * [(\text{skewness})^2/6 + (\text{Excess Kurtosis})^2/24]$, where T is the number of observations. The ARCH(p) test is a Lagrange multiplier test which formally tests the autocorrelations of the squares of the residuals. The squared residuals can be obtained from a preliminary regression. They can then be regressed on a constant and p lagged values to test the null hypothesis of no ARCH(p) effects with a chi-squared distribution of p degrees of freedom. The test statistics is given as $\chi^2 = TR^2$, where T is the number of observations and R^2 is obtained from the regression of the squared residuals.

Table 7.2 Tests for Normality and ARCH Effects

	<i>DLTI</i>	<i>RFX</i>	<i>INF</i>
Bera-Jarque $\chi^2(2)$	92.1672 (0.0000)	53.9808 (0.0000)	651.8288 (0.0000)
ARCH(1) $\chi^2(1)$	70.1399 (0.0000)	73.6070 (0.0000)	52.7753 (0.0000)
ARCH(4) $\chi^2(4)$	73.2922 (0.0000)	81.2809 (0.0000)	57.9918 (0.0000)
Excess Kurtosis (Ku=0)	2.4556 (0.0000)	1.9644 (0.0000)	5.7344 (0.0000)
Skewness (Sk=0)	-0.3978 (0.0032)	-0.10413 (0.4406)	1.8866 (0.0000)

Figure 7.1 Distributions and Correlograms



In table 7.2, parentheses show the significance levels of the tests. The results of the normality tests indicate that the distributions of all three variables are far from normality. Both the ARCH(1) and ARCH(4) tests reveal strong ARCH effects for

all variables. In a normal distribution, the skewness would be zero, thus we can see that the zero skewness hypothesis is only acceptable for the *RFX* variable, and the variable *INF* has a significantly skewed distribution. Consistent with the results of the ARCH tests, excess kurtosis measures show that all variables have a leptokurtic distribution. In Figure 7.1, the frequency distribution of the three variables are given, respectively, for *DLTI*, *RFX* and *INF*. Moreover, we also present the correlogram of the squared residuals which were obtained by regressing the variables on a constant and time dummies. Analysing the correlogram of the squared residuals gives important clues about the lag structure of the model. As found in table 7.2, the inflation rate has a quite skewed distribution, and the three variables have fat tails due to the leptokurtic distribution. When we look at the correlograms of the squared residuals, it is possible to see positive autocorrelation in the long lags for all variables. Thus, a GARCH model is a good candidate to capture the effects of these long lags.

Because of its stationarity and high capability of parsimonious approximation of heteroscedasticity, often the GARCH(1,1) process is employed in the empirical literature. Assuming interest rates and exchange rates as assets, we fit a GARCH(1,1)-M model in which the return becomes a linear function of the conditional variance. For inflation, after a preliminary stepwise regression, we fit a GARCH(1,1) model for an AR(2) process. From equations (8) and (9), using the joint density of the observations, the logarithm of the conditional likelihood function can be derived as

$$L(\Phi) = \sum_{i=1}^T -\frac{1}{2} [\log(\sigma_i^2(\Phi)) + u_i^2(\Phi) / \sigma_i^2(\Phi)] \quad (11)$$

where Φ represents the vector of parameters to be estimated. For the GARCH(1,1)-M model, Φ includes ω , δ and α as the GARCH(1,1) parameters, as in equation (9), and β_0 and β_1 parameters as the constant and the coefficient on the variance term, as in equation (8). For the inflation, β_1 and β_2 parameters become the coefficients for the AR(2) lags. Stationarity requires that $(\delta + \alpha) < 1$. For the maximisation process, as suggested by Bollerslev (1986), the Berndt, Hall, Hall, Hausman (1974) algorithm was used, and to ensure that the global maximum was obtained, different initial values were given for the parameters.

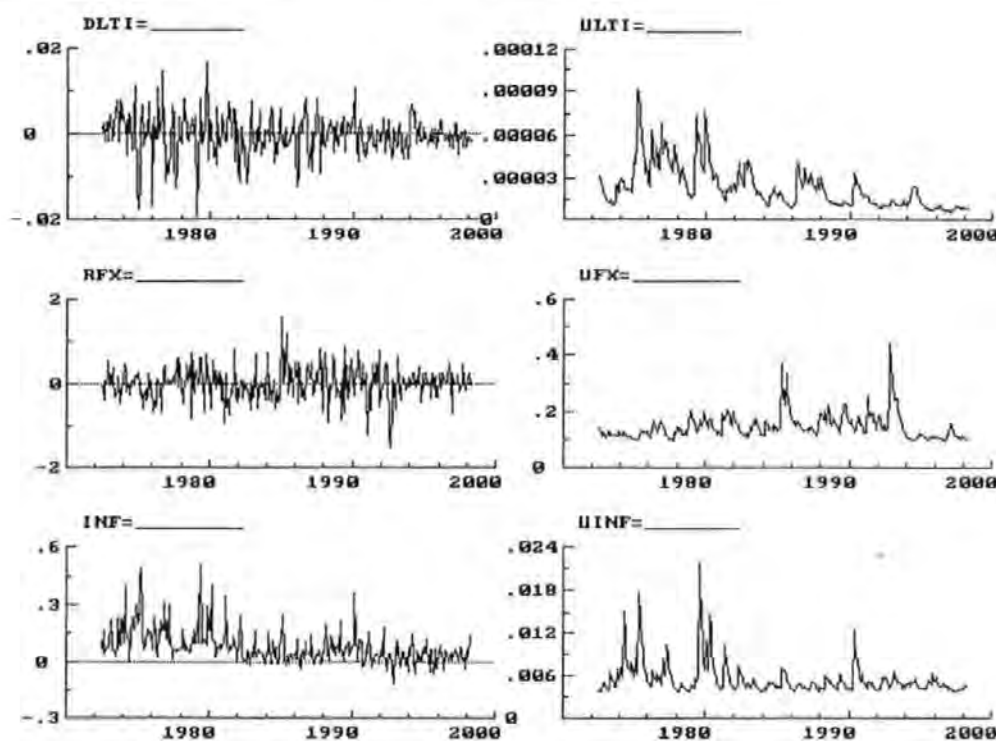
Table 7.3 Maximum Likelihood Estimates of Volatility

Parameter	<i>DLTI</i> GARCH(1,1)-M	<i>RFX</i> GARCH(1,1)-M	<i>INF</i> AR(2), GARCH(1,1)
ω	0.000001 (3.6041)	0.0227 (2.7060)	0.0012 (3.4964)
δ	0.1642 (3.2124)	0.0964 (2.4903)	0.1187 (2.4216)
α	0.7993 (20.9708)	0.7490 (9.6680)	0.6592 (7.3719)
β_0	-0.0003 (-0.7761)	0.0400 (0.4705)	0.0303 (3.7431)
β_1	-6.8742 (-0.3498)	-0.3780 (-0.6183)	0.4200 (5.6144)
β_2	-	-	0.1661 (2.3938)

Table 7.3 gives the estimation results for the three variables, and figure 7.2 shows the volatility estimations together with the series for comparison. The β_1 coefficients on the variance terms appear with insignificant negative signs for the

GARCH(1,1)-M models. For the inflation, both β_1 and β_2 parameters for the lagged values appear with positive significant values. The GARCH(1,1) parameters indicate that $(\delta + \alpha) < 1$ for all estimations, satisfying the stationarity conditions. More importantly, all coefficients appear with very significant t -ratios.

Figure 7.2 Conditional Volatility Estimates



In figure 7.2, the variables *ULTI*, *UFX* and *UINF* represent the estimated uncertainty of the long-term interest rate, the exchange-rate and the inflation rate, respectively. As can be seen, for the three series, conditionally estimated measures successfully mimic the highly volatile periods. For instance, the highly volatile periods for the *ULTI* and *UINF* are the effects of the oil shocks in the

1970's. For the *UFX*, the high volatility in 1985 and in 1992 portray the turmoil in the world markets and the rise of the US dollar and the dropping of the UK from the ERM (exchange rate mechanism), respectively.

Section 7.4 Simulation Results

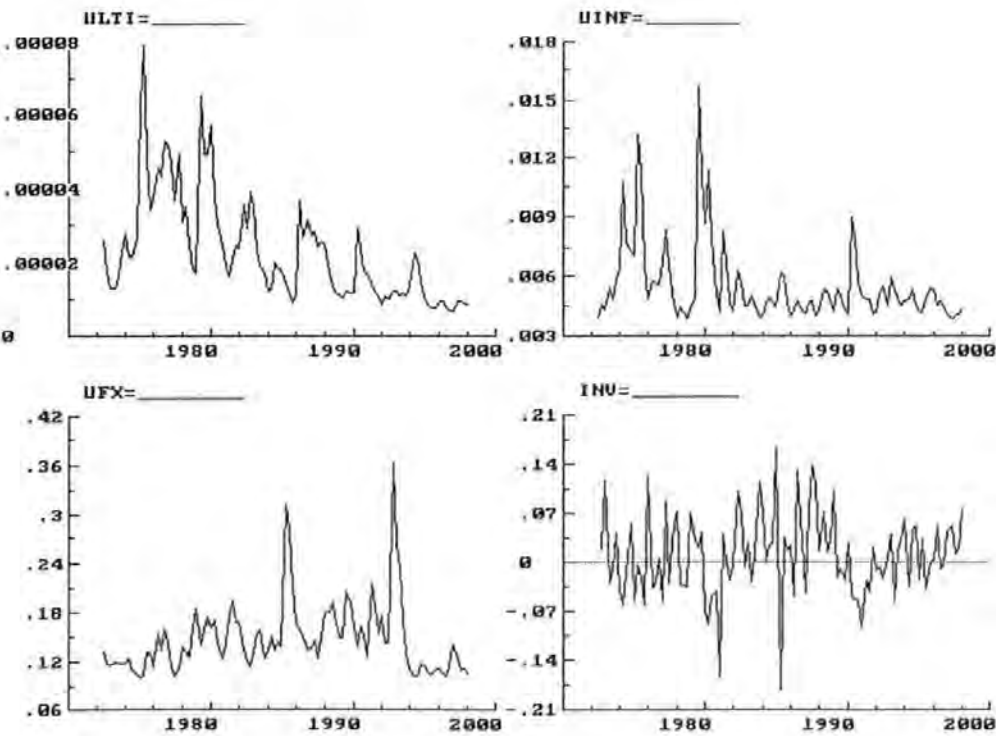
Before estimating the models and carrying out the simulations, possible unit roots were tested for the VAR variables. Investment figures were obtained at a quarterly frequency; thus, to obtain the quarterly figures for the conditional volatility measures, the monthly figures were averaged for each three-month period. The unit root tests were carried out as in the previous section by including quarterly dummies. However, the trend variable was not included for the volatility measures since the inclusion of the trend does not seem appropriate for any of the three variables from figure 7.2. The results in table 7.4 show that the three estimated volatility measures are stationary since the related *t*-ratios are above the critical 5% level.

Table 7.4 Unit Root Test Results for the VAR Variables

<i>n</i> =100	<i>ULTI</i>	<i>UFX</i>	<i>UINF</i>	CV:5%
only constant included				
γ	-3.2103	-4.6022	-4.3448	[-2.89]
trend and constant included				
γ	-2.7743	-3.1669	-2.1601	[-3.45]
only constant included				
γ	-0.3230	-0.5956	-0.6352	[-2.89]

On the other hand, the logarithms of the fixed total investment (*LINV*), the machinery and equipment investment (*LIPM*) and the construction investment (*LIBD*) appear to be difference stationary, since the *t*-ratios are all below the critical ratio. The total fixed investment is the UK gross domestic fixed investment and the other two categories are the disintegrated version of this series. The Datastream codes for the investment variables are, respectively, [UKOCGDFID], [UKOCMEQPD] and [UKOCCNSID], and they were obtained from the OECD database.

Figure 7.3 VAR Variables



Since the three volatility measures are stationary, no cointegration relationship exists between the variables. Thus, the first difference of the investment variables were taken. Before analysing the investment-uncertainty relationship for the different categories of investment, we will first analyse the case for the total investment. Figure 7.3 shows the three volatility measures and the logarithmic difference of the total investment at annual rates for quarterly frequency from 1972:Q3 to 1998:Q1. A VAR model will be quickly over-parameterised with the additional lags. On the other hand, it is also important not to misspecify the model by including less lags than necessary. To decide the lag length of the system, formal tests were carried out. The results are presented in table 7.5 for 6, 4, 3, 2 and 1 lags.

Table 7.5 F-Tests for System Reduction

System Reduction	Signif. Level	System Reduction	Signif. Level
VAR(6) → VAR(4)	(0.2662)	VAR(3) → VAR(2)	(0.7889)
VAR(6) → VAR(3)	(0.3766)	VAR(6) → VAR(1)	(0.0327)
VAR(4) → VAR(3)	(0.6233)	VAR(4) → VAR(1)	(0.0244)
VAR(6) → VAR(2)	(0.5396)	VAR(3) → VAR(1)	(0.0051)
VAR(4) → VAR(2)	(0.8037)	VAR(2) → VAR(1)	(0.0001)

The test is the *F*-test version of likelihood ratio test for the system as given in Anderson (1984). We test the significance of the additional lags by comparing the residual sums of squares of the restricted and the unrestricted forms where the null hypothesis is that the coefficients of the additional lags are zero. The significance levels of the *F*-tests reveal that the lag reductions are acceptable up to 2 lags, and the reduction to 1 lag is rejected from all systems. Thus, the VAR(2) system best

describes the dynamics of the system according to the tests. To satisfy that the given shocks are not explosive, the eigenvalues of the system given in equation (4) should be in the unit circle. Table 7.6 gives the eigenvalues of the VAR(2) system which also includes quarterly dummies. As can be seen, all roots are complex and the modulus is less than unity, satisfying the stability condition.

Table 7.6 Eigenvalues of the VAR(2) System

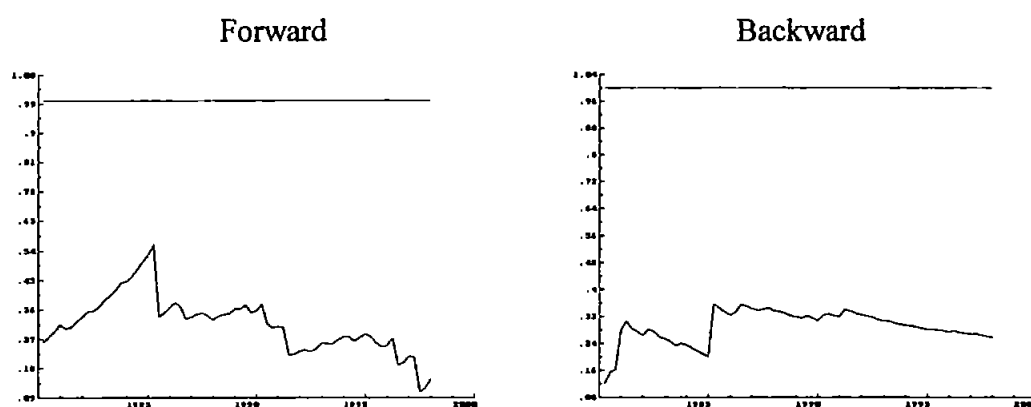
Eigenvalues	Real	Complex	Modulus
$\lambda_{1, 2}$	-0.1598	± 0.3702	0.4032
$\lambda_{3, 4}$	0.7324	± 0.0770	0.7364
$\lambda_{5, 6}$	0.4773	± 0.1853	0.5121
$\lambda_{7, 8}$	-0.0342	± 0.0840	0.0907

In the shock simulation process, possible effects of structural policy changes were also considered. For that purpose, two impulse dummies were incorporated into the model. The first one is for the first quarter of 1985, for the effect of change in the UK corporate tax system on investment. The second one is for the third quarter of 1992, for the effect of Exchange Rate Mechanism on exchange rate volatility.

As a final step, to ensure that the parameters of the system are stable, predictive Chow (1960) tests were carried out recursively. The null hypothesis in this test is that the parameters are constant. First, the estimations can be carried out for a period, and then the predictions can be obtained for the next period. The idea is to test the difference between the two residual sums of squares of two different

periods by using an F -test. In figure 7.4, the results of the recursive F -tests are given at 5% level. The first graph shows the results of the forward recursive tests. The second graph reverses the role of the samples and gives the backward recursive tests. As can be seen, the results of both recursive tests are below the critical 5% line indicating that the parameters of the VAR(2) system are constant.

Figure 7.4 Recursive Chow Tests for System Stability at 5% Level



As explained in the second section, when Choleski decomposition is employed, depending on the structure of the error correlation matrix of the reduced form VAR system, the ordering of the variables can matter. Since we are investigating the effects of various forms of uncertainty on investment decisions, it is reasonable to place the investment variable as the last variable in the ordering. Thus, the contemporaneous effects of the investment variable on the three volatility measures are assumed zero. If one considers a policy driven shock, then it is logical to place the interest rate uncertainty as the first variable. However, one may also want to consider an initial price shock by placing the inflation volatility

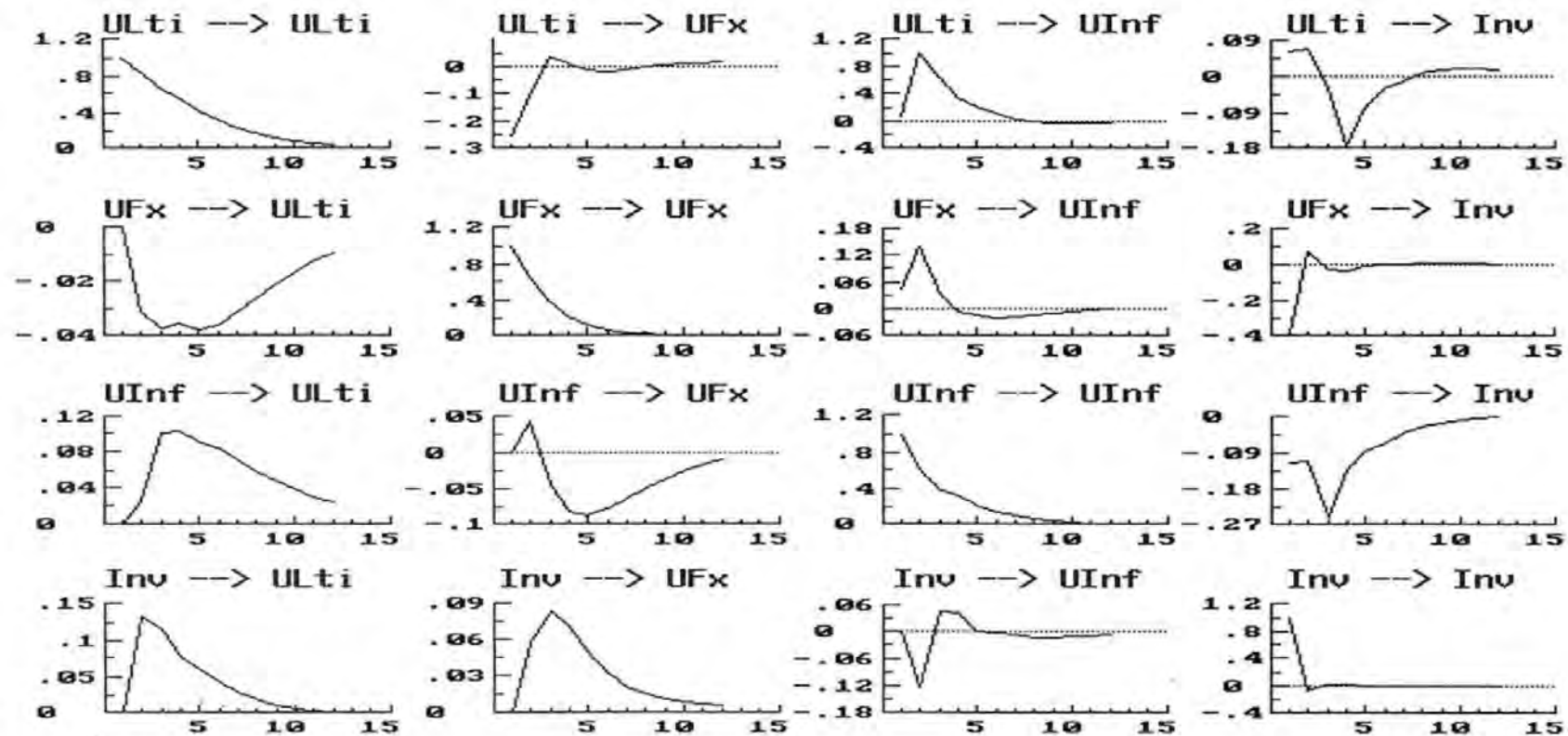
as the first variable. Table 7.7 gives the error correlation matrix for the four dimensional VAR(2) system. As can be seen, except for the negative correlation between the error terms of the interest rate volatility and the exchange rate volatility, the correlation measures between the error terms of the volatility measures are quite small. Thus, the ordering of the three volatility measures should not change the simulation results significantly.

Table 7.7 Error Correlation Matrix of the VAR(2) Model

Variables	<i>ULTI</i>	<i>UFX</i>	<i>UINF</i>	<i>INV</i>
<i>ULTI</i>	1.0000	-	-	-
<i>UFX</i>	-0.2490	1.0000	-	-
<i>UINF</i>	0.0611	0.0261	1.0000	-
<i>INV</i>	0.0543	-0.3605	-0.1186	1.0000

Figure 7.5 shows the impulse response functions of the system *ULTI*, *UFX*, *UINF*, *INV* in the given order for a horizon of 12 quarters. The VAR(2) system includes a constant, quarterly dummies and the two impulse dummies. Each row in the figure traces out the effects of a unit shock to the error term of a variable on the time paths of the whole system. The diagonal shows the response of the variables to their own shocks. The values of the variables converge to their long-run levels, and this convergence is assured by the eigenvalues given in table 7.6. The first row in figure 7.5 plots the impulse response functions of the variables to a unit shock in *ULTI*. After a unit shock in the interest rate uncertainty, the effect of the shock on itself decays slowly. The exchange rate uncertainty gives a negative response initially, and the effect converges to its long-run level after the third

Figure 7.5 Impulse Response Functions of the System $ULTI \rightarrow UFX \rightarrow UINF \rightarrow INV$



quarter. On the other hand, the inflation uncertainty gives an increasing positive response which attains a very high level at the second quarter and vanishes slowly. Interestingly, although small, the initial impact of the shock in the interest rate uncertainty on the total fixed investment is positive. This effect becomes negative after the third quarter, reaches the minimum at the fourth quarter, and then slowly converges to the long-run level. The second row, plots the impulse response functions of the variables to a unit shock in UFX . Because of the Cholesky decomposition and the imposed ordering, the contemporaneous effect of UFX on $ULTI$ was assumed zero. Thus, the initial impact on $ULTI$ is zero. Although small, the overall effect is negative, and starts to converge after the fifth quarter. The effect on the inflation uncertainty is positive, reaching the maximum in the second quarter, and then converging. Unlike the response to the shock in the interest rate volatility, the total fixed investment initially gives a negative and higher response to a shock in the foreign exchange rate uncertainty, and the adjustment to the long-run level happens quickly with an oscillatory movement after the second quarter.

As can be seen from the third row, because of the ordering, the initial responses of $ULTI$ and UFX to the shock in $UINF$ are zero. The interest rate uncertainty gives a positive response, and the effect diminishes slowly. The foreign exchange rate uncertainty gives a positive response, but later the effect becomes negative and then converges. Although not very high, initially the effect on the investment is negative. After the second quarter, the negative effect worsens and dies slowly

after the third quarter. The final row in figure 7.5 plots the impulse response functions of the variables to a unit shock in the error term of the total investment. Because of the imposed ordering, the initial impacts are zero except on itself. Both *ULTI* and *UFX* give positive responses to this shock. On the other hand, in the first three quarters, the effect on the *UINF* is negative, converging with an oscillatory movement thereafter.

Table 7.8 Forecast Error Variance Decomposition of the System

ULTI→UFX→UINF→INV (%)

Variables	<i>ULTI</i>	<i>UFX</i>	<i>UINF</i>	<i>INV</i>
<i>ULTI</i>	96.54	0.30	1.70	1.46
<i>UFX</i>	4.59	92.36	1.92	1.13
<i>UINF</i>	47.36	0.70	51.36	0.58
<i>INV</i>	3.57	11.78	9.11	75.54

Table 7.8 presents the forecast error variance decomposition for the system *ULTI*, *UFX*, *UINF*, *INV* for a horizon of 12 quarters. It shows the proportion of the movements of a variable due to its own shocks versus shocks to the other variables, and each row adds to 100%. Generally, for the three volatility measures, their explanatory power on each other's error variance decomposition results are quite low. Only in the case of *UINF* does an innovation in the interest rate uncertainty explain 47.36% of the forecast error variance of *UINF*. The final row reports the percentage movements of *INV* due to four different shocks given to the system. Its forecast error variance explained by an innovation in the long-term interest rate uncertainty is only 3.57%. On the other side, this is 11.78% and

9.11%, respectively, for the exchange rate uncertainty and the inflation uncertainty.

Overall, although not large, the impulse response functions and the forecast error variance decomposition results reveal that increases in the volatility of the foreign exchange rate and the inflation rate cause reductions in the total investment, and the negative effect of the former is slightly higher than the latter. Obviously, this statistical finding supports the irreversibility argument for the aggregate-level investment-uncertainty relationship. On the other hand, although small, total investment initially gives a positive response to a shock in the interest rate volatility. However, the effect becomes negative in the following periods and the overall effect is ambiguous.

Simulations were also carried out for a different ordering of the same system. For that purpose, the VAR(2) system *UINF*, *ULTI*, *UFEX*, *INV* was employed in the given order. Figure 7.6 plots the impulse response functions, and table 7.9 gives the forecast error variance decomposition results for a horizon of 12 quarters. As can be seen, neither the impulse response functions, nor the variance decomposition results for *INV* change significantly. To check the robustness of the results obtained, variance decomposition results were obtained for four further different orderings, and the obtained results are reported only for *INV* in table 7.10. As can be seen, the results are also insensitive to these different orderings.

Figure 7.6 Impulse Response Functions of the System $UINF \rightarrow ULTI \rightarrow UFX \rightarrow INV$

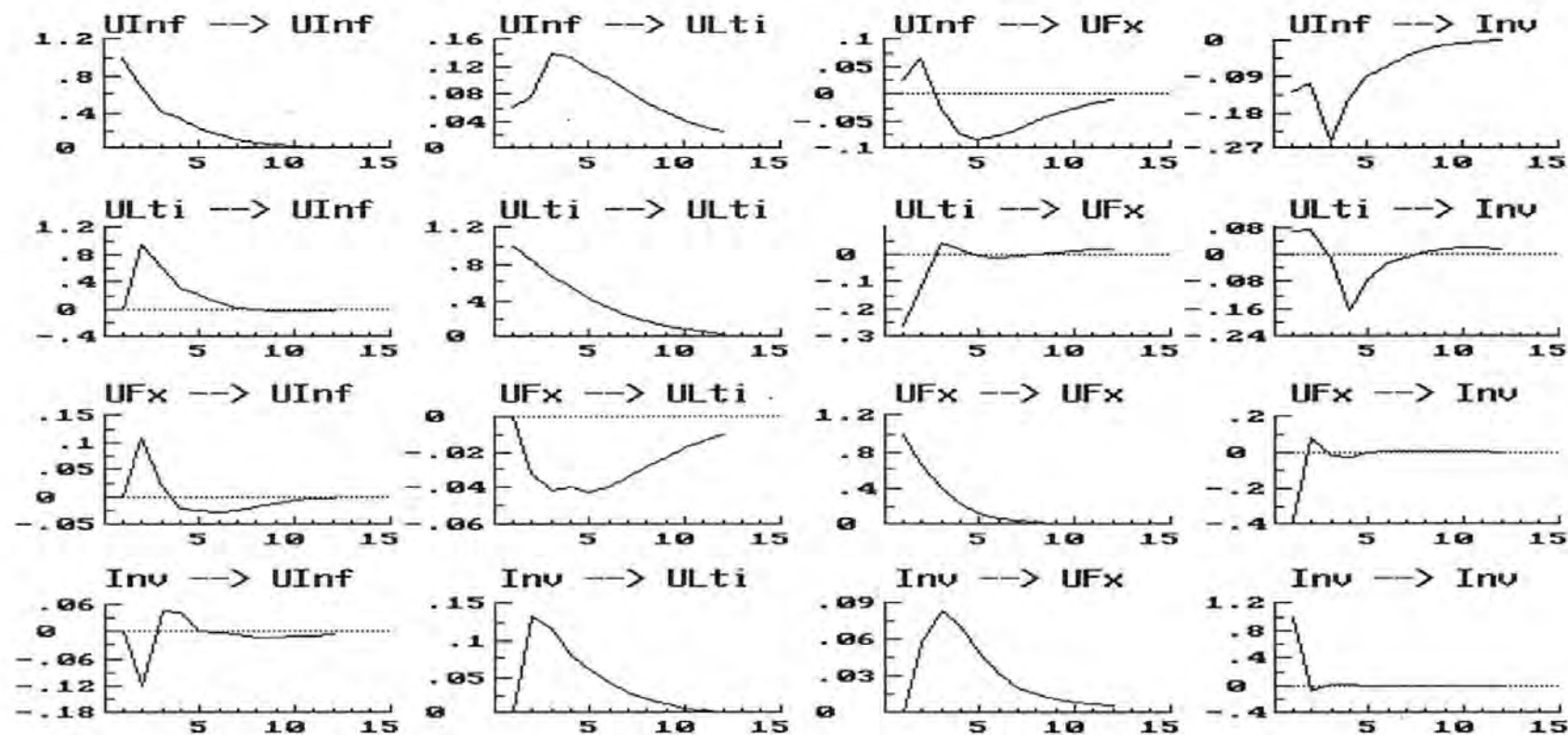


Table 7.9 Forecast Error Variance Decomposition of the System**UINF→ULTI→UFX→INV (%)**

Variables	<i>UINF</i>	<i>ULTI</i>	<i>UFX</i>	<i>INV</i>
<i>UINF</i>	55.57	43.39	0.46	0.58
<i>ULTI</i>	3.01	95.17	0.36	1.46
<i>UFX</i>	1.84	4.71	92.32	1.13
<i>INV</i>	9.65	3.36	11.45	75.54

Table 7.10 Forecast Error Variance Decomposition of Other Orderings (%)

	<i>ULTI</i>	<i>UINF</i>	<i>UFX</i>	<i>INV</i>
<i>INV</i>	3.57	9.44	11.45	75.54
	<i>UINF</i>	<i>UFX</i>	<i>ULTI</i>	<i>INV</i>
<i>INV</i>	9.65	11.44	3.37	75.54
	<i>UFX</i>	<i>ULTI</i>	<i>UINF</i>	<i>INV</i>
<i>INV</i>	11.61	3.74	9.11	75.54
	<i>UFX</i>	<i>UINF</i>	<i>ULTI</i>	<i>INV</i>
<i>INV</i>	11.61	9.48	3.37	75.54

Different investment categories require different decision making processes, thus, the uncertainty measures may have different effects on different categories. To investigate this, the same simulations were carried out for the machinery and equipment investment and the construction investment separately. Again, a VAR(2) model including a constant, quarterly dummies and the two impulse dummies was employed. Figures 7.7 and 7.8 plot the impulse response functions of the system including the three uncertainty measures and the machinery and equipment investment for two different orderings. Similarly, figures 7.9 and 7.10 plot the impulse response functions of the system for the construction investment for two different orderings. Tables 7.11, 7.12, 7.13 and 7.14 give the corresponding variance decomposition results. The final columns of figures 7.7

Figure 7.7 Impulse Response Functions of the System $ULTI \rightarrow UFX \rightarrow UINF \rightarrow IPM$

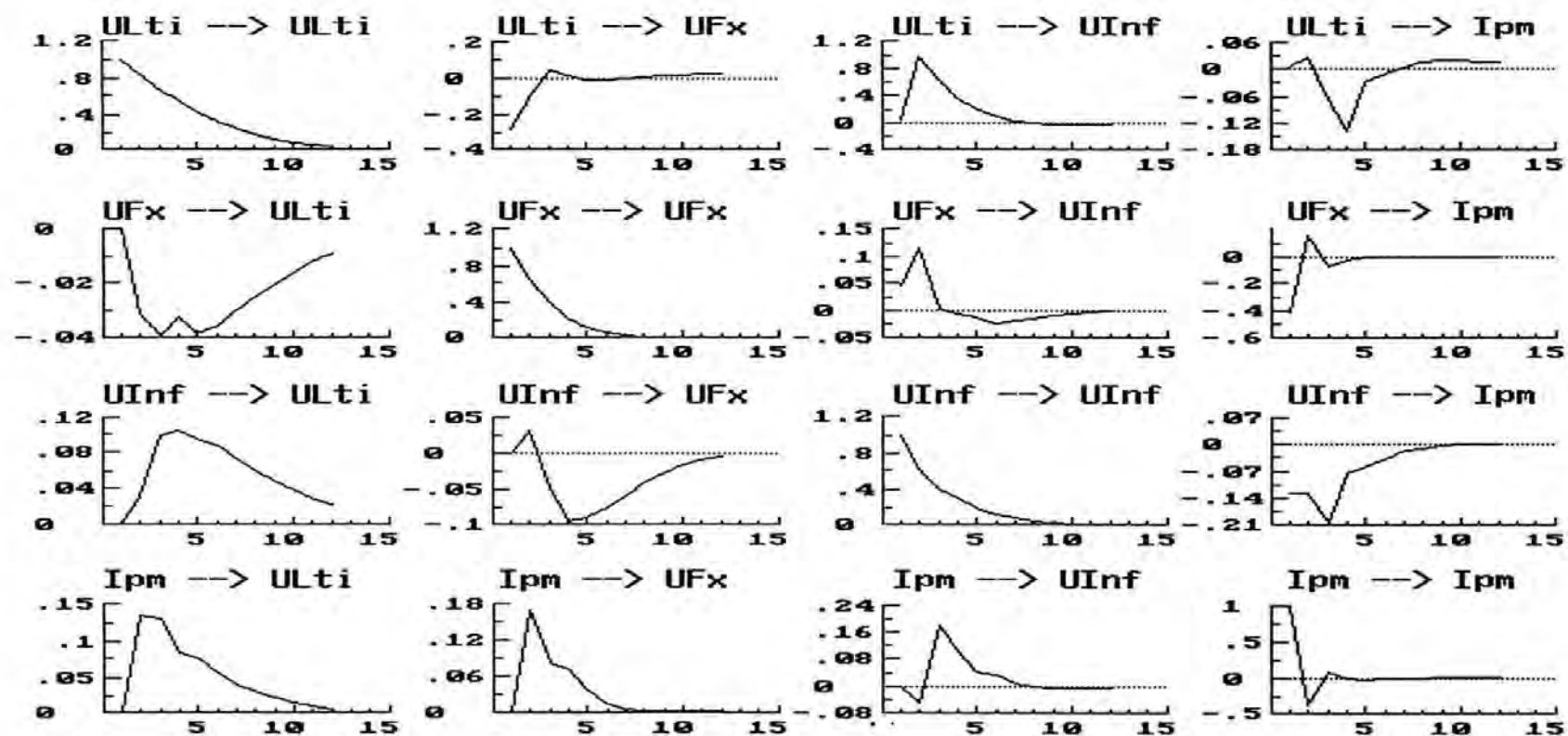


Figure 7.8 Impulse Response Functions of the System $UInf \rightarrow ULti \rightarrow UFx \rightarrow IPm$

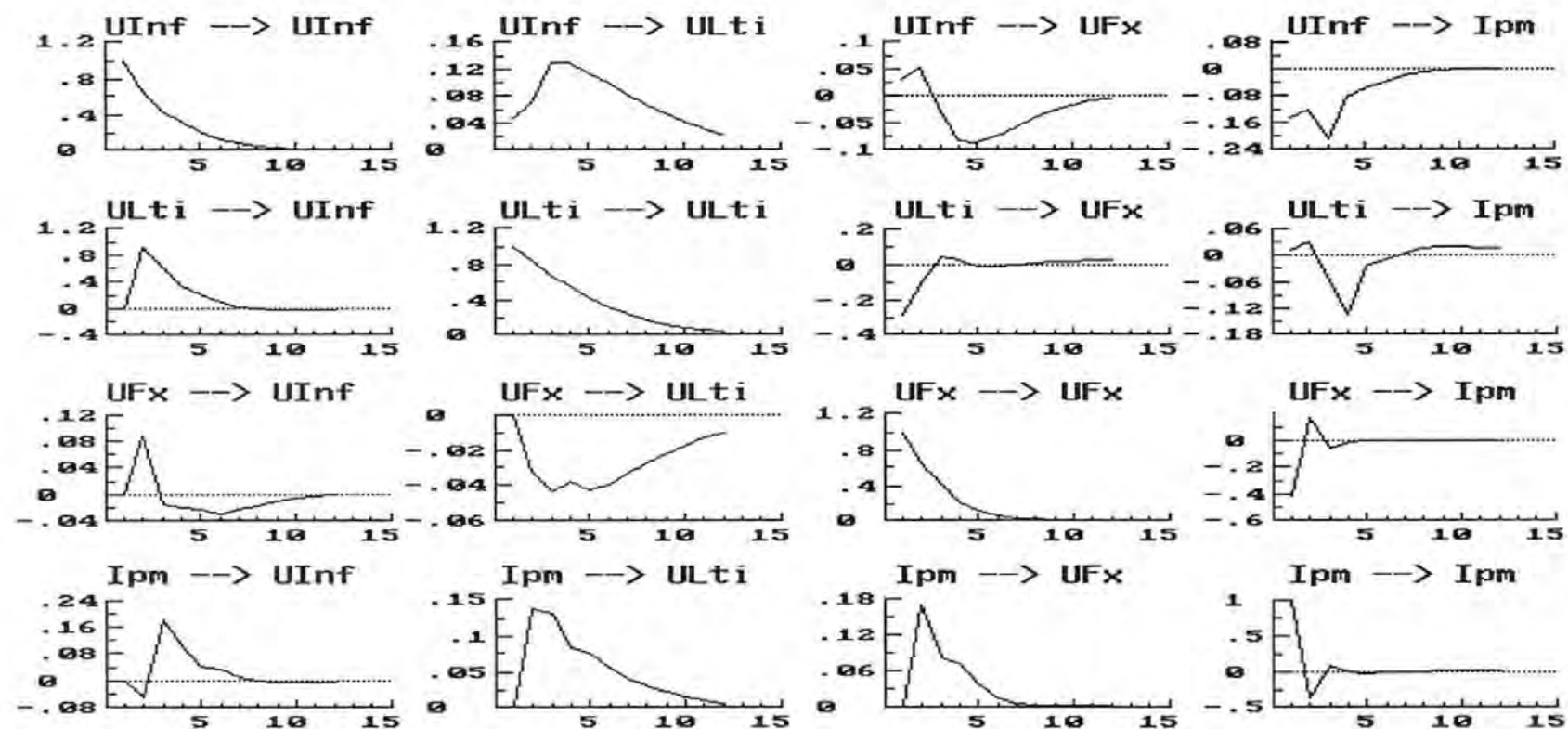


Figure 7.9 Impulse Response Functions of the System $ULTI \rightarrow UFX \rightarrow UINF \rightarrow IBD$

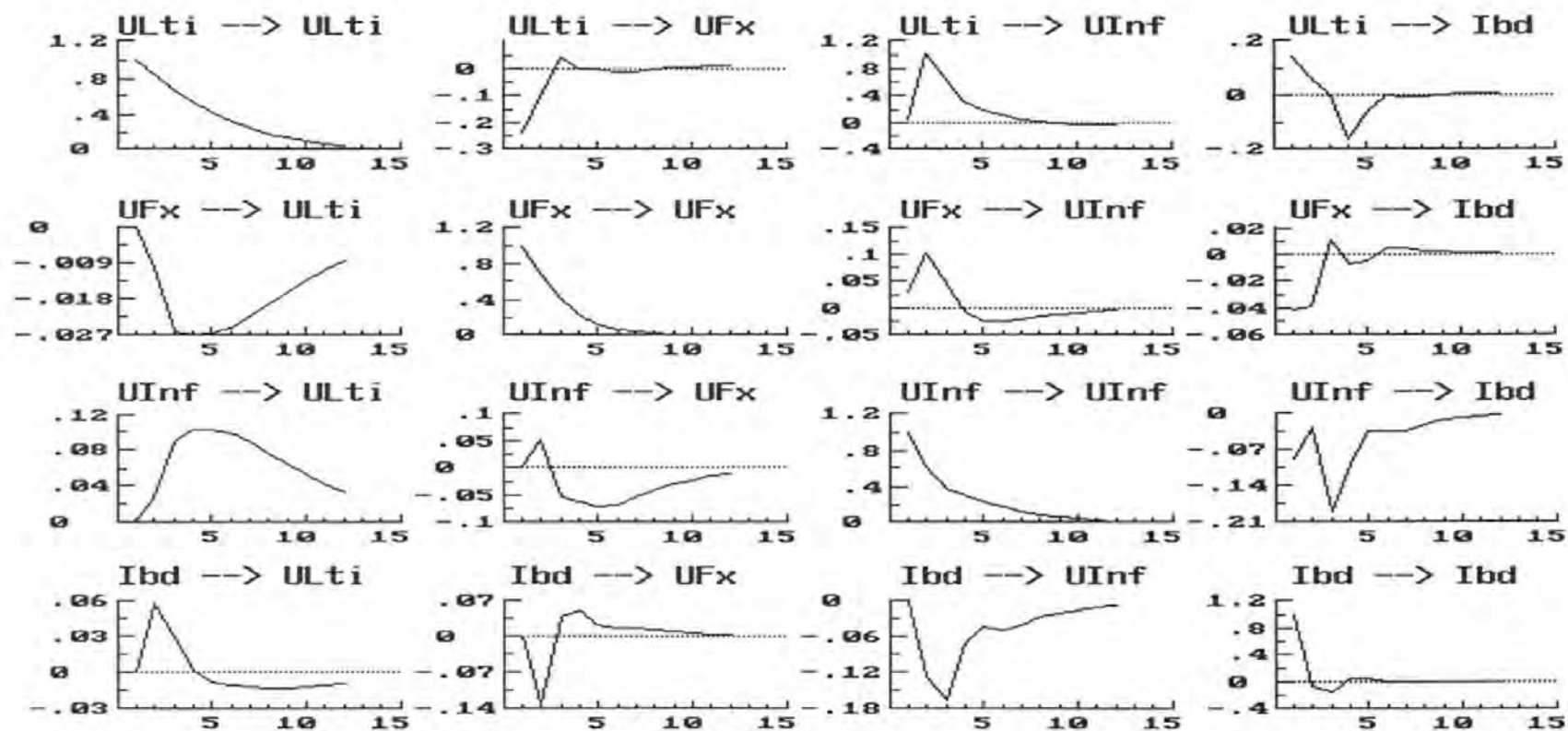
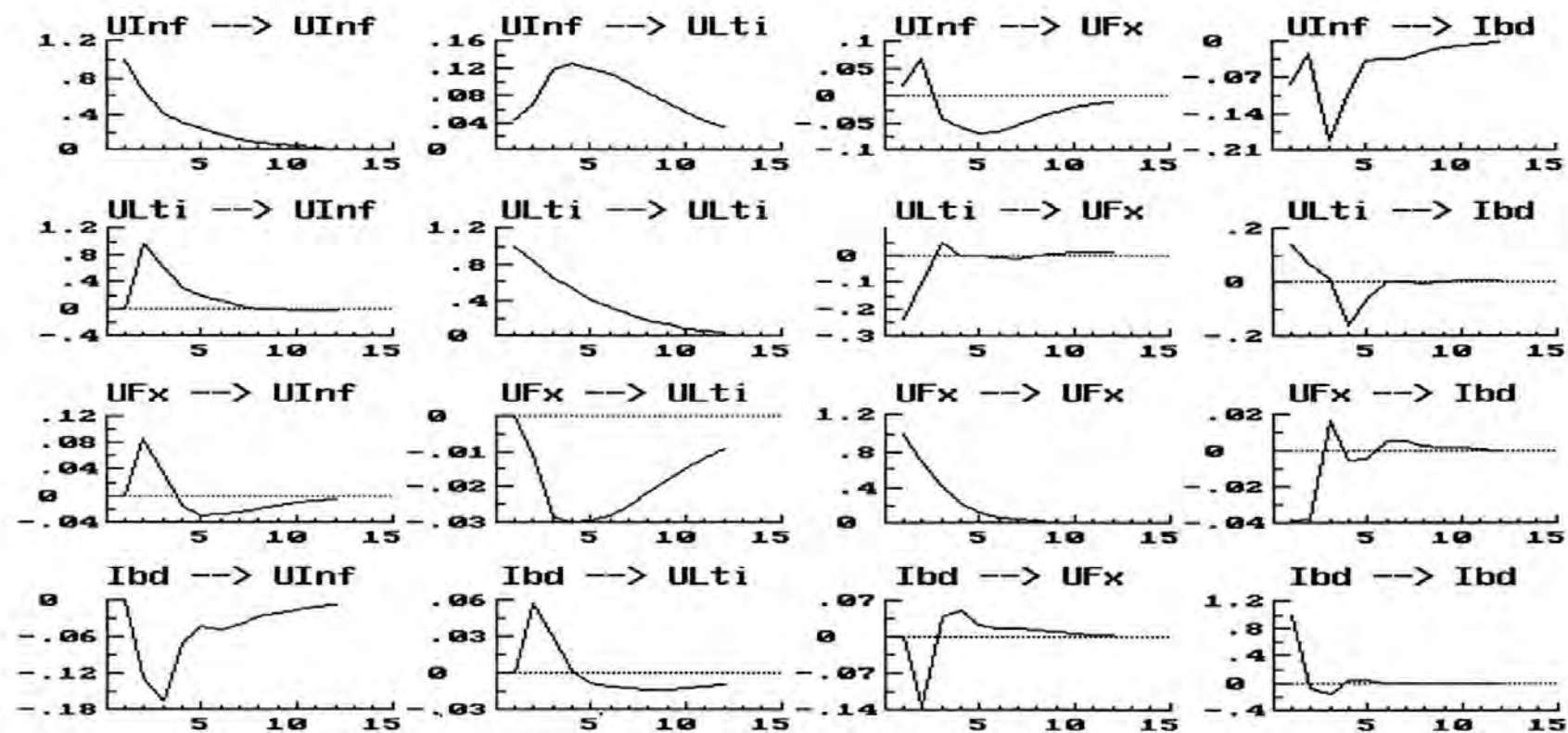


Figure 7.10 Impulse Response Functions of the System $UINF \rightarrow ULTI \rightarrow UFX \rightarrow IBD$



and 7.8 trace the responses of *IPM* (logarithmic difference of the machinery and equipment investment) to the unit shocks given to the system via the error terms of the variables. Comparing the results with the total investment case from figures 7.5 and 7.6 reveal that the effects are qualitatively similar. In this case, the initial negative response of *IPM* to the shocks in *UFX* is higher, and the initial positive response to the shocks in *ULTI* is lower. Also, the negative effect of *UINF* seems slightly less when compared to the total investment case.

Table 7.11 Forecast Error Variance Decomposition of the System

ULTI→UFX→UINF→IPM (%)

Variables	<i>ULTI</i>	<i>UFX</i>	<i>UINF</i>	<i>IPM</i>
<i>ULTI</i>	96.13	0.29	1.77	1.81
<i>UFX</i>	5.33	90.48	1.81	2.38
<i>UINF</i>	46.26	0.51	51.75	1.48
<i>IPM</i>	1.79	14.13	5.82	78.26

Table 7.12 Forecast Error Variance Decomposition of the System

UINF→ULTI→UFX→IPM (%)

Variables	<i>UINF</i>	<i>ULTI</i>	<i>UFX</i>	<i>IPM</i>
<i>UINF</i>	54.95	43.25	0.32	1.48
<i>ULTI</i>	2.72	95.12	0.35	1.81
<i>UFX</i>	1.71	5.43	90.48	2.38
<i>INV</i>	6.27	1.66	13.81	78.26

The forecast error variance decomposition results in tables 7.11 and 7.12 confirm the differences between the observed patterns of the impulse response functions of *INV* and *IPM*. In the case of the machinery and equipment investment, the negative effect of inflation uncertainty becomes less important. On the other hand,

the negative effect of the exchange rate uncertainty is higher, as the proportions in the variance decomposition results are 14.13% and 13.81% for the two different orderings. Although not reported here, the obtained results were insensitive to the other orderings.

The final columns of figures 7.9 and 7.10 plot the responses of *IBD* (logarithmic difference of the construction investment) to the unit shocks given to the system for two different orderings. Unlike the impulse response functions of *IPM*, the impulse response functions of *IBD* exhibit different patterns when compared to the total investment case. Interestingly, in both orderings, the initial positive response of *IBD* to the shocks in *ULTI* is quite high when compared to the responses of *INV*. This positive effect only becomes negative after the third quarter, converging immediately after the fifth quarter. Similar to the *IPM* case, the inflation uncertainty effect becomes less important when compared to the *INV* case, but the effect is still negative regardless of the ordering. The most important difference in the case of *UFX* is that, although the response of *IBD* have similar patterns as the responses of *INV* and *IPM*, the amount of the initial impact and the responses in the following quarters are about 10 times less than the other cases.

As the final rows of tables 7.13 and 7.14 reveal, the proportion of *ULTI* in the variance decomposition of *IBD* increases to 4.8%. The effect is still very small,

Table 7.13 Forecast Error Variance Decomposition of the System**ULTI→UFX→UINF→IBD (%)**

Variables	<i>ULTI</i>	<i>UFX</i>	<i>UINF</i>	<i>IBD</i>
<i>ULTI</i>	97.50	0.15	2.17	0.18
<i>UFX</i>	3.81	93.47	1.43	1.29
<i>UINF</i>	47.02	0.46	50.87	1.65
<i>IBD</i>	4.82	0.30	5.01	89.87

Table 7.14 Forecast Error Variance Decomposition of the System**UINF→ULTI→UFX→IBD (%)**

Variables	<i>UINF</i>	<i>ULTI</i>	<i>UFX</i>	<i>IBD</i>
<i>UINF</i>	53.90	44.11	0.34	1.65
<i>ULTI</i>	3.16	96.48	0.18	0.18
<i>UFX</i>	1.38	3.88	93.45	1.29
<i>IBD</i>	5.05	4.79	0.29	89.87

and this increment is due mainly to the higher initial positive responses in the first three quarters. This finding for the long-term interest rate uncertainty effect on the aggregate-level construction investment does not support the irreversibility argument. The proportion of *UINF* in the variance decomposition of *IBD* is around 5%. Although the effect is small, it is negative and deteriorates the construction investment. As can be seen, the proportion of *UFX* is around 0.3%, supporting the comparative impulse response analysis. Although negative, unlike the case for machinery and equipment investment, the exchange rate uncertainty does not seem to affect the aggregate-level construction investment in a significant way. These findings were again robust to different orderings of the uncertainty variables.

Section 7.5 Concluding Remarks

Using the VAR methodology and employing quarterly data for the period 1972:Q3-1998:Q1, this final chapter gave a statistical account of the aggregate-level investment-uncertainty relation for the UK. In particular, the effects of long-term interest rate uncertainty, exchange rate uncertainty and inflation uncertainty were analysed. The uncertainty measures were estimated by employing conditional volatility models. Although small, impulse response functions and forecast error variance decomposition analyses revealed negative effects of the volatility of exchange rate and inflation rate on the aggregate-level investment. The effect of the exchange rate uncertainty was higher in magnitude when compared to the inflation uncertainty. On the other hand, interest rate volatility did not appear to have a significant effect. These statistical findings do not support the convexity argument, but the irreversibility effect for the aggregate-level investment-uncertainty relationship. The analyses were taken one step further by investigating the effects of the uncertainty measures separately for the machinery and equipment and the construction investment. The simulation results revealed stronger negative effects of exchange rate volatility on the machinery and equipment investment, however, it had almost no effect on the construction investment.

CONCLUDING REMARKS

In this thesis, using large-company panel data, we empirically analysed capital investment decisions in major European countries. We particularly focused on three issues: the taxation of capital in the EU, the role of agency costs of debt on investment decisions, and the empirical analyses of the investment-uncertainty relationship.

Harmonisation of tax rules in the EU has been an important argument. Some studies argued in favour of independent tax systems for demand management and economic stabilisation and adjustment. On the other hand, some argued in favour of harmonisation to prevent discrimination and distortion in investment decisions which will result in inefficient location decisions.

In chapter 2, a dynamic tax simulation analysis was conducted to understand the role of corporate tax policy changes on investment decisions. The theoretical framework was limited by the q model of investment, but this had certain advantages. It was based on the augmented neo-classical model, so it was a structural approach which enabled a study of various tax policy effects. It was a forward-looking model, free of an expectations problem, and also the estimated investment equation was not subject to a direct rational expectations criticism. The analyses were oriented on four major European countries: the United Kingdom, France, Germany and the Netherlands. First, we aimed to measure the dynamic

effects of various corporate tax policy changes to see whether the effects are important, and which policy affects which country more. As a second aim, the policy effects were contrasted between the countries which has important implications for the tax harmonisation issue in the EU.

Simulation results revealed that tax policies affect investment decisions. It was observed that investment was more sensitive to investment tax credit changes relative to other policy effects. Substantial differences were observed for the tax policy effects on investment between the UK and France, Germany, and the Netherlands as a group, and also differences within this group in terms of different policy effects. Among the countries, investment was found least sensitive to all policy shock effects in the UK. More importantly, the harmonisation of the corporate tax rules reduced the observed asymmetry only by a limited amount.

As observed in the literature, the adjustment costs implied by the model were unreasonably high. To overcome this problem, one could introduce a more complicated adjustment cost function. For instance, the irreversibility effect could be introduced implicitly in the model by way of an augmented adjustment cost function as in Eberly (1997). Additionally, the approach taken here was limited to the permanent tax policy shock effects. As an extension of the approach taken here, temporary tax policy effects can be studied. Also, the ignored role of personal taxation can be introduced to the model.

In chapter 3, we analysed the joint effects of income uncertainty and irreversibility of investment decisions on the domestic effective marginal tax rates. Effective tax rates are commonly employed to reveal the role of a tax system in the incentives or disincentives to invest given to firms. However, for simplicity, many studies using these measures ignore the role of uncertainty and irreversibility risks. See Ruding (1992), Devereux and Pearson (1995) and Chennells and Griffith (1997) for instance. Considering a zero loss offset income tax case, it was shown analytically that this joint effect greatly increases the tax distortion measures. By using actual data for the UK, France, Germany and the Netherlands, we presented evidence that the joint effect of uncertainty and irreversibility would increase the commonly used marginal effective tax rates measures to much higher levels. As an extension to chapter 2, the effects of harmonising the corporate tax rules were also analysed. When the joint risk was incorporated, the reduction in the observed asymmetry was far less than the reduction in the case of certainty and reversibility. Similar to the findings in chapter 2 for the dynamic effects of tax policy changes, the results found in this chapter have important implications for the EU since it contradicts the tax competition view for the domestic investment case.

In chapter 3, a fully irreversible case was assumed, whereas in reality not all expenditures can be treated as sunk costs. Investment expenditures would be at least partly reversible. Also, for simplicity, we assumed a no loss offsetting case. However, the assumption of no refundability was not realistic since many corporate income tax systems permit at least a partial refundability of losses. This

was because, the presence of carry-forwards or carry-backs of losses would greatly complicate the employed model. For instance, see Mayer (1986). Another important drawback was the assumption that stock market fluctuations will reflect changes in income which could only be partly true for a real-world case. A possible extension of the approach taken here would be to overcome the above-mentioned drawbacks, at least at some level. Further, the model could be expanded to include personal taxation, other sources of uncertainty or an international investment case.

Within the context of the models employed in chapters 2 and 3, we conclude that the obtained results cast doubt on the tax competition view in the EU for the domestic investment case. Thus, harmonising corporate tax rules may mean the loss of a fiscal tool which can be used for adjustments of asymmetric shocks or for national demand management and economic stabilisation of the member economies.

In the literature, many studies proposed that information and incentive problems may create frictions in financial capital markets. Thus, unlike Modigliani and Miller's irrelevance result, financing conditions may have important implications for investment decisions. Studies testing the possible relations between investment and financing decisions mostly documented cash flow and liquidity effects. However, existing empirical studies about the effects of incentive

problems on investment decisions are not numerous and find controversial results, showing that more empirical investigations of these effects are required.

In chapter 4, using a Euler equation approach and based on the agency/financial distress costs of debt, an investment equation was derived to test the role of debt financing conditions on investment decisions. In the model, we also considered the possible beneficiary role of working capital on the asset side of the balance sheet to smooth these costs and pressures. The study covered large UK, German and French firms. The estimation results revealed that the perfect financial capital markets hypotheses were not acceptable. According to the developed model, the agency/financial distress costs of debt were important so that debt financing had a significant role in management's investment decisions. However, we also found that, to some extent, firms had the ability to smooth these costs and alleviate pressures through their working capital policy on the asset side of their balance sheets. Further analyses revealed that the agency/financial distress cost of debt had negative impacts on the investment behaviour of the high-leverage groups, whereas it was not significant for the low-leverage groups.

In chapter 5, we derived an alternative model in a q theory framework to test the role of agency/financial distress costs of debt on investment. In this formulation, the investment equation included the debt-capital ratio under the hypothesis of incentive problems of debt and capital market imperfections. We tested this alternative model for the UK firms. Similar to the findings in chapter 4, the

estimation results revealed that the agency/financial distress costs of debt had a significant negative role in investment decisions of highly leveraged firms. To some extent, those firms had the ability to smooth these costs through their working capital policy.

Overall, the results of chapters 4 and 5 showed that imperfections in the markets exist, financing and investment decisions interact, and the financing conditions have important implications for investment decisions. The findings imply important effects at the aggregate level since it was conducted by using only large industrial firms which constitute a very large fraction of the total investment in the economies. Leverage increases by corporations may increase the economy-wide costs, risk and financial distress.

In chapters 4 and 5, we neglected the role of informational and incentive problems related to equity finance in the modelling process. However, in practice, there might be manager-shareholder conflicts in some firms. For instance, see Pike (1985), Chen (1995) and Cho (1998) for an argument and evidence of these effects on investment behaviour. As an extension to the models developed in chapters 4 and 5, one may consider the role of fixed capital on the asset side of the balance sheet to smooth the hypothesised agency costs. For instance, this can be the collateral role of fixed assets. The agency/financial distress costs of debt can be analysed in detail for short-term and long-term debt, and the smoothing benefits of working capital for cash, stock and debt policies. Additionally, to

improve the models, the irreversibility of investment decisions and tax issues can be considered. Also, as discussed in Oliner et al. (1996), the stability of the parameters of the Euler equations employed in chapter 4 can be tested as an additional misspecification test.

At a firm level analysis, the theoretical work on the investment-uncertainty relationship suggests that the direction of the sign of this relationship depends on the degree of competition faced by a firm and/or the assumption about the technology that the firm adapts. Empirical studies are far behind the theoretical developments in this field. This is mainly due to the estimation problems involved in stochastic dynamic structural models. See for instance, Marcet (1994) and Pakes (1994). A small number of studies examined the sign of the investment-uncertainty relationship at the firm level and found mostly negative effects.

In chapter 6, we empirically examined the sign of the short-run investment-uncertainty relationship for large UK industrial companies. We particularly considered the product market structure while studying this relation via the product specialisation criteria. We did not attempt to develop a specified structural model, however, to test the robustness of the findings, two different models and two different measures of uncertainty were employed. The first uncertainty measure was based on conditional CAPM, and the second one was based directly on the conditional stock returns. The findings revealed that consideration of the product market structure confirmed the predictions of both theoretical works, and this result

was robust under different model specifications. Moreover, it was observed that one should be careful about the employed uncertainty measure before reaching a conclusion about the nature of this relationship. As a possible extension to the approach taken in chapter 6, other investment models could be considered and other uncertainty measures could be employed. Additionally, other splitting criteria could be used to consider the assumptions of the two opposing views.

Using impulse response functions and forecast error variance decomposition analyses of the vector autoregression methodology, chapter 7 gave a statistical account of the aggregate investment-uncertainty relation in the UK. In particular, the effects of long-term interest rate uncertainty, exchange rate uncertainty and inflation uncertainty were analysed. The uncertainty measures were estimated by employing conditional volatility models. Although they were not large, negative effects of exchange rate and inflation uncertainty were observed on the total investment. To some extent, these findings support the irreversibility argument at the aggregate level. We observed significant differences between the responses of machinery and equipment investment and the construction investment to the exchange rate volatility. The simulation results revealed stronger negative effects of exchange rate volatility on the machinery and equipment investment, however, it had almost no effect on the construction investment. This observed difference is most probably due to the different characteristics of the two types of investment.

APPENDIX

This appendix gives the names of the firms employed throughout chapters 2-6.

Chapter 2 and Chapter 3

United Kingdom (82 Firms)

AGGREGATE INDUST.	IBSTOCK
ALLIED COLLOIDS	IMI
AMEC	IMP.CHM.INDS.
AMSTRAD	JOHNSON MATTHEY
ANTOFAGASTA HDG.	LAIRD GROUP
APV	LAPORTE
ARJO WIGGINS APL	LONRHO
AVON RUBBER	LOW & BONAR
BAIRD (WILLIAM)	MARLEY
BBA GROUP	MCKECHNIE
BIBBY (J)	MEYER INTL.
BLUE CIRCLE INDS.	MORGAN CRUCIBLE
BOC GROUP	PENTLAND GROUP
BOWTHORPE	PILKINGTON
BPB	POWELL DUFFRYN
BRIT.AEROSPACE	RACAL ELECTRONIC

BRIT.POLYTHENE	REDLAND
BRITISH STEEL	REXAM
BRITISH VITA	RMC GROUP
BTP	ROLLS-ROYCE
BTR	RUGBY GROUP
BUNZL	SCAPA GROUP
CARADON	SENIOR ENGR.
CHARTER	SIEBE
COATS VIYELLA	SMITH (DAVID S)
COBHAM	SMITHS INDS.
COOKSON GROUP	SPIRAX-SARCO
COURTAULDS TEXT.	ST.IVES
CRODA INTL.	T & N
DANKA BUS.SYS.	TARMAC
DE LA RUE	TAYLOR WOODROW
DELTA	TI GROUP
FKI	TOMKINS
GENERAL ELEC.	VICKERS
GKN	WADDINGTON
GLYNWED	WASSALL
HANSON	WATMOUGHS HDG.
HARRISONS &CROS.	WEIR GROUP

HEPWORTH

HEWDEN-STUART

HEYWOOD WILLIAMS

WILLIAMS HDG.

WIMPEY (GEORGE)

WOLSELEY

France (26 Firms)

ALCATEL ALSTHOM

BERTRAND FAURE

BOUYGUES

CGIP

CIMENTS FRANCAIS

COLAS

CS (CIE.DES SIN)

DASSAULT AVIATIO

DEGREMONT

DEVANLAY

DMC

ECIA

EIFFAGE

FIVES LILLE

GASCOGNE

GROUPE ANDRE

GTM ENTREPOSE

INTERTECHNIQUE

LABINAL

LAFARGE

LEGRAND

LEGRAND ADP

LEGRIS INDUSTRIE

MANITOU

METALEUROP

MICHELIN

NORD-EST

PEUGEOT SA

PLASTIC OMNIUM

PRIMAGAZ

ROCHETTE (LA)

SAINT GOBAIN

SAT

SFIM

IMETAL

THOMSON-CSF

INGENICO

VALEO

Germany (76 Firms)

AGIV

HOCHTIEF

AHLERS ADOLF

HOECHST

ASEA BROWN BOVER

HOLZMANN (PHILIP)

BASF

INDUSTR.VERWALT.

BAYER

IWKA

BERLINER ELK.HLD

JUNGHEINRICH PRE

BILFINGER & BERG

KAMPA-HAUS

BMW

KLOECKNER-WERKE

BOSS (HUGO)

KM EUROPA METAL

BOSS (HUGO) PREF.

KOLBENSCHMIDT

BUDERUS

KRONES PREF.

C.H.A.BAUELEMENT

KSB

COMPUTER 2000

KSB PREF.

CONTINENTAL

LINDE

DEGUSSA

MAN

DEUTZ

MAN-ROLAND

DIDIER-WERKE

MANNESMANN

DRAEGERWERK PREF.

PHOENIX

DT.BABCOCK

DUERR BET.

DYCKERHOFF

DYCKERHOFF PREF.

DYCK & WIDMANN

ESCADA

ESCADA PREF.

FAG KUGELFISCHER

FELTEN & GUILL.

FPB HOLDING

GEA

GEA PREF.

GILDEMEISTER

GLUNZ PREF.

GOLDSCHMIDT

HARPEN

HEIDELB.ZEMENT

HENKEL PREF.

HERLITZ

HERLITZ INTL.TRA.

PORSCHE PREF.

PREUSSAG

PUMA

PWA

RHEINMETALL BERL

RUETGERS

SALAMANDER

SANDER (JIL) PRE

SCHMALBACH-LUBEC

SCHNEIDER RUND F.

SIEMENS

STRABAG

SUD-CHEMIE

THYSSEN

VARTA

VBH BAUBESCHLAG

VIAG

VOLKSWAGEN

VOSSLOH

ZANDERS FEINPAPI

Netherlands (19 Firms)

AKZO NOBEL	HUNTER DOUGLAS
BOSKALIS WESTMIN	IHC CALAND
CATE. KON.TEN	KON.KNP BT
DSM	KON.PAKHOED
GAMMA HOLDING	OCE VDR.GRINTEN
GETRONICS	PHILIPS ELTN.
HAGEMEYER	SAMAS CERT.
HOEK'S MACHINE	STORK
HOLLANDSCHE BETO	VOLKER STEVIN
HOOGOEVENS	

Chapter 4 and Chapter 5

United Kingdom (76 Firms)

AGGREGATE INDUST.	LAIRD GROUP
ALLIED COLLOIDS	LAPORTE
API GROUP	LONRHO
AVON RUBBER	LOW & BONAR
BEMROSE CORP.	MACFARLANE GROUP
BICC	MARSHALLS
BLUE CIRCLE INDS.	MAYFLOWER CORP.

BOC GROUP	MCKECHNIE
BODYCOTE INTL.	MEGGITT
BOWTHORPE	MORGAN CRUCIBLE
BPB	PILKINGTON
BRIT.AEROSPACE	POWELL DUFFRYN
BRIT.POLYTHENE	RACAL ELECTRONIC
BRITAX INTERNATI	RENOLD
BRITISH VITA	REXAM
BUNZL	RMC GROUP
CHARTER	ROTORK
COBHAM	RUGBY GROUP
COOKSON GROUP	SCAPA GROUP
COURTAULDS	SENIOR ENGR.
CRODA INTL.	SIEBE
DE LA RUE	SMITH (DAVID S)
DELTA	SMITHS INDS.
EIS GROUP	STAVELEY INDS.
ELLIS & EVERARD	T & N
EUROTHERM	TARMAC
GENERAL ELEC.	TI GROUP
GKN	TT GROUP
GLYNWED	VICKERS

HALMA	VITEC GROUP
HANSON	WADDINGTON
HENLYS GROUP	WAGON IND.HDG.
HEPWORTH	WASSALL
HEWDEN-STUART	WATMOUGHS HDG.
IBSTOCK	WEIR GROUP
IMI	WIMPEY (GEORGE)
IMP.CHM.INDS.	WOLSELEY
JOHNSON MATTHEY	YULE CATTO

Germany (38 Firms)

ASEA BROWN BOVER	INDUSTR.VERWALT.
BASF	KLOECKNER-WERKE
BAYER	KRONES PREF.
BILFINGER + BERG	KS PIERBURG
BUDERUS	KSB
CONTINENTAL	KSB PREF.
DEGUSSA	LINDE
DEUTZ	MAN
DT.BABCOCK	MANNESMANN
DYCKERHOFF	PREUSSAG
DYCKERHOFF PREF.	PREUSSAG STAHL

FELTEN & GUILL.

PWA

FPB HOLDING

RHEINMETALL BERL

GERRESHEIMER GLA

RWE-DEA

HEIDELB.ZEMENT

SIEMENS

HENKEL PREF.

STRABAG

HERLITZ

THYSSEN

HOCHTIEF

THYSSEN INDUSTRI

HOECHST

VARTA

France (26 Firms)

AIR LIQUIDE

LEGRIS INDUSTRIE

BERTRAND FAURE

METALEUROP

BOUYGUES

MICHELIN

CARBONE-LORRAINE

NORD-EST

CGIP

PLASTIC OMNIUM

COLAS

PRIMAGAZ

DE DIETRICH

ROCHETTE (LA)

ECIA

SAINT GOBAIN

GASCOGNE

SAT

IMETAL

SFIM

LABINAL

SOMMER-ALLIBERT

LAFARGE

STRAFOR FACOM

LEGRAND

VALEO

Chapter 6

United Kingdom (66 Firms)

API GROUP

LONRHO

AVON RUBBER

LOW & BONAR

BEMROSE CORP.

MACFARLANE GROUP

BICC

MARSHALLS

BLUE CIRCLE INDS.

MAYFLOWER CORP.

BOC GROUP

MCKECHNIE

BODYCOTE INTL.

MEGGITT

BPB

MORGAN CRUCIBLE

BRITISH VITA

PILKINGTON

BUNZL

POWELL DUFFRYN

BOWTHORPE

RACAL ELECTRONIC

CHARTER

RENOLD

COBHAM

REXAM

COOKSON GROUP

RMC GROUP

COURTAULDS

ROTORK

CRODA INTL.

RUGBY GROUP

DE LA RUE

SCAPA GROUP

DELTA	SENIOR ENGR.
EIS GROUP	SMITH (DAVID S)
ELLIS & EVERARD	SMITH INDS.
GENERAL ELEC.	STAVELEY INDS.
GKN	TARMAC
GLYNWED	TI GROUP
HANSON	TT GROUP
HENLEYS GROUP	VICKERS
HEPWORTH	VITEC GROUP
HEWDEN-STUART	WADDINGTON
IBSTOCK	WAGON IND. HDG.
IMI	WASSALL
IMP. CHM. INDS.	WEIR GROUP
JOHNSON MATTEY	WIMPEY (GEORGE)
LAIRD GROUP	WOLSELEY
LAPORTE	

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