The Capital Structure of the Regulated Firm

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Abstract

This thesis studies the capital structure of the regulated firm.

Theoretical models are developed to analyse the relationship between capital structure, the regulator's pricing decision and the allocation of risk between consumers and investors. It is shown that the price-cap system is almost certainly sub-optimal because consumers are willing to trade-off price variations against a lower expected price. There is also a socially optimal capital structure that depends on consumers' and shareholders' attitudes to risk. This is such that there are higher prices for consumers in adverse economic conditions but it is not necessary that shareholders' returns are lower. It might be optimal to insure shareholders against market risk to achieve a lower expected price. There is only one very special set of conditions where it is socially optimal for the firm to be wholly reliant on debt finance and operate on a 'not-for-profit' basis. In all other cases there should either be a combination of equity and debt or no debt at all.

An empirical study investigates whether the behaviour of regulated firms is consistent with the trade-off or pecking order theories of capital structure. The water companies in England and Wales are used as a case study. Econometric models of the relationship between debt and capital value over the period 1990/91 to 2002/03 indicate that water companies, at least when viewed collectively, have behaved as though they had target levels of gearing. While this result could be consistent with the pecking order theory if the companies had attempted to exert a price-influence effect, there is little indication that they have tried to manipulate their financial positions to that end. The overall conclusion of the study is that the empirical evidence relating to water companies is more consistent with the trade-off theory than the pecking order theory.

Contents

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Author's declaration

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Chapter 1

Introduction

1.1 Background

The privatization of state owned industries was one of the most significant developments in the UK economy in the 1980's and 1990's. Although the privatized companies were given the freedom to manage their own affairs the government introduced a form of price-cap regulation and appointed regulators for each industry to protect consumer interests and to stimulate competition. This led to fundamental changes in the structure of many of the industries. In gas and electricity, for example, the forces of regulation and competition have driven the separation of energy production, distribution and supply.

However, the government adopted a relatively cautious approach when it established the financial structure of the companies at privatization. This was necessary to secure the successful flotation of the companies as they would have a continuing need to rely on the capital markets to finance their large investment programmes. In addition, the regulators were given a statutory duty to ensure that the regulated businesses could finance their functions. However, by the turn of the century, some companies began to look at radical ways of improving their financing efficiency.

The most significant proposals came from the water industry. Unlike the other utilities the structure of the water industry has remained largely unchanged since it was privatized in 1989 and the water companies are still vertically integrated regional monopolies with virtually no competition in their product markets. Introducing competition in the water industry has posed special problems; especially regarding compliance with drinking water quality standards. As a consequence regulatory activity has been mainly focused on the Periodic Reviews of water prices. Reviews were carried out in 1994, 1999 and 2004 and each took about three years to complete. The 1999 Periodic Review was particularly important as, at the time, the companies and many commentators considered that it represented a significant tightening of the regulatory contract. Whether or not this was the case, it certainly seems to have provided a stimulus for a number of water companies to consider making fundamental changes to both their structure and their financing arrangements.

Two quite innovative proposals were soon submitted to Office of Water Services (Ofwat), the industry's regulatory body headed by the Director General of Water Services (DGWS)[1]. One concerned a major restructuring of Yorkshire Water and was put forward by its parent company, Kelda. The other came from Glas Cymru, a company set up by the management of Dyr Cymru (Welsh Water), and involved the acquisition and restructuring of Welsh Water after its original owner, Hyder, encountered financial difficulties and was itself acquired by an energy company. Both proposals envisaged separating the ownership of assets from the provision of operational and customer services with the latter being carried out under contract. Although new to the UK, such arrangements are common in the US and Europe where assets are often held in municipal ownership and day-to-day operations are contracted out to private suppliers.

However, both proposals also contained a more radical suggestion. This was to place the ownership of assets in a new 'not-for-profit' company that would be wholly reliant on debt for its external financing needs. As the new company would be run on a 'not-for-profit' basis any surpluses would be used to reduce prices or improve services. The owners would, therefore, have no financial interest in the company as no dividends would be paid nor would they be responsible for the company's liabilities. To this end Glas Cymru was established as a 'not-for-profit' company limited by guarantee but Kelda went further suggesting that the new company should be a mutual with Yorkshire Water's customers owning the company and, therefore, the assets.

Kelda's proposal received a sceptical reaction locally, including from the Yorkshire Ofwat Customer Services Committee, and it was eventually withdrawn in July 2000 when the then DGWS said it could not proceed in its

[1] The Water Industry Act 2003 replaces (after 1 April 2005) the office of the DGWS by a body corporate viz. the Water Services Regulation Authority.

current form. Glas, however, obtained regulatory approval in January 2001 and successfully completed its acquisition of Welsh Water in May 2001. At the time the DGWS said that the Glas proposal was, in many ways a special case, and that he did not see it as a model to be followed by the whole industry. A detailed description and analysis of the Kelda and Glas proposals is contained in Stones (2001).

Shortly afterwards other water companies put forward proposals for capital restructuring but none included the use of 'not-for-profit' companies. However, they all entailed gearing (the ratio of debt to total capital value) increasing to levels well above the industry average which, by 1999/00, had reached 44.2%[2]. These restructurings took one of two basic forms:

- Major financial restructurings based on 'enhanced financial structures' that used debt tranching techniques and tight covenant packages and required regulatory approval. These structures were designed not only to protect the interests of bondholders but also to reduce business risk so that the companies could still sustain investment grade credit ratings at gearing levels in excess of 75% and achieve a lower overall cost of capital.

- Less complex refinancings that did not use enhanced financial structures but where debt was increased to enable special dividends or sharebuy-backs.

By the end of 2002/03 half of the water companies had implemented, or were in the process of implementing, a capital restructuring in one of these two forms.

Such developments, however, have not been confined to the water industry. In October 2002 Network Rail, a 'not-for-profit' company established by the UK government, replaced Railtrack plc as owner and operator of the rail network after the government put Railtrack into administration a year earlier.

Capital structures that rely wholly or predominantly on debt finance clearly represent a significant departure from the conventional model of equity ownership on which the privatizations were based and their use remains controversial

[2] Average gearing is defined for these purposes as the ratio of the total net debt of the regulated water companies to their total capital value at the relevant financial year end. Total capital value is calculated as the total of the net debt and share capital and reserves of the companies on a historical cost accounting basis.

from both and economic and a political perspective. In broad terms, the economic issues that have been raised concern the extent to which such structures might:

- produce benefits for consumers in the form of lower prices through their greater reliance on debt finance,
- increase the risks for consumers by changing the allocation of risks between consumers and the providers of capital,
- adversely affect efficiency incentives and service delivery.

Appendix 1.A illustrates these issues by using simple models to compare the prices that would apply under price-cap regulation in two extreme cases viz. when the firm is financed entirely by equity and when it is wholly debt financed and operates on a 'not-for-profit' basis.

This thesis is in two main parts. The first part looks in detail at the relationship between the capital structure of the regulated firm, the regulator's pricing decision and the allocation of risks between consumers and the providers of capital. In particular, chapter 2 examines the theoretical questions of whether and under what conditions there is a socially optimal capital structure for the regulated firm when the regulator's pricing decision is designed to achieve an optimal allocation of risks. Chapter 3 takes the analysis further and looks at the interaction between the regulator's decision on prices and the cost of equity finance, the effect this has on the socially optimal capital structure and the conditions under which it is socially optimal for the regulated firm to be wholly reliant on debt finance.

The second part of the thesis is an empirical study of the capital structure of the water companies in England and Wales and is presented in chapter 4. There is an extensive literature on both the theory and the empirical evidence relating to the capital structure decisions of firms and two main theories have emerged viz. the 'trade-off' theory and the 'pecking order' theory. The study develops econometric models to test which of these two competing theories is consistent with the behaviour of water companies over the 13 years since they were privatized.

Some overall conclusions from the thesis are presented in chapter 5.

In order to put the various issues considered in this thesis into context, the next section of this introductory chapter summarizes the principles on which the two theories of capital structure are based and then describes how decisions on capital structure can bring about a 'price-influence effect' in the regulated firm. It is not intended to provide an exhaustive review of the literature on the theory of capital structure as there are several well known surveys of the field, for example, Harris and Raviv (1991). Indeed, the significance of these issues for the water industry is such that Ofwat commissioned its own survey, OXERA (2002), for the 2004 Periodic Review. Consequently, the aim here is just to set out the principal arguments. The final section of this introduction provides an outline of the thesis and its main contributions.

1.2 Theories of capital structure

1.2.1 Capital structure and taxation

Among the most important contributions to the theory of finance are the propositions about capital structure that were made by Modigliani and Miller (1958) and (1963). They showed that, in competitive capital markets with full information and no corporate taxes, the value of the firm is unaffected by its capital structure and that an increase in gearing leads to an increase in the cost of equity which leaves the overall (weighted average) cost of capital unchanged. Any gains from using lower cost debt are cancelled out because interest costs are a prior claim on profits and shareholders need to be compensated for increasing financial risk as gearing and interest costs rise. Modigliani and Miller went on to show that, when firms obtain tax relief on their interest payments, the value of the firm will increase in line with its level of debt.

Their arguments can be demonstrated as follows[3]. Let:

$$\begin{aligned}
V_U &= \text{the market value of the unlevered firm (i.e. no debt)} \\
V_L &= \text{the market value of the levered firm (i.e with debt)} \\
D &= \text{the market value of the firm's debt} \\
E &= \text{the market value of the firm's equity}
\end{aligned}$$

[3] It is assumed that there is no system of imputation tax under which dividends are paid net of tax to shareholders who are then credited with a proportion of the corporation tax paid on company profits. Such a system applied in the UK until Advance Corporation Tax and the associated credits on dividends were abolished from 1999/00.

π = the expected pre-interest, pre-tax operating cashflow of the firm (assumed for simplicity to be an annuity)

t_c = the corporation tax rate

t_p = the personal tax rate on equity income

t_d = the personal tax rate on income from debt

r_a = the return on assets for the unlevered firm (pre-personal tax)

r_e = the return on equity (pre-personal tax)

r_d = the return on debt (pre-personal tax)

r_w = the weighted average cost of capital (pre-personal tax) for the levered firm

As the market value of a firm is the present value, PV, of its post-tax cashflows, the value of an unlevered firm is:

$$V_U = PV\left[\pi\left(1-t_c\right)\left(1-t_p\right)\right], \tag{1.1}$$

and the value of a levered firm, which receives tax relief on its interest payments, is:

$$\begin{aligned} V_L &= E + D, & (1.2)\\ &= PV\left[\left(\pi - r_d D\right)\left(1-t_c\right)\left(1-t_p\right) + r_d\left(1-t_d\right)D\right], & (1.3)\\ &= V_U + PV\left[r_d\left(1-t_d\right)D\left(1 - \frac{\left(1-t_c\right)\left(1-t_p\right)}{\left(1-t_d\right)}\right)\right]. & (1.4)\end{aligned}$$

If it is assumed that the discount rate applicable to tax payments is $r_d\left(1-t_d\right)$, then:

$$V_L = V_U + D\left(1 - \frac{\left(1-t_c\right)\left(1-t_p\right)}{\left(1-t_d\right)}\right), \tag{1.5}$$

and if it is also assumed that the personal tax rates of investors in equity and corporate bonds are equal, that is $t_p = t_d$, then:

$$V_L = V_U + t_c D. \tag{1.6}$$

Consequently when $t_c = 0$ then the value of the unlevered firm is the the same as that of the levered firm, which is Modigliani and Miller's Proposition I.

The effect of gearing on the cost of equity can be seen by considering the market value of the equity, that is:

$$E = PV\left[\left(\pi - r_d D\right)\left(1 - t_c\right)\left(1 - t_p\right)\right], \tag{1.7}$$

and since the discount rate on equity is $r_e\left(1 - t_p\right)$:

$$r_e E = \pi\left(1 - t_c\right) - r_d D\left(1 - t_c\right). \tag{1.8}$$

By definition:

$$r_a V_U = r_w V_L = \pi\left(1 - t_c\right), \tag{1.9}$$

and so, from (1.6):

$$r_e = r_a + \left(r_a - r_d\right)\left(1 - t_c\right)\frac{D}{E}. \tag{1.10}$$

This is Modigliani and Miller's Proposition II and shows that the cost of equity increases in proportion to the debt-equity ratio.

It also follows that:

$$r_w = r_a\left(1 - t_c\frac{D}{V_L}\right) = r_e\frac{E}{V_L} + r_d\left(1 - t_c\right)\frac{D}{V_L}. \tag{1.11}$$

Consequently, when $t_c = 0$, the weighted average cost of capital is not affected by the level of gearing and remains the same as for the unlevered firm.

It can be seen from (1.6) that the value of the tax shield on debt is maximized when the firm is wholly financed by debt. However, in practice it is unusual for companies to be 100% financed by debt or even to have a capital structure close to this; the most common examples of such arrangements being 'not-for-profit' organizations, specially created project finance vehicles and highly leveraged management buyouts. The reason why 100% debt finance is so unusual and the factors that determine the optimal balance between debt and equity finance has been the subject of much debate in the literature.

Indeed, Miller (1977) questioned whether firms do gain an advantage from debt finance as the benefits of the tax shield need not necessarily be received by firms and might be received instead by investors in corporate bonds. According to Miller this depends on the relative personal tax position of investors in corporate bonds and equity. As can be seen from (1.5) the value of the tax shield for the firm will be zero when the assumption that $t_p = t_d$ does not apply and:

$$(1 - t_c)(1 - t_p) = (1 - t_d). \tag{1.12}$$

For example, when the personal tax rate on equity income for the marginal investor is zero (or very low) and that on income from corporate bonds is equal to (or above) the rate of corporation tax then interest rates have to be high enough to compensate bond investors for their higher tax payments compared with the tax paid on equity investments of equivalent risk. This implies there is a bond market equilibrium which determines the aggregate level of debt in the economy and where (1.12) applies but there is no tax advantage from debt for any one firm[4].

Firms, however, also have tax shields on profits for reasons other than debt finance. Significant capital allowances on assets can reduce a firm's effective rate of corporation tax thereby reducing the potential value of the tax shield on interest. DeAngelo and Masulis (1980) argued that, where companies have different marginal effective tax rates, only companies with effective tax rates above that of the marginal firm gain an advantage from debt. Consequently, when the personal tax rate on equity income for the marginal investor is zero, the bond market equilibrium is where the personal tax rate on income from corporate bonds for the marginal investor equals the effective rate of corporation tax for the marginal firm[5]. This suggests that, since capital allowances on assets are substitutes for the tax shield on interest, the optimal level of debt is lower for companies that have high capital allowances. Further, as debt levels rise there is greater uncertainty about the level of expected profits which increases the probability that the tax shields may be underutilized and reduces the expected value of the tax shield.

1.2.2 The trade-off theory

These arguments suggest there may be a tax advantage from debt finance at least for some companies. However, if there is a positive tax advantage to debt there must be reasons why 100% debt finance is not more commonplace.

[4] According to this argument the tax rate of the marginal investor t_d is, therefore, not a constant but a function of the aggregate level of debt, D_A; that is, $t_d = t_d(D_A)$ with, at some point, $t_d'(D_A) > 0$.

[5] In this argument neither t_c nor t_d are constants and the corporation tax rate for the marginal firm t_c is also a function of the aggregate level of debt, D_A; that is, $t_c = t_c(D_A)$ with, at some point, $t_c'(D_A) < 0$.

One argument is that there are costs as well as benefits from increasing gearing. These include the costs of 'financial distress', such as bankruptcy costs and the effect of distortions to incentives when close to bankruptcy, and the agency costs associated with debt such as monitoring and bonding costs. This implies there is an optimum level of gearing where its marginal cost equals its marginal benefit, and so this is often described as the 'trade-off' theory of capital structure.

It should be noted that the trade-off theory does not necessarily depend on the existence of a tax advantage to debt. The agency cost model first set out in Jensen and Meckling (1976) argues that agency costs are not only associated with debt but also with external equity. External shareholders incur monitoring costs to ensure that management, the internal shareholders, act in the external shareholders' best interests and do not divert resources to increase managers' wealth. Increasing management's share of the equity by increasing the level of gearing reduces these costs. In addition, as pointed out in Jensen (1986), debt reduces the amount of 'free cashflow' available to managers reducing the scope for unwise investments. Consequently, increased gearing is associated with both agency costs and benefits which creates a trade-off and leads to an optimal capital structure for the firm.

1.2.3 The pecking order theory

The optimal capital structure question has also been approached by introducing a further market imperfection into the analysis, viz. the information asymmetry between a firm's managers and its investors. If managers have better information about the value of the firm then managers will have an incentive to inform the capital market if they consider their firm is undervalued. Clearly, such information has to be credible and this has resulted in the development of models where managers use capital structure decisions as a signal in order to bring the value of the firm as *perceived* by the market into line with its *actual* value. Both Ross (1977) and Leland and Pyle (1977) developed signaling models where higher levels of debt indicate a higher value for the firm. In the former case this is because a higher debt level is associated with a lower probability of bankruptcy while, in the latter, it signifies managers own a greater proportion of the equity.

However, Myers and Majluf (1984) considered the signalling effects of using different forms of finance to fund investment opportunities and came to quite different conclusions. Their model has become known as the 'pecking order' theory. According to this theory, since the firm's managers and shareholders have asymmetric information about its prospects, shareholders assume that the firm's shares are overpriced if it makes a rights issue. Managers might, therefore, reject profitable investment opportunities rather than issue new equity that would be undervalued unless they have access to less costly forms of finance. Consequently, low risk debt, whose pricing is less sensitive to private information, is preferred to equity issues and 'financial slack', in the form of cash and marketable securities, is preferred to both. This implies that firms do not have a target capital structure. Instead, they operate a pecking order or financing hierarchy where they use internal finance before turning to sources of external finance and raise debt rather than issue new equity which is only used as a last resort. A firm's capital structure, therefore, simply reflects its cumulative earnings and investment decisions.[6]

The conclusion that firms do not have an optimal capital structure means the pecking order theory clearly contradicts the predictions of the traditional trade-off theory. There has been extensive empirical research into these two competing theories but OXERA's (2002) overall assessment is that the empirical evidence is inconclusive.

1.2.4 Price-influence effects and the regulated firm

The literature on the theory of capital structure has almost entirely been concerned with firms operating in competitive product markets and very little attention has been paid to the capital structure decision when the firm is a regulated monopoly. In the theories described above it is generally assumed that the firm's revenues are independent of its capital structure. This assumption, however, may not be appropriate for a regulated firm.

In the case of a regulated firm it is possible that its capital structure might influence the prices that are set by the regulator. While virtually all the literature on rate of return regulation makes the implicit assumption that the regulated firm is wholly financed from equity, there are papers that relax this assumption. These papers are reviewed in chapter 2 which finds that, gener-

[6] However, Harris and Raviv (1991) point out that there are other models that allow for a wider range of financing options which produce different results and the firm does not follow this strict pecking order.

ally, they study the firm's decision rather than the regulator's. In particular, they show that a price-influence effect occurs if a firm can use its capital structure to influence the price set by the regulator. This result is based on a moral hazard problem where the firm benefits from a high level of gearing because regulators wish to set prices at a high enough level to avoid the firm becoming financially distressed with adverse effects on services.

However, this literature takes a point of view which is probably more suited to the US experience. In the US most regulated firms are long established and, typically, regulators take capital structure as a given. The UK situation is markedly different. Most regulated firms were privatized relatively recently and at the subsequent reviews of price limits regulators have, in a number of cases, assumed a significant increase in gearing levels.

The regulated firm may, therefore, be subject to a second kind of price-influence effect which depends on the the way the regulator sets prices. For example, if the regulator considers that there is an optimal level of gearing which minimizes the overall cost of capital, price limits will be set to reflect the assessed optimum. It follows that, if the trade-off theory is correct, a price-cap system of regulation reinforces the incentive for the regulated firm to adjust gearing to the level that maximizes its financing efficiency[7]. In addition, different systems of regulation vary in the extent to which variations in the firm's costs are carried through into price variations. This affects the allocation of risk between consumers and investors which, in turn, may have implications for the firm's capital structure. This is because the risks to be carried by investors will influence both the amount of equity finance that is needed and, potentially, its cost. It follows that capital structure may not be irrelevant for the regulated firm even if the conditions underlying the Modigliani and Miller Propositions are satisfied. It is not surprising, therefore, that risk, the cost of capital and capital structure have been the subject of considerable debate between regulators and regulated utilities at price-cap reviews in the UK.

[7]However, as Gordon (1967) points out, to the extent that the regulator passes the tax benefits of debt finance to consumers through lower prices, the firm will become increasingly indifferent to its capital structure. This is more likely to be the case under rate-of-return regulation but, as explained in Chapter 4, it has become an important issue in the UK water industry where a system of price-cap regulation applies.

1.3 Outline of the thesis

1.3.1 Capital structure and the allocation of risk

The relationship between the regulator's pricing decision, the allocation of risk and the firm's capital structure has been largely ignored in the literature and is the subject of chapters 2 and 3. Chapter 2 develops a highly stylized model for this purpose and analyses the regulation of a monopolist that supplies a product which is fixed in quality and for which the demand is price inelastic. The model makes reasonably realistic assumptions about the attitude of the various stakeholders towards risk. Consumers and shareholders are risk averse, managers are risk neutral up to a point, and debtholders are infinitely risk averse. Unlike the standard model of regulation, the financial structure of the regulated firm is determined endogenously. An increase in gearing that reduces the overall cost of capital gives the regulator scope for price reductions, but it also creates a trade-off, because it reduces the amount of equity capital that can be used as a buffer to absorb adverse exogenous shocks. Once the amount of equity capital falls below a certain level, the expected price can be lowered only at the expense of greater price variability. Using this model it is also possible to derive the socially preferred capital structure. This is such that consumers face some risk, in the sense that the price they pay varies according to the underlying economic conditions. One interpretation of this result is that the price cap mechanism, where price variations are allowed only in exceptional circumstances, is suboptimal, even when there is symmetric information as this model assumes.

The model developed in chapter 2 simply assumes the firm's cost of equity to be a function of the level of debt as a proxy for the relationship between the cost of equity and investment risk. The classic formulation of that relationship is the Capital Asset Pricing Model (CAPM) developed in Sharpe (1964), Lintner (1965a) and Lintner (1965b) where shareholders base their investment decisions on the vector of returns and their covariance with the return on the market portfolio. The proxy function used in chapter 2 is consistent with such models because an increase in a firm's level of debt increases the covariance between the returns to shareholders and the market return and, therefore, the cost of equity. However, it is this proxy function which leads to the result that there must some variability in consumer prices once gearing reaches a certain level. Above that level the buffer provided by equity finance is insufficient to aborb all the risk of cost variations and still meet the firm's obligations to lenders and shareholders. Consequently, the model only allows the regulator's decision on prices to influence the cost of equity indirectly through the regulator's choice of capital structure.

Chapter 3 examines the more general case when the level of gearing and the regulator's decision on prices both have an independent and direct effect on the covariance of the shareholders' returns with the market return and, therefore, on the firm's cost of equity. Indeed, a novel feature of the model presented in chapter 3 is that it explicitly allows for the possibility that prices can be set in such a way that the risks and returns for shareholders are either positively correlated, uncorrelated or even negatively correlated with the market return. As a result the firm's cost of equity can either be greater than, equal to or lower than the cost of debt. In other words, the regulator's ability to determine the extent to which prices may vary means that the risks and returns for shareholders need not necessarily be tied to the firm's underlying business risk.

Two sets of results are obtained from this more general model. Firstly, it is shown that, in contrast to chapter 2, some variation in prices is optimal for consumers at all levels of gearing except in an unlikely case where the willingness of managers to carry risk exceeds the inherent risk in the business. Prices are still higher for consumers in adverse economic conditions but it turns out that the returns to shareholders and the cost of equity need not be lower. Indeed, an interesting possibility emerges when comsumers have a relatively low aversion to risk and prefer a lower expected price. In these circumstances it might be optimal for the regulator to set prices so that profits are higher in adverse economic conditions. As this would provide shareholders with a form of insurance against market risk, the cost of equity would be lower than the cost of debt; the result being lower financing costs and a lower expected price for consumers.

Secondly, it is shown that the regulated firm has a socially optimal capital structure that depends on both the consumers' aversion to the risk of price variations and the shareholders' trade-off between risk and returns. A key result is that, in this model, there is only one particular case in which the preferences of consumers and shareholders make it optimal for the regulator to set prices where the rate of return is equal to the cost of debt and such a return is also satisfactory for investors. In all other cases there should either be a combination of equity and debt or no debt at all. In other words, there is only one very special set of conditions where it is socially optimal for the regulated firm to be a 'not-for-profit' company that relies wholly on debt finance. This latter result is of more than just theoretical interest. As noted above, 'not-for profit' utility companies have been established in the UK and similar types of organizations have been increasingly used there to provide public services.

1.3.2 The water industry: an empirical study

Neither of the models developed in chapters 2 and 3 requires a stance to be taken on the competing theories of capital structure summarized in section 1.2. For the regulator, capital structure is a mechanism for allocating risk between consumers and investors and determines the effect of any particular allocation on both consumer prices and the returns required by investors. In addition, although the firm's actual capital structure is generally outside the regulator's direct control, the models give the regulator, *de facto*, control. Once prices have been set it is in the shareholders' own interests to choose the same capital structure as that selected by the regulator. This is a consequence of the assumption that the regulator has complete information and there are no information asymmetries. In practice, of course, this will not be the case and once prices are set by the regulator the actual capital structure decisions that are subsequently taken by regulated firms may well reflect one of the two competing theories described in section 1.2.

Chapter 4 takes an empirical approach to this question and seeks to discover whether the behaviour of regulated firms is consistent with the trade-off theory or the pecking order theory. For this purpose, the water industry over the period 1990/91 to 2002/03 is used as a case study.

Econometric models have been developed with the aim of addressing two specific questions:

- Did the water companies behave as though they had target gearing levels?
- What effect did the regulatory reviews of price limits appear to have on the capital structure decisions of water companies?

The model that is used as a starting point is an unrestricted Autoregressive Distributed Lag Model (ADLM). This incorporates a number of model types according to the restrictions placed on the parameters and of particular interest here are the Static Long Run Model (SLRM), the Partial Adjustment Model (PAM) and the Error Correction Model (ECM). However, the methodology used in this study has a number of novel features compared with other studies that have relied on adjustment models, usually the PAM, to test whether firms move towards target levels of gearing. In particular:

- a general-to-specific model reduction process is applied to the estimated ADLM to determine which model, if any, provides the best explanation,
- target gearing ratios are estimated directly instead of proxy numbers being calculated separately and used as input data,
- cointegration tests are used to assess whether the results reflect causal relationships, although the reliability of these tests is limited by the relatively short time period for which data is available.

In broad terms it is concluded that that the evidence from this case study is more consistent with the trade-off theory of capital structure than the pecking order theory. The econometric models that have been estimated indicate that water companies, at least when viewed collectively, have behaved as though they had target levels of gearing. Although such targets are predicted by the trade-off theory, it should be emphasized that the evidence has been obtained from adjustment models and so does not necessarily demonstrate that a trade-off actually exists. This would require more extensive models to be developed where the target level of gearing is specified as a function of the explanatory variables that determine the costs and benefits of increasing gearing. Unfortunately, a number of those variables, for example, agency costs and the costs of financial distress, are extremely difficult to measure.

Adjustment models can, however, provide evidence that the behaviour of firms is inconsistent with the pecking order theory since it predicts that firms do not have target gearing levels. Even so, as the water companies are highly regulated, it is also important to assess whether they have tried to use gearing levels to exert a price-influence effect on regulatory decisions because it possible that their behaviour might otherwise have reflected the pecking order theory. The study, therefore, assesses whether companies have attempted to exert a price-influence effect by considering:

- the principles used to set price limits in the water industry and, in particular, the effect that gearing levels have on the regulator's decisions,
- whether there are indications that water companies have increased gearing in advance of a Periodic Review to levels that could be regarded as an attempt to put pressure on the regulator to set more favourable price limits.

There appears to be little evidence that water companies have generally tried to manipulate their financial positions in order to exert a price-influence effect and it, therefore, seems reasonable to conclude that their behaviour has not been in accordance with the predictions of the pecking order theory.

Appendix 1.A Prices under the equity and 'not-for-profit' models

This appendix sets out two simplified models to compare the consumer prices that would apply under price-cap regulation when the firm is financed entirely by equity and when it operates on a 'not-for-profit' basis and is wholly debt financed[8]. The aim is to demonstrate how the two models involve making a trade-off between:

- the possible benefits for consumers from lower prices as a result of debt financing,
- the increased the risks for consumers and the adverse effects on costs and prices from reduced efficiency incentives in a 'not-for-profit' firm.

1.A.1 Consumer utility

The utility of the representative consumer is assumed to depend on the consumption of two goods viz. bread, b, and water, w, so that:

$$u = u(b, w).$$

Consumers also face an income constraint, $\overline{Y}$, which limits total consumption given the prices of bread, p_b, and water, p, that is:

$$\overline{Y} = p_b b + pw.$$

The demand for water is assumed to be inelastic. Normalising the consumption of water and the price of bread so that:

$$\begin{aligned} p_b &= 1, \\ w &= 1, \end{aligned}$$

gives:

$$b = \overline{Y} - p.$$

[8] The analysis presented in this Appendix was published in Stones (2001).

This leads to the indirect utility function:

$$U(p) = u\left(\overline{Y} - p\right).$$

For simplicity it is assumed that consumers have constant absolute risk aversion so that, if it is also assumed that p varies in accordance with a normal distribution, the utility function can be expressed in mean-variance form, as follows:

$$U(p) = \overline{Y} - \mathrm{E}(p) - \frac{\gamma}{2}\sigma_p^2,$$

where σ_p^2 is the variance in p and γ is the measure of the consumers' absolute risk aversion to variations in p.

1.A.2 Equity model

In the equity model the regulator sets a price cap, $\overline{p}$, which allows the firm sufficient revenue to earn a reasonable return on its capital and to cover its expected operating costs in meeting consumer demand. It is assumed that:

- the capital stock is fixed with an indefinite asset life and a sunk cost, K, that has been financed entirely by equity,
- the allowed rate of return on equity, r_E, is sufficient to compensate shareholders for carrying all the risk of variations in operating costs,
- the regulator sets an efficiency target, e_E, for the firm to reduce its operating costs below the zero-effort level, L.
- L is subject to uncertainty and is normally distributed with variance, σ_L^2.

Consequently, the price cap set by the regulator is:

$$\overline{p} = r_E K + \mathrm{E}(L) - e_E$$

with:

$$\sigma_{\overline{p}}^2 = 0.$$

Consumer utility is, therefore:

$$U(\overline{p}) = \overline{Y} - \overline{p}.$$

1.A.3 'Not-for-profit' model

In this model the capital stock has been wholly financed by debt and the firm operates on a 'not-for-profit' basis. The cost of debt is r_D. The firm will wish to set the price, $\widetilde{p}$, to ensure that it receives just enough revenue to cover its interest and operating costs. Any surpluses are returned to customers through rebates in prices. It is assumed that:

- all variations in operating costs are passed on to consumers through variations in $\widetilde{p}$ and so $r_E > r_D$,
- efficiency incentives lead management to reduce the zero-effort level of operating costs by e_D.

The price set by the firm is, therefore:

$$\widetilde{p} = r_D K + L - e_D,$$

provided that $\widetilde{p} \leqslant \overline{p}$. Consequently:

$$\begin{aligned} \mathrm{E}(\widetilde{p}) &= r_D K + \mathrm{E}(L) - e_D, \\ \sigma_{\widetilde{p}}^2 &= \sigma_L^2. \end{aligned}$$

Uncertainty in the level of operating costs creates uncertainty in the level of $\widetilde{p}$ and so consumer utility is:

$$U(\widetilde{p}) = \overline{Y} - \mathrm{E}(\widetilde{p}) - \frac{\gamma}{2}\sigma_{\widetilde{p}}^2.$$

1.A.4 Comparison between the models

The price paid by the consumer is lower in the 'not-for-profit' model if:

$$\overline{p} - \widetilde{p} > 0,$$

that is, if:

$$(r_E - r_D) K > [L - \mathrm{E}(L)] + (e_E - e_D).$$

Consequently, for prices to be lower in the 'not-for-profit' model, the savings in financing costs must exceed any additional costs arising because the zero-effort level of actual operating costs is greater than its expected level and efficiency gains are lower than the regulator's target.

Consumer welfare is higher in the 'not-for-profit' model if:

$$U(\widetilde{p}) - U(\overline{p}) > 0,$$

that is, if:

$$\overline{p} - \mathrm{E}(\widetilde{p}) - \frac{\gamma}{2}\sigma_{\widetilde{p}}^2 > 0,$$

or:

$$(r_E - r_D) K > \frac{\gamma}{2}\sigma_{\widetilde{p}}^2 + (e_E - e_D).$$

Consequently, consumers' utility is higher in the 'not-for-profit' model if the savings in financing costs exceed the consumers' aversion to the risk of price variations and any loss of efficiency savings. In other words, consumers may be willing to accept a lower expected price in exchange for a degree of price uncertainty. It follows that the 'not-for-profit' model will be preferred by consumers if they are risk neutral (i.e. $\gamma = 0$) and/or there is no uncertainty ($\sigma_{\widetilde{p}}^2 = 0$) and the savings in financing costs exceed any loss of efficiency savings.

Chapter 2

Risk and Capital Structure in the Regulated Firm

2.1 Introduction

The price cap regulation mechanism, adopted in the UK and in other European countries, allows the regulated firm's owners to benefit from a reduction in cost below the level assumed by the regulator in setting the prices the firm is allowed to charge for a given period. Cost reductions may come both from improved productive efficiency, and from lower financing costs. To the extent that debt is cheaper than equity, increasing the proportion of debt finance would lower total cost. This can be taken to its extreme by the radical step of dispensing with equity finance altogether. For example, in May 2001 Glas Cymru, a 'not-for-profit' company limited by guarantee and 100% reliant on debt for its external finance, acquired Welsh Water after its original owner, Hyder plc, had encountered financial problems. As another example, Network Rail was established by the UK government using the same corporate structure and replaced Railtrack plc as owner and operator of the rail network in October 2002 after the government had put Railtrack into administration a year earlier.

This leaves open the theoretical question as to whether there is a socially optimal capital structure for the regulated firm; the question which is investigated in this chapter. Surprisingly, given its prominence both in practice and in the theoretical study of unregulated firms, the issue of the choice of capital structure by the regulator has been largely ignored. As Spiegel (1996) notes, virtually all the literature on rate of return regulation makes the implicit assumption that the regulated firm is wholly financed from equity. Some papers relax this assumption. Typically, however, they study the firm's decision rather than the regulator's; the firm uses its capital structure to influence the price set by the regulator. In these papers, firms benefit from a high debt-capital ratio (leverage, or gearing) because regulators will wish to set prices high enough to avoid the firm becoming financially distressed with adverse effects on services (e.g. Taggart (1981) and (1985), Dasgupta and Nanda (1993), Spiegel (1994), and Spiegel and Spulber (1994) and (1997)).[1] This literature takes a point of view probably suited to the American situation, where most regulated firms are long established, and where, typically, regulators do take the capital structure as given. Indeed, US regulators generally set the allowed rate of return as the weighted average of the cost of debt and equity, with weights given by the proportions of debt and equity finance, measured according to the firm's book value (Sidak and Spulber (1997)). The UK situation is markedly different. Most regulated firms were privatized relatively recently and at subsequent reviews of prices regulators have, in a number of cases, assumed a significant increase in the debt-capital ratio (leverage).

We study the role of the capital structure of the regulated firm with a highly stylized model. The firm's chosen policy turns out to depend on the risk attitude of the various stakeholders, and we make specific, but, we believe, realistic assumptions in this respect. Consumers and shareholders are risk averse, managers are risk neutral up to a point, and debtholders are infinitely risk averse. Unlike the standard model of regulation, we let the financial structure of the regulated firm be determined endogenously, either by the regulator itself, or - equivalently in our simplified set-up - as a consequence of the shareholders' attempt to maximize the return on their shares. An increase in leverage that reduces the overall cost of capital gives the regulator room for price reductions, but it also creates a trade-off, because it reduces the amount of equity capital that can be used as a buffer to absorb negative exogenous shocks. Once the equity capital falls below a certain level, the expected price can be lowered only at the expense of greater price variability.

In section 2.4, we derive the socially preferred capital structure. This is

[1] The effect of the firm's capital structure is considered by Kale and Noe (1995) where regulation creates underinvestment incentives and by Spiegel (1996) who argues that regulatory opportunism can lead to an inefficient (low fixed cost) choice of technology. They conclude that debt finance can alleviate both these problems although some of these results have been questioned: see Kühn (2002a) and Kühn (2002b) and Spiegel (2002).

such that consumers face some risk, in the sense the price they pay varies according to the underlying economic conditions. One interpretation of this result is that the price cap mechanism, where such variability is allowed only in exceptional circumstances, is suboptimal, even in the conditions of symmetric information posited in the paper.

The format of the paper is as follows. Section 2.2 sets out the model. The optimal prices when the capital structure is exogenously given are developed in section 2.3. Section 2.4 considers the case when the capital structure varies. Finally, some conclusions are provided in section 2.5, which places the results of the analysis in the context of recent developments in the UK.

2.2 The model

We study the regulation of a monopolist. The product it supplies is fixed in quality, and demand is price inelastic[2] and normalized to 1. There are four groups of agents with an interest in how the firm is run; managers, shareholders, debtholders and of course consumers. The rest of this section focuses on the stylized assumptions we make concerning the attitude of these agents towards risk.

The firm is run by a management, who can reduce cost by exerting effort, $e > 0$, and whose utility is given by their remuneration, w, reduced by the cost of their effort. This is measured by a function $\psi(e)$, satisfying $\psi'(e), \psi''(e) > 0$. Managers will only accept employment if they are guaranteed to receive at least their reservation level of expected utility, $u_0 > 0$. They are risk neutral down to zero utility, but infinitely risk averse below that level; they will not accept employment if there is a positive probability of negative utility.

The variable cost of production is made up of three components; an exogenously given component $\theta > 0$, the cost reducing effort by the management, $-e$, with $e > 0$, and a random cost reducing component, which is either $-c$ or 0, with $c > 0$. The probability of the last being $-c$ is $x \in [0, 1]$.

We can therefore write the firm's variable cost as:

$$\begin{array}{lll} \theta - e - c & \text{with probability} & x, \\ \theta - e & \text{with probability} & 1 - x. \end{array}$$

[2] This reflects the fact that the product is necessary and justifies it being regulated.

We make the following assumption:

$$xc > u_0. \tag{2.1}$$

The interpretation of (2.1) is that the firm can, in expected terms, reduce its costs by more than the amount necessary to entice the manager to accept employment.

Production also requires a capital investment $M > 0$, which is exogenously given and which can be financed by a mixture of debt and equity. We denote by $D \in [0, M]$ the extent of debt financing. The maintenance and depreciation costs of such assets are included in θ, and/or $-c$.

The cost of debt is exogenously given at the market interest rate $r_D > 0$. Moreover, lenders are infinitely risk averse. They must be guaranteed that the debt and the interest will be paid under all circumstances.[3] Consequently, the firm cannot go bankrupt, and hence there are no costs of financial distress, so that r_D equals the risk free rate of return.

Shareholders are risk averse, and therefore they require a higher expected rate of return to compensate for an increase in the variance in the return, depending on the covariance of the shareholders' rate of return with the return on the market portfolio. In a world where shareholders take their decisions using all the information available, they would base their investment decisions on the vector of returns and their probabilities and covariance with the market return. In practice, shareholders use a limited set of indicators to assess the riskiness of a given firm. We proxy this behavior with the assumption that shareholders require a higher rate of return when the debt of their firm is higher. Their required rate of return is $r_E(D)$, with $r'_E(D) \geqslant 0$. Since r_D is the risk free rate,

$$r_E(D) > r_D \tag{2.2}$$

for every $D \in [0, M]$.

Shareholders also have limited liability in the sense that they cannot be obliged to finance a shortfall in revenue through, for example, a rights issue.

The regulator's objective is to maximize the representative consumer's

[3] In practice, lenders do accept some risk, as they typically recover only part of their loan in the event of bankruptcy. The extreme assumption that they accept no risk at all simplifies the model, while capturing the essential fact that lenders bear lower risks than shareholders, and their expected rate of return is lower.

expected utility. This is given by a standard von Neumann-Morgenstern utility function in income, $\widetilde{U}(Y)$, with $\widetilde{U}'(Y) > 0$, $\widetilde{U}''(Y) < 0$, to reflect risk aversion. From this, in view of the assumption of inelastic demand, it is straightforward to derive the indirect utility function, $U(p) = \widetilde{U}(Y-p)$, with $U'(p), U''(p) < 0$, where p is the price charged by the regulated firm.

It is worth comparing the assumptions made with respect to the utility functions of the various stakeholders. Consumers, managers and debtholders have standard utility functions, concave in income, though the managers' income is reduced by the cost of effort, and the utility function has the extreme shape of being vertical at u_0 and linear for higher values. The debtholders' utility function is even more extreme and is horizontal beyond their reservation value. The shareholders, on the other hand, have a utility function depending on both their income and the debt level of their firm. Thus debtholders are the most risk averse. Managers are "locally" risk neutral, but there is a limit to the amount of risk they can bear. Shareholders' and consumers' risk aversions are determined by the shape of the functions $r_E(D)$ and $\widetilde{U}(Y)$.

While the price is set by the regulator before the value of the cost parameter is realized, it can be made conditional on this realization.[4] Since there are only two states of the world, this amounts to choosing p_H, the price when the cost is high (i.e. the random component is 0), and p_L, the price when the cost is low (i.e. the random component is $-c$). Once prices are fixed by the regulator, shareholders buy shares, raise debt from lenders, and decide the reward structure for the management. The managerial compensation can be conditioned on the realized profit, and therefore, in our simple case, it is given by a pair (w_H, w_L), the remuneration in the two possible states of the world. Finally, cost is realized, production and consumption take place, the price chosen by the regulator is paid by the consumers, the lenders are paid back, the managers receive their remuneration, the shareholders keep what is left, and the game ends.

[4] There are many ways of achieving this; for example, rather than allowing the regulated firm to increase prices in adverse economic circumstances, regulators can require them to lower their prices in favorable conditions. While equivalent from a mathematical viewpoint, it may be radically different as a public relations exercise.

2.3 Prices with a given capital structure

We begin with analysis of the regulator's pricing decision when the capital structure is exogenously given. This has independent interest, and is a first step in the analysis of the general model set out in the previous section.

Note that, although shareholders and managers can negotiate any contract, the regulator will factor their negotiations into the price formula, and will, essentially, operate in such a way so as not to leave the managers any additional rent over and above what is strictly necessary to ensure their participation. Therefore we can solve the game as if the regulator could choose the managerial compensation mechanism, as well as the prices. In view of this, the regulator's problem is the choice of p_L, p_H, e, w_L, and w_H to maximize the consumer's expected utility subject to a number of constraints, described in what follows. Firstly, the regulator must ensure that the managers are willing to accept the contract. They must be guaranteed non-negative utility in each of the two states of the world, and their expected utility must be at least equal to its reservation level:[5]

$$w_H - \psi(e) \geqslant 0, \tag{2.3}$$

$$w_L - \psi(e) \geqslant 0, \tag{2.4}$$

$$x w_L + (1-x) w_H - \psi(e) \geqslant u_0. \tag{2.5}$$

There are also two break even constraints imposed by the shareholders' limited liability and the lenders' unwillingness to allow the possibility of bankruptcy as there must be sufficient revenues to ensure that the debt and the interest can be paid in full in both states of the world.

$$p_H - (w_H + \theta - e) - (1 + r_D) D \geqslant 0, \tag{2.6}$$

$$p_L - (w_L + \theta - e - c) - (1 + r_D) D \geqslant 0. \tag{2.7}$$

The last constraint ensures that the expected profits are sufficient for shareholders to be willing to invest, that is, the expected profits are high enough to

[5] Note that an increase in u_0 increases not only the cost of the managerial input, but also the potential variability in the wage received by the managers, that is, their willingness to bear risk.

pay shareholders their required rate of return and to recover their investment.

$$x\left(p_L - w_L + c\right) + (1-x)\left(p_H - w_H\right) - \theta + e - \left(1 + r_D\right) D \geqslant \left(1 + r_E\left(D\right)\right)\left(M - D\right). \tag{2.8}$$

To sum up, the regulator will:

$$\max_{\substack{p_L, p_H, e,\\ w_H, w_L}} xU\left(p_L\right) + (1-x)\,U\left(p_H\right) \qquad \text{subject to: (2.3)-(2.8).} \tag{2.9}$$

We can now state the main result of this section.

Proposition 1 *Let p_L^*, p_H^*, e^*, w_L^*, and w_H^* be the solution to problem (2.9). Then $\psi'\left(e^*\right) = 1$, and the managers and the shareholders receive their reservation expected utility.*

Moreover, let $\overline{D}$ satisfy:

$$\overline{D} = M - \frac{xc - u_0}{1 + r_E\left(\overline{D}\right)}.$$

Then, $p_L^* = p_H^*$ if and only if $D \leqslant \overline{D}$. If $D > \overline{D}$, $p_L^* < p_H^*$ and $p_H^* - \left(w_H^* + \theta - e^*\right) - \left(1 + r_D\right) D = 0$; the shareholders make zero profit when the random component of cost is high.

Proof. See appendix 2.A. ∎

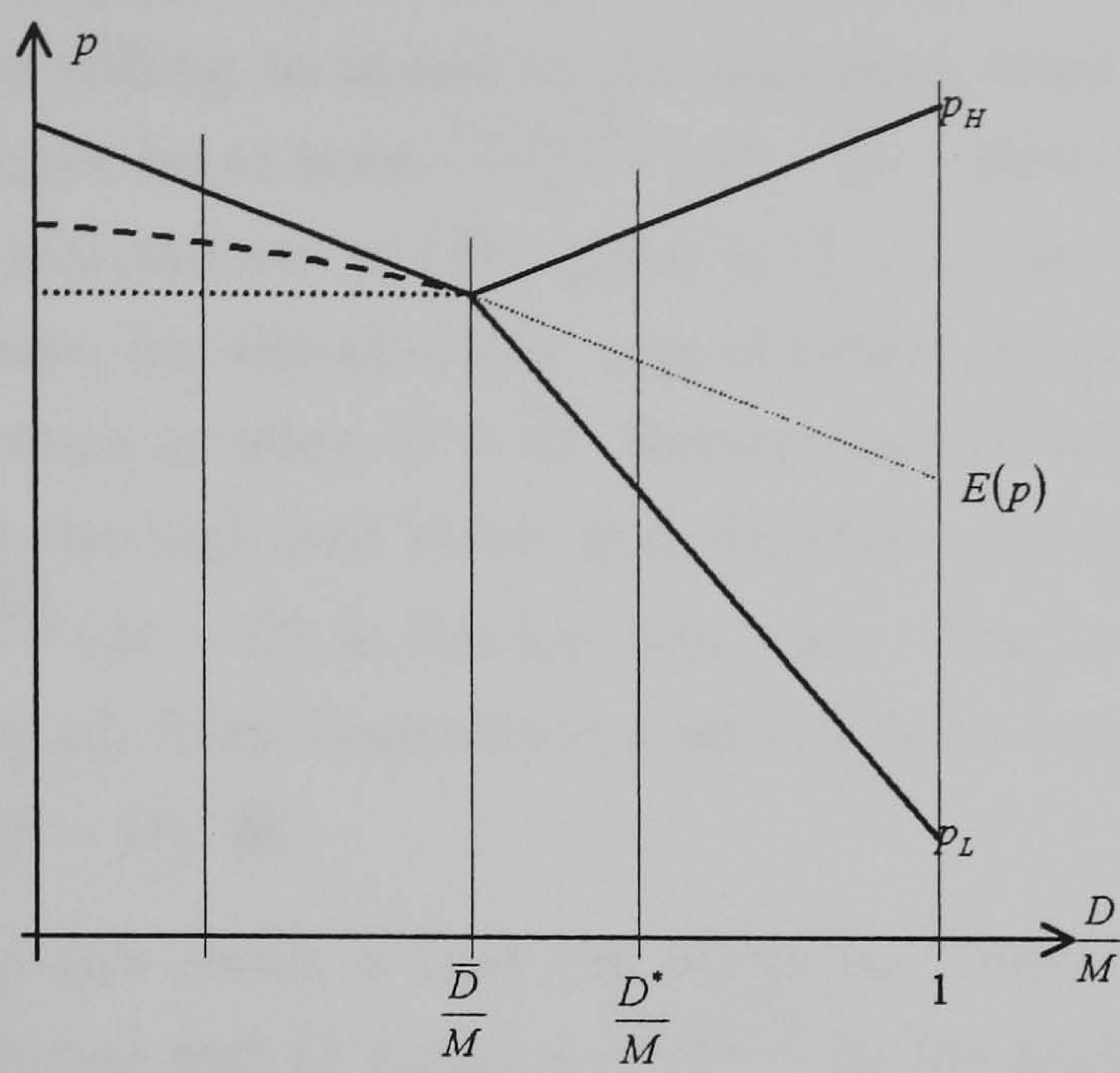
The prices derived in Proposition 1 are illustrated in Figure 2.1.

When $D \leqslant \overline{D}$, price is given by:

$$p_L^* = p_H^* = p^*\left(D\right) = u_0 + \psi\left(e^*\right) + \theta - e^* - xc + \left(1 + r_D\right) D + \left(1 + r_E\left(D\right)\right)\left(M - D\right). \tag{2.10}$$

Note that the slope of the function $p^*\left(D\right)$ depends on the relationship between the level of debt, D, and the rate of return required by the shareholders, $r_E\left(D\right)$. The latter has generated substantial interest since Modigliani and Miller's celebrated seminal analysis (1958 and 1963). Thus, for example, if the conditions underlying Modigliani and Miller's propositions are satisfied, so that the overall cost of capital is in fact independent of the level of debt, then $r_D D + r_E\left(D\right)\left(M - D\right)$ is constant and, therefore, so is $p^*\left(D\right)$. This is the dotted line in Figure 2.1. On the other hand, if an increase in leverage did reduce the overall cost of capital, then $p^*\left(D\right)$ would be decreasing, as shown by the dashed line, up to the point where r_E is independent of D, in

Figure 2.1: The prices chosen by the regulator as a function of the debt ratio



which case $r'_E(D) = 0$ and the slope of the curve is constant and given by $-(r_E(D) - r_D)$. However, the circumstances where the debt level is lower than $\overline{D}$, and the relationship between the level of debt and the rate of return required by shareholders may affect the price that the regulator can set, are, in a sense, outside the scope of this paper. This is because, as the Figure illustrates, as far as the regulator is concerned, debt levels lower than $\overline{D}$ are (at least) weakly dominated by $\overline{D}$, and therefore will not be chosen by the regulator (this is shown precisely in Lemma 1 below).

At debt levels higher than $\overline{D}$, it is impossible to pay the debt and the interest charges in both states of the world and keep the price independent of the realized cost without violating the shareholders' limited liability constraint (2.6). So, as the debt level increases, a scissor is opened between the prices in the two states of the world. These are given in the next proposition.

Proposition 2 *Let $D > \overline{D}$. The prices chosen by the regulator when cost is high and low, p_H^* and p_L^*, respectively, are given by:*

$$p_H^* = \psi(e^*) + \theta - e^* + (1 + r_D) D, \tag{2.11}$$

$$p_L^* = \frac{u_0}{x} + \psi(e^*) + \theta - e^* - c + (1 + r_D) D + \frac{(1 + r_E(\overline{D}))}{x}(M - D). \tag{2.12}$$

Proof. The key to the proof is the observation that at $D = \overline{D}$ the shareholders lose their entire investment when the cost realization is high. In order for shareholders to be willing to invest in the company, their total returns when the cost is low must be at least $\frac{1+r_E(\overline{D})}{x}\left(M - \overline{D}\right)$. This determines the price for the two cost realizations, $p^*\left(\overline{D}\right)$, given in (2.10). Next note that, for a higher level of leverage, the shareholders' rate of return in the two states of the world will be the same as when $D = \overline{D}$. Returns cannot be negative (due to limited liability) in the high cost state, and therefore they do not need to be higher than $\frac{1+r_E(\overline{D})}{x}(M - D)$ in the low cost state. The rest of the proof is obtained by deriving p_H^* from Proposition 1 and p_L^* from equating the LHS of (2.7) to $\frac{1+r_E(\overline{D})}{x}(M - D)$. ■

The implication of this result is that the prices are linear in the level of debt (with slopes $(1 + r_D)$ and $(1 + r_D) - \frac{1+r_E(\overline{D})}{x}$ in the high and low cost case, respectively). The expected price,

$$E(p^*) = u_0 + \psi(e^*) + \theta - e^* - xc + (1 + r_D) D + \left(1 + r_E\left(\overline{D}\right)\right)(M - D), \quad (2.13)$$

is also decreasing in the level of debt.

2.4 The choice of capital structure

In the above section the level of debt is taken as given. As prices vary with D, so does welfare, which is obtained by substituting the values of p_H^* and p_L^* given in (2.11) and (2.12), into the regulator's payoff (2.9).

$$W(D) = \begin{cases} U\left(u_0 + \psi(e^*) + \theta - e^* - xc + (1 + r_D) D + (1 + r_E(D))(M - D)\right), \\ \text{if } D \leqslant \overline{D}; \\ \\ xU\left(\frac{u_0}{x} + \psi(e^*) + \theta - e^* - c + (1 + r_D) D + \frac{1+r_E(\overline{D})}{x}(M - D)\right) \\ \qquad + (1 - x) U\left(\psi(e^*) + \theta - e^* + (1 + r_D) D\right), \\ \text{if } D > \overline{D}. \end{cases}$$

While the determination of the firm's actual capital structure is generally outside the regulator's control, it should be apparent from the discussion in the above section, that, by selecting prices and then letting the firm choose its preferred capital structure, the regulator can, *de facto*, choose the capital structure itself. To see this, suppose that the regulator's preferred value of debt is $D_0 > \overline{D}$. Suppose also that the regulator imposes the prices obtained by substituting D_0 into (2.11) and (2.12). The regulated firm will then have no choice but to select $D = D_0$. This follows from the fact that if it has a leverage ratio lower that that implied by $D = D_0$, then the shareholders would be able to increase their return by increasing the leverage. On the other hand, if the level of debt were higher than D_0, the firm would not be able to satisfy the lenders' requirement that the debt and the interest charges be paid in both states of the world.

In the rest of this section we therefore study the regulator's preferred level of debt. The following lemma is an immediate consequence of Proposition 2.

Lemma 1 *The regulator's payoff is non-decreasing in D for every $D \in \left[0, \overline{D}\right]$.*

Proof. Simply differentiate $W(D)$ for $D \leqslant \overline{D}$:

$$W'(D) = U'(p^*)\left(r_E'(D)(M - D) - (r_E(D) - r_D)\right).$$

From Proposition 1, the overall cost of capital is non-increasing when $D \leqslant \overline{D}$ and so $r_E(D) - r_D \geqslant r_E'(D)(M - D)$. The Lemma then follows using (2.2) and $U'(p) < 0$. ■

The following is the main contribution of this paper.

Proposition 3 *Let D^* be the socially optimal level of debt. Then $D^* > \overline{D}$.*

Proof. From Lemma 1, we know that, if it exists, D^* is in $\left[\overline{D}, M\right]$. Since $W(D)$ is continuous in the compact interval $\left[\overline{D}, M\right]$, it has a maximum in $\left[\overline{D}, M\right]$. Now we simply need to show that this maximum is not at $D^* = \overline{D}$. To this end, differentiate $W(D)$:

$$W'(D) = xU'(p_L^*)\left(1 + r_D - \frac{1 + r_E\left(\overline{D}\right)}{x}\right) + (1-x)U'(p_H^*)(1 + r_D), \quad (2.14)$$

We need to show is that $W'\left(\overline{D}\right) > 0$. At $D = \overline{D}$, $p_L^* = p_H^*$, and so we have:

$$\begin{aligned} W'\left(\overline{D}\right) &= U'(p^*)\left(x(1 + r_D) - \left(1 + r_E\left(\overline{D}\right)\right) + (1 - x)(1 + r_D)\right) \\ &= -U'(p^*)\left(r_E\left(\overline{D}\right) - r_D\right) > 0. \end{aligned}$$

This establishes the result. ■

In terms of the diagram in Figure 2.1, the proposition shows that the socially optimal level of debt D^* is to the right of $\overline{D}$. In words, *the socially optimal capital structure leaves some price uncertainty.* This runs counter to the practice of price cap regulation in most countries, but the intuition for this conclusion is quite natural. Increasing debt reduces the expected value of the price, but it also increases the variability of prices. The former is a social benefit, the latter, with risk aversion, a social cost. The optimal capital structure will be set where the benefit of an expected price reduction balances exactly the cost of the increase in variability. But now note that when $p_L^* = p_H^*$, the benefit is a first order effect, measured by $U'\left(xp_L^* + (1-x)\, p_H^*\right)$, and the welfare loss a second order effect, and it is, therefore, dominated by the welfare gain.

We close this section with a brief analysis of the effect of changes in the exogenous variables on the preferred level of debt. We take the case in which the optimal leverage is strictly less than 1 (otherwise the debt level remains at M for sufficiently small changes in exogenous variables).

Corollary 1 *If $D^* < M$, then:*

$$\frac{dD^*}{dc} = \frac{(1-x)\, U''\left(p_L^*\right) \frac{U'\left(p_H^*\right)}{U'\left(p_L^*\right)} \left(1+r_D\right)}{-W''\left(D\right)} < 0, \tag{2.15}$$

$$\frac{dD^*}{d\theta} = \frac{\left(\frac{U''\left(p_H^*\right)}{U'\left(p_H^*\right)} - \frac{U''\left(p_L^*\right)}{U'\left(p_L^*\right)}\right)(1-x)\, U'\left(p_H^*\right)\left(1+r_D\right)}{-W''\left(D\right)}, \tag{2.16}$$

$$\frac{dD^*}{du_0} = -\frac{1}{x}\frac{dD^*}{dc} > 0, \tag{2.17}$$

$$\frac{dD^*}{dr_D} = \frac{dD^*}{d\theta} D^* + \frac{xU'\left(p_L^*\right) + (1-x)\, U'\left(p_H^*\right)}{-W''\left(D\right)}. \tag{2.18}$$

Proof. Take (2.15). Total differentiation of the first order condition for an interior optimum, $W'\left(D\right) = 0$, keeping θ, u_0, r_D, and $r_E\left(\overline{D}\right)$ constant, where $W'\left(D\right)$ is given in (2.14), yields:

$$W''\left(D\right) dD - xU''\left(p_L^*\right)\left(1 + r_D - \frac{1 + r_E\left(\overline{D}\right)}{x}\right) dc = 0.$$

From which it is immediate to derive (2.15), using (2.14), which can be written as:

$$\left(1+r_D-\frac{1+r_E\left(\overline{D}\right)}{x}\right)=-\frac{1-x}{x}\frac{U'\left(p_H^*\right)}{U'\left(p_L^*\right)}\left(1+r_D\right).$$

The remaining statements in the Corollary are obtained in the same manner.
■

Further insight into the effects of changes in θ and r_D can be gained with the assumption that the representative consumer has decreasing absolute risk aversion (this is a realistic restriction, as noted by Hirshleifer and Riley (1992). Use the direct utility function $\widetilde{U}(Y-p)$ to write the first term in the numerator of (2.16) as:

$$\frac{-\widetilde{U}''(Y-p_H^*)}{\widetilde{U}'(Y-p_H^*)}-\frac{-\widetilde{U}''(Y-p_L^*)}{\widetilde{U}'(Y-p_L^*)}. \tag{2.19}$$

This is the difference in the coefficient of absolute risk aversion evaluated at $Y-p_H^*$ and $Y-p_L^*$, which is positive, as $Y-p_H^*<Y-p_L^*$. Therefore, if the consumers have decreasing absolute risk aversion, then both $\frac{dD^*}{d\theta}$ and $\frac{dD^*}{dr_D}$ are negative.

The interpretation of the results in Corollary 1 is fairly straightforward, keeping in mind the main trade-off between lower expected price but higher variation in this price.

Consider an increase in c. This reduces the expected cost by xc, and therefore the expected price, but it also increases the gap between the prices (see (2.11) and (2.12), or (2.32) in the proof of Proposition 1). The regulator, therefore, takes the benefit of the reduction in the expected cost with a reduction in both the expected price and in the variability of the price; the latter being achieved via a reduction in debt. An increase in θ increases the overall cost of the industry, making the consumers poorer (the expected price increase by the same amount as θ, see (2.13)). When consumers display decreasing absolute risk aversion, then they prefer less risk the poorer they are, and the regulator reduces the amount of risk they carry by setting prices such that the level of debt is lower and the overall cost of providing the good increases. An increase in r_D has clearly the same effect as an increase in θ. In addition, there is also a substitution away from the form of financing that is becoming more expensive. Finally, the overall cost of an increase in u_0 means both that managers become more "expensive" and that they are willing to accept more risk. This is, therefore, analogous to a reduction in c (higher cost, but less variability). The effect on the preferred value of D is therefore the same, and for the same reason.

2.5 Concluding remarks

The paper studies the role of the financial structure in a regulated firm. It is found that the price cap mechanism, which fixes the prices and thus permits no cost sharing between shareholders and consumers, is sub-optimal. If the regulator maximizes the welfare of consumers with a standard von-Neumann-Morgenstern utility function, the optimal regulatory mechanism is such that the consumers pay more when the underlying economic conditions are bad. From a practical point of view, of course, it is conceptually much simpler to say "no price variation" than to say "some price variation, but not too much". The former is unambiguous, the latter would be likely to open the gates for endless negotiations about the price level, whereas with a price cap negotiations occur only at the periodic price review. It is however important to note that, from a theoretical viewpoint, there are welfare losses determined by the imposition of a fixed price rule, even in the symmetric information set-up of the paper.

Our analysis also indicates that the regulator should take a view on the optimal capital structure of the regulated firm, as this may affect the cost of capital, and therefore, ultimately, the price paid by consumers. This is very much reflected in the practice of regulators in the UK. During recent periodic reviews, UK regulators have stated explicitly their opinion about what constitutes an efficient capital structure. Table 1 summarizes a number of regulators' most recent judgments of the industry efficient capital structure. The assumptions made by the regulators with regard to the level of leverage significantly exceeded the actual level at the time of the relevant Periodic Review in virtually all cases, suggesting that UK regulators would somehow welcome an increase in the level of debt of regulated companies, to the extent that it translates into lower prices paid by the consumers.

Although there is no requirement that the regulated firms adjust their capital structures in line with these figures, as argued in the present paper, they clearly have an incentive to do so to the extent that this reduces the cost of capital.

Table 1: Recent assumptions by UK regulators about efficient capital structures.

Regulator (Reference)	Leverage assumption
Water companies (Ofwat 1999)	45%-55%
Railtrack (ORR 1999)	50%
Public electricity suppliers (Ofgem 1999)	50%
National Grid Company (Ofgem 2000)	60%-70%
Transco (Ofgem 2001)	62.5%
Mobile phone operators (Oftel 2001)	10%-30%

What constitutes an efficient capital structure has become a significant issue in the UK. For example, after the 1999 Periodic Review several water companies took action to increase leverage well above the level assumed by the regulator. A significant recent development has been the use of 'not-for-profit' companies limited by guarantee that rely 100% on debt for external finance to replace privatized utilities with serious financial problems. Glas Cymru and Network Rail were both established on this basis to replace, respectively, Welsh Water in May 2001 and Railtrack plc as owner and operator of the rail network in October 2002. However, as our analysis illustrates, there is no theoretical reason to suggest that a 100% debt financed company is socially optimal. Too much debt may imply too much variability in the prices paid by the consumers. This possibility seems to have been recognized in the design of 'not-for-profit' structures. Such structures require the creation of a buffer in the form of liquid reserves to protect consumers and lenders from unexpected variations in costs in the event of adverse economic conditions. Even so, consumers pay for this protection and, in effect, take on the role of shareholders (but without the ownership rights) to the extent that these reserves have to be built up initially and then replenished out of charges to consumers.

How UK regulators will respond to these developments remains to be seen. However, the water regulator (Ofwat (2002)) has expressed the view that the assumptions about the cost of capital used to set prices should not pressure companies to adopt highly geared capital structures that create undue risks for consumers.

Appendix 2.A Proof of Proposition 1

Proof. The Lagrangian function for the problem (2.9) is:

$$\begin{aligned}\mathcal{L} &= xU(p_L) + (1-x)U(p_H) \\ &+ \mu_H(w_H - \psi(e)) + \mu_L(w_L - \psi(e)) + \mu(xw_L + (1-x)w_H - \psi(e) - u_0) \\ &+ \pi_H(p_H - (w_H + \theta - e) - (1+r_D)D) + \pi_L(p_L - (w_L + \theta - e - c) - (1+r_D)D) \\ &+ \pi(x(p_L - w_L + c) + (1-x)(p_H - w_H) - \theta + e - (1+r_D)D - (1+r_E(D))(M-D)).\end{aligned}$$

where μ_H, μ_L, μ, π_H, π_L and π are the multipliers associated to constraints (2.3) (2.4) (2.5) (2.6) (2.7) and (2.8), respectively. The first order conditions are:

$$\frac{\partial \mathcal{L}}{\partial p_L} = xU'(p_L) + \pi_L + x\pi = 0, \tag{2.20}$$

$$\frac{\partial \mathcal{L}}{\partial p_H} = (1-x)U'(p_H) + \pi_H + (1-x)\pi = 0, \tag{2.21}$$

$$\frac{\partial \mathcal{L}}{\partial e} = -(\mu_H + \mu_L)\psi'(e) - \mu\psi'(e) + \pi_H + \pi_L + \pi = 0, \tag{2.22}$$

$$\frac{\partial \mathcal{L}}{\partial w_L} = \mu_L + \mu x - \pi_L - x\pi = 0, \tag{2.23}$$

$$\frac{\partial \mathcal{L}}{\partial w_H} = \mu_H + \mu(1-x) - \pi_H - (1-x)\pi = 0. \tag{2.24}$$

Suppose that managers' utility is above 0 in each state of the world; then $\mu_H = \mu_L = 0$. Notice that if both (2.6) and (2.7) are binding, $\pi_H > 0$ and $\pi_L > 0$, the shareholders' participation constraint (2.8) would be violated. So it must be the case that at least one of the constraints (2.6) and (2.7) is slack. Begin with (2.7): when it is slack, the firm makes positive profit when the cost is low. Therefore $\pi_L = 0$. And, from (2.20):

$$-U'(p_L) = \pi. \tag{2.25}$$

Using this, we can obtain:

$$\begin{aligned}
\mu &= \pi, && \text{from (2.23);} \\
\pi_H &= 0, && \text{from the above and (2.24);} \\
p_L &= p_H, && \text{from (2.25) and (2.21);} && (2.26) \\
\psi'(e) &= 1, && \text{from (2.22).} && (2.27)
\end{aligned}$$

So the consumers pay the same price (they do not carry any risk) and the shareholders and the managers are kept at their reservation expected utility (both μ and π are strictly positive). Let e^* be the value of e determined by (2.27).

While the expected salary is given by $u_0 + \psi(e^*)$, the two salaries w_L and w_H are indeterminate. One way of fixing these values could be to let managers be at their reservation utility and only be paid for the cost of their effort when costs are high so that:

$$w_H^* = \psi(e^*), \tag{2.28}$$

which implies that:

$$w_L^* = \frac{\psi(e^*) + u_0 - (1-x)w_H}{x} = \psi(e^*) + \frac{u_0}{x}. \tag{2.29}$$

In this case, the profit in the two states of the world is:

$$\begin{aligned}
&p_H^* - \psi(e^*) - \theta + e^* - (1 + r_D) D, \\
&p_L^* - \psi(e^*) - \frac{u_0}{x} - \theta + e^* + c - (1 + r_D) D,
\end{aligned}$$

in the high cost and the low cost states respectively. By (2.1), profit is higher when the random component of cost is low, and therefore our starting assumption that (2.7) is slack is verified.

To ensure that the shareholders receive their reservation utility, the price must satisfy:

$$p_H^* = p_L^* = p^* = u_0 + \psi(e^*) + \theta - e^* - xc + (1 + r_D) D + (1 + r_E(D))(M - D). \tag{2.30}$$

This is possible without violating (2.6) if and only if:

$$(1 + r_E(D))(M - D) \geqslant xc - u_0. \tag{2.31}$$

Note that, by (2.1), the RHS of (2.31) is positive, and therefore, when $D = M$, (2.31) is certainly violated. Let $\overline{D}$ be the solution to (2.31) when it holds as an equality, if one exists, otherwise let $\overline{D} = 0$. Note that the LHS of (2.31) is decreasing in D since the overall cost of capital $r_D D + r_E(D)(M - D)$ is either constant or decreasing in debt. This implies that there is only one value of D such that (2.31) holds as an equality, implying that $\overline{D}$ is well defined. Therefore, for $D \leqslant \overline{D}$, (2.31) holds, the solution to the regulator's problem is given by (2.27), (2.28), (2.29) and (2.30). This proves the first two parts of Proposition 1.

Now suppose that $D > \overline{D}$. In this case, (2.31) is violated, and therefore the above cannot be the solution. If salaries are fixed on the same principle as before so that $w_L > w_H$, we will have: $\mu_L = 0$, and $w_H = \psi(e)$. Rearrange the first order conditions as follows:

$$\begin{aligned}
\pi_L &= x(\mu - \pi), && \text{from (2.23);} \\
x\left(U'(p_L) + \pi\right) + x(\mu - \pi) &= 0, && \text{from (2.20);} \\
\mu &= -U'(p_L); && \\
\pi_H &= -(1 - x)\left(U'(p_H) + \pi\right), && \text{from (2.21);} \\
\mu_H &= (1 - x)\left(U'(p_L) - U'(p_H)\right), && \text{from (2.24).}
\end{aligned}$$

Note that $\mu_H > 0$ implies $U'(p_L) > U'(p_H)$, that is $p_L < p_H$. Putting the values of the multipliers derived in the above into (2.22) gives:

$$\begin{aligned}
&-(1 - x)\left(U'(p_L) - U'(p_H)\right)\psi'(e) + U'(p_L)\psi'(e) \\
&\quad -(1 - x)\left(U'(p_H) + \pi\right) - x\left(U'(p_L) + \pi\right) + \pi = 0,
\end{aligned}$$

Rearranging gives:

$$-(1 - \psi'(e))\left(xU'(p_L) + (1 - x)U'(p_H)\right) = 0,$$

which implies:

$$\psi'(e) = 1.$$

Effort is, therefore, still set optimally at $e = e^*$ and salaries will be at the same level as before in (2.28) and (2.29):

$$w_L^* = \psi(e^*) + \frac{u_0}{x},$$
$$w_H^* = \psi(e^*).$$

Next note that:

$$\pi_L = -x\left(U'(p_L) + \pi\right),$$
$$\pi_H = -(1-x)\left(U'(p_H) + \pi\right).$$

and therefore, because $U'(p_L) > U'(p_H)$, we can have $\pi_H > 0$, and $\pi_L = 0$, but not vice versa. Consequently, the profit is 0 when the firm has high cost. From (2.6) this determines the price in this case as:

$$p_H^* = w_H^* - \theta + e^* - (1 + r_D) D$$

Using (2.28) gives the price p_H^* in (2.11). From Proposition 2 the price when the cost is low, p_L^* given in (2.12), is obtained using (2.8):

$$x(p_L - w_L^* + c) + (1-x)(p_H^* - w_H^*) - \theta + e^* - (1 + r_D) D = \left(1 + r_E\left(\overline{D}\right)\right)(M - D).$$

For this solution to be consistent with the assumption made at the outset, the price difference,

$$p_H^* - p_L^* = c - \frac{u_0}{x} - \frac{1 + r_E\left(\overline{D}\right)}{x}(M - D), \tag{2.32}$$

must be positive. That is:

$$xc - u_0 > \left(1 + r_E\left(\overline{D}\right)\right)(M - D),$$

which is precisely the case when (2.31) is violated. This ends the proof. ■

Chapter 3

Risk Sharing, the Cost of Equity and the Optimal Capital Structure of the Regulated Firm

3.1 Introduction

The worldwide trend to privatize utilities and liberalize the markets for providing public services has been accompanied by a considerable amount of research on incentive schemes for controlling monopoly power when there are asymmetries in the information available to the regulator and the firm; a classic example being Laffont and Tirole (1993). In practice, however, price controls are the only mechanism that is generally used to regulate privately owned monopolies. Armstrong, Cowan and Vickers (1994), in their study of the UK's experience, point out that design of the price control system involves making a trade-off between allocative and productive efficiency because a firm's costs are determined by factors outside its control as well as by its own efforts, both of which are largely unobservable by a regulator. There has, therefore, been much discussion about the relative merits of the 'price-cap' and the 'rate-of-return' systems of regulation. In its extreme form, rate-of-return regulation is simply an arrangement under which the firm's prices are determined by, and continuously adjusted in accordance with, its actual costs. Although this might achieve allocative efficiency and avoid excessive profits it provides no incentive for the firm to reduce costs and achieve productive efficiency. Conversely, under a pure price-cap system, there is a predetermined upper limit on prices and while this creates strong incentives to increase productive efficiency it is likely to result in allocative inefficiency since prices can be out of line with costs. It also leads to the possibility of monopoly rents. Consequently, neither mechanism has been implemented in its extreme form and regulatory systems in many parts of the world have evolved into hybrids of both these methods of price control.

While the literature has concentrated on the effect of different price control mechanisms on incentives and the behaviour of the firm, little attention has been given to their effect on consumers and investors. In particular, a rate-of-return system with an annual adjustment of prices in line with actual costs is likely to result in greater variability in prices than a price-cap system where an upper limit on prices is set prospectively and remains unchanged for a considerable period of time; generally four or five years in the UK. This greater variability in prices implies a higher level of risk for consumers and a lower level of risk for the firm. This in turn suggests that the cost of capital and the financing costs of the regulated firm should be lower under rate-of-return regulation if the firm's business risks are positively correlated with the return on the market portfolio. There is, therefore, a further potential trade-off to consider when making decisions on regulatory policy viz. the trade-off for the consumer between greater price variability and the possibility of a lower expected price. Although Cowan (2004) acknowledges the possibility of a relationship between the form of the price control and the cost of capital, his analysis of the optimal allocation of risk between consumers and the regulated firm takes a different approach and the firm is assumed, instead, to be risk averse with a utility function that is solely dependent on the firm's profits.

In addition, little attention has been paid in the literature to the capital structure of the regulated firm. Typically, as Spiegel (1996) notes, an implied assumption is made that the regulated firm is wholly financed by equity with the cost of equity being determined exogenously in the capital markets. For example, this is the approach in Laffont and Tirole (1993). As described in chapter 2, even where the firm's capital structure has been considered, the focus is again on the firm's behaviour and the potential use of high levels of gearing (the debt-capital ratio) to exert a price-influence effect on regulatory decisions.

In an early important contribution to finance theory Modigliani and Miller (1958) and (1963) showed that, in the absence of corporate taxation, the value of a firm and its overall cost of capital is unaffected by its capital structure. However, their analysis makes the key assumption that the firm's revenue is determined exogenously and so is not affected by its capital structure. Although this is a reasonable assumption for a firm that is not regulated, it is argued here that this may not be the case for a regulated firm which is subject to price controls. The form of the price control mechanism will determine the risks to be carried by investors and this will influence both the amount of equity finance that is needed and, potentially, its cost. It follows that capital structure may not be irrelevant for the regulated firm even in the absence of corporate taxation. It is not surprising, therefore, that risk, the cost of capital and capital structure have been the subject of considerable debate between regulators and regulated utilities at price-cap reviews in the UK. For example, there was a particularly extensive exchange of views on these issues shortly after privatization of the water industry as can be seen in Ofwat (1991) and WSA/WCA (1991).

The aim of this chapter is to examine the relationship between the form of the price control and the allocation of risk between consumers, the firm's managers and its shareholders and to determine under what conditions there is a social optimum. The question of whether there is a socially optimal capital structure for a regulated firm has previously been considered by De Fraja and Stones (2004) and their paper is included here as chapter 2. They developed a model of a regulated firm in which its capital structure is determined endogenously and, in effect, by the regulator and they showed that an increase in gearing which reduces the overall cost of capital not only gives the regulator scope for price reductions but also creates a trade-off. Increasing the level of gearing reduces the amount of equity capital that can be used to absorb the cost of downside risks and so, once gearing rises above a certain level, a reduction in the expected price can only be achieved at the expense of greater price variability. De Fraja and Stones (2004) concluded that, when consumers are risk averse, there is a socially optimal capital structure in which in consumers carry some risk, in the sense that they are willing to accept a degree of price variability and pay higher prices when there are adverse economic conditions. It follows that a price cap system, in which prices are fixed or only varied in exceptional circumstances, is sub-optimal.

In De Fraja and Stones (2004) the cost of equity was simply assumed to be a function of the level of debt as a proxy for the relationship between the firm's cost of equity and investment risk. The classic formulation of that relationship is the Capital Asset Pricing Model (CAPM) developed in Sharpe (1964), Lintner (1965a) and (1965b) where shareholders base their investment decisions on the vector of returns and their covariance with the return on the market portfolio. The proxy function used by De Fraja and Stones (2004) is consistent with such models because an increase in a firm's level of debt increases the covariance of the returns to shareholders with the market return and, therefore, the cost of equity. However, it is this proxy function which leads to their result that there must some variability in consumer prices once gearing reaches a certain level. Above that level the buffer provided by equity finance is insufficient to aborb all the risk of cost variations and still meet the firm's obligations to lenders and shareholders. Consequently, their model only allows the regulator's decision on prices to influence the cost of equity indirectly through the regulator's choice of capital structure.

This chapter examines the more general case when the level of gearing and the regulator's decision on prices both have an independent and direct effect on the covariance of the shareholders' returns with the market return and, therefore, on the firm's cost of equity. Indeed, a novel feature of the model presented in this chapter is that it explicitly allows for the possibility that prices can be set in such a way that the risks and returns for shareholders are either positively correlated, uncorrelated or even negatively correlated with the market return. As a result the firm's cost of equity can either be greater than, equal to or lower than the cost of debt. In other words, the regulator's ability to determine the extent to which prices can vary means that the risks and returns for shareholders need not necessarily be tied to the firm's underlying business risk. It is by recognising this point that the model takes into account the consumer's trade-off between increasing price volatility and a lower expected price.

Two sets of results are obtained from the analysis. Firstly, it is shown, in contrast to De Fraja and Stones (2004), that some variation in prices is optimal for consumers at all levels of gearing except in the unlikely case where the willingness of managers to carry risk exceeds the inherent risk in the business. Although prices are higher for consumers in adverse economic conditions, the returns to shareholders need not be lower. Indeed, an interesting possibility emerges when comsumers have a relatively low aversion to risk and prefer a lower expected price. In these circumstances it might be optimal for the regulator to set prices so that profits are higher in adverse economic conditions. As this would provide shareholders with a form of insurance against market risk the cost of equity would be lower than the cost of debt; the result being lower financing costs and a lower expected price for consumers.

Secondly, it is shown that even in the absence of corporate taxation the regulated firm has a socially optimal capital structure that depends on both the consumers' aversion to the risk of price variations and the shareholders' trade-off between risk and returns. A key result is that, in this model, there is only one particular case in which the preferences of consumers and shareholders make it optimal for the regulator to set prices where the rate of return is equal to the cost of debt and such a return is also satisfactory for investors. In all other cases there should either be a combination of equity and debt or no debt at all. In other words, there is only one very special set of conditions where it is socially optimal for the regulated firm to be a 'not-for-profit' company or a similar entity that relies wholly on debt finance.

This latter result is of more than just theoretical interest. The use of not-for profit companies to provide public services can have political attractions and in the UK, for example, such companies have been established to take over the assets and operations of privatized utilities that have encountered financial difficulties. However, these developments remain controversial and, as Stones (2001) describes in his commentary on the water industry, not all proposals to introduce such structures have been successful.

The format of this chapter is as follows. Section 3.2 sets out the model. Section 3.3 considers the regulator's pricing decision if the firm's capital structure is given exogenously and the results of the analysis lead to a number of Lemmas and Propositions. The detailed analysis of the regulator's problem is given in appendix 3.A while the proofs of the Lemmas and Propositions are provided in appendices 3.B and 3.C respectively. In section 3.4 the regulator can vary the firm's capital structure and the conditions under which there will be a social optimum are similarly set out in the form of a series of Propositions. Appendix 3.D sets out the solutions for a social optimum in detail and the proofs of the associated Propositions are contained in appendix 3.E. Finally some conclusions are presented in section 3.5.

3.2 The model

3.2.1 Demand and variable costs

It is assumed that a monopoly firm supplies a product that is fixed in quality. Demand for the product is price inelastic and normalized to 1. The regulator's objective is to maximize the representative consumer's expected utility by choosing the price p that the firm can charge. Assuming the consumer has a standard von Neumann-Morgenstern utility function in income, the consumer's indirect utility function is $U(p)$ with $U'(p), U''(p) < 0$ to reflect risk aversion.

The firm is run by a management who can reduce costs by exerting effort, $e > 0$. Managers' utility can be measured by their remuneration, w which is reduced by the cost of their effort. This cost is measured by a function $\psi(e)$, satisfying $\psi'(e), \psi''(e) > 0$. Managers will only accept employment if they are guaranteed that their expected remuneration will be at least their reservation level of expected utility, $u_0 > 0$.

The variable cost of production is made up of three components:

- an exogenously given component $\theta > 0$;
- the cost reducing effort by the management, $-e$, with $e > 0$; and
- a random cost reducing component, which is either $-c$ or 0, with $c > 0$. The probability of this component being $-c$ is $x \in [0, 1]$.

Consequently, there are only two states of the world in cost terms. The variable cost is either high (i.e. the random component is 0) or low (i.e. the random component is $-c$). Subscripts are used to indicate the values of variables in each state of the world (e.g. p_H is the price when cost is high and p_L is the price when cost is low.)

3.2.2 Investment and financing

Production also requires a capital investment $M > 0$, which is exogenously given and financed by a mixture of debt and equity. The extent of debt financing is denoted by $D \in [0, M]$.

The cost of debt is exogenously given at the market interest rate $r_D > 0$. Moreover, lenders are guaranteed that the debt and the interest will be paid under all circumstances and so the firm cannot go bankrupt. Consequently, r_D is also the risk free rate of return.

The firm's shareholders are risk averse and have limited liability in the sense that they cannot be obliged to finance a shortfall in revenue.

3.2.3 The cost of equity

So far the structure of the model is the same as that used by De Fraja and Stones (2004) but they go on to make the simplifying assumption that the cost of equity is a function of the level of debt. This is used as a proxy for the relationship between the firm's cost of equity and investment risk. However, this chapter considers the more general case where, in accordance with asset pricing models such as the CAPM, the cost of equity finance r_E depends on the covariance of the shareholder's rate of return R_E with the return on the market portfolio R_m, that is:

$$r_E = r_E\left(cov\left(R_E, R_m\right)\right) \tag{3.1}$$

Using the notation $r_E\left(cov\left(R_E, R_m\right)\right) = r_E\left(.\right)$ it is assumed that the cost of equity will vary directly with the covariance between the shareholder's rate of return and the market return, that is:

$$r_E'\left(.\right) > 0. \tag{3.2}$$

It is also assumed that the rate of return on the market portfolio is higher when the firm's costs are low so that[1]:

$$\Delta R_m = \left(R_{mL} - R_{mH}\right) > 0. \tag{3.3}$$

The above model leads to the following Lemma[2].

[1] Although R_{mL} is the return on the market portfolio when the firm's costs are low, and R_{mH} is the return when the firm's costs are high, it should be noted that this does not imply there are two states of the world for the return on the market portfolio. It is only necessary to assume that each outcome for the firm's costs always coincides with a particular level of R_m.

[2] The proof is given in appendix 3.B.

Lemma 1 *The covariance of the shareholder's rate of return R_E with the return on the market portfolio R_m is:*

$$cov\left(R_E, R_m\right) = \frac{x\left(1-x\right)}{M-D}\left(c-\left(w_L-w_H\right)-\left(p_H-p_L\right)\right)\Delta R_m. \tag{3.4}$$

The cost of equity in this model is, therefore, not only a function of the level of debt but, crucially, it is also a function of the regulator's decision on prices. This approach, therefore, allows both effects to be taken into account independently.

It can also be seen from Lemma 1 that, under a price cap system of regulation where the upper limit on prices is invariant to cost levels and the firm charges at the limit (i.e. $p_H = p_L$), the cost of equity does not depend on the level of the price cap set by the regulator. At first sight this might seem counterintuitive as it suggests a price cap review which tightens the regulatory contract and decreases revenue would not result in higher rates of return being required by shareholders. The point to note here is that cost of equity is determined by the covariance of the shareholders' returns with the market and this would be unaffected by a 'one-off' reduction in revenue[3]. Of course, the decrease in revenue would lead to a reduction in the market value of the equity but the cost of equity would not rise. However, as Grout (1995) points out, the rate of return required by shareholders in normal times will exceed the cost of equity if the regulator's decision leads shareholders to expect that future price cap reviews will result in negative shocks to the firm's future revenues from further tightening of the contract.

3.3 Prices with a given capital structure

3.3.1 The regulator's problem

It is assumed that the regulator has complete information and so there is no information asymmetry between the regulator and the firm. As there are only two states of the world in cost terms the regulator's problem when the capital structure is given exogenously is to choose p_L, p_H, e, w_L, and w_H in order to

[3] This is because the size of the covariance between two variables is not affected if one of the variables is increased or decreased by a constant amount.

maximize the consumer's expected utility subject to a number of constraints[4].

Firstly, there are two rationality constraints and a participation constraint to ensure the managers are willing to accept employment:

$$w_H - \psi(e) \geqslant 0, \tag{3.5}$$

$$w_L - \psi(e) \geqslant 0, \tag{3.6}$$

$$x w_L + (1-x) w_H - \psi(e) \geqslant u_0. \tag{3.7}$$

Secondly, there are two break even constraints on the firm's profits, Π_H and Π_L, and a shareholders' participation constraint. The former preserve the limited liability of shareholders and ensure that the firm meets its obligations to lenders while the latter ensures that the firm's expected profits, $E(\Pi)$, are high enough to cover the cost of equity and the repayment of the initial equity investment:

$$\Pi_H = (1 + R_{EH})(M - D) \geqslant 0, \tag{3.8}$$

$$\Pi_L = (1 + R_{EL})(M - D) \geqslant 0, \tag{3.9}$$

$$E(\Pi) \geqslant (1 + r_E(.))(M - D), \tag{3.10}$$

where:

$$\begin{aligned}
\Pi_H &= p_H - (w_H + \theta - e) - (1 + r_D) D, && (3.11) \\
\Pi_L &= p_L - (w_L + \theta - e - c) - (1 + r_D) D, && (3.12) \\
E(\Pi) &= x(p_L - w_L + c) + (1-x)(p_H - w_H) + \theta - e - (1 + r_D) D. && (3.13)
\end{aligned}$$

The regulator's problem is, therefore:

$$\max_{\substack{p_L, p_H,\\ w_H, w_L, e}} xU(p_L) + (1-x)U(p_H) \text{ subject to (3.5) - (3.10)} \tag{3.14}$$

The feasible solutions to this problem are derived in appendix 3.A while the proofs of the associated Lemmas are given in appendix 3.B. This section sets out the main results in the form of a series of Propositions and associated

[4] Although the regulator must set the price before the random component of costs is realised it can be made conditional on the outcome. A more detailed description of the sequence of events in this model is given in Chapter 2.

Corollaries for which the proofs are given in appendix 3.C.

For these purposes p_L^*, p_H^*, e^*, w_L^*, and w_H^* are used to represent the solution to the problem (3.14) while Π_L^* and Π_H^* are the firm's profits, R_{EL}^* and R_{EH}^* are the shareholders' rates of return and $r_E^*(.)$ is the cost of equity produced by that solution. The resulting covariance of shareholder returns with the market return is denoted $cov^*(.)$.

3.3.2 Consumer preferences and risk

The first proposition is concerned with the consumer preferences regarding the risk of price variations.

Proposition 1 *If $u_0 > xc$ then the prices chosen by the regulator are such that $p_H^* = p_L^*$ when $w_L^* > w_H^* > \psi(e^*)$, $\Pi_H^* > 0$ and $\Pi_L^* = 0$, otherwise $p_H^* > p_L^*$.*

Proposition 1 states that consumers prefer some variation in prices, with prices being higher when the firm's costs are high, unless certain conditions apply. Firstly, for price certainty to be optimal the managers' reservation level of expected utility u_0 must exceed xc, the expected variation in the firm's costs[5]. In other words, managers must be willing to absorb the whole of the firm's business risk. Secondly, the managers' remuneration must exceed the cost of effort and provide positive utility in both states of the world to ensure they receive their reservation level. Thirdly, profits must be zero when the firm's costs are low and positive when costs are high so that financing costs and, therefore, prices are minimized. This means the cost of equity is lower than the cost of debt. It follows that to maintain price certainty the difference in managers' remuneration between the two states of the world must be sufficient to cover both the variation in variable costs and the returns received by shareholders when costs are high.

In practice, however, it is unlikely that x and/or c would be so small or u_0 so large that the optimum for consumers would be a pure price cap system of regulation in which there is price certainty for consumers and no sharing of risks. It should also be noted that there are no feasible solutions to the problem where $p_H^* < p_L^*$.

[5]This possibility is not considered by De Fraja and Stones (2004) as they specifically assume that $xc > u_0$.

This conclusion applies at all levels of gearing whereas in De Fraja and Stones (2004) it is only optimal for prices to vary once gearing increases beyond a certain level. In De Fraja and Stones (2004), once gearing reaches a certain level the cost of equity is fixed and the risk that is carried by consumers through price variations can, therefore, only be adjusted by varying the total amount of equity finance and hence the capital structure of the firm. This model, however, allows price variations and capital structure to have separate and independent effects on the cost of equity. As both effects can be taken into account an optimal variation in consumer prices can be determined at any level of debt.

Proposition 1 also demonstrates a key feature of this model in that, unlike De Fraja and Stones (2004), it provides the regulator with the option of setting prices that allow shareholders to receive higher profits when the firm's variable costs are high. In other words, by manipulating consumer prices, the regulator changes the risks carried by shareholders and it is possible to set prices so that the shareholders' returns are positively correlated, uncorrelated or even negatively correlated with the risk of variations in the firm's costs (which are assumed to be positively correlated with the market return). Consequently, it is possible that $cov^*(.) \gtreqless 0$ and so the cost of equity can be higher than, lower than or equal to the cost of debt.

Two Corollaries follow from this Proposition.

Corollary 1 *When* $p_H^* > p_L^*$ *then* $w_L^* = \psi(e^*) + \frac{u_0}{x}$ *and* $w_H^* = \psi(e^*)$.

When the optimum for consumers is a variation in prices the managers' remuneration provides zero utility when costs are high. This is because managers need only receive their reservation level of expected utility and so once the optimum variation in prices has been determined the balance of the remaining risk must be carried by shareholders.

Corollary 2 *If* $u_0 \geqslant xc$ *then* $r_E^*(.) < r_D$ *i.e. the cost of equity is lower than the cost of debt.*

If managers are willing to carry all the firm's business risk then financing costs are minimized by providing the shareholders with higher returns when costs are high so that the cost of equity is lower than the cost of debt. As shown in Proposition 1 this is a requirement when the optimum is price certainty but it also applies when the optimum is such that $p_H^* > p_L^*$.

3.3.3 Consumer risk and the cost of equity

The next three propositions are concerned with the relationship between consumers' and shareholders' preferences and their aversion to risk when $p_H^* > p_L^*$. Proposition 2 sets out the conditions for an internal optimum while Propositions 3 and 4 describe the 'corner' solutions.

Proposition 2 *When* $p_H^* > p_L^*$ *and* $\Pi_H^*, \Pi_L^* > 0$ *then* $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} = \frac{dp_H^*}{dp_L^*}$.

Proposition 2 states that, when there is an interior solution for the optimum, the consumer's marginal rate of substitution between a change in p_L^* and p_H^* equals the slope of the shareholders' participation constraint (3.10). Further, the slope of (3.10) itself reflects the effect of the change in p_L^* and p_H^* on the cost of equity as can be seen from the following Lemma.

Lemma 2 *When* $p_H^* > p_L^*$ *the shareholders' participation constraint satisfies* $\frac{dp_H^*}{dp_L^*} = -\frac{x\left(1-r_E^{*\prime}(.)(1-x)\Delta R_m\right)}{(1-x)\left(1+r_E^{*\prime}(.)x\Delta R_m\right)}$.

In other words, at the optimum the consumers' aversion to risk is such that the loss of utility from a marginal increase in the price variation is just matched by the benefit of the associated reduction in the cost of equity.

In addition, since shareholders receive positive returns in both states of the world it is possible for the cost of equity to be higher than, lower than or equal to the cost of debt depending on the different risk profiles of consumers and shareholders.

Proposition 3 *When* $p_H^* > p_L^*$, $\Pi_H^* = 0$, *and* $\Pi_L^* > 0$ *then* $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} > \frac{dp_H^*}{dp_L^*}$ *and* $r_E^*(.) > r_D$.

Proposition 3 concerns the case when the consumer's marginal rate of substitution between a change in p_L^* and p_H^* is greater than the slope of the shareholders' participation constraint at the optimum. Consumers have a relatively high aversion to risk compared with shareholders and it is optimal for consumers to carry relatively less risk and for profits to be higher when the firm's costs are low and zero when its costs are high. As shareholder returns vary directly with the market return the cost of equity is higher than the cost of debt.

Proposition 4 *When* $p_H^* > p_L^*$, $\Pi_H^* > 0$, *and* $\Pi_L^* = 0$ *then* $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} < \frac{dp_H^*}{dp_L^*}$ *and* $r_E^*(.) < r_D$.

If the converse applies and the consumer's marginal rate of substitution between a change in p_L^* and p_H^* is less than the slope of the shareholders' participation constraint then consumers have a relatively low aversion to risk compared with shareholders. Proposition 4 states that it is then optimal for consumers to carry relatively more risk. Profits are higher when costs are high and zero when costs are low. Consequently, shareholder returns vary inversely with the market return and the cost of equity is lower than the cost of debt.

3.3.4 Manager remuneration and shareholder returns

The final proposition in this section relates to the remuneration of the managers and the returns for shareholders when prices are at an optimum.

Proposition 5 *The prices chosen by the regulator are such that the marginal cost of managers' effort equals the marginal reduction in variable costs, i.e.* $\psi'(e^*) = 1$, *the managers' expected utility equals their reservation level* u_0, *and the shareholders' expected rate of return equals the cost of equity* $r_E^*(.)$.

In all the solutions for an optimum described above the regulator wishes to ensure that the expected price is at a minimum. Consequently, it is always optimal for the level of managerial effort to be where the marginal cost of their effort equals the marginal reduction in the variable cost of production. Similarly, the managers' expected utility should equal their reservation level of utility and the shareholders' expected rate of return should be in line with the cost of equity. It follows that in all solutions to the problem the managers' and the shareholders' participation constraints (3.7) and (3.10) are binding. The prices charged by the firm will, therefore, always be at the level chosen by the regulator.

3.4 The socially optimal capital structure

3.4.1 The regulator's problem

In the previous section the level of debt was taken as given. However, since prices vary with D, so does welfare which is obtained by substituting the values of p_H^* and p_L^* into the regulator's payoff function in (3.14):

$$W(D) = xU(p_L^*(D)) + (1-x)U(p_H^*(D)). \tag{3.15}$$

Consequently, the regulator's problem when the capital structure can be varied is to choose D in order to maximize (3.15) subject to the constraints that the capital investment is financed wholly from equity or debt finance or a mixture of both:

$$D \geqslant 0, \tag{3.16}$$
$$M - D \geqslant 0. \tag{3.17}$$

The problem can, therefore, be stated as:

$$\max_D \; xU(p_L^*(D)) + (1-x)U(p_H^*(D)) \text{ subject to } D \geqslant 0 \text{ and } M - D \geqslant 0. \tag{3.18}$$

Appendix 3.D derives the solutions to (3.18) and the conditions under which the socially optimal level of debt D^* is either an internal optimum (i.e. $0 < D^* < M$) or a corner solution where the social optimum is 100% equity finance (i.e. $D^* = 0$) or 100% debt finance (i.e. $M = D^*$).

By comparing the solutions to problem (3.18) with the solutions to problem (3.14) it is possible to determine the conditions under which an optimum for consumer prices is not only feasible but also when the firm's capital structure is such that this represents a social optimum. This section sets out the main results in the form of five propositions for which the proofs are provided in appendix 3.E. Propositions 6 and 7 describe the conditions where zero debt is the social optimum while Propositions 8 to 10 set out the conditions where a mixture of debt and equity finance and where 100% debt finance is socially optimal.

3.4.2 Zero debt

Proposition 6 *When* $p_L^* = p_H^*$ *then* $D^* = 0$.

This Proposition concerns the conditions for an optimum in the unlikely case when $p_L^* = p_H^*$ as described in Proposition 1. Proposition 6 states that there is a corner solution to (3.18) at which the socially optimal level of debt is zero when $p_L^* = p_H^*$. The reason is that, in this case, the managers' willingness to carry risk exceeds the inherent business risk in the firm. This allows the cost of equity to be lower than the cost of debt and so the firm should be 100% financed from equity to minimize prices for consumers[6].

Proposition 7 *When* $p_H^* > p_L^*$ *and* $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} \neq \frac{dp_H^*}{dp_L^*}$ *then* $D^* = 0$.

Propositions 3 and 4 set out the conditions for an optimum when $p_H^* > p_L^*$ and there is a corner solution where the consumer's marginal rate of substitution between a change in p_L^* and p_H^* does not equal the slope of the shareholders' participation constraint. Proposition 7 states that, in these circumstances, the social optimum is again where the level of debt is zero. There are two possibilities here.

Firstly, if consumers' risk aversion is relatively high the optimum is the lowest possible variation in prices. This is where the firm only makes profits when its costs are low, in which case the cost of equity exceeds the cost of debt. Even though a reduction in the level of debt increases the expected price this is more than offset by the benefit obtained from a smaller variation in prices[7]. This is because, with high risk aversion, the gain in consumers' utility is relatively large compared to the loss of utility from the increase in the expected price. Consequently, the socially optimal capital structure is a corner solution to (3.18) where the firm is wholly financed from equity.

Secondly, if the converse applies and consumers have a relatively low aversion to risk then the optimum is the lowest possible expected price. This is where the firm makes profits when costs are high and no profits when costs are low. The cost of equity is then lower than the cost of debt. Although a

[6] Lemma 5 in Appendix 3.B shows that $\frac{d(p^*)}{dD} > 0$.

[7] When $\frac{dp_H^*}{dp_L^*} < -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}$ Lemma 5 in Appendix 3.B shows that $\frac{d(E(p^*))}{dD} < 0$ and Lemma 6 shows that $p_H^{*\prime}(D) - p_L^{*\prime}(D) > 0$.

reduction in the level of debt results in a lower expected price it also produces an increase in the variation in prices[8]. However, the loss in consumers' utility is relatively small with low risk aversion and this is more than offset by the benefit from the lower expected price. The socially optimal capital structure is, therefore, a corner solution where the firm is, again, wholly financed from equity. The regulator's ability to reduce the cost of equity below the cost of debt through the decision on price variations also explains why there is no corner solution in which 100% debt finance is the social optimum.

3.4.3 A combination of debt and equity

Proposition 8 *When $p_H^* > p_L^*$ and $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} = \frac{dp_H^*}{dp_L^*}$ then $0 < D^* < M$ if $r_E^*(.) \neq r_D$ otherwise $D^* = M$.*

Proposition 8 states that when $p_H^* > p_L^*$ the socially optimal capital structure can be a combination of debt and equity finance provided that Proposition 2 applies, that is, it must be an internal optimum where the consumer's marginal rate of substitution between a change in p_L^* and p_H^* is equal to the slope of the shareholders' participation constraint. In this case the cost of equity can be higher than, lower than or equal to the cost of debt. However, if the cost of equity at the optimum does not equal the cost of debt then the socially optimal level of debt is less than 100%. Clearly, if the optimum for prices coincides with the position where the cost of equity equals the cost of debt the social optimum is equivalent to the firm being wholly financed by debt and consumers carry all the business risk that is not allocated to managers[9].

3.4.4 100% debt finance

The conditions under which 100% debt finance is the social optimum can be examined further by considering the relationship between the cost of equity and the cost of debt at a social optimum and the circumstances in which they are equal. This is the subject of Proposition 9.

[8] When $\frac{dp_H^*}{dp_L^*} > -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}$ Lemma 5 in Appendix 3.B shows that $\frac{d(E(p^*))}{dD} > 0$ and Lemma 6 shows that $p_H^{*\prime}(D) - p_L^{*\prime}(D) < 0$.

[9] When $cov^*(.) = 0$ it can be seen from Lemma 1 and Corollary 1 that $p_H^* - p_L^* = c - \frac{u_0}{x}$.

Proposition 9 *When $p_H^* > p_L^*$ and $D = D^*$ then $r_E^*(.) = r_D + cov^*(.)\, r_E^{*\prime}(.)$.*

This Proposition states that when $p_H^* > p_L^*$ the cost of equity at a social optimum is a linear function of the covariance of the shareholders' returns with the market return. As shown in appendix 3.E this is because, firstly, the shareholders' participation constraint (3.10) must be binding at all levels of debt and, secondly, at a social optimum, the ratio of the changes in p_L^* and p_H^* from a marginal increase in debt must equal the slope of that constraint given in Lemma 2. These two conditions require the following relationship to hold at a social optimum:

$$r_E^*(.) = r_D + cov^*(.)\, r_E^{*\prime}(.)\,. \tag{3.19}$$

This relationship demonstrates the linkage between the general form of the function for the cost of equity in (3.1) used in this model and the specific case of the CAPM. Appendix 3.F shows that $r_E^{*\prime}(.)$ is a constant in the CAPM and, specifically, that:

$$r_E^{*\prime}(.) = \frac{(E(R_m) - r_D)}{\sigma_m^2}, \tag{3.20}$$

where σ_m^2 is the variance of the return on the market portfolio. The relationship in (3.19) also leads to the following Proposition.

Proposition 10 *When $p_H^* > p_L^*$ and $D = D^*$ then there is a social optimum where $D^* = M$ if $r_E^{*\prime\prime}(.) \neq 0$. However, if $r_E^{*\prime\prime}(.) = 0$ then the social optimum satisfies $D^* = M$ for a set of parameter values that has measure zero in the parameter space.*

The main conclusion of this section is set out in Proposition 10 which specifies the conditions under which it is socially optimal for the regulated firm to be wholly reliant on debt for its external finance. This Proposition can be explained by noting that differentiating (3.19) with respect to $cov^*(.)$ requires that the following is satisfied:

$$r_E^{*\prime\prime}(.)\, cov^*(.) = 0. \tag{3.21}$$

Consequently, if $r_E^{*\prime}(.)$ is not a constant (i.e. $r_E^{*\prime\prime}(.) \neq 0$) there can only be a social optimum where the cost of equity is equal to the cost of debt which is equivalent to the firm being wholly financed by debt. Although the cost of equity in this model is determined by the general function (3.1), which makes no assumptions about $r_E^{*\prime\prime}(.)$, much of finance theory assumes that the shareholders' utility is determined by the mean and standard deviation of portfolio income. In these circumstances the CAPM would apply, $r_E^{*\prime}(.)$ would be a constant and the socially optimal capital structure when $r_E^{*\prime}(.)$ is not a constant would be of no significance[10].

Clearly. when $r_E^{*\prime}(.)$ is a constant then (3.21) is satisfied by any value of $cov^*(.)$. However, from Propositions 7 and 8, if the cost of equity does not equal the cost of debt at the optimum for prices then the socially optimal level of debt is less than 100%. In addition, from Lemma 2, when $r_E^{*\prime}(.)$ is a constant the slope of the shareholders' participation constraint is also a constant. Since the consumers' utility function is concave it follows that there is only one very special case in which the consumer's marginal rate of substitution between a change in p_L^* and p_H^* is equal to the slope of the shareholders' participation constraint at a point where the cost of equity is equal to the cost of debt. The set of parameter values that would produce such a solution, therefore, has measure zero in the parameter space. In other words, any change in the value of any of the parameters, however small, would move the social optimum away from the position where all investors are satisfied with a rate of return equal to the cost of debt. This is the only case where it is possible for 100% debt finance to be the socially optimal capital structure as Propositions 7 and 8 also show that such a solution can only apply at an internal optimum.

3.5 Conclusions

Although the model considered in this chapter is highly stylized and assumes the regulator has complete information, it has features that are of interest from a regulatory policy perspective.

Firstly, it is shown that the regulated firm's cost of equity will be affected by the extent to which the regulator allows prices to be adjusted in line with the firm's costs and these costs vary with fluctuations in the economy as a whole. In practice, even under price cap systems, prices do change in response to changes in the firm's costs. For example, there are often cost pass through

[10] For example, see Hirshleifer and Riley (1992) for a derivation of the CAPM from these assumptions.

arrangements which allow price adjustments in specified circumstances and there is generally a complete reassessment of costs when a price cap is reviewed. The design of the price control mechanism can, therefore, determine the degree to which systematic risks are carried by shareholders and, in turn, the cost of equity. Similarly, any changes to the operational principles and methodologies used by regulators to assess allowable costs at a review of the price cap can also have an effect. Indeed, this chapter shows that prices can be set so that shareholders' returns are either positively correlated, uncorrelated or even negatively correlated with the market return. In other words, the shareholders' risks and rewards need not be tied to the regulated firm's business risks and so its cost of equity can either be greater than, equal to or lower than the cost of debt. The effect of such decisions on shareholder risk should, however, be distinguished from the term regulatory risk which is normally used to describe the asymmetric downside risks of arbitrary regulatory or political interventions that tighten the regulatory contract. The model assumes that the cost of equity used to set prices is fully adjusted in accordance with changes in the allocation of systematic risks between shareholders and consumers. The regulatory risk is that, in practice, this might not occur.

Secondly, by allowing explicitly for the effect of the regulator's pricing decision on the cost of equity, the analysis shows that some variation in consumer prices is optimal at all levels of gearing except in the unlikely case that the managers' willingness to carry risk exceeds the inherent risk in the business. A price cap system in which prices are fixed or vary only in exceptional circumstances is, therefore, almost certainly sub-optimal. Further, although prices should be higher when there are adverse economic conditions, it is not necessary for the returns to shareholders to be lower. Whether or not this is optimal depends on the consumers' and the shareholders' relative aversion to risk. For example, consumers might have such a low aversion to risk that prices should be set to provide shareholders with higher returns when economic conditions are unfavourable. Shareholder returns would then be negatively correlated with the market return providing shareholders with insurance against market risk. As result the cost of equity would be lower than the cost of debt leading to lower financing costs and a lower expected price for consumers.

Thirdly, it is concluded that capital structure does matter for the regulated firm even in the absence of corporate taxation. This is because it determines the amount of equity finance and, in conjunction with the regulator's decision on price variations, the distribution of risks between consumers and shareholders. There is, therefore, a socially optimal capital structure that depends not only on consumers' aversion to the risk of price variations but also on the shareholders' trade-off between risk and returns.

Finally, differences in the attitudes of consumers and shareholders towards risk are shown to have implications for the socially optimal capital structure. If the optimum for consumer prices is such that, at the margin, consumers and shareholders do not have the same aversion to risk then the social optimum is a capital structure with no debt. When consumers have relatively high risk aversion compared to shareholders then consumers prefer the lowest possible price variation even though this produces a higher expected price. Conversely, when consumers' risk aversion is relatively low, it is optimal to set prices so that the risks for shareholders are consistent with a cost of equity that is lower than the cost of debt in order to produce the lowest possible expected price. In either case, debt finance produces no benefit for consumers.

However, if consumers and shareholders both have the same aversion to the risk of price variations at the margin, then there is only one very special set of conditions in the model where it is socially optimal for the regulated firm to be a 'not-for-profit' company or some other organization which relies wholly on debt for its external finance. For this to be the case, the prices that are optimal for consumers must produce a rate of return on equity that is equal to the cost of debt and this return must also be sufficient to satisfy shareholders. Apart from this unique case the social optimum is the combination of debt and equity finance that balances the distribution of risks. At the optimum consumers accept some variation in prices in exchange for a lower expected price and the residual risk is carried by shareholders for a reward that is in line with the relevant cost of equity.

In the UK here have been two recent cases where 'not-for-profit' companies have been established to replace privatized utilities. In 2001 Glas Cymru acquired Welsh Water and in the following year Network Rail was created to take over the operations of Railtrack. The new owners are both companies limited by guarantee which have no equity interest and can only obtain external finance from the debt markets. It is noticeable that, in both cases, the companies that previously supplied the services were in financial difficulties and a primary aim of the new arrangements was to secure the companies' long term finances. Consequently, when the new companies were being established, the attitude of lenders towards risk and, therefore, the terms on which the new debt finance could be raised, was a key consideration. While the outcome might have been satisfactory for the lenders this chapter shows it is almost certain that the resulting risk profile for consumers will not be optimal.

Appendix 3.A Solutions for a given capital structure

This appendix derives the feasible solutions to the problem (3.14).

The Lagrangian function for the problem (3.14) is:

$$
\begin{aligned}
\mathcal{L} &= xU(p_L) + (1-x)U(p_H) \\
&+ \mu_H (w_H - \psi(e)) + \mu_L (w_L - \psi(e)) + \mu (x w_L + (1-x) w_H - \psi(e) - u_0) \\
&+ \pi_H (p_H - (w_H + \theta - e) - (1 + r_D) D) \\
&+ \pi_L (p_L - (w_L + \theta - e - c) - (1 + r_D) D) \\
&+ \pi(x (p_L - w_L + c) + (1-x)(p_H - w_H) - \theta + e - (1 + r_D) D \\
&\qquad - (1 + r_E(.))(M - D)).
\end{aligned} \tag{3.22}
$$

where μ_H, μ_L, μ, π_H, π_L and π are the Lagrange multipliers associated with constraints (3.5) to (3.10). Let p_L^*, p_H^*, e^*, w_L^*, and w_H^* be the solution to this problem and let Π_L^* and Π_H^* be the firm's profits, R_{EL}^* and R_{EH}^* be the shareholders' rates of return and $r_E^*(.)$ be the cost of equity produced by that solution, that is:

$$
\begin{aligned}
\Pi_L^* &= (1 + R_{EL}^*)(M - D) && (3.23) \\
&= p_L^* - w_L^* - \theta + e^* + c - (1 + r_D) D, \\
\Pi_H^* &= (1 + R_{EH}^*)(M - D) && (3.24) \\
&= p_H^* - w_H^* - \theta + e - (1 + r_D) D, \\
r_E^*(.) &= r_E^*(cov(R_E^*, R_m))
\end{aligned}
$$

Using Lemma 1 in appendix 3.B the first order conditions for an optimum are:

$$\frac{\partial \mathcal{L}}{\partial p_L} = xU'(p_L) + \pi_L + x\pi - \pi r'_E(.)\, x(1-x)\,\Delta R_m = 0, \tag{3.25}$$

$$\frac{\partial \mathcal{L}}{\partial p_H} = (1-x)\,U'(p_H) + \pi_H + (1-x)\,\pi + \pi r'_E(.)\, x(1-x)\,\Delta R_m = 0, \tag{3.26}$$

$$\frac{\partial \mathcal{L}}{\partial w_L} = \mu_L + \mu x - \pi_L - x\pi + \pi r'_E(.)\, x(1-x)\,\Delta R_m = 0, \tag{3.27}$$

$$\frac{\partial \mathcal{L}}{\partial w_H} = \mu_H + \mu(1-x) - \pi_H - (1-x)\,\pi - \pi r'_E(.)\, x(1-x)\,\Delta R_m = 0, \tag{3.28}$$

$$\frac{\partial \mathcal{L}}{\partial e} = -(\mu_H + \mu_L + \mu)\,\psi'(e) + \pi_H + \pi_L + \pi = 0. \tag{3.29}$$

Rearranging these gives:

$$\begin{aligned}
\pi_L &= -xU'(p_L) - x\pi\left(1 - r'_E(.)\,(1-x)\,\Delta R_m\right), && (3.30)\\
\pi_H &= -(1-x)\,U'(p_H) - (1-x)\,\pi\left(1 + r'_E(.)\,x\Delta R_m\right), && (3.31)\\
\mu_L &= \pi_L - \mu x + x\pi\left(1 - r'_E(.)\,(1-x)\,\Delta R_m\right) && (3.32)\\
&= -x\left(U'(p_L) + \mu\right), &&\\
\mu_H &= \pi_H - \mu(1-x) + (1-x)\,\pi\left(1 + r'_E(.)\,x\Delta R_m\right) && (3.33)\\
&= -(1-x)\left(U'(p_H) + \mu\right), &&\\
0 &= \left(xU'(p_L) + (1-x)\,U'(p_H)\right)\left(1 - \psi'(e)\right). && (3.34)
\end{aligned}$$

Also adding (3.30) and (3.31) and adding (3.32) and (3.33) gives:

$$\begin{aligned}
\pi_L + \pi_H &= -xU'(p_L) - (1-x)\,U'(p_H) - \pi, && (3.35)\\
\mu_L + \mu_H &= -xU'(p_L) - (1-x)\,U'(p_H) - \mu. && (3.36)
\end{aligned}$$

It follows from (3.34) that in all solutions to this problem the optimum level of effort e^* will be where:

$$\psi'(e^*) = 1, \tag{3.37}$$

that is, the marginal cost of effort will equal the marginal reduction in the variable cost of production, 1.

The feasibility of solutions to this problem can be determined by examining the implications of different values for the Lagrange multipliers π, π_L, π_H, μ, μ_L and μ_H which must all be greater than or equal to zero at an optimum. The four Cases shown in Table 3.1 provide a framework for identifying all the feasible solutions when the capital structure of the firm is exogenously given. Each Case is analysed individually below and the Cases which have a feasible solution lead to a number of Propositions for which the proofs are given in appendix 3.C.

Table 3.1: Multiplier values

		$\pi_H = 0$	$\pi_L = 0$	$\mu_H = 0$	$\mu_L = 0$
Case 1		×	×	✓	✓
		×	×	×	✓
		×	×	✓	×
		✓	✓	×	×
		×	✓	×	×
		✓	×	×	×
		×	×	×	×
Case 2	2(1)	✓	✓	✓	✓
	2(2)	×	✓	✓	✓
	2(3)	✓	×	✓	✓
Case 3	3(1)	✓	✓	✓	×
	3(2)	×	✓	✓	×
	3(3)	✓	×	✓	×
Case 4	4(1)	✓	✓	×	✓
	4(2)	×	✓	×	✓
	4(3)	✓	×	×	✓
Note:	✓ multiplier value applies				
	× multiplier value does not apply				

3.A.1 Case 1: Both manager rationality constraints and/or both break even constraints binding ($\pi_H, \pi_L > 0$ and/or $\mu_H, \mu_L > 0$)

Firstly, if $\pi_H > 0$ and $\pi_L > 0$ then both the shareholders' break even constraints (3.8) and (3.9) are binding and so:

$$1 + R_{EL} = 1 + R_{EH} = 0. \tag{3.38}$$

However, as the shareholders would make zero profits and lose the whole of their investment in both states of the world, the shareholders' participation constraint (3.10) would be violated. It would not be rational for shareholders to invest if profits were to be zero in both states of the world. They would be better off investing in the risk free asset[11]. Consequently, in all feasible solutions to the problem:

$$1 + r_E(.) > 0 \tag{3.39}$$

As it is not feasible to have both $\pi_H > 0$ and $\pi_L > 0$ it must be the case that at least one of the multipliers π_H and π_L is 0. It follows that the conditions $\pi_H > 0$ and $\pi_L > 0$ restrict the problem to finding a solution when there are no shareholders and there is, therefore, only one possible level of debt, viz. $D = M$. However, this restricted form of the problem does not need to be considered separately and can be treated as a special case of the more general problem in which shareholders do participate. This is because the solution to the restricted form of the problem will be equivalent to a solution to the more general problem in which $cov(R_E^*, R_m) = 0$ and, therefore, $r_E^*(.) = r_D$. In other words the optimum for consumers and managers when there is 100% debt finance will be the same as where the solution to the more general problem produces the result that shareholders carry no risk and receive the same returns as the providers of debt finance.

Secondly, if $\mu_H > 0$ and $\mu_L > 0$ then both the managers' rationality constraints (3.5) and (3.6) are binding and so:

$$w_L = w_H = \psi(e). \tag{3.40}$$

As it is assumed that:

$$u_0 > 0 \tag{3.41}$$

the managers would not, therefore, receive their reservation utility and their participation constraint (3.7) would be violated. Consequently, it is not feasible to have both $\mu_H > 0$ and $\mu_L > 0$ and so it must be the case that at least one of the multipliers μ_H and μ_L is 0.

[11] Indeed, even when $r_E(.) < r_D$ it would be not be rational for shareholders to invest unless they were to receive more than $(1 + r_D)(M - D)$ in one state of the world if their income was to be lower than $(1 + r_D)(M - D)$ in the other state of the world.

3.A.2 Case 2: Managers' utility above zero ($\mu_H = \mu_L = 0$)

Relationship between p_L^* and p_H^*

If $\mu_H = \mu_L = 0$ then neither (3.5) nor (3.6) are binding and the managers' utility is above zero in each state of the world. It follows from (3.32) and (3.33) that, in this case, the optimum must satisfy:

$$-U'(p_L^*) = \mu = -U'(p_H^*). \tag{3.42}$$

Since $U'(p) < 0$ then in all solutions for this case:

$$\mu > 0, \tag{3.43}$$

and:

$$p_L^* = p_H^*. \tag{3.44}$$

Consequently, the managers' participation constraint (3.7) is binding i.e. managers are held at their reservation level of expected utility, and consumers pay the same price in both states of the world.

To assess the feasibility of solutions when $\mu_H = \mu_L = 0$ the following three specific cases must be considered:

$$\begin{aligned} &\text{Case 2(1)} &:& \quad \pi_H = \pi_L = 0, \\ &\text{Case 2(2)} &:& \quad \pi_H > 0 \text{ and } \pi_L = 0, \\ &\text{Case 2(3)} &:& \quad \pi_H = 0 \text{ and } \pi_L > 0. \end{aligned}$$

Case 2(1): $\pi_L = \pi_H = 0$

If $\pi_L = \pi_H = 0$ then neither of the break even constraints (3.8) and (3.9) are binding and the firm makes positive profits in both states of the world, that is, $\Pi_L^*, \Pi_H^* > 0$. It follows from (3.30), (3.31) and (3.35) that the optimum must satisfy:

$$\pi = \frac{-U'(p_L^*)}{1 - r_E^{*\prime}(.)(1-x)\Delta R_m} = \frac{-U'(p_H^*)}{1 + r_E^{*\prime}(.)x\Delta R_m} = -\left(xU'(p_L^*) + (1-x)U'(p_H^*)\right). \tag{3.45}$$

Since $U'(p) < 0$ it follows from (3.45) that:

$$\pi > 0, \tag{3.46}$$

and so (3.10) is binding. This means that the expected income to shareholders is just high enough to meet the cost of equity and to recover their investment, that is:

$$r_E^*(.) = xR_{EL}^* + (1-x)R_{EH}^*. \tag{3.47}$$

It also follows from (3.42) and (3.45) that:

$$\pi\left(1 - r_E^{*\prime}(.)(1-x)\Delta R_m\right) = \pi\left(1 + r_E^{*\prime}(.)x\Delta R_m\right),$$

and from (3.46), that:

$$-r_E^{*\prime}(.)\Delta R_m = 0. \tag{3.48}$$

However, (3.48) is not consistent with the assumptions (3.2), and (3.3) and so Case 2(1) is not a feasible solution.

Case 2(2): $\pi_H > 0$ and $\pi_L = 0$

If $\pi_H > 0$ and $\pi_L = 0$ then (3.8) is the only binding break even constraint and so the firm makes positive profit when its costs are low and zero profit when its costs are high, that is, $\Pi_L^* > 0$, $\Pi_H^* = 0$ and $R_{EL}^* > R_{EH}^*$. Consequently, $cov(R_E^*, R_m) > 0$ and so $r_E^*(.) > r_D$.

When $\pi_L = 0$ it follows from (3.30) and (3.42) that the optimum must satisfy:

$$-U'(p_L^*) = -U'(p_H^*) = \pi\left(1 - r_E^{*\prime}(.)(1-x)\Delta R_m\right). \tag{3.49}$$

Since $U'(p) < 0$ and $\pi < 0$ is not feasible it follows that:

$$\pi > 0, \tag{3.50}$$

and so (3.10) is binding.

It also follows from (3.31) and (3.49) that:

$$\pi_H = -\pi r_E^{*\prime}(.)(1-x)\Delta R_m. \tag{3.51}$$

However, (3.50), (3.51) and the assumptions (3.2) and (3.3) would require

$\pi_H < 0$. Consequently, Case 2(2) is not a feasible solution.

Case 2(3): $\pi_H = 0$ and $\pi_L > 0$

If $\pi_H = 0$ and $\pi_L > 0$ then (3.9) is the only binding break even constraint and so the firm makes positive profit when its costs are high and zero profit when its costs are low, that is, $\Pi_H^* > 0$, $\Pi_L^* = 0$ and $R_{EL}^* < R_{EH}^*$. Consequently, $cov\left(R_E^*, R_m\right) < 0$ and so $r_E^*\left(.\right) < r_D$.

When $\pi_H = 0$ it follows from (3.31) and (3.42) that the optimum must satisfy:

$$-U'\left(p_L^*\right) = -U'\left(p_H^*\right) = \pi\left(1 + r_E^{*\prime}\left(.\right) x\Delta R_m\right). \tag{3.52}$$

Since $U'\left(p\right) < 0$ it follows from the assumptions (3.2), and (3.3) that:

$$\pi > 0, \tag{3.53}$$

and so (3.10) is binding.

It also follows from (3.30) that:

$$\pi_L = \pi r_E^{*\prime}\left(.\right) x\Delta R_m. \tag{3.54}$$

Consequently, from (3.53) and the assumptions (3.2) and (3.3) the values of the multipliers in this case are consistent with a feasible solution.

However, the prices for consumers when $\pi_H = 0$ and $\pi_L > 0$ are:

$$\begin{aligned} p_H^* &= w_H^* + \theta - e^* + \left(1 + r_D\right) D + \frac{1 + r_E^*\left(.\right)}{1 - x}\left(M - D\right), & (3.55) \\ p_L^* &= w_L^* + \theta - e^* - c + \left(1 + r_D\right) D. & (3.56) \end{aligned}$$

and so, from (3.7), (3.43) and (3.44):

$$p^* = u_0 + \psi\left(e^*\right) + \theta - e^* - xc + \left(1 + r_D\right) D + \left(1 + r_E^*\left(.\right)\right)\left(M - D\right). \tag{3.57}$$

where $p^* = p_H^* = p_L^*$.

This solution also requires that:

$$p_H^* - p_L^* = 0 \tag{3.58}$$

that is:

$$u_0 = xc + w_H^* - \psi(e^*) + \frac{x}{1-x}(1 + r_E^*(.))(M - D). \tag{3.59}$$

Since $\mu_H = 0$, that is $w_H^* > \psi(e^*)$, it follows from (3.39) and (3.59) that Case 2(3) is only feasible if:

$$u_0 > xc, \tag{3.60}$$

which means managers' reservation level of expected utility must exceed the firm's ability, in expected terms, to reduce its costs. This will be the case if x and or c are relatively small. Consequently, consumers can be given price certainty because the managers' willingness to carry risk exceeds the inherent risk in the business. However, in practice it is unlikely that $u_0 > xc$ and indeed, De Fraja and Stones (2004) specifically assumed that $xc > u_0$. In these circumstances Case 2(3) would not be a feasible solution[12].

Also from (3.39), (3.44), (3.55), and (3.56):

$$w_L^* - w_H^* = c + \frac{1 + r_E^*(.)}{1-x}(M - D) > 0, \tag{3.61}$$

that is:

$$w_L^* > w_H^*. \tag{3.62}$$

Summary Case 2

There are no feasible solutions for Case 2 ($\mu_H = \mu_L = 0$) unless $u_0 > xc$. In this unlikely case consumers pay the same price in both states of the world, i.e. $p_L^* = p_H^*$. Managers are also held at their reservation level of expected utility ($\mu > 0$) and their remuneration is higher when costs are low, i.e. $w_L^* > w_H^*$. Shareholders' expected income is just high enough to meet the cost of equity and to recover their investment ($\pi > 0$) but their returns are high when the firm's costs are high ($\pi_H = 0$) and zero when the firm's costs are low ($\pi_L > 0$) and so $r_E^*(.) < r_D$.

Consequently, when $xc \geqslant u_0$ a solution will only be feasible if the managers' utility is zero in at least one state of the world (i.e. either $\mu_H > 0$ or $\mu_L > 0$).

[12] In a more simplified model without managers this solution would require $c < 0$ which is clearly not feasible. The solution would also not be feasible if $u_0 = 0$.

3.A.3 Case 3: Managers' utility zero when costs are high ($\mu_H > 0$ and $\mu_L = 0$)

Relationship between p_L^* and p_H^* and w_L^* and w_H^*

If $\mu_H > 0$ and $\mu_L = 0$ the manager's utility is zero when the firm's costs are high and (3.5) is the only binding managers' rationality constraint. When $\mu_L = 0$ it follows from (3.32) that, in this case, the optimum must satisfy:

$$\mu = -U'(p_L^*). \tag{3.63}$$

Since $U'(p) < 0$ then:

$$\mu > 0, \tag{3.64}$$

also applies in all solutions for this case. However, when $\mu_H > 0$ then from (3.33):

$$\mu < -U'(p_H^*),$$

and so:

$$U'(p_L^*) > U'(p_H^*), \tag{3.65}$$

that is:

$$p_H^* > p_L^*. \tag{3.66}$$

Consequently, (3.7) is binding, i.e. managers are held at their reservation level of expected utility, and consumers pay a higher price when the firm's costs are high.

Also from (3.64) and (3.7):

$$\begin{aligned} w_H^* &= \psi(e^*), & (3.67) \\ w_L^* &= \psi(e^*) + \frac{u_0}{x}, & (3.68) \end{aligned}$$

and so:

$$w_L^* > w_H^*. \tag{3.69}$$

To assess the feasibility of solutions when $\mu_H > 0$ and $\mu_L = 0$ the following three specific cases must be considered:

$$\begin{aligned}
\text{Case } 3(1) &\quad : \quad \pi_H = \pi_L = 0, \\
\text{Case } 3(2) &\quad : \quad \pi_H > 0 \text{ and } \pi_L = 0, \\
\text{Case } 3(3) &\quad : \quad \pi_H = 0 \text{ and } \pi_L > 0.
\end{aligned}$$

Case 3(1): $\pi_H = \pi_L = 0$

If $\pi_L = \pi_H = 0$ then neither of the break even constraints (3.8) and (3.9) are binding and the firm makes positive profits in both states of the world, that is, $\Pi_L^*, \Pi_H^* > 0$.. It follows from (3.30), (3.31) and (3.35) that the optimum must satisfy:

$$\pi = \frac{-U'(p_L^*)}{1 - r_E^{*\prime}(.)(1-x)\Delta R_m} = \frac{-U'(p_H^*)}{1 + r_E^{*\prime}(.)x\Delta R_m} = -\left(xU'(p_L^*) + (1-x)U'(p_H^*)\right). \tag{3.70}$$

Since $U'(p) < 0$, it follows from (3.70) that:

$$\pi > 0, \tag{3.71}$$

and so (3.10) is binding. Case 3(1) is, therefore, a feasible solution only if:

$$1 > r_E^{*\prime}(.)(1-x)\Delta R_m. \tag{3.72}$$

Also from (3.70) Case 3(1) is only feasible if:

$$\frac{U'(p_L^*)}{U'(p_H^*)} = \frac{1 - r_E^{*\prime}(.)(1-x)\Delta R_m}{1 + r_E^{*\prime}(.)x\Delta R_m}, \tag{3.73}$$

or:

$$-\frac{U'(p_L^*) - U'(p_H^*)}{xU'(p_L^*) + (1-x)U'(p_H^*)} = r_E^{*\prime}(.)\Delta R_m. \tag{3.74}$$

When $\pi_L = \pi_H = 0$ the prices for consumers are:

$$p_H^* = w_H^* + \theta - e^* + (1 + r_D)D + (1 + R_{EH}^*)(M - D), \tag{3.75}$$

$$p_L^* = w_L^* + \theta - e^* - c + (1 + r_D)D + (1 + R_{EL}^*)(M - D). \tag{3.76}$$

and so from (3.7) and (3.64) the expected price is:

$$E(p^*) = u_0 + \psi(e^*) + \theta - e^* - xc + (1 + r_D) D + (1 + r_E^*(.))(M - D). \quad (3.77)$$

As the price difference for this solution is:

$$p_H^* - p_L^* = c - \frac{1}{x}(u_0 + \psi(e^*) - w_H^*) - (R_{EL}^* - R_{EH}^*)(M - D). \qquad (3.78)$$

it follows from (3.66), (3.67) and (3.78), that Case 3(1) is only feasible if:

$$xc - u_0 > x(R_{EL}^* - R_{EH}^*)(M - D). \qquad (3.79)$$

Consequently, a feasible solution for Case 3(1) does not require the assumption made by De Fraja and Stones (2004) that $xc > u_0$. If $xc \leqslant u_0$ then $R_{EL}^* < R_{EH}^*$, that is, profits are lower when the firm's costs are low ($\Pi_L^* < \Pi_H^*$) and so $r_E^*(.) < r_D$. However, if $xc > u_0$ then the price difference determines whether profits are higher or lower when the firm's costs are low (and vice versa) and so whether $r_E^*(.) \gtreqless r_D$.

Case 3(2): $\pi_H > 0$ and $\pi_L = 0$

If $\pi_H > 0$ and $\pi_L = 0$ then (3.8) is the only binding break-even constraint and so the firm makes positive profit when its costs are low and zero profit when its costs are high, that is, $\Pi_L^* > 0$, $\Pi_H^* = 0$ and $R_{EL}^* > R_{EH}^*$. Consequently $cov(R_E^*, R_m) > 0$ and so $r_E^*(.) > r_D$.

When $\pi_L = 0$ it follows from (3.30) that the optimum must satisfy:

$$-U'(p_L^*) = \pi\left(1 - r_E^{*\prime}(.)(1 - x)\Delta R_m\right). \qquad (3.80)$$

Since $U'(p) < 0$ and $\pi < 0$ is not feasible, it follows that:

$$\pi > 0, \qquad (3.81)$$

and so (3.10) is binding. Case 3(2) is, therefore, a feasible solution only if (3.72) also applies here.

Consequently, from (3.31) and (3.80):

$$\pi_H = -(1 - x)U'(p_H^*) + \frac{(1 - x)U'(p_L^*)(1 + r_E^{*\prime}(.)x\Delta R_m)}{(1 - r_E^{*\prime}(.)(1 - x)\Delta R_m)},$$

and so $\pi_H > 0$ if:

$$\frac{U'(p_L^*)}{U'(p_H^*)} < \frac{1 - r_E^{*\prime}(.)(1-x)\Delta R_m}{1 + r_E^{*\prime}(.)x\Delta R_m}, \tag{3.82}$$

or:

$$-\frac{U'(p_L^*) - U'(p_H^*)}{xU'(p_L^*) + (1-x)U'(p_H^*)} > r_E^{*\prime}(.)\Delta R_m. \tag{3.83}$$

It not, therefore, possible for Case 3(2) to be a feasible solution at the same time as Case 3(a).

When $\pi_H > 0$ and $\pi_L = 0$ the prices for consumers are:

$$p_H^* = w_H^* + \theta - e^* + (1 + r_D) D. \tag{3.84}$$

$$p_L^* = w_L^* + \theta - e^* - c + (1 + r_D) D + \frac{1 + r_E^*(.)}{x}(M - D). \tag{3.85}$$

and so from (3.7) and (3.64) the expected price is:

$$E(p^*) = u_0 + \psi(e^*) + \theta - e^* - xc + (1 + r_D) D + (1 + r_E^*(.))(M - D). \tag{3.86}$$

As the price difference for this solution is:

$$p_H^* - p_L^* = c - \frac{1}{x}\left(u_0 + \psi(e^*) - w_H^* + (1 + r_E^*(.))(M - D)\right), \tag{3.87}$$

it follows from (3.66) and (3.67) and (3.87) that:

$$xc - u_0 > (1 + r_E^*(.))(M - D). \tag{3.88}$$

Consequently, from (3.39), Case 3(2) is only feasible if:

$$xc > u_0, \tag{3.89}$$

which is also the assumption made by De Fraja and Stones (2004).

Case 3(3): $\pi_H = 0$ and $\pi_L > 0$

If $\pi_H = 0$ and $\pi_L > 0$ then (3.9) is the only binding break even constraint and so the firm makes positive profit when its costs are high and zero profit when its costs are low, that is, $\Pi_H^* > 0$, $\Pi_L^* = 0$ and $R_{EL}^* < R_{EH}^*$. Consequently,

$cov\left(R_E^*, R_m\right) < 0$ and so $r_E^*(.) < r_D$.

When $\pi_H = 0$ it follows from (3.31) that the optimum must satisfy:

$$-U'\left(p_H^*\right) = \pi\left(1 + r_E^{*\prime}(.)\, x\Delta R_m\right). \tag{3.90}$$

Since $U'(p) < 0$ it follows from the assumptions (3.2), and (3.3) that:

$$\pi > 0, \tag{3.91}$$

and so (3.10) is binding.

Consequently, from (3.30) and (3.90):

$$\pi_L = -xU'\left(p_L^*\right) + \frac{xU'\left(p_H^*\right)\left(1 - r_E^{*\prime}(.)\,(1-x)\,\Delta R_m\right)}{\left(1 + r_E^{*\prime}(.)\, x\Delta R_m\right)},$$

and so $\pi_L > 0$ if:

$$\frac{U'\left(p_L^*\right)}{U'\left(p_H^*\right)} > \frac{1 - r_E^{*\prime}(.)\,(1-x)\,\Delta R_m}{1 + r_E^{*\prime}(.)\, x\Delta R_m} \tag{3.92}$$

or:

$$-\frac{U'\left(p_L^*\right) - U'\left(p_H^*\right)}{xU'\left(p_L^*\right) + (1-x)\,U'\left(p_H^*\right)} < r_E^{*\prime}(.)\,\Delta R_m. \tag{3.93}$$

It is not, therefore, possible for Case 3(3) to be a feasible solution at the same time as Case 3(1) or Case 3(2).

Note that (3.90) and (3.92) do not require the condition in (3.72) to apply for Case 3(3) to be a feasible solution and so there are two possibilities.

Firstly, if (3.72) does apply then:

$$\frac{1 - r_E^{*\prime}(.)\,(1-x)\,\Delta R_m}{1 + r_E^{*\prime}(.)\, x\Delta R_m} > 0 \tag{3.94}$$

Secondly, if (3.72) does not apply, that is:

$$1 \leqslant r_E^{*\prime}(.)\,(1-x)\,\Delta R_m, \tag{3.95}$$

then:

$$\frac{1 - r_E^{*\prime}(.)\,(1-x)\,\Delta R_m}{1 + r_E^{*\prime}(.)\, x\Delta R_m} \leqslant 0 \tag{3.96}$$

When $\pi_L > 0$ and $\pi_H = 0$ the prices for consumers are:

$$p_H^* = w_H^* + \theta - e^* + (1 + r_D) D + \frac{1 + r_E^*(.)}{1 - x} (M - D), \quad (3.97)$$

$$p_L^* = w_L^* + \theta - e^* - c + (1 + r_D) D, \quad (3.98)$$

and so from (3.7) and (3.64) the expected price is:

$$E(p^*) = u_0 + \psi(e^*) + \theta - e^* - xc + (1 + r_D) D + (1 + r_E^*(.)) (M - D). \quad (3.99)$$

As the price difference for this solution is:

$$p_H^* - p_L^* = c - \frac{1}{x} (u_0 + \psi(e^*) - w_H^*) + \frac{1 + r_E^*(.)}{1 - x} (M - D), \quad (3.100)$$

it follows from (3.66), (3.67) and (3.100) that:

$$xc - u_0 > -\frac{x}{1 - x} (1 + r_E^*(.)) (M - D). \quad (3.101)$$

Consequently, from (3.39) it is not necessary to make the assumption that $xc > u_0$ for Case 3(3) to be a feasible solution.

Summary Case 3

All the solutions in Case 3 are feasible under certain conditions. In all solutions consumers pay a higher price when costs are high i.e. $p_H^* > p_L^*$, managers are held at their reservation level of expected utility ($\mu > 0$) and shareholders' expected income is just high enough to meet the cost of equity and to recover their investment ($\pi > 0$). The conditions under which the solutions in Case 3 are feasible are summarized below. The assumption made by De Fraja and Stones (2004) that $xc > u_0$ is only required for a solution to be feasible when shareholder returns are high when the firm's costs are low ($\pi_L = 0$) and zero when the firm's costs are high ($\pi_H > 0$) and so $r_E^*(.) > r_D$.

The intuition behind the conditions for an optimum in (3.73), (3.82) and (3.92) is that they show how the consumer's marginal rate of substitution between a change in p_L^* and p_H^* compares with the slope of the shareholders' participation constraint (3.10) which itself reflects the effect of the change in p_L^* and p_H^* on the cost of equity. This can be seen by considering the shareholders' participation constraint at an optimum which, from Lemma 2 in appendix 3.B, satisfies:

$$\frac{dp_H^*}{dp_L^*} = -\frac{x\left(1 - r_E^{*\prime}(.)\left(1-x\right)\Delta R_m\right)}{\left(1-x\right)\left(1 + r_E^{*\prime}(.)\,x\Delta R_m\right)}. \tag{3.102}$$

Consequently, the solutions for Case 3 are feasible if they satisfy the following mutually exclusive conditions:

$$\text{Case 3(1)}: \frac{dp_H^*}{dp_L^*} = -\frac{xU'\left(p_L^*\right)}{\left(1-x\right)U'\left(p_H^*\right)} \text{ and } 1 > r_E^{*\prime}(.)\left(1-x\right)\Delta R_m, \tag{3.103}$$

$$\text{Case 3(2)}: \frac{dp_H^*}{dp_L^*} < -\frac{xU'\left(p_L^*\right)}{\left(1-x\right)U'\left(p_H^*\right)},\ 1 > r_E^{*\prime}(.)\left(1-x\right)\Delta R_m \text{ and } xc > u_0. \tag{3.104}$$

$$\text{Case 3(3)}: \frac{dp_H^*}{dp_L^*} > -\frac{xU'\left(p_L^*\right)}{\left(1-x\right)U'\left(p_H^*\right)}. \tag{3.105}$$

Case 3(1) is the solution for an internal optimum while Case 3(2) and Case 3(3) are corner solutions.

Since $U'(p) < 0$ it also follows from (3.102) that in:

$$\begin{aligned} \text{Cases 3(1) and 3(2) } \frac{dp_H^*}{dp_L^*} &< 0 \text{ since } 1 > r_E^{*\prime}(.)\left(1-x\right)\Delta R_m, \\ \text{Case 3(3) } \frac{dp_H^*}{dp_L^*} &< 0 \text{ when } 1 > r_E^{*\prime}(.)\left(1-x\right)\Delta R_m, \\ \text{and } \frac{dp_H^*}{dp_L^*} &\geqslant 0 \text{ when } 1 \leqslant r_E^{*\prime}(.)\left(1-x\right)\Delta R_m. \end{aligned}$$

3.A.4 Case 4: Managers' utility zero when costs are low ($\mu_H = 0$ and $\mu_L > 0$)

Relationship between p_L^* and p_H^*

If $\mu_L > 0$ and $\mu_H = 0$ the manager's utility is zero when the firm's costs are low and (3.9) is the only binding managers' rationality constraint. When $\mu_H = 0$ it follows from (3.31) and (3.33) that the optimum must satisfy:

$$\mu = -U'\left(p_H^*\right) \tag{3.106}$$

Since $U'(p) < 0$ then:

$$\mu > 0, \tag{3.107}$$

also applies in all solutions for this case. However, when $\mu_L > 0$ then from (3.32):

$$\mu < -U'(p_L^*)$$

and so:

$$U'(p_H^*) > U'(p_L^*) \tag{3.108}$$

that is:

$$p_L^* > p_H^* \tag{3.109}$$

Consequently, (3.7) is binding i.e. managers are held at their reservation level of expected utility and consumers pay a higher price when the firm's costs are low.

To assess the feasibility of solutions when $\mu_L > 0$ and $\mu_H = 0$ the following three specific cases must be considered:

$$\begin{aligned}
\text{Case } 4(1) \quad &: \quad \pi_H = \pi_L = 0, \\
\text{Case } 4(2) \quad &: \quad \pi_H > 0 \text{ and } \pi_L = 0, \\
\text{Case } 4(3) \quad &: \quad \pi_H = 0 \text{ and } \pi_L > 0.
\end{aligned}$$

Case 4(1): $\pi_H = \pi_L = 0$

If $\pi_L = \pi_H = 0$ it follows from (3.30), (3.31) and (3.35) that the optimum must satisfy:

$$\pi = \frac{-U'(p_L^*)}{1 - r_E^{*\prime}(.)(1-x)\Delta R_m} = \frac{-U'(p_H^*)}{1 + r_E^{*\prime}(.)\, x\Delta R_m} = -\left(xU'(p_L^*) + (1-x)U'(p_H^*)\right). \tag{3.110}$$

Since $U'(p) < 0$ it follows that:

$$\pi > 0, \tag{3.111}$$

and so (3.10) is binding.

When $\mu_H = 0$ it also follows from (3.33) that:

$$\mu = \pi\left(1 + r_E^{*\prime}(.)\, x\Delta R_m\right), \tag{3.112}$$

and from (3.32) that:

$$\mu_L = -\pi r_E^{*\prime}(.)\, x\Delta R_m. \tag{3.113}$$

However, (3.111), (3.113) and the assumptions (3.2) and (3.3) would require $\mu_L < 0$. Consequently, Case 4(1) is not a feasible solution.

Case 4(2): $\pi_H > 0$ and $\pi_L = 0$

If $\pi_L = 0$ it follows from (3.30) that the optimum must satisfy:

$$-U'(p_L^*) = \pi\left(1 - r_E^{*\prime}(.)(1-x)\,\Delta R_m\right). \tag{3.114}$$

Since $U'(p) < 0$ and $\pi < 0$ is not feasible, it follows that:

$$\pi > 0, \tag{3.115}$$

and so (3.10) is binding.

When $\mu_H = 0$ it also follows from (3.33) that:

$$\mu = \frac{\pi_H}{1-x} + \pi\left(1 + r_E^{*\prime}(.)\, x\Delta R_m\right), \tag{3.116}$$

and from (3.32) that:

$$\mu_L = -\frac{x}{1-x}\pi_H - \pi r_E^{*\prime}(.)\, x\Delta R_m. \tag{3.117}$$

However, since $\pi_H > 0$, then (3.115), (3.117) and the assumptions (3.2) and (3.3) would require that $\mu_L < 0$. Consequently, Case 4(2) is not a feasible solution.

Case 4(3): $\pi_H = 0$ and $\pi_L > 0$

If $\pi_H = 0$ it follows from (3.31) that the optimum must satisfy:

$$-U'(p_H^*) = \pi\left(1 + r_E^{*\prime}(.)\, x\Delta R_m\right). \tag{3.118}$$

Since $U'(p) < 0$ it follows from the assumptions (3.2) and (3.3) that:

$$\pi > 0, \tag{3.119}$$

and so (3.10) is binding.

When $\mu_H = 0$ it also follows from (3.33) that:

$$\mu = \pi \left(1 + r_E^{*\prime}(.)\, x\Delta R_m\right), \tag{3.120}$$

and from (3.32) that:

$$\mu_L = \pi_L - \pi r_E^{*\prime}(.)\, x\Delta R_m. \tag{3.121}$$

Since $\pi_L > 0$, the values of the multipliers are consistent with a feasible solution.

However, when $\pi_L > 0$ and $\pi_H = 0$ the prices for consumers are:

$$\begin{aligned} p_H^* &= w_H^* + \theta - e^* + (1 + r_D)\, D + \frac{1 + r_E^*(.)}{1 - x}(M - D), && (3.122)\\ p_L^* &= w_L^* + \theta - e^* - c + (1 + r_D)\, D. && (3.123) \end{aligned}$$

From (3.7) and (3.107) the price difference is, therefore:

$$p_L^* - p_H^* = -c - \frac{1}{1 - x}\left(u_0 + \psi(e^*) - w_L^*\right) - \frac{1 + r_E^*(.)}{1 - x}(M - D). \tag{3.124}$$

Since $\mu_L > 0$, that is $w_L^* = \psi(e^*)$, then from (3.109) Case 4(3) is only feasible if :

$$-(1 - x)\, c - u_0 > (1 + r_E^*(.))\,(M - D).$$

However, from (3.39) this would require:

$$-(1 - x)\, c - u_0 > 0. \tag{3.125}$$

Consequently, from the assumption (3.41) Case 4(3) is not a feasible solution.

Summary Case 4

There are no feasible solutions for Case 4.

3.A.5 Summary of results

The conditions under which the solutions to the problem (3.14) are feasible or not are summarized in Table 3.2 and the relative magnitudes of the variables in each feasible solution are given in Table 3.3.

Table 3.2: Feasibility conditions

		Conditions
Case 1	$\pi_H, \pi_L > 0$	Not feasible as $(1 + r_E^*(.))(M - D) > 0$
	$\mu_H, \mu_L > 0$	Not feasible as $u_0 > 0$
	$\pi_H, \pi_L, \mu_H, \mu_L > 0$	Not feasible as $(1 + r_E^*(.))(M - D) > 0$ and $u_0 > 0$
Case 2 $(p_H^* = p_L^*)$ $\mu_H = \mu_L = 0$	2(1) $\pi_H = \pi_L = 0$	Not feasible as $r_E^{*\prime}(.) > 0$ and $\Delta R_m > 0$
	2(2) $\pi_H > 0$, $\pi_L = 0$	
	2(3) $\pi_H = 0$, $\pi_L > 0$	If $u_0 > xc$
Case 3 $(p_H^* > p_L^*)$ $\mu_H > 0$, $\mu_L = 0$	3(1) $\pi_H = \pi_L = 0$	If $\frac{dp_H^*}{dp_L^*} = -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}$ and $1 > r_E^{*\prime}(.)(1-x)\Delta R_m$
	3(2) $\pi_H > 0$, $\pi_L = 0$	If $\frac{dp_H^*}{dp_L^*} < -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}$, $1 > r_E^{*\prime}(.)(1-x)\Delta R_m$ and $xc > u_0$
	3(3) $\pi_H = 0$, $\pi_L > 0$	If $\frac{dp_H^*}{dp_L^*} > -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}$(n.b. $\frac{dp_H^*}{dp_L^*} \geqslant 0$ if $1 \leqslant r_E^{*\prime}(.)(1-x)\Delta R_m$)
Case 4 $(p_H^* < p_L^*)$ $\mu_H = 0$, $\mu_L > 0$	4(1) $\pi_H = \pi_L = 0$	Not feasible as $r_E^{*\prime}(.) > 0$ and $\Delta R_m > 0$
	4(2) $\pi_H > 0$, $\pi_L = 0$	
	4(3) $\pi_H = 0$, $\pi_L > 0$	Not feasible as $u_0 > 0$

Table 3.3: Feasible solutions - relative magnitude of variables

	Exogenous Variables	Prices	Managers' remuneration	Profits	Cost of equity and debt
Case 2(3)	$u_0 > xc$	$p_H^* = p_L^*$	$w_L^* > w_H^* > \psi(e^*)$	$\Pi_H^* > \Pi_L^* = 0$	$r_E^*(.) < r_D$
Case 3(1)	$u_0 \geqslant xc$	$p_H^* > p_L^*$	$w_L^* > w_H^* = \psi(e^*)$	$\Pi_H^* > \Pi_L^* > 0$	$r_E^*(.) < r_D$
	$xc > u_0$			$0 < \Pi_H^* \gtreqless \Pi_L^* > 0$	$r_E^*(.) \lesseqgtr r_D$
Case 3(2)	$xc > u_0$			$\Pi_L^* > \Pi_H^* = 0$	$r_E^*(.) > r_D$
Case 3(3)	$xc \gtreqless u_0$			$\Pi_H^* > \Pi_L^* = 0$	$r_E^*(.) < r_D$

Appendix 3.B Lemmas

Lemma 1 *The covariance of the shareholder's rate of return R_E with the return on the market portfolio R_m is:*

$$cov\left(R_E, R_m\right) = \frac{x\left(1-x\right)}{M-D}\left(c - \left(w_L - w_H\right) - \left(p_H - p_L\right)\right)\Delta R_m.$$

Proof. In this model $cov\left(R_E, R_m\right)$ is:

$$\begin{aligned} cov\left(R_E, R_m\right) &= E\left(\left(R_E - E\left(R_E\right)\right)\left(R_m - E\left(R_m\right)\right)\right) \\ &= E\left(\left(\frac{\Pi - E\left(\Pi\right)}{M-D}\right)\left(R_m - E\left(R_m\right)\right)\right). \end{aligned}$$

where the firm's profits are Π. Using subscripts to indicate the values of variables in the two states of the world (e.g. R_{EL} is the rate of return on equity when the firm's costs are low and R_{EH} is the rate of return on equity when its costs are high) then:

$$\begin{aligned} cov\left(R_E, R_m\right) &= x\left(\left(\frac{\Pi_L - E\left(\Pi\right)}{M-D}\right)\left(R_{mL} - E\left(R_m\right)\right)\right) + \\ & \quad \left(1-x\right)\left(\left(\frac{\Pi_H - E\left(\Pi\right)}{M-D}\right)\left(R_{mH} - E\left(R_m\right)\right)\right). \end{aligned}$$

Since

$$\begin{aligned} \Pi_L &= \left(1 + R_{EL}\right)\left(M-D\right) = p_L - w_L - \theta + e + c - \left(1 + r_D\right)D, \\ \Pi_H &= \left(1 + R_{EH}\right)\left(M-D\right) = p_H - w_H - \theta + e - \left(1 + r_D\right)D, \\ E\left(\Pi\right) &= x\left(p_L - w_L + c\right) + \left(1-x\right)\left(p_H - w_H\right) - \theta + e - \left(1 + r_D\right)D, \end{aligned}$$

it follows that:

$$\begin{aligned} \Pi_L - E\left(\Pi\right) &= \left(1-x\right)\left(p_L - w_L + c - p_H + w_H\right), \\ \Pi_H - E\left(\Pi\right) &= -x\left(p_L - w_L + c - p_H + w_H\right). \end{aligned}$$

Consequently, from (3.3):

$$cov\left(R_E, R_m\right) = \frac{x\left(1-x\right)}{M-D}\left(c - \left(w_L - w_H\right) - \left(p_H - p_L\right)\right)\Delta R_m.$$

This ends the proof.

Using the notation $cov(.) = cov(R_E, R_m)$ note that:

$$cov(.) = x(1-x)(R_{EL} - R_{EH})\Delta R_m,$$

and so, from (3.3), $cov(.) \gtreqqless 0$ when $R_{EL} \gtreqqless R_{EH}$.

Note also that:

$$\frac{\partial cov(.)}{\partial p_L} = -\frac{\partial cov(.)}{\partial p_H} = -\frac{\partial cov(.)}{\partial w_L} = \frac{\partial cov(.)}{\partial w_H} = \frac{x(1-x)}{M-D}\Delta R_m.$$

■

Lemma 2 *When $p_H^* > p_L^*$ the shareholders' participation constraint satisfies* $\frac{dp_H^*}{dp_L^*} = -\frac{x\left(1-r_E^{*\prime}(.)(1-x)\Delta R_m\right)}{(1-x)\left(1+r_E^{*\prime}(.)x\Delta R_m\right)}$.

Proof. Since $\pi > 0$ at an optimum in Case 3, from (3.7), and (3.64), the shareholders' participation constraint (3.10) becomes the following:

$$x(p_L^* + c) + (1-x)p_H^* - u_0 - \psi(e^*) - \theta + e^* - (1+r_D)D = (1 + r_E^*(.))(M-D).$$

Differentiating with respect to p_L^* and p_H^* gives:

$$xdp_L^* + (1-x)dp_H^* = r_E^{*\prime}(.)\frac{\partial cov}{\partial p_L^*}(M-D)dp_L^* + r_E^{*\prime}(.)\frac{\partial cov}{\partial p_H^*}(M-D)dp_H^*.$$

From Lemma 1 this can be written as:

$$dp_L^*\left(x - r_E^{*\prime}(.)x(1-x)\Delta R_m\right) = -dp_H^*\left((1-x) + r_E^{*\prime}(.)x(1-x)\Delta R_m\right),$$

that is:

$$\frac{dp_H^*}{dp_L^*} = -\frac{x(1-r_E^{*\prime}(.)(1-x)\Delta R_m)}{(1-x)\left(1+r_E^{*\prime}(.)x\Delta R_m\right)}.$$

This ends the proof. ■

Lemma 3 *In Case 2(3), Case 3(2) and Case 3(3) the optimum satisfies* $\frac{d\left(cov\left(R_E^*, R_M\right)\right)}{dD} = 0$.

Proof. Using the notation $cov^*(.) = cov\left(R_E^*, R_M\right)$, it follows from Lemma 1, from (3.44) and (3.61) in Case 2(3) and from (3.67) and (3.100) in Case 3(3) that, at the optimum in both Case 2(3) and Case 3(3):

$$cov^*(.) = -x\left(1 + r_E^*(.)\right)\Delta R_m.$$

Differentiating with respect to D gives:

$$\frac{d\left(cov^*(.)\right)}{dD} = -r_E^{*\prime}(.)\, x \frac{d\left(cov^*(.)\right)}{dD}\Delta R_m,$$

and so:

$$\frac{d\left(cov^*(.)\right)}{dD}\left(1 + r_E^{*\prime}(.)\, x\Delta R_m\right) = 0.$$

From the assumptions (3.2) and (3.3) this can only hold when:

$$\frac{d\left(cov^*(.)\right)}{dD} = 0.$$

In Case 3(2) from (3.67) and (3.87) it follows from Lemma 1 that:

$$cov^*(.) = (1 - x)\left(1 + r_E^*(.)\right)\Delta R_m.$$

Differentiating with respect to D gives:

$$\frac{d\left(cov^*(.)\right)}{dD} = r_E^{*\prime}(.)\,(1 - x)\frac{d\left(cov^*(.)\right)}{dD}\Delta R_m,$$

and so:

$$\frac{d\left(cov^*(.)\right)}{dD}\left(1 - r_E^{*\prime}(.)\,(1 - x)\,\Delta R_m\right) = 0.$$

However, Case 3(2) is only feasible if (3.72) applies and so this can only hold if:

$$\frac{d\left(cov^*(.)\right)}{dD} = 0.$$

This ends the proof. ■

Lemma 4 *In Case 3(2) and Case 3(3)* $\frac{dp_H^*}{dp_L^*}$ *does not vary with D.*

Proof. According to Lemma 2:

$$\frac{dp_H^*}{dp_L^*} = -\frac{x\left(1 - r_E^{*\prime}(.)\left(1-x\right)\Delta R_m\right)}{\left(1-x\right)\left(1 + r_E^{*\prime}(.)\,x\Delta R_m\right)}.$$

Consequently the Lemma will hold if:

$$\frac{d\left(r_E^{*\prime}(.)\right)}{dD} = 0.$$

Since:

$$\frac{d\left(r_E^{*\prime}(.)\right)}{dD} = r_E^{*\prime\prime}(.)\,\frac{d\left(cov^*(.)\right)}{dD},$$

and from Lemma 3 in Case 3(2) and Case 3(3):

$$\frac{d\left(cov^*(.)\right)}{dD} = 0,$$

it follows that the condition for the Lemma to hold is satisifed.

This ends the proof.

In the case of the CAPM it should be noted that the Lemma holds because $r_E'(.)$ is a constant, and so $r_E''(.) = 0$, as shown in Appendix 3.F. ■

Lemma 5 *In Case 2(3)* $\frac{d(p^*)}{dD} > 0$*, in Case 3(2)* $\frac{d(E(p^*))}{dD} < 0$ *and in Case 3(3)* $\frac{d(E(p^*))}{dD} > 0$.

Proof. In Case 2(3) differentiating (3.57) with respect to D gives:

$$\frac{d\left(p^*\right)}{dD} = 1 + r_D - \left(1 + r_E^*(.)\right) + \left(M - D\right) r_E^{*\prime}(.)\,\frac{d\left(cov^*(.)\right)}{dD},$$

since e^* is determined by (3.37), which is independent of D. However, from Lemma 3:

$$\frac{d\left(cov^*(.)\right)}{dD} = 0,$$

and since $r_E^*(.) < r_D$ in Case 2(3):

$$\frac{d\left(p^*\right)}{dD} = r_D - r_E^*(.) > 0.$$

In Case 3(2) differentiating (3.86) with respect to D gives:

$$\frac{d\left(E\left(p^*\right)\right)}{dD} = 1 + r_D - \left(1 + r_E^*\left(.\right)\right) + \left(M - D\right) r_E^{*\prime}\left(.\right) \frac{d\left(cov^*\left(.\right)\right)}{dD},$$

since e^* is determined by (3.37), which is independent of D. However, from Lemma 3:

$$\frac{d\left(cov^*\left(.\right)\right)}{dD} = 0,$$

and since $r_E^*\left(.\right) > r_D$ in Case 3(2):

$$\frac{d\left(E\left(p^*\right)\right)}{dD} = r_D - r_E^*\left(.\right) < 0.$$

Similarly, in Case 3(3) it follows that:

$$\frac{d\left(E\left(p^*\right)\right)}{dD} = r_D - r_E^*\left(.\right) > 0,$$

since $r_E^*\left(.\right) < r_D$.

This ends the proof. ■

Lemma 6 *In Case 3(2)* $p_H^{*\prime}\left(D\right) - p_L^{*\prime}\left(D\right) > 0$ *and in Case 3(3)* $p_H^{*\prime}\left(D\right) - p_L^{*\prime}\left(D\right) < 0$.

Proof. In Case 3(2) differentiating (3.84) and (3.85) with respect to D gives:

$$\begin{aligned} p_H^{*\prime}\left(D\right) &= 1 + r_D, \\ p_L^{*\prime}\left(D\right) &= 1 + r_D - \frac{\left(1 + r_E^*\left(.\right)\right)}{x} + \left(M - D\right) r_E^{*\prime}\left(.\right) \frac{d\left(cov^*\left(.\right)\right)}{dD}. \end{aligned}$$

since w_H^*, w_L^* and e^* are determined by (3.37), which is independent of D. However, from Lemma 3:

$$\frac{d\left(cov^*\left(.\right)\right)}{dD} = 0.$$

Consequently:

$$p_H^{*\prime}\left(D\right) - p_L^{*\prime}\left(D\right) = \frac{\left(1 + r_E^*\left(.\right)\right)}{x} > 0.$$

In Case 3(3) differentiating (3.97) and (3.98) with respect to D gives:

$$\begin{aligned} p_H^{*\prime}\left(D\right) &= 1 + r_D - \frac{\left(1 + r_E^*\left(.\right)\right)}{1 - x} + \left(M - D\right) r_E^{*\prime}\left(.\right) \frac{d\left(cov^*\left(.\right)\right)}{dD}, \\ p_L^{*\prime}\left(D\right) &= 1 + r_D. \end{aligned}$$

since w_H^*, w_L^* and e^* are determined by (3.37), which is independent of D. However, from Lemma 3:

$$\frac{d\left(cov^*\left(.\right)\right)}{dD} = 0.$$

Consequently:

$$p_H^{*\prime}\left(D\right) - p_L^{*\prime}\left(D\right) = -\frac{\left(1 + r_E^*\left(.\right)\right)}{1 - x} < 0.$$

This ends the proof ■

Appendix 3.C Propositions for a given capital structure

Let p_H^*, p_L^*, e^*, w_H^*, and w_L^* be a feasible solution to the problem (3.14).

Proposition 1 *If $u_0 > xc$ then the prices chosen by the regulator are such that $p_H^* = p_L^*$ when $w_L^* > w_H^* > \psi(e^*)$, $\Pi_H^* > 0$ and $\Pi_L^* = 0$, otherwise $p_H^* > p_L^*$.*

Proof. The only feasible solution where $p_H^* = p_L^*$ is Case 2(3). In Case 2(3) the only break even constraint that is binding is (3.9) and so $\Pi_H^* > 0$ and $\Pi_L^* = 0$. In addition neither (3.5) nor (3.6) are binding and the solution is only feasible when (3.60) and (3.62) both apply. The only other feasible solutions are in Case 3 where $p_H^* > p_L^*$. This ends the proof ■

Corollary 1 *When $p_H^* > p_L^*$ then $w_L^* = \psi(e^*) + \frac{u_0}{x}$ and $w_H^* = \psi(e^*)$.*

Proof. The only feasible solutions when $p_H^* > p_L^*$ are in Case 3. In Case 3 (3.5) is binding and the solutions for w_L^* and w_H^* are (3.67) and (3.68). This ends the proof. ■

Corollary 2 *If $u_0 \geqslant xc$ then $r_E^*(.) < r_D$ i.e. the cost of equity is lower than the cost of debt.*

Proof. The only feasible solutions when $u_0 \geqslant xc$ are Case 2(3), Case 3(1) and Case 3(3). In Case 2(3) and Case 3(3) (3.9) is the only binding break even constraint and so the firm makes positive profit when its costs are high and zero profit when its costs are low, that is, $\Pi_H^* > 0$, $\Pi_L^* = 0$ and $R_{EL}^* < R_{EH}^*$. Consequently, $cov(R_E^*, R_m) < 0$ and so $r_E^*(.) < r_D$. In Case 3(1) from (3.79) if $xc \leqslant u_0$ then $R_{EL}^* < R_{EH}^*$ and so $r_E^*(.) < r_D$. This ends the proof. ■

Proposition 2 *When $p_H^* > p_L^*$* and $\Pi_H^*, \Pi_L^* > 0$ then $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} = \frac{dp_H^*}{dp_L^*}$.

Proof. Case 3(1) provides the only feasible solution when $p_H^* > p_L^*$, and $\Pi_H^*, \Pi_L^* > 0$. In Case 3(3) there is an optimum where (3.103) applies. This ends the proof.

Note that, in addition (3.79) must apply and if $xc \leqslant u_0$ then $R_{EL}^* < R_{EH}^*$. Consequently, $cov(R_E^*, R_m) < 0$ and so $r_E^*(.) < r_D$. However, if $xc > u_0$ then $R_{EL}^* \gtreqless R_{EH}^*$. Consequently, $cov(R_E^*, R_m) \gtreqless 0$ and so $r_E^*(.) \gtreqless r_D$. ■

Proposition 3 *When* $p_H^* > p_L^*$, $\Pi_H^* = 0$, and $\Pi_L^* > 0$ then $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} > \frac{dp_H^*}{dp_L^*}$ and $r_E^*(.) > r_D$.

Proof. Case 3(2) provides the only feasible solution when $p_H^* > p_L^*$, $\Pi_H^* = 0$, and $\Pi_L^* > 0$. In Case 3(2) there is an optimum where (3.104) applies. Also since $\Pi_H^* = 0$, $\Pi_L^* > 0$ then $R_{EL}^* > R_{EH}^*$. Consequently, $cov(R_E^*, R_m) > 0$ and so $r_E^*(.) > r_D$. This ends the proof. ■

Proposition 4 *When* $p_H^* > p_L^*$, $\Pi_H^* > 0$, and $\Pi_L^* = 0$ then $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} < \frac{dp_H^*}{dp_L^*}$ and $r_E^*(.) < r_D$.

Proof. Case 3(3) provides the only feasible solution when $p_H^* > p_L^*$, $\Pi_H^* > 0$, and $\Pi_L^* = 0$. In Case 3(3) there is an optimum where (3.105) applies. Also since $\Pi_H^* > 0$, $\Pi_L^* = 0$ then $R_{EL}^* < R_{EH}^*$. Consequently, $cov(R_E^*, R_m) < 0$ and so $r_E^*(.) < r_D$. This ends the proof. ■

Proposition 5 *The prices chosen by the regulator are such that the marginal cost of managers' effort equals the the marginal reduction in variable costs, i.e.* $\psi'(e^*) = 1$, *the managers' expected utility equals their reservation level* u_0, *and the shareholders' expected rate of return equals the cost of equity* $r_E^*(.)$.

Proof. From (3.34) in all solutions to the problem the optimum level of effort e^* is where (3.37) applies. In addition, the only feasible solutions to the problem are in Case 2(3) and Case 3. In all these solutions the managers' participation constraint (3.7) and the shareholders' participation constraint (3.10) are both binding. This ends the proof. ■

Appendix 3.D Solutions for a socially optimal capital structure

This appendix derives the solutions to the problem (3.18) and the conditions for a socially optimal capital structure. Comparing these solutions to the feasible solutions to the problem (3.14) set out in appendix 3.A leads to a number of Propositions concerning the social optimum for which the proofs are given in appendix 3.E.

The Lagrangian function for the problem (3.18) is:

$$\mathcal{L} = xU\left(p_L^*(D)\right) + (1-x)\,U\left(p_H^*(D)\right) + \lambda D + \gamma\,(M - D)\,, \tag{3.126}$$

where λ and γ are the multipliers associated with constraints (3.16) to (3.17). Let D^* be the solution to this problem.

The first order condition for an optimum is:

$$\frac{\partial \mathcal{L}}{\partial D} = xU'\left(p_L^*\right) p_L^{*\prime}(D) + (1-x)\,U'\left(p_H^*\right) p_H^{*\prime}(D) + \lambda - \gamma = 0, \tag{3.127}$$

and so there are four cases to consider:

$$\begin{aligned} \text{Case A} \quad &: \quad \lambda > 0 \text{ and } \gamma > 0, \\ \text{Case B} \quad &: \quad \lambda = \gamma = 0, \\ \text{Case C} \quad &: \quad \lambda > 0 \text{ and } \gamma = 0, \\ \text{Case D} \quad &: \quad \lambda = 0 \text{ and } \gamma > 0. \end{aligned}$$

3.D.1 Case A

If $\lambda > 0$ and $\gamma > 0$ then $D^* = 0$ and $M - D^* = 0$. This is not feasible as $M > 0$.

3.D.2 Case B

If $\lambda = \gamma = 0$ then $M > D^* > 0$ and so the solution is an internal optimum where $W'(D) = 0$. From (3.127) this is where:

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} = -\frac{xU'\left(p_L^*\right)}{(1-x)\,U'\left(p_H^*\right)}. \tag{3.128}$$

Since $U'(p) < 0$ it follows that if $p_L^{*\prime}(D) > 0$ then $p_H^{*\prime}(D) < 0$ and vice versa. This is a global optimum if it is assumed that $W'(D) < 0$ when $D < D^*$ and $W'(D) > 0$ when $D > D^*$.

3.D.3 Case C

If $\lambda > 0$ and $\gamma = 0$ then $D^* = 0$ and the optimum is 100% equity finance. This is a corner solution where $W'(D) < 0$. Since $U'(p) < 0$ then from (3.127) this is where:

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} > -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} \text{ if } p_L^{*\prime}(D) > 0, \tag{3.129}$$

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} < -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} \text{ if } p_L^{*\prime}(D) < 0. \tag{3.130}$$

This is a global optimum if it is assumed that $W'(D) < 0$ when $D > 0$.

3.D.4 Case D

If $\lambda = 0$ and $\gamma > 0$ then $D^* = M$ and the optimum is 100% debt finance. This is a corner solution where $W'(D) > 0$. Since $U'(p) < 0$ then from (3.127) this is where:

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} < -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} \text{ if } p_L^{*\prime}(D) > 0, \tag{3.131}$$

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} > -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} \text{ if } p_L^{*\prime}(D) < 0. \tag{3.132}$$

This is a global optimum if it is assumed that $W'(D) > 0$ when $D > 0$.

Appendix 3.E Propositions for a socially optimal capital structure

Let D^* be a feasible solution to the problem (3.18)

Proposition 6 *When* $p_L^* = p_H^*$ *then* $D^* = 0$.

Proof. When $p_L^* = p_H^*$ the only feasible solution is given by Case 2(3) and:

$$p_L^{*\prime}(D) = p_H^{*\prime}(D).$$

Consequently, from (3.42) and since $U'(p) < 0$:

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} > -\frac{xU'(p_L^*)}{(1-x)\,U'(p_H^*)}.$$

From (3.129) in Case C this is the condition for a social optimum where $D^* = 0$ only if $p_L^{*\prime}(D) > 0$.

In Case 2(3) differentiating (3.56) with respect to D gives:

$$p_L^{*\prime}(D) = w_L^{*\prime}(D) + 1 + r_D,$$

since e^* is determined by (3.37), which is independent of D, and $w_L^* > w_H^* > \psi(e^*)$.

From (3.7) and (3.43):

$$xw_L^* + (1-x)\,w_H^* = \psi(e^*) + u_0$$

and so:

$$w_L^{*\prime}(D) = -\frac{(1-x)}{x} w_H^{*\prime}(D).$$

However, (3.61) also applies if Case 2(3) is feasible so that:

$$w_H^* = w_L^* - c - \frac{1 + r_E^*(.)}{(1-x)}(M - D),$$

and so:

$$w_H^{*\prime}(D) = w_L^{*\prime}(D) - \frac{1}{(1-x)}\left(-(1 + r_E^*(.)) + (M - D)\,r_E^{*\prime}(.)\frac{d(cov^*(.))}{dD}\right).$$

From Lemma 3:

$$\frac{d\left(cov^*\left(.\right)\right)}{dD}=0$$

which means:

$$w_H^{*\prime}\left(D\right)=w_L^{*\prime}\left(D\right)+\frac{\left(1+r_E^*\left(.\right)\right)}{\left(1-x\right)}.$$

Consequently:

$$\begin{aligned} w_L^{*\prime}\left(D\right) &= -\frac{\left(1-x\right)}{x}w_L^{*\prime}\left(D\right)-\frac{\left(1+r_E^*\left(.\right)\right)}{x}, \\ w_L^{*\prime}\left(D\right) &= -\left(1+r_E^*\left(.\right)\right). \end{aligned}$$

Since $r_E^*\left(.\right)<r_D$ in Case 2(3), it follows that:

$$p_L^{*\prime}\left(D\right)=r_D-r_E^*\left(.\right)>0.$$

This ends the proof. ■

Proposition 7 *When* $p_H^*>p_L^*$ *and* $-\frac{xU'\left(p_L^*\right)}{(1-x)U'\left(p_H^*\right)}\neq\frac{dp_H^*}{dp_L^*}$ *then* $D^*=0$.

Proof. When $p_H^*>p_L^*$ and

$$-\frac{xU'\left(p_L^*\right)}{\left(1-x\right)U'\left(p_H^*\right)}\neq\frac{dp_H^*}{dp_L^*},$$

the only feasible solutions are given by Case 3(2) and Case 3(3).

From Lemmas 2 and 4 the solution for a social optimum must satisfy:

$$\frac{p_H^{*\prime}\left(D\right)}{p_L^{*\prime}\left(D\right)}=\frac{dp_H^*}{dp_L^*}=-\frac{x\left(1-r_E^{*\prime}\left(.\right)\left(1-x\right)\Delta R_m\right)}{\left(1-x\right)\left(1+r_E^{*\prime}\left(.\right)x\Delta R_m\right)}.$$

Firstly, consider the solution to Case 3(2) where from (3.104):

$$\frac{dp_H^*}{dp_L^*}<-\frac{xU'\left(p_L^*\right)}{\left(1-x\right)U'\left(p_H^*\right)}<0.$$

Consequently, Case3(2) only applies at a social optimum if:

$$\frac{p_H^{*\prime}\left(D\right)}{p_L^{*\prime}\left(D\right)}<-\frac{xU'\left(p_L^*\right)}{\left(1-x\right)U'\left(p_H^*\right)}.$$

From (3.130) in Case C if $p_L^{*\prime}\left(D\right)<0$ this is the condition for a social optimum where $D^*=0$.

In Case 3(2) differentiating (3.84) with respect to D gives:

$$p_H^{*\prime}(D) = 1 + r_D > 0,$$

since e^* is determined by (3.37), which is independent of D, and, from (3.67) and (3.68) w_L^* and w_H^* are, therefore, also independent of D. It follows that the solution for Case 3(2) will only be feasible if $p_L^{*\prime}(D) < 0$.

Secondly, consider the solution to Case 3(3) where from (3.105):

$$\frac{dp_H^*}{dp_L^*} > -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}.$$

Consequently, Case3(3) only applies at a social optimum if:

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} > -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}.$$

From (3.129) in Case C if $p_L^{*\prime}(D) > 0$ this the condition for a social optimum where $D^* = 0$.

In Case 3(3) differentiating (3.98) with respect to D gives:

$$p_L^{*\prime}(D) = 1 + r_D > 0,$$

since e^* is determined by (3.37), which is independent of D, and, from (3.67) and (3.68) w_L^* and w_H^* are, therefore, also independent of D.

This ends the proof. ■

Proposition 8 *When* $p_H^* > p_L^*$ *and* $-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} = \frac{dp_H^*}{dp_L^*}$ *then* $0 < D^* < M$ *if* $r_E^*(.) \neq r_D$ *otherwise* $D^* = M$.

Proof. When $p_H^* > p_L^*$ and:

$$-\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} = \frac{dp_H^*}{dp_L^*},$$

From (3.103) the only feasible solution is given by Case 3(1).

In Case B the solution for a social optimum where $0 < D^* < M$ satisfies:

$$\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} = -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)}$$

Proposition 7 shows that Case 3(2) and Case 3(3) can only be a social optimum when Case C applies. As (3.103), (3.104) and (3.105) show that the solutions for Case 3(1),Case 3(2) and Case 3(3) are mutually exclusive it follows that a solution for a social optimum in Case B can only be feasible if Case 3(1) also applies, that is:

$$\frac{dp_H^*}{dp_L^*} = \frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} = -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} = -\frac{x\left(1 - r_E^{*\prime}(.)(1-x)\Delta R_m\right)}{(1-x)\left(1 + r_E^{*\prime}(.)x\Delta R_m\right)}.$$

In Case 3(1) if $xc \leqslant u_0$ then $r_E^*(.) < r_D$. However, if $xc > u_0$ then the price difference determines whether profits are higher or lower when the firm's costs are low (and vice versa) and so whether $r_E^*(.) \gtreqless r_D$. It is, therefore, possible for Case B to apply when $R_{EL}^* = R_{EH}^*$, that is, when $cov\left(R_E^*, R_m\right) = 0$ and $r_E^*(.) = r_D$. In these circumstances the optimum for consumer prices is such that the returns received by shareholders in both states of the world are the same as for lenders and so the overall cost of finance is the same as when $D^* = M$. Consequently, a social optimum where $0 < D^* < M$ is only possible when $r_E^*(.) \neq r_D$.

This ends the proof. ■

Proposition 9 *When* $p_H^* > p_L^*$ *and* $D = D^*$ *then* $r_E^*(.) = r_D + cov^*(.)\, r_E^{*\prime}(.)$.

Proof. Since $\pi > 0$ at an optimum in Case 3 then, from (3.7), and (3.64), the shareholders' participation constraint (3.10) becomes the following:

$$x(p_L^* + c) + (1-x)p_H^* - u_0 - \psi(e^*) - \theta + e^* - (1 + r_D)D = (1 + r_E^*(.))(M - D).$$

Differentiating with respect to D gives:

$$xp_L^{*\prime}(D) + (1-x)p_H^{*\prime}(D) = r_D - r_E^*(.) + r_E^{*\prime}(.)\frac{d(cov^*(.))}{dD}(M - D)$$

since e^* is determined by (3.37), which is independent of D.

From (3.67) and (3.68) at an optimum in Case 3 :

$$cov^*(.) = \frac{x(1-x)}{M-D}\left(c - \frac{u_0}{x} - (p_H^* - p_L^*)\right)\Delta R_m.$$

Differentiating $cov^*(.)$ with respect to D gives:

$$\frac{d(cov^*(.))}{dD} = \frac{x(1-x)}{M-D}\left(p_L^{*\prime}(D) - p_H^{*\prime}(D)\right)\Delta R_m + \frac{cov^*(.)}{M-D}.$$

It follows that:

$$\begin{aligned} & xp_L^{*\prime}(D)\left(1-r_E^{*\prime}(.)(1-x)\Delta R_m\right)+(1-x)p_H^{*\prime}(D)\left(1+r_E^{*\prime}(.)x\Delta R_m\right) \\ = \; & r_D - r_E^*(.) + r_E^{*\prime}(.)\,cov^*(.). \end{aligned}$$

However, from Propositions 7 and 8 when $D = D^*$:

$$\frac{dp_H^*}{dp_L^*} = \frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} = -\frac{x\left(1-r_E^{*\prime}(.)(1-x)\Delta R_m\right)}{(1-x)\left(1+r_E^{*\prime}(.)x\Delta R_m\right)}.$$

Consequently:

$$r_E^*(.) = r_D + r_E^{*\prime}(.)\,cov^*(.).$$

This ends the proof. ■

Proposition 10 *When $p_H^* > p_L^*$ and $D = D^*$ then there is a social optimum where $D^* = M$ if $r_E^{*\prime\prime}(.) \neq 0$. However, if $r_E^{*\prime\prime}(.) = 0$ then the social optimum satisfies $D^* = M$ for a set of parameter values that has measure zero in the parameter space.*

Proof. From Proposition 9 when $p_H^* > p_L^*$ and $D = D^*$ then:

$$r_E^*(.) = r_D + r_E^{*\prime}(.)\,cov^*(.).$$

Differentiating $r_E^*(.)$ with respect to $cov^*(.)$ gives:

$$r_E^{*\prime}(.) = r_E^{*\prime\prime}(.)\,cov^*(.) + r_E^{*\prime}(.),$$

that is:

$$r_E^{*\prime\prime}(.)\,cov^*(.) = 0.$$

Consequently, if $r_E^{*\prime\prime}(.) \neq 0$ then $cov^*(.) = 0$ and so $r_E^*(.) = r_D$. The overall cost of finance is then the same as when $D^* = M$. Conversely, if $r_E^*(.) \neq r_D$ then $cov^*(.) \neq 0$ and so $r_E^{*\prime\prime}(.) = 0$ and, from Proposition 8, $0 < D^* < M$.

However, if $r_E^{*\prime\prime}(.) = 0$ it is also possible that $cov^*(.) = 0$ but, from Proposition 8, this can only be where Case 3(1) applies and, therefore:

$$\frac{dp_H^*}{dp_L^*} = \frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)} = -\frac{xU'(p_L^*)}{(1-x)U'(p_H^*)} = -\frac{x\left(1-r_E^{*\prime}(.)(1-x)\Delta R_m\right)}{(1-x)\left(1+r_E^{*\prime}(.)x\Delta R_m\right)}.$$

Further, if $r_E^{*\prime\prime}(.) = 0$ then $r_E^{*\prime}(.)$is a constant and so is the ratio $\frac{p_H^{*\prime}(D)}{p_L^{*\prime}(D)}$. Since it is assumed the consumer's utility function satisfies $U'(p), U''(p) < 0$ there can, therefore, be only one combination of consumer prices p_H^* and p_L^* at which there is a social optimum when $r_E^{*\prime\prime}(.) = 0$ and $cov^*(.) = 0$.

This ends the proof. ■

Appendix 3.F The Capital Asset Pricing Model

According to the CAPM the cost of equity, r_E, is a linear function of the risk free return, r_D , the equity beta, β_E, and the equity risk premium associated with the expected rate of return on the market portfolio, $E(R_m) - r_D$, that is:

$$r_E = r_D + \beta_E \left(E(R_m) - r_D\right).$$

In addition, β_E is the ratio of the covariance of the rate of return on equity with the return on the market portfolio, $cov(R_E, R_m)$, to the variance of the return on the market portfolio, σ_m^2:

$$\beta_E = \frac{cov(R_E, R_m)}{\sigma_m^2}.$$

Consequently:

$$r_E'(.) = \frac{(E(R_m) - r_D)}{\sigma_m^2}.$$

As it is assumed that r_D is given exogenously and that $E(R_m)$ and σ_m^2 are determined by the market equilibrium, then $r_E'(.)$ is a constant and so:

$$r_E''(.) = 0.$$

In the model considered in this chapter it follows from (??) that if the CAPM applies:

$$\begin{aligned} r_E &= r_D + \Phi \frac{x(1-x)}{M-D} (c - (w_L - w_H) - (p_H - p_L)) \Delta R_m, \\ \text{where } \Phi &= \frac{(E(R_m) - r_D)}{\sigma_m^2}. \end{aligned}$$

Chapter 4

The Capital Structure of Water Companies in England and Wales: An Empirical Study

4.1 Introduction

4.1.1 Background

When the water industry in England and Wales was privatized in December 1989 the water companies faced a continuing need for large amounts of external finance. Substantial investment programmes were needed to make the improvements in drinking and waste water quality required by domestic and European Union (EU) legislation. However, a flotation with the prospect of relatively large rights issues to shareholders being required in the foreseeable future was not considered feasible, and so the UK government ensured that the opening balance sheets of the privatized water companies had the capacity to accommodate a significant increase in gearing (i.e. the ratio of a firm's debt to its capital value). In fact, all the previous public sector debt was written off and all but one of the privatized water companies received a so-called 'green-dowry'. This was a cash injection which, according to the regulator in Ofwat (1992), amounted in total to some £1.5 billion as compared with the companies' market capitalization of £6.1 billion at the end of the first day's trading.

Ofwat (1991) shows that in 1989 the government had projected that average gearing for the industry as a whole would rise from zero in 1990/91 to 25% by 1994/95 and then stay in the range 24-28% for the following five years[1]. In the first five years following privatization actual gearing increased broadly in line with these projections rising from an average of 4.0% in 1990/91 to 20.9% in 1994/95. However, by the end of 1999/00 gearing had risen to 44.2% and then, following the regulator's review of price limits in 1999, it increased sharply reaching 59.5% by the end of 2002/03. The rapid increase after the 1999 review was of particular significance because, in large part, it reflected the actions of a number of companies to implement major capital restructurings that would allow their gearing levels to rise above 75%. It would seem, therefore, that the increase in the water industry's gearing has been influenced by factors beyond a simple need to finance capital investment.

4.1.2 Theories of capital structure

The two main theories of capital structure decisions by firms viz. the 'trade-off' theory and the 'pecking order' theory are described in chapter 1. However, neither of these theories has proved to be entirely satisfactory and, to varying degrees, empirical studies support both approaches.

The trade-off theory says that as gearing increases there is a trade-off between the increasing value of the tax shield on debt finance and increases in agency costs and/or the costs of financial distress and bankruptcy. This suggests, therefore, that firms have an optimal capital structure at which the marginal benefit of the tax shield equals the marginal increase in agency and other costs and that they move towards the optimum depending on the adjustment costs[2].

The pecking order theory argues, however, that firms do not have a target capital structure but, instead, adopt a financing hierarchy. It is argued that firms prefer to use internal finance before turning to sources of external finance and will then prefer to raise debt rather than issue new equity which would

[1] The average gearing of the industry as a whole is defined for these purposes as the ratio of the total net debt of the regulated water companies to their total capital value at the relevant financial year end. Total capital value is calculated as the total of the net debt and share capital and reserves of the companies on a historical cost accounting basis.

[2] There are also agency cost models (e.g. Jensen and Meckling (1976)) which do not rely on the existence of a tax shield on debt finance to produce a trade-off.

only be used as a last resort. The rationale behind this theory is that a firm's managers and shareholders have asymmetric information about its prospects. This will lead shareholders, for example, to assume that the firm's shares are overpriced if it makes a rights issue and managers will not wish to issue new equity that is undervalued. As a result, the firm's managers will prefer to issue low risk debt, whose pricing is less sensitive to private information, placing debt finance higher in the pecking order than equity issues. Similarly, cash and marketable securities, are preferred to both debt and equity. A firm's capital structure will, therefore, simply reflect its cumulative earnings and investment requirements.

In a regulated environment the position is further complicated by the potential interaction between decisions on gearing and the price limits that are set by the regulator. This 'price-influence effect' can arise in two ways and these can work in opposite directions.

Firstly, if the regulator considers that there is an optimal level of gearing which minimizes the overall cost of capital then price limits will be set to reflect the assessed optimum. Consequently, if the trade-off theory is correct, a price-cap system of regulation reinforces the incentive for the regulated firm to adjust gearing to the level that maximizes its financing efficiency. Shareholder value will clearly be enhanced if the firm can find ways to reduce its overall cost of capital below the regulator's assessment. Firms would not normally be expected to behave this way according to the pecking-order theory.

Secondly, there is a moral hazard problem. If the regulated firm believes that the regulator will be influenced by the risk of financial distress and the associated risk of disruption to services then, as Taggart (1981) notes, the firm will have an incentive to increase gearing to obtain more favourable price limits. Consequently, a regulated firm might still have a target capital structure even if it might otherwise behave in accordance with the pecking-order theory. This suggests that if there is evidence that regulated firms do have target capital structures then it would be important to consider whether there is any evidence of companies attempting to exert a price-influence effect before drawing conclusions about which of the two competing theories provides a better explanation of events.

The capital structure decisions of regulated firms have received little attention in the literature and there have been few empirical studies; a notable exception being Taggart's (1985) study of the response of electricity utilities in the US to changes in the regulatory regime. Taggart concluded that the evidence was most consistent with the trade-off theory but that the evidence did not eliminate all ambiguity. The pecking order theory was supported by some, but not all, of the results and there was also some evidence of firms adopting price-influence financing strategies although these seemed to be short-lived as regulators took measures to combat them.

No empirical studies have been undertaken to investigate the capital structure decisions of regulated firms in the UK. However, Mayer's (2003) assessment of the water industry is that, while both the trade-off and pecking order theories provide a partial explanation of events, they do not explain the rapid increase in gearing after the review of price limits in 1999. He argues that this was a response to a much tighter regulatory contract and reflected attempts by water companies both to minimize financing costs and to protect their financial positions by restricting the regulator's ability to tighten the contract further. If so the capital restructurings undertaken by some companies would reflect the operation of the trade-off theory in conjunction with a defensive price-influence effect, albeit in a rather extreme form.

4.1.3 Outline of the study

This chapter attempts to take an empirical approach to the question of whether the behaviour of regulated firms is consistent with the trade-off or pecking order theories by using the water industry over the period 1990/91 to 2002/03 as a case study. A number of econometric models have been developed for this purpose and to address two specific questions:

- Did the water companies behave as though they had target gearing levels?
- What effect did the regulatory reviews of price limits appear to have on the capital structure decisions of water companies?

As there are two published measures of gearing an interesting associated question concerns which measure seems to have been more important to the water companies: the measure based on capital values derived from the companies' published accounts or that based on the regulator's calculation of capital value and used to set price limits?

Section 4.2 explains how the water companies have been classified for the purpose of this study. The classification reflects both the structure of the water industry in England and Wales and the capital restructurings which occurred shortly after the review of price limits in 1999. The aim was to place the companies in categories where the behaviour of companies within each category is likely to be relatively homogeneous even though the various categories might exhibit different patterns of behaviour. This enables separate models to be estimated for each category using pooled data as only a relatively short time series of data is available for individual companies. Possible connections between the capital restructurings that occurred after 1999/00 and the ownership of the water companies are then discussed in section 4.3.

Section 4.4 describes the sources and definitions of the data on net debt and capital values that have been used in the study. Descriptive statistics are also provided including the means and standard deviations of the variables and the correlations between them.

The models that have been developed to estimate the relationships between the variables and the methodology that has been applied are explained and discussed in section 4.5. An unrestricted Autoregressive Distributed Lag Model (ADLM) is used as the starting point. This incorporates a number of model types according to the restrictions placed on the parameters. Of particular interest here are the Static Long Run Model (SLRM), the Partial Adjustment Model (PAM) and the Error Correction Model (ECM). The methodology used in this study has a number of novel features compared with other studies that use adjustment models, usually the PAM, to test whether firms move towards target gearing ratios. In particular:

- a general-to-specific model reduction process is applied to the estimated ADLM to determine which model, if any, provides the best explanation.
- target gearing ratios are estimated directly instead of proxy numbers being calculated separately and used as input data.
- cointegration tests are used to assess whether the results reflect causal relationships, although the reliability of these tests is limited by the relatively short time period for which data is available.

Section 4.6 presents the results of the model reduction process for each category of company and comments on the tests that have been carried out.

The models derived in section 4.6 were also applied to the data on individual companies and these results are discussed in section 4.7.

Section 4.8 provides an interpretation of the results taking into account policy statements about capital structure that have been made by the regulator at reviews of price limits. From this it possible to assess whether companies have tried to exert a price-influence effect.

Finally, some overall conclusions on which theory of capital structure is consistent with the evidence in this case study are set out in section 4.9. In broad terms it is concluded that that the evidence from this case study is more consistent with the trade-off theory of capital structure than the pecking order theory. The econometric models that have been estimated provide reasonable support for the proposition that water companies, at least when viewed collectively, have behaved as though they had target levels of gearing. Although such targets are predicted by the trade-off theory, it is important to emphasize that the evidence has been obtained from adjustment models and so does not necessarily demonstrate that a trade-off actually exists. This would require more extensive models to be developed where the target level of gearing is specified as a function of the explanatory variables that determine the costs and benefits of increasing gearing. Unfortunately, a number of those variables, for example, agency costs and the costs of financial distress, are extremely difficult to measure.

Adjustment models can, however, provide evidence that the behaviour of firms is inconsistent with the pecking order theory since it predicts that firms do not have target gearing levels. Even so, as the water companies are highly regulated, it is also important to assess whether they have tried to use gearing levels to exert a price-influence effect because it possible that their behaviour might otherwise have reflected the pecking order theory. There appears to be little evidence that water companies have generally tried to manipulate their financial positions to that end and, therefore, it seems reasonable to conclude that their behaviour has not been consistent with the predictions of the pecking order theory.

4.2 Classification of Water Companies and Industry Structure

4.2.1 Types of water company

There are two main *types* of water company in England and Wales, viz:

- the 10 Water and Sewerage Companies (WaSC's) that were privatized in 1989. The WaSC's were created from the 10 publicly owned regional water authorities established by the Government in 1974 to rationalize the provision of water supplies and sewerage services. These services had previously been the responsibility of a large number of municipal authorities.

- the relatively small 'Water only' Companies (WoC's) that have been in private sector ownership for many years. These companies are only responsible for water supply in their areas; the sewerage services being supplied by the relevant WaSC. The relatively small size of the WoC's is illustrated by the capital value figures reported in the water companies' accounts for 2002/03 which show that the WoC's accounted for only 4.7% of the industry's total capital value.

4.2.2 Regulatory framework

As part of the privatization arrangements a price-cap system of regulation was also introduced in 1989 and it was applied to both the WaSC's and the WoC's. The regulatory body established for this purpose was the Office of Water Services (Ofwat), headed by the Director General of Water Services (DGWS)[3]. The government set the initial price limits for the water companies in 1989 and these were subsequently reviewed by Ofwat in 1994, 1999 and 2004 with the new price limits coming into effect in 1995/96, 2000/01 and 2005/06 respectively. These 'Periodic Reviews' take place every five years and companies that are unwilling to accept the price limits set by the DGWS at a Periodic Review can seek a reference to the Competition Commission whose decision is binding.

[3] The Water Industry Act 2003 replaces (after 1 April 2005) the office of the DGWS by a body corporate viz. the Water Services Regulation Authority.

Each water company has an Instrument of Appointment or 'Licence' which contains the detailed conditions that govern the company's activities and its relationship with the regulator. These include, for example, the controls on charges and tariffs, the submission of information to Ofwat, and various requirements relating to corporate governance. It also sets out the circumstances under which there can be an interim determination of price limits between Periodic Reviews and the basis on which such adjustments to price limits are to be calculated.

The water companies are usually subsidiary companies within a group structure and the Licence imposes strict 'ring-fencing' arrangements to protect the assets and the financial resources that the companies need to provide water services. These arrangements are intended to ensure each water subsidiary acts as a free-standing company. Any significant unregulated commercial activities are, therefore, normally undertaken by other subsidiary companies created for that purpose by the water subsidiary's parent company. In addition to the economic regulator there are two quality regulators; the Drinking Water Inspectorate (DWI) and the Environment Agency (EA). These monitor and enforce compliance with the standards for, respectively, drinking water and waste water quality specified by domestic and EU legislation.

4.2.3 Rationalization since 1989

Although there has been some rationalization within the water industry since 1989 this has been limited by statutory controls over takeovers and mergers. The Competition Commission has not been willing to approve mergers between large companies because of the potentially adverse effect on the regulator's ability to use 'comparative competition' to regulate the industry. Rationalization within the industry has, therefore, been confined to the smaller WoC's. In 1989 there were 28 WoC's of which 11 were already owned by three French water groups[4]. Formalization of these common ownership arrangements through mergers subsequently reduced the number of WoC's by six. In addition six WoC's were taken over by WaSC's and four by other WoC's so that by 2003 the number had fallen to 12. The data on the WoC's that were merged or taken over have been combined with that of the current owner for the years prior to merger or takeover as the data for those years is not available for all

[4] This excludes Cholderton and District Water. Ofwat does not publish data for this WoC as it is exceptionally small and the figures are not material.

of the individual WoC's concerned. However, any effects on the results of this study from this procedure are not likely to be significant in view of the relatively small size of the WoC's and, in particular, the size of those WoC's that have been absorbed within other companies. This can be illustrated by using the turnover figures for 1990/91. In that year the WoC's accounted for some 12% of total industry turnover while the turnover of the six WoC's eventually taken over by WaSC's was less than 10% of the total turnover of the WaSC's concerned. The turnover of the four WoC's taken over by other WoC's was about 30% of the total turnover of the WoC's concerned.

4.2.4 Company categories

For the purposes of this study the WaSC's and WoC's have both been divided into two *categories* in order to distinguish between companies that had implemented, or were in the process of implementing, a capital restructuring after the 1999 Periodic Review and those companies that had not done so by the end of 2002/03. The abbreviations CR and NCR respectively are used to distinguish between the companies in each of these categories.

By the end of 2002/03 half of the WaSC's and half of the WoC's had implemented, or were in the process of implementing, a capital restructuring. Table 4.1 identifies the companies by type and by category. The company abbreviations are the same as those used by Ofwat.

Table 4.1: Classification of water companies

	WaSC's	WoC's
Capital restructuring post 1999/00 (CR)	Anglian (ANH) Dyr Cymru (WSH) Northumbrian (NES) Southern (SRN) Wessex (WSX)	Bristol (brl) Dee Valley (dvw) Mid Kent (mkt) Portsmouth (prt) South Staffordshire (sst) Sutton and East Surrey (ses)
No capital restructuring (NCR)	Severn Trent (SVT) South West (SWT) Thames (TMS) United Utilities (UUW) Yorkshire (YKY)	Bournemouth and West Hampshire (bwh) Cambridge (cam) Folkestone and Dover (flk) South East (mse) Tendring Hundred (thd) Three Valleys (tvn)

The capital restructurings that occurred after 1999/00 took two forms:

- Major financial restructurings that relied on 'enhanced financial structures' using debt tranching techniques and tight covenant packages to permit gearing levels in excess of 75%. The companies that took this route were Anglian (2002/03), Southern (2003/04), Dee Valley (2002/03), Mid Kent (2002/03), Portsmouth (2002/03), and Sutton and East Surrey (2000/01). In addition, there was the special case of Dyr Cymru (Welsh) which was acquired in May 2001 by Glas Cymru, a 'not-for-profit' company limited by guarantee and with no equity interest. All of these arrangements, with the exception of Sutton and East Surrey, required regulatory approval and Licence modifications to strengthen the financial ring-fence.

- Less complex refinancings that did not use enhanced financial structures but where debt has been increased to permit special dividends or sharebuybacks. Wessex, Bristol, and South Staffordshire adopted this approach in 2002/03. In Northumbrian's case, however, the restructuring took place at parent company level. In January 2003 Northumbrian's parent company was offered for sale by its then owner, Suez, and in May 2003 Suez sold 75% of its shareholding to a consortium of institutional investors. The parent company was subsequently listed on the London Stock Exchange. Although Northumbrian's gearing was not directly affected, the parent company's gearing increased to 77%[5]. As the parent company's debt is supported by the free cashflows from Northumbrian Ofwat took action to ensure Northumbrian protected its financial position.

4.3 Capital Restructuring and Ownership

Although this chapter is not primarily concerned with a possible relationship between capital structure decisions and the ownership of the companies, some observations can be made about this aspect of the capital restructurings that took place after 1999/00 which will be of assistance in interpreting the empir-

[5] The ratio of net debt to net debt plus share capital and reserves in the unaudited interim results of Northumbrian Water Group plc as at 30 September 2003. The results also showed that gearing at 30 September 2002 was 51%.

ical results. These ownership characteristics also indicate why the behaviour of companies within each of the two categories is likely to be relatively homogeneous while different categories may exhibit different patterns of behaviour.

Only two of the five WaSC restructurings followed directly as a result of a change of ownership and in each case the sale was brought about by the financial problems of the previous owner. The acquisition of Dyr Cymru in May 2001 by Glas Cymru occurred after Hyder, the original owner of Dyr Cymru, encountered financial difficulties while the Wessex restructuring occurred after its acquisition by a Malaysian company, YTLPI in May 2002 following the collapse of its former owner, Enron. The restructurings of Anglian and Southern were both initiated by their parent companies both of which were listed on the London Stock Exchange. Anglian represented the most significant part of its parent company's activities but this was not the case for Southern. Indeed, shortly after obtaining Ofwat's approval for the restructuring, Southern was sold in April 2002 by its then owner, Scottish Power, to a trade buyer with the Royal Bank of Scotland taking a majority stake in April 2003. This delayed execution of the restructuring until 2003. As noted above, the restructuring of Northumbrian's parent company resulted from the decision of its then owner to sell 75% of its shareholding with, it appears, the aim of securing benefits from such a restructuring.

The restructurings of Dyr Cymru and Anglian also included proposals to separate ownership of the water company's assets from the provision of operational services so that the latter could be contracted out. These arrangements prompted Ofwat to impose further Licence modifications to ensure the asset owner, who was still the Licence holder, remained accountable for the delivery of services and achievement of quality standards and that adequate internal control procedures were put in place.

Similarly, among the WoC's, only two of the six restructurings were directly associated with a change of ownership. In both cases the parent was listed on the London Stock Exchange and was acquired by a special financial vehicle. Mid Kent was purchased in April 2001 by Swan Capital Investments, owned by the German bank West LB, and in December 2001 Portsmouth was acquired by South Downs, which was 45% owned by the Royal Bank of Scotland; the balance being owned by management and an employees' trust. The other four restructurings, viz. Bristol, Dee Valley, South Staffordshire and Sutton and East Surrey, were all initiated and implemented by their existing owners; all of which were companies listed on the London Stock Exchange[6].

The main features of the capital restructurings and company ownership described above are summarized in Table 4.2.

Table 4.2: Capital restructuring and ownership

	WaSC's	WoC's
Restructuring proposed by new owner	WSH, WSX	mkt, prt
Acquired by special financial vehicle	WSH, NES, SRN	mkt, prt
Enhanced financial structure utilized	ANH, WSH, SRN	dvw, mkt, prt, ses
Owner listed prior to restructuring	ANH, WSH	brl, dvw, mkt, prt, sst, ses
Owner listed post restructuring	ANH, NES	brl, dvw, sst, ses
Asset ownership separated from operations	ANH, WSH	
Licence modified	ANH, WSH, NES, SRN	dvw, mkt, prt

The characteristics of the parent companies of the WaSC's and the WoC's that did not implement a capital restructuring after 1999/00 are also interesting and, in some respects, are quite similar. Except for Thames, which was taken over by RWE, a large German utility company, the parents of the WaSC's were all listed on the London Stock Exchange at the end of 2000 and the WaSC subsidiary also represented a significant part of each group's activities. The managements of Severn Trent, South West, Thames and United Utilities indicated that they did not see benefits from a restructuring. Kelda, however, proposed in early 2000 to restructure its main subsidiary Yorkshire and establish a 'not-for-profit' mutual as owner of the assets. In many respects the proposal was similar to the restructuring of Dyr Cymru but Kelda withdrew the proposal when the then DGWS decided, in July 2000, that it could not proceed in its current form. The parents of the WoC's that did not implement a capital restucturing were all part of much larger European utility groups. Three Valleys, Tendring Hundred and Folkestones and Dover were owned by the French group, Vivendi. Another French group, Bouygues, owned South East until it was sold to Macquarie Bank, an Australian banking group, in October 2003. Cambridge was a listed company until its acquisition by Union Fenosa, a Spanish multi-utility, in December 1999. Union Fenosa subsequently sold Cambridge to CKI, a Hong Kong based multinational infrastructure company, in April 2004. Bournemouth and West Hampshire was

[6] However, the restructuring of South Staffordshire was followed by the water company's demerger from its parent in April 2004.

owned by Biwater, a British multinational water engineering group until it became the principal part of a joint venture between Biwater and Nuon, a Dutch multi-utilty, in April 2000.

This examination of the ownership of water companies gives added insight to Mayer's (2003) interpretation of events after the 1999 Periodic Review. Mayer argues that the restructurings were a response to a tighter regulatory contract and that companies increased gearing both to achieve a lower cost of capital and to obtain greater exit rights. Higher levels of gearing reduce the owner's commitment to the business and the resulting increase in exit rights then restricts the potential for further tightening of the contract by the regulator. He also points out that, even though increased gearing also increases the regulator's exit rights, there is a net gain for the owner if there are greater downside losses from regulatory intervention as a result of staying in the business.

The above discussion of ownership patterns indicates that the value attached to the benefits of restructuring by the parent companies depended on the importance of the water company subsidiary to each group's strategic development. In most cases, the capital restructurings were undertaken by owners who seem to have perceived they had less scope to use the water company as a foundation for further growth either in the UK or globally. Such owners would attach a relatively high value to the option of being able to exit. Indeed, in some cases the owners were forced to exit because the whole group was in financial difficulty while others chose to exit in whole or in part; perhaps because the water company concerned was small or had a poor strategic fit with the group's other activities. Where this occurred the new owners were usually financial institutions. Such organizations would be likely to have a greater understanding of the scope for using debt finance to reduce the cost of capital and would be attracted by the release of equity in a restructuring. They would also be likely to attach a high value to the option to exit. In addition, it seems that they faced little competition in making these acquisitions from other water companies. This might have been because such acquisitions are constrained by the regulator and the competition authorities. Other water companies could, therefore, have been deterred from proposing mergers between water companies even if they considered that mergers provide opportunities to create added value.

The companies that did not pursue a capital restructuring were, however, all part of groups in which the water company was likely to be considered as strategically important for the group's future growth prospects. In these circumstances management would attach a relatively high value to having flexibility in its arrangements for the control of the water company. This flexibility is restricted at high levels of gearing and especially if enhanced financial structures are introduced. The covenant packages used in such structures place much tighter disciplines and controls on a company. For example, shareholder distributions are linked to meeting financial ratio tests and such tests are also used to define certain 'trigger events' and events of default. If trigger events occur bondholders generally have 'step-in' rights permitting the appointment of independent experts. The regulator has also imposed much tighter Licence conditions in these circumstances. As explained in Stones (2001) the aim of such structures is to change the underlying risk profile of the business so that investment grade credit ratings can be maintained at high levels of gearing and the overall cost of capital can be reduced. Consequently, for the companies that did not pursue a capital restructuring, the costs of reduced management flexibility would seem to have outweighed the potential benefits.

4.4 Data and Key Statistics

4.4.1 Definitions and sources

The models have been estimated using data on two variables viz. the net debt and the capital value of each water company as at the end of each financial year i.e. 31st March. The data set covers all of the 22 regulated water companies in existence in 2003 and extends over the 13 year period from 1990/91 to 2002/03; the latest year for which data was available at the time of this study.

The net debt of each water company consists of its long and short term borrowings after deducting cash and short term investments. Each company's capital value is measured in two ways:

- Historical Cost Asset Value (HCAV) - the net assets of each company as reported in its Historical Cost Accounts (HCA) balance sheet (which, by definition, equals the total of its net debt and share capital and reserves) and

- Regulatory Capital Value (RCV) - the capital value that Ofwat assigns to each company for the purpose of setting price limits[7].

The data on net debt and HCAV were provided by Ofwat from the regulatory accounting information included in the annual 'June Returns' submitted by each water company.

To eliminate the effect of inflation the figures have been adjusted to a common price base of March 2003 using the Retail Price Index at the relevant financial year end. The data on RCV are published in Ofwat (2004a) and have been adjusted by Ofwat to the same price base and in the same way prior to publication.

Ofwat specifies that the regulatory accounting information submitted by each company must only relate to the 'appointed business' of the company. The data, therefore, exclude the effect of any commercial activities that are not regulated unless those figures are not material.

Appendix 4.A contains the data sets for net debt, HCAV and RCV. These are set out in Tables 4.23, 4.24 and 4.25 respectively together with the Retail Price Index data in Table 4.29. The gearing ratios for each company using both the HCAV and RCV measures of capital value and the mean values for each type and category of company are given in Tables 4.26, 4.27 and 4.28 respectively. In addition, appendix 4.A provides graphical plots of the data for the WaSC's in Figure 4.6 and in Figure 4.7 for the WoC's. Graphical plots of the means and standard deviations for each category of company are given in Figures 4.8 and 4.9 respectively.

4.4.2 The pattern and trend of gearing

There are two measures of gearing corresponding to the two measures of capital value:

- HCAV gearing - the ratio of net debt to HCAV
- RCV gearing - the ratio of net debt to RCV

In the first ten years or so following privatization the capital markets, the water companies and Ofwat focused on financial ratios calculated according

[7]The financing costs that Ofwat allows within each company's price limits are calculated by multiplying the company's RCV by the regulator's assessment of the cost of capital.

to HCA conventions and so more attention was given to the HCAV gearing measure. However, the emphasis in the 2004 Periodic Review has moved to the RCV based measure. For example, Ofwat (2003b) (p.62) states:

> "Our analysis has focused on the net debt/RCV measure of gearing which is now the most widely used measure of gearing for water companies".

This measure is considered particularly important by the providers of debt finance who have become much larger investors in the industry as a result of the capital restructurings. For example, in Moody's (2002), the rating agency considers RCV gearing to be one of the two key ratios that should be used to assess and monitor the financial strength of water companies[8]. It is also the measure of gearing that is used in the covenant packages for enhanced financial structures to determine trigger events and events of default. RCV gearing appears to have become the primary measure of gearing because it reflects the capital value on which Ofwat allows a return in setting price limits. For debt providers, therefore, it is a key determinant of a water company's capacity to pay interest charges.

Graphical plots of the two measures of gearing are presented in Figure 4.1 for the WaSC's and in Figure 4.2 for the WoC's. Separate plots are given for companies in the CR and the NCR categories.

These plots show clear differences in pattern and trend of gearing between the WaSC's and the WoC's. They also illustrate the similarity between the two measures of capital value. It can be seen that the gearing of WaSC's increased over the whole of the 13 year period to 2002/03 with, as would be expected, a sharper increase for companies in the WaSC CR category in the three years after the 1999 Periodic Review. Although there was a wide variation in both measures of gearing for the WaSC's at the start of the period they quickly converged after the 1994 Periodic Review. This convergence was maintained by the WaSC NCR category after 1999 Periodic Review while there was a slight increase in variation for the WaSC CR category reflecting differences in the timing of individual capital restructurings. The picture for the WoC's is quite different. They appear to be less homogeneous than the WaSC's with a

[8] The other key ratio is the Adjusted Interest Cover Ratio which measures the cash interest cover after deducting the portion of capital expenditure required to maintain the company's asset base from the post-tax cash flows available to cover cash interest expenses.

Figure 4.1: Gearing based on Historical Cost Asset Value and Regulatory Capital Value - Water and Sewerage Companies

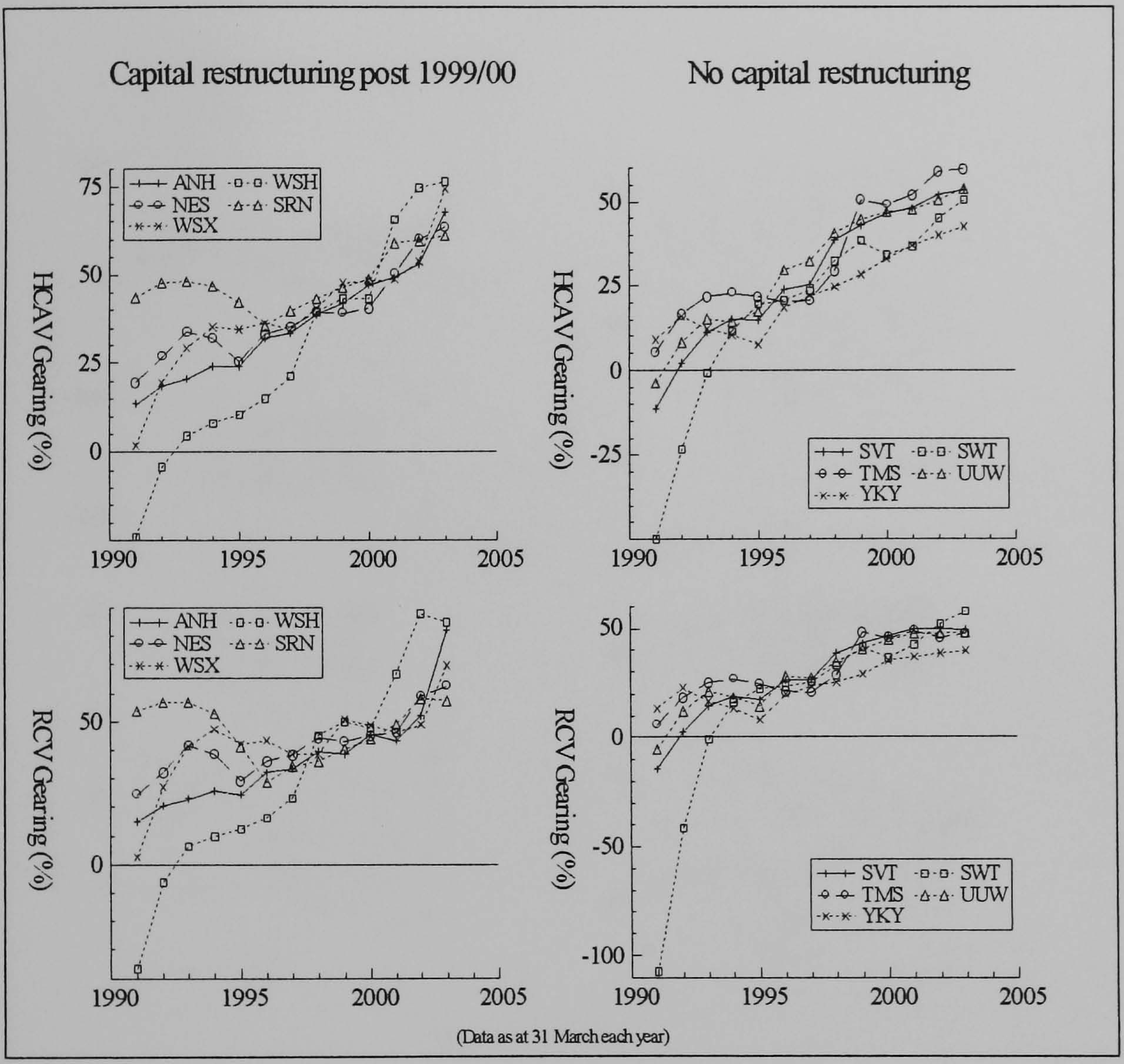
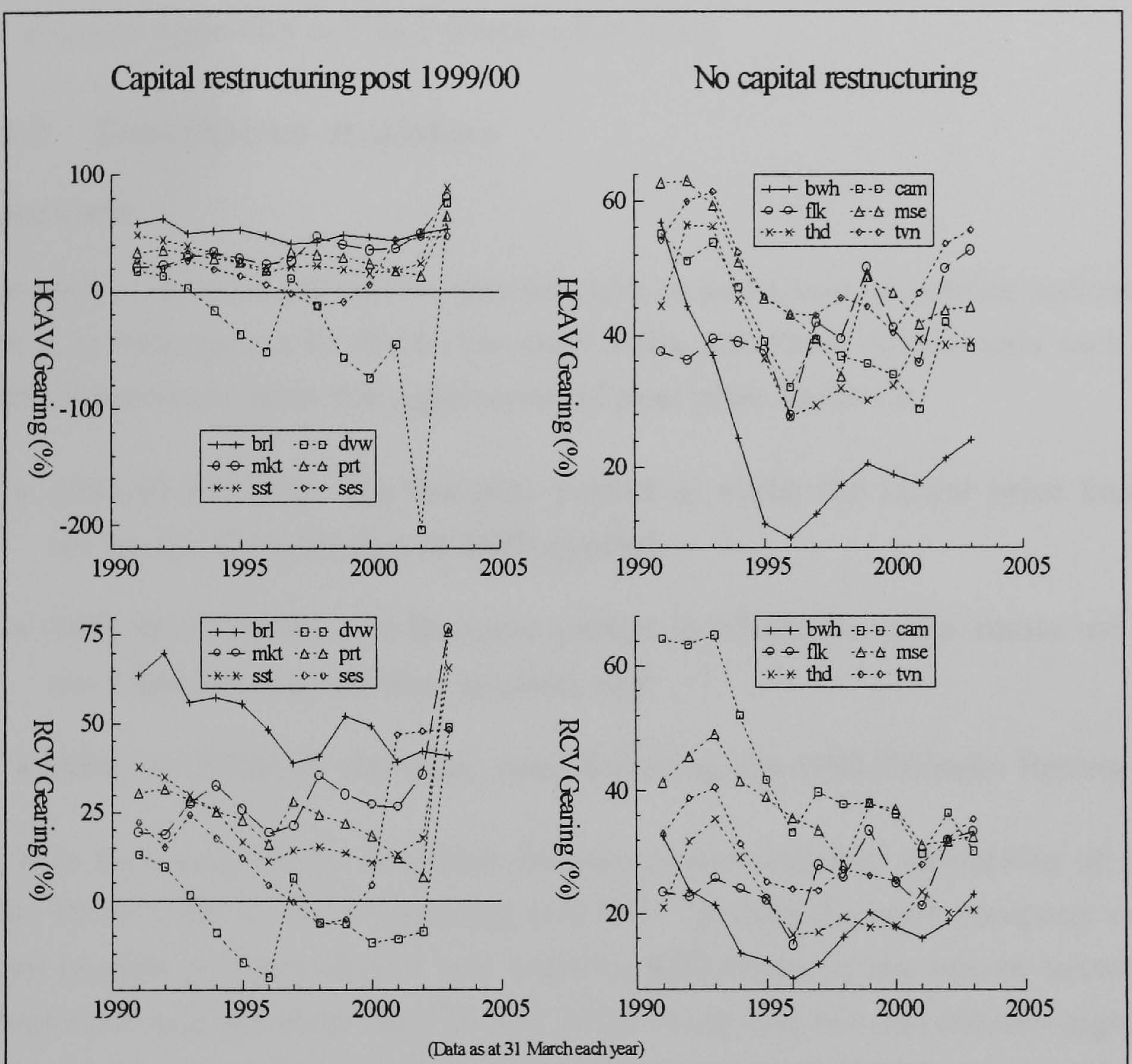


Figure 4.2: Gearing based on Historical Cost Asset Value and Regulatory Capital Value - Water only Companies



much wider variation in gearing throughout the latter half of the period and no clear pattern of convergence. However, in overall terms, the WoC's gearing declined over the ten years to 1999/00. In the following three years the gearing of the WoC NCR category seems to have stabilized while that of the WoC CR category, of course, increased.

These patterns and trends in gearing can be seen more clearly in Figures 4.3 and 4.4 which, respectively, contain plots of the means and standard deviations of both gearing measures for each type and category of company. Plots of the profiles of the means and standard deviations of net debt, HCAV and RCV are given in appendix 4.A in Figures 4.8 and 4.9.

4.4.3 Descriptive statistics

Approach

The above commentary on the general pattern and trend of gearing indicates that it is appropriate to divide the time series into three sub-periods each of which commences with the application of new price limits i.e.

- 1990/91-1994/95: the five-year period in which the initial price limits set by the Government in 1989 applied,
- 1995/96-1999/00: the five-year period in which the price limits set in the 1994 Periodic Review applied, and
- 2000/01-2002/03: the three years following the 1999 Periodic Review.

It is then possible to calculate the means and standard deviations of net debt, HCAV, RCV, HCAV gearing and RCV gearing for each company category in each sub-period and test whether differences in the means between sub-periods and between the CR and NCR categories are statistically significant. A t-test that allows for heteroscedasticity has been used for this purpose; the t-statistic, t, being:

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{\frac{s_1^2}{m} + \frac{s_2^2}{n}}}, \tag{4.1}$$

Figure 4.3: Mean Values of Gearing based on Historical Asset Value and Regulatory Capital Value

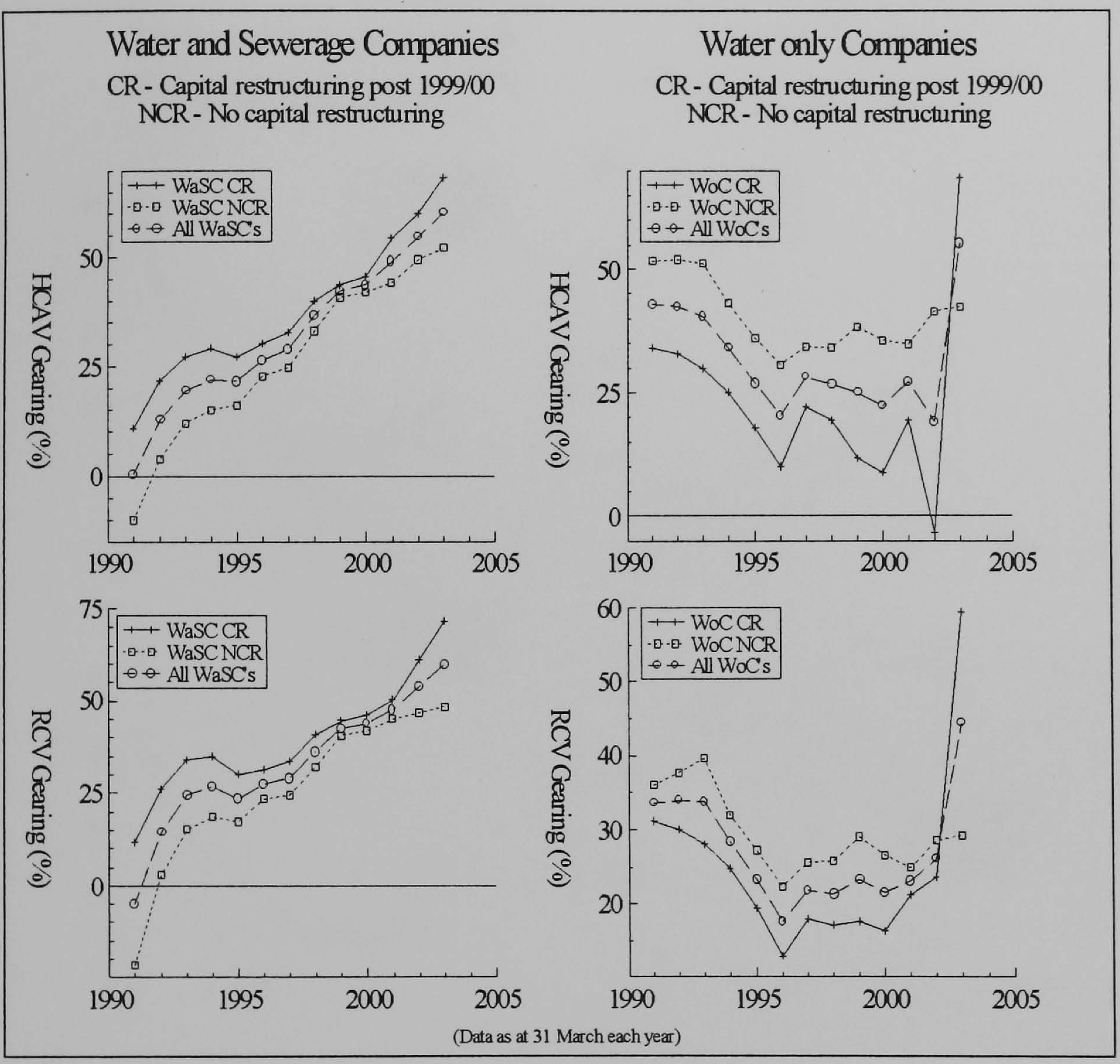
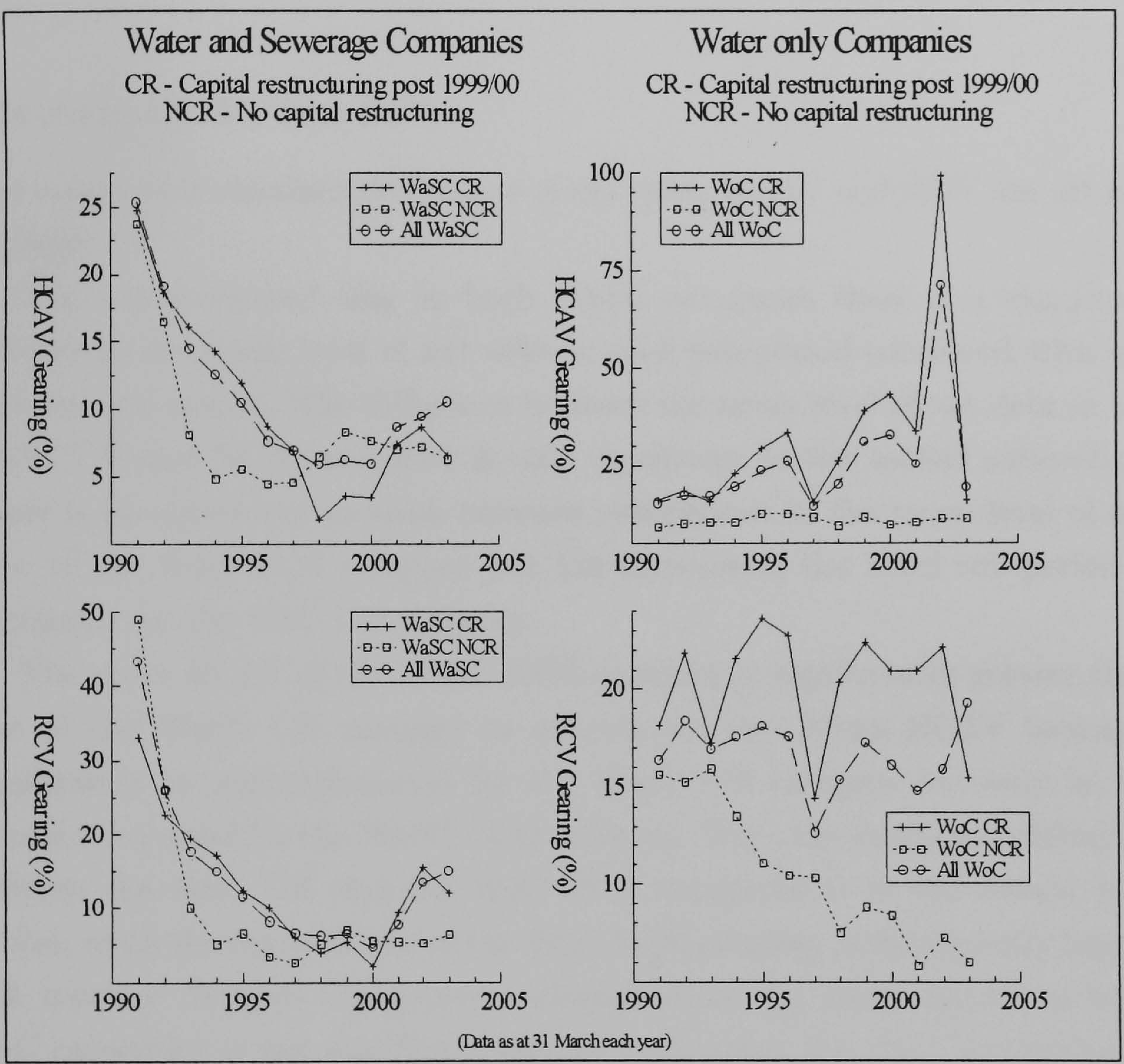


Figure 4.4: Standard Deviations of Gearing based on Historical Cost Asset Value and Regulatory Capital Value



with degrees of freedom, df, given by:

$$df = \frac{\left(\frac{s_1^2}{m} + \frac{s_2^2}{n}\right)^2}{\frac{\left(\frac{s_1^2}{m}\right)^2}{m-1} + \frac{\left(\frac{s_2^2}{n}\right)^2}{n-1}}, \tag{4.2}$$

where $\overline{x}_1$ and $\overline{x}_2$ are the two means being compared, s_1 and s_2 are the associated standard deviations and m and n are the respective number of observations. Critical values based on a one-tail test at the 5% significance level have been used.

Net debt, HCAV and RCV

The means and standard deviations of net debt, HCAV and RCV are set out in Table 4.3.

The t-tests showed that in both WaSC categories there is a significant increase in the mean level of net debt in each sub-period compared with the previous sub-period. The difference between the mean level of net debt in the WaSC CR and NCR categories is only significant in the second sub-period. There is no significant increase between sub-periods in the mean level of net debt in the WoC NCR category but the increase in the third sub-period is significant for the WoC CR category.

The mean HCAV of the WaSC NCR category is significantly greater than that of the WaSC CR category in all sub-periods. Mean HCAV increases significantly in each sub-period for the WaSC CR category but only in the second sub-period for the WaSC NCR category. The only significant difference between the WoC CR and the WoC NCR categories is in the second sub-period, when the mean HCAV of the WoC NCR category is significantly larger. The increase between consecutive sub-periods in the mean HCAV of both WoC categories is not significant but, in both cases, the third sub-period is significantly higher than the first.

The differences in mean RCV between categories and sub-periods that are significant for WaSC's are the same as for mean HCAV. The mean RCV of the WoC NCR category is significantly larger than the WoC CR category in the first and second sub-periods. Mean RCV increases significantly in the second sub-period for the WoC CR category but not in the third. There is no significant increase in mean RCV between consecutive sub-periods for the

Table 4.3: Mean and Standard Deviation of Net Debt, Historical Cost Asset Value and Regulatory Capital Value

	Mean			Standard Deviation		
	1991-1995	1996-2000	2001-2003	1991-1995	1996-2000	2001-2003
	£m	£m	£m	£m	£m	£m
Net Debt						
WaSCs						
CR	296.9	714.5	1455.2	211.0	329.5	674.1
NCR	247.9	1076.7	1716.0	283.4	629.8	679.6
All WaSCs	272.4	895.6	1585.6	248.5	530.0	678.2
WoCs						
CR	23.6	20.1	45.7	20.5	23.3	35.7
NCR	43.7	47.9	59.7	47.5	53.5	67.8
All WoCs	33.6	34.0	52.7	37.7	43.3	53.9
Historical Cost Asset Value						
WaSCs						
CR	1291.0	1838.6	2368.9	540.1	715.4	998.7
NCR	2248.3	3094.6	3441.0	858.9	1090.8	1106.0
All WaSCs	1769.6	2466.6	2905.0	859.0	1111.7	1170.2
WoCs						
CR	68.7	73.9	94.1	30.7	39.1	46.9
NCR	84.5	122.9	136.0	83.6	117.5	134.1
All WoCs	76.6	98.4	115.1	62.9	90.2	101.3
Regulatory Capital Value						
WaSCs						
CR	1094.3	1819.3	2371.1	562.2	755.4	869.5
NCR	1850.5	3166.5	3656.0	851.2	1257.9	1338.1
All WaSCs	1472.4	2492.9	3013.5	809.7	1231.9	1287.0
WoCs						
CR	76.5	97.3	117.8	25.9	33.4	45.6
NCR	121.7	173.0	197.2	128.4	182.4	206.0
All WoCs	99.1	135.2	157.5	94.6	135.5	152.5

Note: Data as at 31 March each year and at March 2003 prices.

WoC NCR category but the third sub-period is significantly higher than the first.

HCAV gearing and RCV gearing

The means and standard deviations of HCAV gearing and RCV gearing are set out in Table 4.4.

The t-tests showed that in both WaSC categories there is a significant increase in both mean HCAV gearing and RCV gearing in each sub-period. Mean HCAV gearing and RCV gearing are also both higher in the WaSC CR category in each sub-period. The standard deviations of both measures are lower in the second sub-period than in the first reflecting the convergence in gearing referred to above. They continue to decline for the WaSC NCR category in the third period with a slight increase in the WaSC CR category reflecting the shorter time period and the different timings of the capital restructurings.

Mean HCAV gearing and RCV gearing both decline significantly in the second sub-period in both WoC categories and, on both measures, mean gearing is higher in the WoC NCR category in the first two sub-periods. The slight increase in HCAV gearing and RCV gearing in the third sub-period for the WoC NCR category is not significant. The increase in gearing in the third sub-period for the WoC CR category is only significant for the RCV gearing measure. There is, however, no significant difference in mean gearing on either measure between the WoC categories in the third sub-period. This seems to reflect the fact that the WoC capital restructurings were in companies with relatively low gearing and the restructurings largely impacted on gearing in 2002/03, the last year of the third sub-period. This holds down the mean values of gearing for the WoC CR category in that sub-period and, as can be seen from Table 4.4, increases their standard deviations. As Figure 4.3 shows, average HCAV gearing in 2002/03 was, in fact, 69% for both the WaSC and the WoC CR categories.

Comparing the gearing of the WaSC's and the WoC's there is no significant difference between the CR categories on both gearing measures in the first sub-period but the WaSC NCR category is significantly lower than the WoC NCR category. However, in the second and third sub-periods the gearing of the WaSC's is significantly higher than that of the WoC's on both measures and in both the CR and NCR categories except in the second sub-period where

Table 4.4: Mean and Standard Deviation of Gearing based on Historical Cost Asset Value and Regulatory Capital Value

	Mean			Standard Deviation		
	1991-1995	1996-2000	2001-2003	1991-1995	1996-2000	2001-2003
	%	%	%	%	%	%
HCAV Gearing						
WaSCs						
CR	23.3	38.6	61.0	17.5	7.9	9.3
NCR	7.4	32.8	48.6	16.1	10.0	7.2
All WaSCs	15.4	35.7	54.8	18.5	9.4	10.3
WoCs						
CR	27.9	14.4	28.2	20.5	31.0	65.2
NCR	46.8	34.5	39.6	11.8	10.5	10.9
All WoCs	37.4	24.5	33.9	19.1	25.1	46.5
RCV Gearing						
WaSCs						
CR	27.3	39.3	60.9	21.9	8.2	14.6
NCR	6.4	32.4	46.8	27.9	9.0	5.5
All WaSCs	16.9	35.8	53.8	27.0	9.2	13.0
WoCs						
CR	26.7	16.3	34.7	19.6	19.0	25.8
NCR	34.5	25.9	27.6	14.1	8.8	6.3
All WoCs	30.6	21.1	31.1	17.4	15.5	18.8

Note: Data as at 31 March each year.

there is no significant difference in HCAV gearing in the NCR category.

Correlations

The trends in gearing would seem to indicate a high degree of correlation between net debt, HCAV and RCV. This is confirmed by the correlation matrix in Table 4.5. The Table shows that, over the whole 13 year period the correlation coefficient for net debt and HCAV varies across the four categories from 0.85 to 0.97 while the coefficient for net debt and RCV varies from 0.73 and 0.97. The correlation coefficients in the two NCR categories are generally higher in each sub-period than the CR categories. The coefficients are generally higher for the WoC's than the WaSC's. However, in the WaSC categories, the coefficients increase in each sub-period, while those in the WoC categories are more stable. The differences between the WaSC's and the WoC's could reflect the fact that the WaSC's were newly established and privatized in 1989 with more varied capital structures than the WoC's which were already mature companies that had existed in the private sector for many years. This seems to be supported by the standard deviations of RCV gearing for the WaSC categories which are higher than the WoC's in the first sub-period, although this is only applies to the WaSC NCR category for HCAV gearing.

The correlation coefficient between HCAV and RCV is consistently high in all company categories and in all sub-periods and is never lower than 0.94. Although the methodologies used to calculate HCAV and RCV are technically different this high correlation reflects two factors. Firstly, both measures of capital value have increased as a result of the very large investment programmes required to meet domestic and EU legislation and, secondly, both measures of capital value use the same data on capital investment. As noted above the regulatory accounts, from which this data is obtained, exclude any investment relating to unregulated commercial activities.

Table 4.5: Correlation between Net Debt, Historical Cost Asset Value and Regulatory Capital Value

	1991 - 1995			1996 - 2000			2001 - 2003			1991 - 2003		
	Net Debt	HCAV	RCV	Net Debt	HCAV	RCV	Net Debt	HCAV	RCV	Net Debt	HCAV	RCV
WaSCs												
CR												
Net Debt	1.000			1.000			1.000			1.000		
HCAV	0.497	1.000		0.907	1.000		0.938	1.000		0.851	1.000	
RCV	0.571	0.990	1.000	0.913	0.972	1.000	0.805	0.953	1.000	0.833	0.970	1.000
NCR												
Net Debt	1.000			1.000			1.000			1.000		
HCAV	0.759	1.000		0.882	1.000		0.962	1.000		0.846	1.000	
RCV	0.785	0.943	1.000	0.890	0.985	1.000	0.980	0.963	1.000	0.906	0.966	1.000
All WaSCs												
Net Debt	1.000			1.000			1.000			1.000		
HCAV	0.498	1.000		0.878	1.000		0.915	1.000		0.796	1.000	
RCV	0.579	0.963	1.000	0.890	0.986	1.000	0.853	0.959	1.000	0.840	0.971	1.000
WoCs												
CR												
Net Debt	1.000			1.000			1.000			1.000		
HCAV	0.886	1.000		0.909	1.000		0.843	1.000		0.871	1.000	
RCV	0.760	0.942	1.000	0.736	0.921	1.000	0.721	0.910	1.000	0.731	0.905	1.000
NCR												
Net Debt	1.000			1.000			1.000			1.000		
HCAV	0.980	1.000		0.983	1.000		0.981	1.000		0.971	1.000	
RCV	0.959	0.975	1.000	0.969	0.972	1.000	0.993	0.989	1.000	0.966	0.979	1.000
All WoCs												
Net Debt	1.000			1.000			1.000			1.000		
HCAV	0.956	1.000		0.971	1.000		0.948	1.000		0.950	1.000	
RCV	0.928	0.956	1.000	0.933	0.963	1.000	0.924	0.976	1.000	0.919	0.967	1.000

Implications

The above analysis of the data and descriptive statistics indicates that, in addition to the obvious difference in their relative size, the WaSC's and the WoC's exhibit significant differences in the pattern and trend of gearing. It also appears that there are significant differences between companies in the CR and NCR categories and that there have been significant changes in gearing levels between Periodic Reviews of price limits. The models that have been developed to estimate the relationship between net debt and capital value have, therefore, been applied separately to each type and category of company and the parameters have been tested for significant differences. The models have also been designed to test for structural changes in the relationships following Periodic Reviews.

4.5 The Models

4.5.1 Unrestricted ADLM

The starting point for the empirical analysis was an unrestricted ADLM of the following form:

$$D_{it} = \beta_0 + \beta_1 V_{it} + \beta_2 V_{it-1} + \beta_3 D_{it-1} + \beta_4 D_{it-2} + u_{it}, \tag{4.3}$$

where:

D_{it} = the level of net debt reported by company i at the end of year t,

V_{it} = the capital value of company i at the end of year t,

u_{it} = an error term.

The general form of the ADLM in (4.3) incorporates a number of model types which can be obtained by placing various restrictions on the parameters. The SLRM, the PAM and the ECM are of particular interest for this study because, potentially, they provide plausible explanations of the data generation process for capital structure decisions. These model types are, therefore, discussed in detail in subsections 4.5.2 to 4.5.5 below and the various restrictions on the parameters of (4.3) relating to each model type are set out in Table 4.6 in subsection 4.5.6.

4.5.2 Static Long Run Model

The SLRM simply assumes that, subject to an error term, D_{it} adjusts each period to maintain its long run equilibrium relationship with V_{it}:

$$D_{it} = g^{*} V_{it} + u_{it}, \tag{4.4}$$

where g^{*} represents the long-run equilibrium or target level of gearing.

4.5.3 Partial Adjustment Model

In the PAM D_{it} moves each period towards its target level, D^{*}_{it}, by a constant proportion of the gap between D_{it-1} and D^{*}_{it}:

$$D_{it} - D_{it-1} = \alpha(D^{*}_{it} - D_{it-1}). \tag{4.5}$$

If D^{*}_{it} is itself determined by a target level of gearing, g^{*}, that is:

$$D^{*}_{it} = g^{*} V_{it}, \tag{4.6}$$

then substituting (4.6) into (4.5) and adding an error term gives the PAM:

$$D_{it} = \alpha g^{*} V_{it} + (1 - \alpha) D_{it-1} + u_{it}. \tag{4.7}$$

Gearing will converge to g^{*} provided the adjustment factor, α, satisfies the condition $0 < \alpha < 1$.

A possible rationale for the PAM was provided by Griliches (1967) using a very simplified example which assumed firstly, that the firm incurs costs both for deviating from and in moving towards D^{*}_{it} and secondly, that these cost functions are quadratic. In this particular case, it means assuming that deviations from the target capital structure result in a higher cost of capital for the firm and that there are transactions costs in raising or repaying debt finance. As shown in appendix 4.B this produces a PAM in which α depends on the relative size of these two types of cost.

However, as Waud (1966) points out, a relationship containing the variables in (4.7) can also be derived from an Adaptive Expectations Model (AEM) where the long run expected capital value of the firm V^{*}_{it} is given by:

$$V^{*}_{it} - V^{*}_{it-1} = \lambda \left(V_{it} - V^{*}_{it-1} \right), \tag{4.8}$$

and $0 < \lambda < 1$. If it is then assumed that the level of net debt is determined by the firm's long run expected capital value, that is:

$$D_{it} = g^* V_{it}^*, \tag{4.9}$$

combining (4.8) and (4.9) and adding an error term gives:

$$D_{it} = \lambda g^* V_{it} + (1 - \lambda) D_{it-1} + u_{it}. \tag{4.10}$$

From an estimation perspective the two models in (4.7) and (4.10) cannot be distinguished although both will provide an estimate of the economically interesting parameter g^*. However, even if the evidence is consistent with either model, the way in which capital investment is determined in the regulatory system would support the view that the PAM is the more likely description of the data generation process.

4.5.4 Combined Partial Adjustment and Adaptive Expectations Model

Waud (1966) also shows that both the PAM and the AEM are special cases of a more general model in which they are both combined and where D_{it}^* is no longer determined by V_{it} but by its unobserved expected value:

$$D_{it}^* = g^* V_{it}^*. \tag{4.11}$$

Combining (4.5), (4.8) with (4.11) and including an error term gives:

$$D_{it} = \alpha\lambda g^* V_{it} + (1 - \alpha + 1 - \lambda) D_{it-1} - (1 - \alpha)(1 - \lambda) D_{it-2} + u_{it}, \tag{4.12}$$

adding the lagged variable D_{it-2} to the simple partial adjustment model. The derivation of (4.12) is given in appendix 4.B.

It should be noted that it is not possible to identify α and λ separately from an estimate of (4.12) but only the values of $\alpha\lambda$ and $\alpha + \lambda$. However, it is possible to obtain an estimate of g^*.

The formulation of the AEM in (4.8) adjusts expectations according to the difference between the actual capital value in the current period and the expected capital value in the previous period. However, the more conventional 'error correction' version of the AEM uses the difference between the actual and expected capital value in the previous period:

$$V_{it}^{*} - V_{it-1}^{*} = \lambda \left(V_{it-1} - V_{it-1}^{*} \right). \tag{4.13}$$

The difference between the two formulations depends on whether the distributed lag model, from which the AEM can be derived, includes the actual capital value in the current period or not. The formulation in (4.8) is based on the distributed lag model:

$$V_{it}^{*} = b_1 V_{it} + b_2 V_{it-1} + ... + b_k V_{it-(k-1)}, \tag{4.14}$$

where b_i are geometrically decreasing weights that reflect the adjustment factor λ so that:

$$b_i = b_1 \left(1 - \lambda\right)^{i-1} \quad \text{where} \quad b_1 = \lambda, \tag{4.15}$$

and the weights sum to unity, in which case:

$$\sum_{i=1}^{\infty} b_i = \lambda \sum_{i=1}^{\infty} \left(1 - \lambda\right)^{i-1} = 1. \tag{4.16}$$

The alternative formulation in (4.13) is derived by excluding the first term on the right hand side of (4.14). If this alternative is used then the capital value in the current period in (4.12) would be replaced by its lagged value, that is:

$$D_{it} = \alpha \lambda g^{*} V_{it-1} + \left(1 - \alpha + 1 - \lambda\right) D_{it-1} - \left(1 - \alpha\right)\left(1 - \lambda\right) D_{it-2} + u_{it}. \tag{4.17}$$

4.5.5 Error Correction Model

The ECM allows for both short-run and long-run effects by assuming that the change in D_{it} in each period reflects both the change in V_{it} and a partial adjustment towards its long run target so that:

$$D_{it} - D_{it-1} = \gamma \left(V_{it} - V_{it-1}\right) + \alpha (D_{it-1}^{*} - D_{it-1}), \tag{4.18}$$

where $0 < \gamma < 1$ and $0 < \alpha < 1$. As in the PAM, D_{it}^{*} is determined by (4.6) which, when substituted into (4.18) and adding an error term, gives the ECM relationship:

$$\Delta D_{it} = \gamma \Delta V_{it} - \alpha \left(D_{it-1} - g^{*} V_{it-1}\right) + u_{it}. \tag{4.19}$$

This can also be expressed in distributed lag form as:

$$D_{it} = \gamma V_{it} + (\alpha g^* - \gamma) V_{it-1} + (1 - \alpha) D_{it-1} + u_{it}. \tag{4.20}$$

It follows that the PAM is a special case of the ECM in which $\gamma = \alpha g^*$.

The ECM is also of particular interest because, as Engle and Granger (1987) have shown, if two non-stationary variables are cointegrated then there must exist an ECM and vice versa. In terms of this model, D_{it} and V_{it} will be non-stationary if they contain stochastic trends and, in this case, they will both have unit roots if they are integrated of order 1, denoted $I(1)$. According to Engle and Granger's (1987) definition of cointegration the two variables will be cointegrated of order $CI(1,1)$ if the residuals from the regression of (4.4) are $I(0)$ [9].

A rationale for the ECM can be derived in a similar way to that described above for the PAM. As before it is assumed, firstly, that the firm incurs two types of cost; a higher cost of capital if it deviates from the optimal level of debt and transactions costs in moving towards the optimum. Secondly, it is assumed that these cost functions are quadratic. However, it is now assumed, in addition, that the cost of deviating from the optimum level of debt has two components; the cost of deviating from D^*_{it-1} and the effect on that cost of moving from D^*_{it-1} to D^*_{it} as a result of a change in V_{it}. Appendix 4.B shows how an ECM can be derived on the basis of these assumptions. It is also shown that:

- α depends on the relative size of the transactions costs and the cost of deviating from D^*_{it-1},
- γ depends not only on these costs but also on the effect on the latter cost of moving from D^*_{it-1} to D^*_{it} because of a change in V_{it},
- the cost of deviating from the optimal level of debt is based on the deviation from the weighted average of D^*_{it} and D^*_{it-1} where the weight attached to D^*_{it} is inversely related to g^* and, conversely, the weight attached to D^*_{it-1} varies directly with g^*. Consequently, when g^* is high, a change in the optimal level of debt following a change in V_t has a smaller effect on costs. This is consistent with an assumption that the

[9] More generally, if two variables are integrated of order a and the residuals are integrated of order $a - b$ where $b > 0$ then the two variables are cointegrated of order $CI(a, b)$.

cost of debt rises with the target level of gearing and so the loss from not being at the optimum is lower.

There is another model that produces a relationship containing the variables in (4.20). If it is assumed, in addition, that V_{it} grows at a constant rate, μ:

$$V_{it} = (1+\mu)\,V_{it-1}, \tag{4.21}$$

and that D_{it} adjusts fully to the change in V_{it} , that is $\gamma = g^*$, then:

$$D_{it} - D_{it-1} = g^*\,(V_{it} - V_{it-1}) + \alpha(D^*_{it-1} - D_{it-1}). \tag{4.22}$$

Substituting (4.6) and (4.21) into (4.22) and adding an error term gives:

$$D_{it} = \alpha g^* V_{it} + \mu g^*\,(1-\alpha)\,V_{it-1} + (1-\alpha)\,D_{it-1} + u_{it}. \tag{4.23}$$

Again (4.20) and (4.23) cannot be distinguished from an estimation perspective but, while both equations give consistent estimates of α, they imply different values for g^*. However, the way in which capital investment is determined in the regulatory system suggests (4.21) would not be a reasonable assumption nor is there any obvious justification for assuming that $\gamma = g^*$. Consequently, even if the evidence is consistent with either model, the ECM would seem to be a more plausible description of the data generation process.

4.5.6 Summary of model types

The model types which are incorporated by the ADLM in (4.3) are summarized in Table 4.6 together with the associated restrictions on the parameters and the relationship between the parameters in (4.3) and those in each model type.

Table 4.6: Summary of Model Types

Model type (Equation)	Parameter restrictions	Model parameters
SLRM (4.4)	$\beta_0 = \beta_2 = \beta_3 = \beta_4 = 0$	$\beta_1 = g^*$
PAM (4.7)	$\beta_0 = \beta_2 = \beta_4 = 0$	$\beta_1 = \alpha g^*$, $\beta_3 = (1-\alpha)$
Combined PAM and AEM (4.12)	$\beta_0 = \beta_2 = 0$	$\beta_1 = \alpha\lambda g^*$, $\beta_3 = (2-\alpha+\lambda)$, $\beta_4 = -(1-\alpha)(1-\lambda)$
Combined PAM and AEM (4.17)	$\beta_0 = \beta_1 = 0$	$\beta_2 = \alpha\lambda g^*$, $\beta_3 = (2-\alpha+\lambda)$, $\beta_4 = -(1-\alpha)(1-\lambda)$
ECM (4.20)	$\beta_0 = \beta_4 = 0$	$\beta_1 = \gamma$, $\beta_2 = (\alpha g^* - \gamma)$, $\beta_3 = (1-\alpha)$

4.5.7 Methodology

The methodology used in this study has a number of features that should be noted.

A single equation model of the kind decribed above can only indicate whether firms behave as though they have target levels of gearing. Evidence of target gearing ratios does not necessarily mean that a trade-off actually exists. This would require the target level of gearing to be specified as a function of the explanatory variables that determine the costs and benefits of increasing gearing. Unfortunately, a number of those variables, for example, agency costs and the costs of financial distress, are extremely difficult to measure. However, adjustment models can provide evidence that the behaviour of firms is inconsistent with the pecking order theory since it predicts that firms do not have target gearing levels. Consequently, empirical studies often use single equation models and the PAM, in particular, has been used in several papers to test the trade-off theory e.g. Taggart (1977), Jalilvand and Harris (1984) and Shyam-Sunder and Myers (1999)[10].

Empirical studies which use the PAM generally start by making the implicit assumption that this is the most appropriate adjustment model to be tested although Shyam-Sunder and Myers (1999) recognize that the PAM is a very simplified model of adjustment and that more sophisticated models could be tested. However, this study follows a different approach and uses a 'general-to-specific' model reduction procedure to identify which of the various models accommodated by the unrestricted ADLM in (4.3) provides the best explanation.

A critical assumption in using a single equation model is that the variable V_{it} is at least weakly exogenous. Aside from the theoretical arguments that support the separation of investment and financing decisions, the regulatory framework in the water industry operates in a way that makes such an assumption reasonable. Indeed, there are grounds for considering V_{it} to be strongly exogenous[11]. Water companies have very little discretion over their investment programmes which, as noted above, are driven by the require-

[10] Both Taggart (1977) and Jalilvand and Harris (1984) estimate combined systems of partial adjustment equations relating to various balance sheet items using Zellner's seemingly unrelated regression technique.

[11] In this context V_{it} would be weakly exogenous if it is not influenced by D_{it} but is influenced by lagged values of D_{it}. If V_{it} is not even influenced by lagged values of D_{it} it would be strongly exogenous.

ments of domestic and EU legislation. Indeed, following discussions with the DWI, the EA and Ofwat the government specifies at each Periodic Review the improvements in drinking and waste water quality that each company must achieve in the following five year period. When it sets price limits Ofwat then makes an explicit allowance for the investment it considers necessary to make these improvements and to maintain asset serviceability. Consequently, water companies only have discretion about the way they achieve the required improvements; giving them a strong incentive to maximize productive efficiency and keep costs below the amounts assumed in price limits. An effect of the regulatory system is, therefore, to reinforce the separation of each water company's investment and financing decisions. Further, as noted above, the regulatory accounting information from which the data used in this study has been obtained excludes the effect of any discretionary investment relating to unregulated commercial activities even if this might be influenced by financing considerations.

Another important implicit assumption in empirical studies which use adjustment models is that the firms in the dataset all have the same adjustment coefficients, although Jalilvand and Harris (1984) allow for variations between firms according to factors such as firm size. As explained in sections 4.2 and 4.4 this study allows for variations between companies by dividing each of the two types of water company into two categories within which it seems reasonable to assume the behaviour of companies is relatively homogeneous given the highly regulated nature of the water industry. It is assumed, therefore, that the coefficients are the same for all companies within each type and/or category. However, by estimating separate models, the adjustment and other coefficients are allowed to vary between each company type and/or category. The relatively short time period for which data on individual companies is available means that the results obtained by applying the models to each company separately are not very reliable as can be seen in section 4.7.

This approach also makes it possible to estimate target gearing ratios for each category directly. In other empirical studies this is not possible because they use data from a cross-section of industries. Consequently, other studies separately calculate proxy numbers for each firm's target gearing ratio, for example as a moving average of its actual gearing ratio over a number of years, and then use these calculated numbers as input data.

The possibility of structural changes in the model following the 1994 and

1999 Periodic Reviews has been tested by including dummy variables in (4.3) that allow for changes in the constant term and the slope coefficients between the three sub-periods.

Empirical studies which use adjustment models to test the trade-off theory generally only apply the normal diagnostic tests to the estimates. A novel feature of this study is that it explicitly tests for cointegration between the variables to assess whether the results reflect a causal relationship and not merely stochastic trends in the data, although the reliability of these tests is limited by the relatively short time period for which data is available.

Shyam-Sunder and Myers (1999) argue that the empirical studies which support the trade-off theory do so by finding evidence of mean reversion in debt ratios or of firms appearing to follow partial adjustment mechanisms towards debt targets and do not test the explanatory power of other hypotheses. Using data on a 157 US firms over the period 1971 to 1989 they compare the explanatory power of the trade-off and pecking order theories using two single equation models. The simple PAM described above is used to test the trade-off theory while a model which relates changes in debt levels to a firm's funds flow deficit is used to test the pecking order theory[12]. They conclude that, while the PAM performs well, their pecking order model provides a better explanation of the debt-equity choice than the trade-off theory. It should be noted that their conclusions are not applicable to regulated utilities as such firms were specifically excluded from their data set.

Although Shyam-Sunder and Myers (1999) make an important methodological point about the advantage of comparing the explanatory power of different models there are a number of reasons it would be inappropriate to follow their approach in this study. Firstly, as noted in subsection 4.1.2, evidence of a target level of gearing for a regulated firm might not be inconsistent with the pecking order theory because of the possibility of firms seeking to exert a price-influence effect. It is, therefore, also necessary to consider whether there is any evidence of such behaviour by water companies which requires a more judgmental approach. This issue is discussed in detail in section 4.8. Secondly, Shyam-Sunder and Myers (1999) accept that their pecking order model cannot be generally correct, especially at very low and very high gearing lev-

[12]Under the pecking order theory equity is issued as a last resort so the coefficient of the funds flow deficit variable should be equal or close to 1.0. Shyam-Sunder and Myers (1999) obtain an estimate of 0.85.

els, and they consider it to be most applicable to companies with moderate debt ratios. This suggests it would not be appropriate to apply their model to water companies. As described in sections 4.1 and 4.2 the gearing of water companies has increased from very low levels following privatization in 1989 to very high levels as a result of the capital restructurings that occurred after the 1999 Periodic Review. The data from water company June Returns also shows that only two WaSC's and five WoC's out of the 22 water companies have undertaken material share issues or buybacks prior to 2000/01 and only one WaSC and two WoC's have done so on more than one occasion. Consequently, it is likely that the absence of any equity transactions by most water companies would be interpreted by the Shyam-Sunder and Myers (1999) model as supporting the pecking order theory even if water companies were actually moving towards a well-defined target level of gearing[13]. Finally, Chirinko and Singha (2000) raise some serious questions about the pecking order model used by Shyam-Sunder and Myers (1999) and the conclusions they reach.

4.6 The Results: Cross-section Panel Data

4.6.1 Estimation procedure

Initial equation

The initial equation that has been estimated for each type and category of company is an unrestricted ADLM in the form of (4.3) but including dummy variables to allow for structural changes following the 1994 and 1999 Periodic Reviews. The equation can be written as follows. Firstly, stacking the data according to time for company i, where $i = 1, ..., 22$, gives an equation with 15 parameters:

$$\mathbf{D}_i = \mathbf{X}_i\boldsymbol{\beta}_0 + \mathbf{T}_{1i}\mathbf{X}_i\boldsymbol{\beta}_1 + \mathbf{T}_{2i}\mathbf{X}_i\boldsymbol{\beta}_2 + \mathbf{u}_i, \tag{4.24}$$

[13] Specifically Shyam-Sunder and Myers (1999) argue the funds flow deficit variable in their pecking order model is not an accounting identity because it excludes equity issues or repurchases. Consequently, the absence of such transactions for most water companies in the period being studied means it is likely that the pecking order coefficient would be close to 1.0.

where the vectors and matrices are:

$$
\begin{aligned}
\mathbf{D}_i' &= \begin{bmatrix} D_{i3} & D_{i4} & . & D_{it} & . & D_{i13} \end{bmatrix}, \\
\mathbf{X}_i &= \begin{bmatrix} 1 & V_{i3} & V_{i2} & D_{i2} & D_{i1} \\ 1 & V_{i4} & V_{i3} & D_{i3} & D_{i2} \\ . & . & . & . & . \\ 1 & V_{it} & V_{it-1} & D_{it-1} & D_{it-2} \\ . & . & . & . & . \\ 1 & V_{i13} & V_{i12} & D_{i12} & D_{i11} \end{bmatrix}, \\
\boldsymbol{\beta_0}' &= \begin{bmatrix} \beta_{00} & \beta_{10} & \beta_{20} & \beta_{30} & \beta_{40} \end{bmatrix}, \\
\boldsymbol{\beta_1}' &= \begin{bmatrix} \beta_{01} & \beta_{11} & \beta_{21} & \beta_{31} & \beta_{41} \end{bmatrix}, \\
\boldsymbol{\beta_2}' &= \begin{bmatrix} \beta_{02} & \beta_{12} & \beta_{22} & \beta_{32} & \beta_{42} \end{bmatrix}, \\
\mathbf{u}_i' &= \begin{bmatrix} u_{i3} & u_{i4} & . & u_{it} & . & u_{i13} \end{bmatrix}.
\end{aligned}
$$

The matrices $\mathbf{T_{1}}_i$ and $\mathbf{T_{2}}_i$ contain the dummy variables that allow for changes in the constant term and slope coefficients between the three sub-periods and are common to all companies.

As the explanatory variables include the dependent variable with a two period lag, equation (4.24) has 11 observations from $t = 3, ..., 13$ (i.e. 1992/93 - 2002/03). Consequently, $\mathbf{T_{1}}_i$ and $\mathbf{T_{2}}_i$ are 11x11 diagonal matrices where the diagonal elements are, respectively, the dummy variables $T1_t$ and $T2_t$ for $t = 3, ..., 13$ which are determined as follows:

$$
\begin{aligned}
T1_t &= 0 \text{ when } t = 1, ..., 5 \text{ (i.e. 1990/91-1994/95) and } t = 11, ..., 13 \text{ (i.e.2000/01-2002/03)}, \\
&= 1 \text{ when } t = 6, ..., 10 \text{ (i.e. 1995/96-1999/00)}, \\
T2_t &= 0 \text{ when } t = 1, ..., 10 \text{ (i.e. 1990/91-1999/00)}, \\
&= 1 \text{ when } t = 11, ..., 13 \text{ (i.e.2000/01-2002/03)}.
\end{aligned}
$$

Secondly, stacking all 22 companies together then gives the initial equation to be estimated as:

$$\mathbf{D} = \mathbf{X}\boldsymbol{\beta_0} + \mathbf{T_1}\mathbf{X}\boldsymbol{\beta_1} + \mathbf{T_2}\mathbf{X}\boldsymbol{\beta_2} + \mathbf{u}, \tag{4.25}$$

which can be written in the general form:

$$\mathbf{D} = \mathbf{W}\boldsymbol{\beta} + \mathbf{u}, \tag{4.26}$$

where:

$$\mathbf{W} = \begin{bmatrix}\mathbf{X} & \mathbf{T}_1\mathbf{X} & \mathbf{T}_2\mathbf{X}\end{bmatrix},$$
$$\boldsymbol{\beta}' = \begin{bmatrix}\boldsymbol{\beta}_0' & \boldsymbol{\beta}_1' & \boldsymbol{\beta}_2'\end{bmatrix}.$$

For these purposes each row of $\mathbf{W}$ is denoted by the vector $\mathbf{w}_{it}$.

Estimation method and assumptions

Ordinary Least Squares (OLS) has been used to estimate (4.26) for each type and category of company using the relevant pooled data. However, when the explanatory variables are not fixed but random, OLS will only provide a consistent estimate of $\boldsymbol{\beta}$ and the usual OLS statistics will only be valid if certain assumptions apply. In this case, where OLS is applied to the data pooled across $i = 1, ..., 22$ and $t = 3, ..., 13$, the assumptions can be summarized, following Wooldridge (2002), as:

$$\begin{aligned}
&\text{Assumption 1} : && \mathrm{E}\left(\mathbf{w}_{it}' u_{it}\right) = \mathbf{0}. \\
&\text{Assumption 2} : && \operatorname{rank}\left[\sum_{t=3}^{13} \mathrm{E}\left(\mathbf{w}_{it}' \mathbf{w}_{it}\right)\right] = 15. \\
&\text{Assumption 3(a)}: && \mathrm{E}\left(u_{it}^2 \mathbf{w}_{it}' \mathbf{w}_{it}\right) = \sigma^2 \mathrm{E}\left(\mathbf{w}_{it}' \mathbf{w}_{it}\right). \\
&\qquad \text{where } \sigma^2 = && \mathrm{E}\left(u_{it}^2\right) \text{ for all } i \text{ and all } t. \\
&\text{Assumption 3(b)}: && \mathrm{E}\left(u_{it} u_{is} \mathbf{w}_{it}' \mathbf{w}_{is}\right) = \mathbf{0},\ t \neq s.
\end{aligned}$$

Assumptions 1 and 2 are necessary for OLS to provide a consistent estimate of $\boldsymbol{\beta}$. Assumption 1 states that the error term u_{it} is uncorrelated with the explanatory variables in $\mathbf{w}_{it}$. It also implies the error term has mean zero, that is $\mathrm{E}(\mathbf{u}_i) = \mathbf{0}$, as $\mathbf{w}_{it}$ includes a constant. Assumption 2 excludes linear dependencies amongst the explanatory variables.

The usual OLS tests are only valid if Assumptions 3(a) and 3(b) apply. Assumption 3(a) means there is no heteroscedasticity in the error term while Assumption 3(b) excludes any autocorrelation in the error term. Together they imply $\mathrm{E}\left(\mathbf{u}_i \mathbf{u}_i'\right) = \sigma^2 \mathbf{I}_{11}$. In other words, it is assumed the the variance of the error term is the same for each firm and in each time period and that the error terms for each firm are independently and identically distributed over time. It should be noted that Assumption 3 is necessary for the usual

OLS tests to be valid asymptotically. However, the initial equation to be estimated for each type and category of company only has 11 observations for each company which leaves few degrees of freedom. Consequently, the test results might not be completely reliable.

If the assumption of no heteroscedasticity in Assumption 3(a) fails the OLS estimator of $\boldsymbol{\beta}$ would still be consistent but it would be inefficient. In addition, the usual estimates of the variance would be biased but it is possible to correct for this problem by calculating heteroscedasticity-robust standard errors as described, for example, in White (1980).

As the explanatory variables in (4.26) include lagged dependent variables, failure of Assumption 3(b) from autocorrelation in the error term would also lead to failure of Assumption 1. This is because the lagged dependent variable D_{it-1} would then be correlated with the error term u_{it}. In this case OLS would not even provide a consistent estimate of $\boldsymbol{\beta}$.

Model reduction

A stepwise procedure has been used for model reduction in which the least significant variable in the initial equation, as indicated by the t-value of its coefficient, is eliminated and the equation is then re-estimated. The procedure is repeated and the variables are eliminated in turn until an equation is obtained which only contains variables with significant t-values. Where diagnostic tests indicate the presence of heteroscedasticity then t-tests based on heteroscedasticity-consistent standard errors are used for this purpose.

As the initial equation contains a two period lag the reduction procedure uses equations based on 11 observations for each company. However, as the variable D_{it-2} is eliminated by the procedure, the last equation in each category has been re-estimated to include an additional observation for each company and these are the final estimates that are described below. Table 4.7 shows the number of observations used in the estimation process.

Modelling package

The modelling package PcGive 10.3 has been used to calculate the OLS estimate of (4.26) for each type and category of company and to carry out the model reduction procedure. The package carries out the usual diagnostic tests including tests for the presence of heteroscedasticity, based on White (1980),

Table 4.7: Number of observations

Category	No of companies	Model reduction	Final estimate
WaSC CR	5	55	60
WaSC NCR	5	55	60
All WaSC's	10	110	120
WoC CR	6	66	72
WoC NCR	6	66	72
All WoC's	12	132	144

and the Regression Specification Test (RESET) for specification error due to Ramsey (1969).

Two tests against heteroscedasticity are provided. The 'Hetero test' uses an auxilliary regression of the squares of the residuals on the original regressors and all their squares to test the null of homoscedasticity while the 'Hetero-X' tests uses a regression of the squares of the residuals on the all squares and cross-products of the original regressors. PcGive also provides the heteroscedasticity-robust standard errors described in White (1980) and MacKinnon and White (1985) and the associated t-statistics.

The RESET in PcGive tests the null that the model is correctly specified against the alternative that the square of the predicted value of the dependent variable has been omitted. Although the RESET is often used as a test for a wide range of specification problems, Wooldridge (2002) argues that it should be viewed as a test of whether the relationship between the dependent and the explanatory variables in the regression is linear.

The PcGive software package incorporates a module, DPD v1.22, which estimates panel data models. This module has also been used in the computation of the final estimates following model reduction because it provides additional diagnostic tests which recognize the panel nature of the data. These include tests for serial correlation, as described in Arellano and Bond (1991), and a Wald test of the null hypothesis that all the coefficients are zero. The estimates of the parameters are, of course, unaffected. The t-statistics that are calculated by this module, and which are given in the Tables of results below, correct for heteroscedasticity by using the robust variance estimator in Arellano (1987) which is similar, but not identical, to that in White (1980). As before the RESET and the tests for heteroscedasticity on the final estimates were obtained from the OLS estimates using the pooled data.

4.6.2 Results based on HCAV

Initial equation

The PcGive outputs containing the OLS estimates of (4.26) for each type and category of company when HCAV is used as the measure of capital value are given in appendix 4.C.1.

The initial equations for 'All WaSC's', 'All WoC's' and for the WaSC CR and NCR categories accept the test against heteroscedasticity and the RESET. However, the initial equation for the WoC CR category fails the RESET while that for the WoC NCR category shows evidence of heteroscedasticity. The t-statistics in all six equations are low indicating that model reduction is required. Although the RESET indicates the initial equation for the WoC CR category is misspecified the model reduction procedure has still been applied for information purposes.

The model reduction procedure described above is only valid if the initial equation provides consistent estimates of $\boldsymbol{\beta}$. As explained above the presence of lagged dependent variables among the regressors means that this will not be the case when there is serial correlation in the error term. Three tests for first order serial correlation have, therefore, been applied to the initial estimates of (4.26), the first two of which are suggested in Wooldridge (2002). Writing the serial correlation model as:

$$u_{it} = \rho u_{it-1} + \varepsilon_{it},$$

where ε_{it} is an error term, the three tests are as follows:

1. The residuals $\widehat{u}_{it-1}$ from the initial equations are included in (4.26) as an additional explanatory variable. The coefficient of $\widehat{u}_{it-1}$ from this regression then provides an estimate of ρ to which a t-test can be applied.

2. An estimate of ρ is obtained from the regression of $\widehat{u}_{it}$ on $\widehat{u}_{it-1}$ using the pooled data and a t-test is applied to the coefficient of $\widehat{u}_{it-1}$[14].

3. Separate estimates of ρ are calculated for each company from regressions

[14] Wooldridge (2002) points out that, unlike the first test, the second test is only valid if it is assumed that the explanatory variables in equation (4.26) are strictly exogenous. This is effectively the same as assuming fixed regressors. Assumption 1 only requires contemporaneous exogenity and says nothing about the relationship between $\mathbf{w}_{it}$ and u_{is} for $t \neq s$.

of $\widehat{u}_{it}$ on $\widehat{u}_{it-1}$ based on the residuals relating to each company obtained from the initial equations .

The results of the tests for serial correlation are given in appendix 4.C.2. The first two tests show no evidence of significant serial correlation in any of the six initial equations. Although the third test provides some evidence of serial correlation the extent of the problem is quite limited. Just two companies show evidence of serial correlation using the residuals from the All WaSC's equation and there is no evidence of serial correlation for any of the WaSC's when the residuals from the equations for the CR and NCR categories are used. The All WoC's equation exhibits serial correlation in the residuals for only one company while the residuals from the WoC NCR equation show serial correlation for a different company. However, the residuals from the WoC CR equation indicate there is no serial correlation for companies in that category.

These results suggest it is reasonable to conclude that the initial equations do provide consistent estimates of $\boldsymbol{\beta}$ and that the model reduction procedure is acceptable.

Form of final equation

The results of the model reduction procedure when HCAV is used as the measure of V_{it} are given in appendix 4.C.3. It shows the effects of the eliminating each variable on three information criteria viz. the Schwarz criterion (SC), the Hanna-Quinn criterion (HQC) and the Akaike information criterion (AIC).

When applied to the initial equation for All WaSC's the model reduction procedure is relatively straightforward. At each stage in the procedure the elimination of the least significant variable produces an improvement in the SC while last equation produces no improvement in the HQC and a small deterioration in the AIC. The final equation has the following form:

$$D_{it} = \widehat{\beta}_{10} HCAV_{it} + \widehat{\beta}_{11} HCAV_{it} T1_t + \widehat{\beta}_{12} HCAV_{it} T2_t + \widehat{\beta}_{20} HCAV_{it-1} + \widehat{\beta}_{30} D_{it-1} + \widehat{u}_{it}, \tag{4.27}$$

which can be regarded as an ECM in distributed lag form comparable to (4.20).

However, when the procedure is applied to the CR and the NCR categories it seems that having to use a much smaller number of observations makes the elimination of variables more sensitive to collinearity problems. In the WaSC CR category the variable $HCAV_{it}T1_t$ is eliminated and $HCAV_{it-1}T1_t$

retained. These two variables are highly collinear; the correlation coefficient being 0.997. Similarly, the variable $HCAV_{it}T2_t$ is eliminated in the WaSC NCR category while $D_{it-2}T2_t$ is retained. Again there is high collinearity between these variables; the correlation coefficient being 0.980. These high collinearities and the results for All WaSC's indicate that it is reasonable to reinstate the variables $HCAV_{it}T1_t$ and $HCAV_{it}T2_t$ in their respective categories in place of those selected by the model reduction procedure. There is, however, a slight deterioriation in the three information criteria following the re-instatement. The procedure also produces a relatively large deterioration in all three criteria following the elimination of $D_{it-2}T2_t$ in the WaSC CR category on the basis of a t-statistic adjusted for heteroscedasticity. There is also a small deterioration following the elimination of $T1_t$ WaSC NCR category. The final estimates for the CR and the NCR categories are, therefore, based on an equation with the same form as that derived for All WaSC's in (4.27).

Unlike the WaSC's, $HCAV_{it}T1_t$ is not a significant variable when the procedure is applied to All WoC's. Again, the procedure is relatively straightforward and produces an improvement in all three information criteria after the elimination of each variable, but also indicates that the variable $HCAV_{it-1}T2_t$ should be retained. However, $HCAV_{it-1}T2_t$ has been eliminated from the final estimate because it is not significant when the last equation is re-estimated using the larger number of observations available at this stage. When applied to the WoC CR category the procedure is also relatively straightforward and similarly produces an improvement in all three information criteria after the elimination of each variable. The final equations for All WoC's and for the WoC CR category, therefore, have the following form:

$$D_{it} = \widehat{\beta}_{10}HCAV_{it} + \widehat{\beta}_{12}HCAV_{it}T2_t + \widehat{\beta}_{20}HCAV_{it-1} + \widehat{\beta}_{30}D_{it-1} + \widehat{u}_{it}, \quad (4.28)$$

that is, equation (4.27) with $\widehat{\beta}_{11} = 0$.

Applying the model reduction procedure to the WoC NCR category produces an estimated equation in the form of a simple PAM with only the variables $HCAV_{it}$ and D_{it-1} being retained. However, there is a relatively large deterioration in all three information criteria after the elimination of $D_{it-2}T1_t$ using a t-statistic adjusted for heteroscedasticity. The elimination of the constant term at the last stage in the procedure also produces a small deterioration in the AIC but small improvements in the other two criteria. It is possible that the elimination of $HCAV_{it-1}$ occurs because it is highly collinear with D_{it-1}. The correlation coefficient is 0.971. Consequently, an equation in the form of (4.28) has been estimated instead and shows, as would be expected for this category, that $HCAV_{it}T2_t$ is not significant but that the three other variables, $HCAV_{it}$, $HCAV_{it-1}$ and D_{it-1}, are all significant. Eliminating $HCAV_{it}T2_t$ from this equation, however, produces a small deterioration in the information criteria. The outcome of the reduction procedure for the WoC NCR category is, therefore, less clear than for other categories but, based on the results for All WoC's and the WoC CR category, a final equation of the following form has been selected:

$$D_{it} = \widehat{\beta}_{10} HCAV_{it} + \widehat{\beta}_{20} HCAV_{it-1} + \widehat{\beta}_{30} D_{it-1} + \widehat{u}_{it}, \tag{4.29}$$

which is equation (4.27) with $\widehat{\beta}_{11} = \widehat{\beta}_{12} = 0$. A model in the form of an ECM also has the benefit noted above that, according to Engle and Granger (1987), such a model must exist if it can be shown that D_{it} and $HCAV_{it}$ are cointegrated.

The final estimates of (4.27), (4.28) and (4.29), therefore, provide estimates of the parameters of the corresponding ECM. However, the form of these equations also imposes a number of restrictions on the parameters.

Firstly, in all equations the constant term is eliminated[15]. This is consistent with empirical findings for the PAM in other studies, such as Jalilvand and Harris (1984) and Shyam-Sunder and Myers (1999), and with the form of the ECM derived in (4.20).

Secondly, in all equations $\widehat{\beta}_{30} > 0$ and $\widehat{\beta}_{31} = \widehat{\beta}_{32} = 0$ (i.e. the slope dummies are not significant). Consequently, the coefficient of D_{it-1} does not vary between sub-periods which implies that the long-run adjustment factor in (4.20), does not change following Periodic Reviews. In terms of the notation used in (4.20) the long-run adjustment factor is, therefore, estimated by:

$$\alpha = 1 - \widehat{\beta}_{30}. \tag{4.30}$$

Thirdly, in all equations $\widehat{\beta}_{10} > 0$. In (4.27) both the associated slope dummies are significant as $\widehat{\beta}_{11}, \widehat{\beta}_{12} > 0$ implying that the short-run adjustment factor in (4.20) varies between sub-periods for both WaSC categories and for

[15] The calculation of the Adjusted R^2 statistic has been amended accordingly.

All WaSC's. Again, following the notation used in (4.20), the estimates of the short-run adjustment factor for each sub-period are denoted by:

$$\gamma_0 = \widehat{\beta}_{10}, \tag{4.31}$$
$$\gamma_1 = \widehat{\beta}_{10} + \widehat{\beta}_{11}, \tag{4.32}$$
$$\gamma_2 = \widehat{\beta}_{10} + \widehat{\beta}_{12}. \tag{4.33}$$

However, since $\widehat{\beta}_{11} = 0$ and $\widehat{\beta}_{12} > 0$ in (4.28), the short-run adjustment factors only vary between the second and third sub-periods in the WoC CR category and for All WoC's (i.e. $\gamma_0 = \gamma_1$). Further, there are no changes in the short run adjustment factors in any of the sub-periods for the WoC NCR category taken on its own as $\widehat{\beta}_{11} = \widehat{\beta}_{12} = 0$ in (4.29) (i.e. $\gamma_0 = \gamma_1 = \gamma_2$).

Finally, in all equations $\widehat{\beta}_{20} > 0$ but $\widehat{\beta}_{21} = \widehat{\beta}_{22} = 0$ which implies that the parameter $(\alpha g^* - \gamma)$ in (4.20) is unchanged between sub-periods and, therefore, that the following relationship holds:

$$\widehat{\beta}_{20} = \alpha g_0^* - \gamma_0 = \alpha g_1^* - \gamma_1 = \alpha g_2^* - \gamma_2, \tag{4.34}$$

where g_0^*, g_1^* and g_2^* are the estimates of the target levels of HCAV gearing in each sub-period. The target level of HCAV gearing, therefore, varies between sub-periods for the WaSC categories. In addition, it follows from (4.34) that increases in the target gearing level are proportional to the change in the short-run adustment factor. However, from (4.28), the target gearing level only varies between the second and third sub-periods in the WoC CR category and for All WoC's (i.e. $g_0^* = g_1^*$ since $\gamma_0 = \gamma_1$) while (4.29) indicates target gearing does not change in any of the sub-periods for the WoC NCR category (i.e. $g_0^* = g_1^* = g_2^*$ since $\gamma_0 = \gamma_1 = \gamma_2$).

Final estimates

The results of the model reduction procedure where HCAV is used as the measure of capital value are set out in Table 4.8. The outputs from PcGive are given in appendix 4.C.4.

Table 4.8: Distributed lag ECM results based on HCAV

Equation		Variable					Adjusted R^2	ADF t-test	Unit root t-test	Diagnostic tests rejected
		$HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	$HCAV_{it-1}$	D_{it-1}				
WaSCs										
CR	Coefficient	0.717	0.045	0.118	-0.696	0.850	0.992	-6.67 [1]	-2.59	N [1], H [1], HX [5]
	t-statistic	8.61	4.95	4.14	-6.70	14.70				
NCR	Coefficient	0.419	0.058	0.061	-0.386	0.861	0.990	-7.40 [1]	-5.52 [5]	N [1]
	t-statistic	17.60	8.18	9.59	-13.60	34.30				
All WaSCs	Coefficient	0.640	0.051	0.083	-0.627	0.894	0.990	-10.00 [1]	-3.67 [10]	N [1], HX [5]
	t-statistic	6.87	5.38	6.40	-6.09	31.00				
WoCs										
CR	Coefficient	0.894	-	0.114	-0.873	0.864	0.948	-6.42 [1]	-6.16 [1]	N [1], R [5]
	t-statistic	8.08		3.35	-7.87	39.20				
NCR	Coefficient	0.391	-	-	-0.306	0.821	0.987	-4.54 [1]	-1.68	N [1], H [1], HX [1]
	t-statistic	4.00			-4.40	7.71				
All WoCs	Coefficient	0.806	-	0.070	-0.758	0.810	0.977	-9.01 [1]	-2.48	N [1], H [5], HX [1]
	t-statistic	8.01		3.19	-7.05	10.50				

NOTES

t-statistic Calculated using robust standard errors from panel data models.

Adjusted R^2 Calculated from $1 - AdjR^2 = (1 - R^2)(n-1)/(n-k)$ where $1 - R^2 = RSS / \Sigma D_{it}^2$,
RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.

ADF t-test Augmented Dickey-Fuller test on t-statistic for the coefficient of $residual_{it-1}$ with $\Delta residual_{it}$ as the regressand.
Critical values (for test including a constant) are from MacKinnon (1991).

Unit root t-test Test on t-statistic for the coefficient of D_{it-1} with ΔD_{it} as the regressand instead of D_{it}
Critical values (for test with no deterministic components) are from Ericsson and MacKinnon (1999).

Diagnostic tests

		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	All the models reject the null that all the coefficients are zero at the 1% significance level.
	AR(1)	A1	Tests the null of no first order serial correlation) All the models accept these tests.
	AR(2)	A2	Tests the null of no second order serial correlation)
Significance levels	1%	[1]	
	5%	[5]	
	10%	[10]	

Diagnostic tests

The diagnostic tests that have been applied to the final estimates are shown in Table 4.8. They indicate the most serious problem is heteroscedasticity with three of the six equations failing the test using the squares of the regressors and four equations failing the test based on the squares and the cross-products of the regressors. The t-statistics that are given in the Table correct for this problem by using robust standard errors[16]. All equations except those for the WaSC NCR and the WoC CR categories fail the heteroscedasticity tests. The results for the individual companies discussed below indicate that the heteroscedasticity problem has arisen because of the different sizes of the companies in each category. However, only the WoC CR equation fails the RESET as did the initial equation for that category. There is no evidence of serial correlation in any of the equations and in all cases a Wald test decisively rejects the null hypothesis that all of the coefficients are zero.

Tests for cointegration

Augmented Dickey-Fuller (ADF) tests have been carried out on the variables D_{it} and $HCAV_{it}$ and the form of the tests and the results are shown in appendix 4.D. The results indicate the presence of unit roots in both variables, that is, both variables are non-stationary and, therefore, contain stochastic trends. The tests were applied to the pooled data for each type and category of company and also to individual companies.

In order to determine whether the estimated equations in Table 4.8 reflect a causal relationship and are not spurious, in the sense that they are simply the result of stochastic trends, it is necessary to test whether D_{it} and $HCAV_{it}$ are cointegrated. Three approaches to testing for cointegration have been used. However, the reliability of these tests is limited by the relatively short time period for which data is available and so the results should only be regarded as indicative.

[16] Studies based on adjustment models generally try to eliminate the heteroscedasticity problem by normalizing the data using a scalar variable such as asset value (i.e. converting the data to ratios). Test checks were carried out on the final estimates using this approach and, while the heteroscedasticity problem was reduced, there was very little change in the estimated coefficients.

1. ADF tests on the residuals from the final estimates.

2. The Engle-Granger procedure.

3. Unit root t-test on the coefficient of D_{it-1} in the ECM

The first approach simply applies ADF tests to the residuals, $\widehat{u}_{it}$, of the equations in Table 4.8 using the pooled data[17]. Although this is not strictly a test for cointegration it is suggestive as it tests whether the residuals are stationary and, therefore, indicates whether it would be worthwhile to conduct more sophisticated tests. As shown in the column headed 'ADF t-test' in Table 4.8 these tests reject the null hypothesis that the residuals from all equations are non-stationary at the 1% significance level. As the residuals are, therefore, almost certainly stationary two further tests for cointegration were carried out.

The second approach uses Stage I of the two-stage procedure in Engle and Granger (1987) by estimating the long-run relationship between D_{it} and $HCAV_{it}$ and then testing whether the residuals are stationary. The results in Table 4.8 indicate the long-run relationship for all the WaSC equations should be estimated in the following form:

$$D_{it} = \widehat{b}_1 HCAV_{it} + \widehat{b}_2 HCAV_{it} T1_t + \widehat{b}_3 HCAV_{it} T2_t + \widehat{e}_{it}, \tag{4.35}$$

where $\widehat{e}_{it}$ are the residuals. Similarly, for All WoC's and the WoC CR category the long-run relationship should be (4.35) with $\widehat{b}_2 = 0$ while that for WoC NCR category should be (4.35) with $\widehat{b}_2 = \widehat{b}_3 = 0$.

The Engle-Granger Stage I results are set out in Table 4.9. As no lagged variables are included in these equations it is possible to add another observation and all 13 observations for each company have been used.

The ADF tests on the residuals of the equations in Table 4.9 show that only two of the equations reject the null hypothesis of no cointegration viz. the equations for All WaSC's and for the WaSC NCR category. The equation for All WaSC's was only significant at the 10% level. The critical values are derived from the response surfaces in MacKinnon (1991). The critical values are given in appendix 4.E and they are from the response surface for an ADF

[17] The form of an ADF test is explained in Appendix 4.D. None of the equations in Table 4.8 contain a constant term and so the residuals have a non-zero means. The ADF test regressions, therefore, include a constant term.

Table 4.9: Engle-Granger Stage I results based on HCAV

Equation		Variable $HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	Adjusted R^2	ADF t-test	Diagnostic tests rejected
WaSCs							
CR	Coefficient	0.225	0.167	0.392	0.963	-2.49	H [1], HX [1]
	t-statistic	5.38	5.13	6.58			
NCR	Coefficient	0.128	0.238	0.379	0.950	-10.00 [1]	A1 [5], H [1], HX [1], R [1]
	t-statistic	5.90	8.56	22.40			
All WaSCs	Coefficient	0.152	0.220	0.392	0.947	-4.90 [10]	A1 [1], H [1], HX [1]
	t-statistic	6.68	8.97	18.00			
WoCs							
CR	Coefficient	0.353	-	0.162	0.855	-3.04	A1 [5], N [1], H [5], HX [5], R [1]
	t-statistic	5.14		2.00			
NCR	Coefficient	0.460	-	-	0.967	-2.16	N [5], H [1], HX [1]
	t-statistic	26.00					
All WoCs	Coefficient	0.433	-	0.046	0.936	-3.56	A1 [5], A2 [5], N [1], H [1], HX [1], R [1]
	t-statistic	18.10		1.47			

NOTES

t-statistic Calculated using robust standard errors from panel data models.

Adjusted R^2 Calculated from $1 - AdjR^2 = (1 - R^2)(n - 1)/(n - k)$ where $1 - R^2 = RSS / \Sigma D_{it}^2$,
RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.

ADF t-test Augmented Dickey-Fuller test on t-statistic for the coefficient of the $residual_{it-1}$ with $\Delta residual_{it}$ as the regressand.
Critical values (for test including a constant) are from MacKinnon (1991).

Diagnostic tests

		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	All the models reject the null that all the coefficients are zero at the 1% significance level.
	AR(1)	A1	Tests the null of no first order serial correlation.
	AR(2)	A2	Tests the null of no second order serial correlation.
Significance levels	1%	[1]	
	5%	[5]	
	10%	[10]	

test including a constant [18].

A problem with the Engle-Granger approach, as Ericsson and MacKinnon (1999) point out, is that it imposes a common factor restriction on the dynamics of the relationship. In this particular case, the common factor is $[1-(1-\alpha)L]$ where L is the lag operator and, as shown in appendix 4.F, this restriction has the effect of imposing the condition in (4.19) that:

$$\gamma = g^{*}, \tag{4.36}$$

that is, the short-run adjustment factor is the same as the long run effect in equilibrium. It is likely that this assumption is invalid, in which case as Ericsson and MacKinnon (1999) note, the Engle-Granger approach will have a loss of power relative to the test based on the ECM which is considered below (i.e. it is less likely to reject the null of no cointegration when it is false).

It should also be noted, in small samples such as in this study, the estimates of the parameters are likely to be biased and the standard significance tests will be invalid because the terms describing the short-run dynamics are omitted in Stage I equations. This effect is illustrated in Table 4.9 by the relatively large number of failures in the diagnostic tests.

The third approach to testing for cointegration is based on the ECM. When the ECM is transformed by using ΔD_{it} as the regressand instead of D_{it}, a direct estimate of the long-run adjustment factor can obtained together with a t-statistic which can be tested for significance. For example, the final equation for the WaSC's (4.27) can also be estimated as:

$$\begin{aligned}\Delta D_{it} &= \widehat{\beta}_{10} HCAV_{it} + \widehat{\beta}_{11} HCAV_{it} T1_t + \widehat{\beta}_{12} HCAV_{it} T2_t + \widehat{\beta}_{20} HCAV_{it-1} \\ &\quad + \left(1-\widehat{\beta}_{30}\right) D_{it-1} + \widehat{u}_{it},\end{aligned} \tag{4.37}$$

which, using (4.30), gives α directly as the coefficient of D_{it-1}. It is, therefore, possible to test for the presence of a unit root because the condition $0 < \alpha < 1$ must hold if the model is to converge to a long-run equilibrium. If the significance test indicates $\alpha = 0$ then the null hypothesis of no cointegration between the variables D_{it} and $HCAV_{it}$ should be accepted, while $\alpha > 0$

[18] The form of an ADF test is explained in Appendix 4.D. As there is no constant term in the equations for the Engle-Granger Stage I models, the residuals have non-zero means. The ADF test regressions, therefore, include a constant term.

implies it should be rejected and that the variables are cointegrated[19]. This is the 'Unit root t-test' in PcGive. The t-values of the coefficients of D_{it-1} are compared with critical values derived from the response surfaces in Ericsson and MacKinnon (1999). The critical values are given in appendix 4.E and are calculated from the response surface for an ECM with no deterministic components as there is no constant in the estimated equation. The results are given in the column headed 'Unit root t-test' in Table 4.8 and show that, in addition to the equations identified by the Engle-Granger approach, the equation for the WoC CR category rejects the null of no cointegration. However, the equation for All WaSC's is again only significant at the 10% level. According to this test, therefore, half of the equations tested demonstrate evidence of cointegration between D_{it} and $HCAV_{it}$.

A final point worth noting is that the significance of the dummy variables in the estimated equations indicates the presence of structural breaks in the time series data and, therefore, in the residuals. Perron (1989) has shown that structural breaks can result in a loss of power in testing for unit roots making such tests more likely to accept the null of no cointegration.

Adjustment factors

Direct estimates of the short-run adjustment factors and the long run adjustment factor can be obtained from the estimated equations for the ECM in Table 4.8 by using (4.31), (4.32), (4.33) and (4.30). The estimates are set out in Table 4.10.

As noted earlier the long-run adjustment factor is constant throughout the period in all equations while the short-run adjustment factors vary between sub-periods depending on the significance of the dummy variables in each equation.

[19] Appendix 4.F illustrates how this tests for cointegration when (4.36) applies.

Table 4.10: Estimated adjustment factors based on HCAV

Equation	Short run adjustment γ_0	γ_1	γ_2	Long run adjustment α
WaSCs				
CR	0.717	0.762	0.835	0.150
NCR	0.419	0.476	0.480	0.139
All WaSCs	0.640	0.690	0.722	0.106
WoCs				
CR	0.894	0.894	1.008	0.136
NCR	0.391	0.391	0.391	0.179
All WoCs	0.806	0.806	0.876	0.190

The significance of the differences between the CR and the NCR categories was tested by re-estimating the equations for All WaSC's and All WoC's with the addition of slope dummy variables to distinguish companies in the CR category. The results are shown in Table 4.11. The coefficients and t-statistics of the variables without the CR dummy are shown in the 'No CR dummy' lines while those of the variables with the CR dummy applied are shown in the 'CR dummy' lines. The coefficients and t-statistics of the former variables are therefore the same as those in the equations for the WaSC NCR and the WoC NCR categories in Table 4.8. For comparison purposes Table 4.11 also gives the coefficients and t-statistics of the equations for the WaSC CR and the WoC CR categories in Table 4.8. This confirms that the sum of the two coefficients for each variable (i.e. with and without the CR dummy) in the re-estimated All WaSC's and All WoC's equations equals the coefficient of that variable in the respective equations for the CR categories.

Table 4.11 shows that there is no significant difference between the coef-

Table 4.11: Differences between CR and NCR categories based on HCAV

Equation		$HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	$HCAV_{it-1}$	D_{it-1}
All WaSCs						
No CR dummy	Coefficient	0.419	0.058	0.061	-0.386	0.861
	t-statistic	17.60	8.18	9.59	-13.60	34.30
CR dummy	Coefficient	0.299	-0.013	0.057	-0.310	-0.011
	t-statistic	3.45	-1.10	1.94	-2.88	-0.18
WaSC CR	Coefficient	0.717	0.045	0.118	-0.696	0.850
	t-statistic	8.61	4.95	4.14	-6.70	14.70
All WoCs						
No CR dummy	Coefficient	0.391	-	-	-0.306	0.821
	t-statistic	4.00	-	-	-4.40	7.71
CR dummy	Coefficient	0.502	-	0.114	-0.567	0.043
	t-statistic	3.40	-	3.35	-4.33	0.39
WoC CR	Coefficient	0.894	-	0.114	-0.873	0.864
	t-statistic	8.08	-	3.35	-7.87	39.20

ficients of D_{it-1} in the CR and the NCR categories indicating no significant difference in the long-run adjustment factors. Indeed, the long-run factors for both the WaSC and the WoC CR and NCR categories are all within the relatively narrow range of 0.14-0.18; the average being 0.15.

The short-run adjustment factors are higher than those for the long run in all categories indicating a more rapid response to short-run movements in $HCAV_{it}$. The short-run factors for the WaSC NCR and the WoC NCR categories are close in the first sub-period; being respectively 0.42 and 0.39. The difference in the first sub-period is wider in the CR category where the factor for the WaSC's is 0.72 while that for the WoC's is 0.89.

The short-run factors for the two CR categories are significantly higher than for the comparable NCR categories in all three sub-periods indicating that companies which have undertaken a capital restructuring since 1999/00 have consistently exhibited a faster response to short-run changes in $HCAV_{it}$ over the whole period.

The WaSC CR category shows a rising short-run factor that increases significantly after each Periodic Review and reaches 0.84 in the third sub-period. In the WaSC NCR category the short-run factors only increase from 0.42 to 0.48 in both the second and third sub-periods but the increase over the first sub-period is still significant[20]. As the CR slope dummy on $HCAV_{it}T1_t$ in the WaSC equation is not significant, the increase in the short-run factor between the first and second sub-periods is not significantly different between the two categories. However, the increase in the short-run factor appears to be significantly greater in the third-sub period for the CR category[21].

The short-run factor for WoC CR category remains at 0.89 in the second sub-period as the variable $HCAV_{it}T1_t$ is not significant but it rises to 1.0 in the third sub-period when D_{it} is, therefore, moving in step with $HCAV_{it}$. The short-run factor for the WoC NCR category remains stable at 0.39 in all three sub-periods as the variables $HCAV_{it}T1_t$ and $HCAV_{it}T2_t$ are not significant.

Target HCAV gearing levels

The parameters of the SLRM can be obtained from the estimated ECM's in Table 4.8. In the three WaSC equations the coefficients of $HCAV_{it-1}$ and D_{it-1} are constant in all sub-periods and the only significant dummy variables are the slope dummies applied to $HCAV_{it}T1_t$ and $HCAV_{it}T2_t$. Consequently, from (4.27), (4.30), (4.31), (4.32), (4.33) and (4.34), the estimated target levels of HCAV gearing for each sub-period, denoted g_0^*, g_1^* and g_2^*, are:

$$g_0^* = \frac{\widehat{\beta}_{10} + \widehat{\beta}_{20}}{1 - \widehat{\beta}_{30}}, \tag{4.38}$$

$$g_1^* = \frac{\widehat{\beta}_{10} + \widehat{\beta}_{11} + \widehat{\beta}_{20}}{1 - \widehat{\beta}_{30}}, \tag{4.39}$$

$$g_2^* = \frac{\widehat{\beta}_{10} + \widehat{\beta}_{12} + \widehat{\beta}_{20}}{1 - \widehat{\beta}_{30}}, \tag{4.40}$$

[20] The CR slope dummy on $HCAV_{it}T2_t$ gives the difference between the short-run factors in the first and third sub-periods. The difference between the short-run factors in the second and third sub-periods was tested by reconfiguring the $T1_t$ dummy so that the coefficient on $HCAV_{it}T2_t$ represented the marginal increase over that on $HCAV_{it}T1_t$. The relevant t-statistic for the WaSC CR category was 2.78. The comparable t-statistic for the WaSC NCR category was 0.90 and so the small increase in this category was not significant.

[21] Although the t-statistic for the CR slope dummy on $HCAV_{it}T2_t$ for the WaSCs is only borderline significant the t-statistic is significant if the insignificant CR slope dummies on $HCAV_{it}T1_t$ and D_{it-1} are omitted from the re-estimated All WaSCs equation.

and the long-run solution to the estimated ECM is:

$$\widehat{D^*}_{it} = \left(\frac{\widehat{\beta}_{10} + \widehat{\beta}_{20}}{1 - \widehat{\beta}_{30}}\right) HCAV_{it} + \left(\frac{\widehat{\beta}_{11}}{1 - \widehat{\beta}_{30}}\right) HCAV_{it}T1_t + \left(\frac{\widehat{\beta}_{12}}{1 - \widehat{\beta}_{30}}\right) HCAV_{it}T2_t. \tag{4.41}$$

Similar solutions can be derived from the three WoC equations. In addition, PcGive uses an algorithm to derive standard errors for the long-run parameters from which t-statistics can be obtained to test their significance. The solutions for each of the equations in Table 4.8 are set out in Table 4.12.

Table 4.12: SLRM results based on HCAV

Equation		Variable			HCAV Gearing		
		$HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	g_0* %	g_1* %	g_2* %
WaSCs							
CR	Coefficient	0.143	0.301	0.785	14.3	44.4	92.8
	t-statistic	1.53	2.36	5.49			
NCR	Coefficient	0.236	0.418	0.441	23.6	65.4	67.7
	t-statistic	9.65	9.63	10.13			
All WaSCs	Coefficient	0.120	0.478	0.781	12.0	59.8	90.1
	t-statistic	1.53	5.82	4.01			
WoCs							
CR	Coefficient	0.154	-	0.837	15.4	15.4	99.1
	t-statistic	2.91		4.33			
NCR	Coefficient	0.478	-	-	47.8	47.8	47.8
	t-statistic	12.13					
All WoCs	Coefficient	0.252	-	0.368	25.2	25.2	61.9
	t-statistic	2.99		1.55			

The estimates of the target level of HCAV gearing for the WaSC CR category increase significantly after each Periodic Review while for the NCR category there is only a significant increase in the second sub-period[22]. The

[22] Similarly to the test for the short-run adjustment factors the difference between the target level of gearing in the second and third sub-periods was tested by reconfiguring the $T1_t$ dummy so that the coefficient on $HCAV_{it}T2_t$ represented the marginal increase over that on $HCAV_{it}T1_t$. The relevant t-statistic for the WaSC CR category was 20.68. The comparable t-statistic for the WaSC NCR category was 0.88 and so the small increase in this category was not significant.

estimated target of 14.3% for the WaSC CR category in the first sub-period is not significant and is relatively low compared with the figure of 23.6% for the WaSC NCR category. This might reflect the fact that, unlike the NCR category, average HCAV gearing in the CR category actually declined in 1994/95; the last year of the sub-period. The target for the WaSC CR category is also lower than that for the WaSC NCR category in the second sub-period.

In the the third period the estimated targets for both the WaSC and WoC CR categories increase to more than 90%. While the capital restructurings were intended to achieve gearing levels in excess of 75% these estimates should be treated with caution. They could be distorted because the third sub-period only covers three years and many of the companies in these categories only implemented the restructuring in 2002/03; the last year of the sub-period.

The estimate of target HCAV gearing for the WoC CR category in the first two sub-periods is unchanged at 15.4% as the variable $HCAV_{it}T1_t$ is not significant. This is considerably lower than the estimated target for the WoC NCR category which is constant at 47.8% in all three sub-periods as the variables $HCAV_{it}T1_t$ and $HCAV_{it}T2_t$ are not significant.

Supplementary results

The predicted values of the long-run equilibrium level of debt obtained from the SLRM results can also be used to estimate an ECM similar in form to (4.19), that is:

$$\begin{aligned}\Delta D_{it} &= \widehat{\beta}_{10}\Delta HCAV_{it} + \widehat{\beta}_{11}\Delta\left(HCAV_{it}T1_t\right) + \widehat{\beta}_{12}\Delta\left(HCAV_{it}T2_t\right) \\ &\quad - \left(1 - \widehat{\beta}_{30}\right) CI_{it-1} + \widehat{u}_{it}, \end{aligned} \tag{4.42}$$

where:

$$CI_{it} = D_{it} - \widehat{D^*}_{it}, \tag{4.43}$$

and $\widehat{D^*}_{it}$ is calculated from (4.41).

The variables $\Delta(HCAV_{it}T1_t)$ and $\Delta(HCAV_{it}T2_t)$ are included in the estimates of (4.42) when $HCAV_{it}T1_t$ and $HCAV_{it}T2_t$ are present in the corresponding ECM equation for each category. The estimated parameters of (4.42), therefore, provide further estimates of the short-run and long-run adjustment factors.

Stage II of the Engle-Granger procedure follows a similar approach by using the predicted values from the long-run model in Stage I to estimate the ECM. The form of the Stage II equation in this instance is, therefore:

$$\begin{aligned}\Delta D_{it} &= \widehat{\beta}_{10}\Delta HCAV_{it} + \widehat{\beta}_{11}\Delta\left(HCAV_{it}T1_t\right) + \widehat{\beta}_{12}\Delta\left(HCAV_{it}T2_t\right) \\ &\quad - \left(1-\widehat{\beta}_{30}\right)R_{it-1} + \widehat{u}_{it},\end{aligned} \tag{4.44}$$

where R_{it} are the residuals ($= \widehat{e}_{it}$) calculated from (4.35).

The results for both (4.42) and (4.44) are presented in appendix 4.G. As both equations use predicted values from other estimated equations the results are less satisfactory than the results in Table 4.8. There are more failures in the diagnostic tests and, in some equations, the t-statistics are not significant. However, the values of the estimated adjustment factors are very similar in absolute terms to those in Table 4.10.

4.6.3 Results based on RCV

Initial equation

RCV's were introduced by Ofwat for the 1994 Periodic Review and the original method of calculation is described in Ofwat (1993). Briefly, an initial value for each WaSC was established using their market values following privatization and a broadly similar measure was devised for each of the WoC's since they were already in the private sector. This initial value was then adjusted to take account of new capital expenditure allowed in setting price limits net of current cost depreciation. At the 1999 Periodic Review the methodology was amended and a rolling annual adjustment was introduced under which RCV's were reduced to reflect past capital efficiencies. This allowed the benefit of capital efficiencies to be passed to customers through lower prices after being retained by the companies for five years. It also avoided a growing divergence between the increase in RCV and the actual change in asset values recorded in the companies' regulatory accounts.

The methodology and the estimation procedure used to produce the initial equations when RCV is used as the measure of capital value are the same as described above for the HCAV measure. The PcGive outputs containing the OLS estimates of (4.26) for each type and category of company are given in appendix 4.H.1.

The initial equations for All WaSC's, and for the WaSC NCR, WoC CR and NCR categories accept the test against heteroscedasticity and the RESET. However, the initial equations for All WoC's and the WaSC CR category fail both the RESET and the heteroscedasticity test. The t-statistics in all six equations are low indicating that model reduction is required.

As before three tests for first order serial correlation have been applied and the results of the tests are given in appendix 4.H.2. Only the WaSC CR equation fails test 1 while none of the six initial equations fail test 2. Very limited evidence of serial correlation is provided by test 3. Just two companies exhibit evidence of serial correlation using the residuals from the All WoC's equation and there is no evidence of serial correlation for any of the companies when the residuals from the All WaSC's equation and any of the equations for the CR and NCR categories are used.

It seems reasonable to conclude from these results that the initial equations provide consistent estimates of $\boldsymbol{\beta}$.

Model reduction

The results of the model reduction procedure are much less satisfactory when RCV is used as the measure of capital value. The variables that are retained as significant vary considerably between equations as can be seen in Table 4.13.

Table 4.13: Model reduction based on RCV

Equation	Significant variables after model reduction
WaSC CR	$RCV_{it-1}T1_t, D_{it-1}, D_{it-1}T1_t$.
WaSC NCR	$RCV_{it}, RCV_{it}T1_t, RCV_{it-1}T1_t, D_{it-1}, D_{it-2}T2_t$.
All WaSCs	$RCV_{it}T2_t, RCV_{it-1}T1_t, D_{it-1}, D_{it-1}T1_t, D_{it-2}, D_{it-2}T1_t$.
WoC CR	$RCV_{it-1}T2_t, D_{it-1}, D_{it-2}T2_t$.
WoC NCR	$RCV_{it}, RCV_{it-1}, RCV_{it}T1_t, RCV_{it-1}T1_t, RCV_{it}T2_t, RCV_{it-1}T2_t, D_{it-1}$.
All WoCs	$RCV_{it}, RCV_{it-1}, RCV_{it-1}T2_t, D_{it-1}, D_{it-2}T2_t$.

As the reduction procedure does not produce plausible models a different approach has been adopted. In view of the high correlation between HCAV and RCV shown in Table 4.5, models corresponding to those derived using HCAV data have been tested and, as might be expected, these are more successful. However, the lagged variable RCV_{it-1} is not significant in the any of the resulting equations and its coefficient, $\widehat{\beta}_{20}$, also has the lowest t-statistic in the equations for All WaSC's, All WoC's and the WoC NCR category. Consequently, the final estimated equations take the form of a PAM as follows:

$$D_{it} = \widehat{\beta}_{10} RCV_{it} + \widehat{\beta}_{11} RCV_{it} T1_t + \widehat{\beta}_{12} RCV_{it} T2_t + \widehat{\beta}_{30} D_{it-1} + \widehat{u}_{it}. \quad (4.45)$$

with the variables $RCV_{it}T1_t$ and $RCV_{it}T2_t$ being eliminated if the coefficients of either or both are not significant.

As in the equations based on HCAV, $\widehat{\beta}_{10}, \widehat{\beta}_{11}, \widehat{\beta}_{12} > 0$ in all the WaSC equations, $\widehat{\beta}_{10} > 0, \widehat{\beta}_{11} = 0$ in all the WoC equations while $\widehat{\beta}_{12} > 0$ for the WoC CR category and $\widehat{\beta}_{12} = 0$ for the WoC NCR category. However, unlike the HCAV results, $\widehat{\beta}_{12} = 0$ in the equation for All WoC's.

Estimates of the parameters of the PAM can, therefore, be obtained from the final equations and the form of these equations imposes a number of restrictions on the parameters.

Firstly, in all equations the constant term is eliminated. This is consistent with the form of the PAM derived in (4.7).

Secondly, in all equations $\widehat{\beta}_{30} > 0$ and $\widehat{\beta}_{31} = \widehat{\beta}_{32} = 0$ (i.e. the associated slope dummies are not significant). Consequently, the coefficient of D_{it-1} does not vary between sub-periods which implies that the adjustment factor in (4.7), does not change following Periodic Reviews as it is estimated by:

$$\alpha = 1 - \widehat{\beta}_{30}. \quad (4.46)$$

Thirdly, in all equations $\widehat{\beta}_{10} > 0$. As $\widehat{\beta}_{11}, \widehat{\beta}_{12} > 0$ in the WaSC equations (i.e. the associated slope dummies are significant), this implies that, g^*, the target level of RCV gearing in (4.7) varies between sub-periods. In terms of the notation used in (4.7) the estimated target level of RCV gearing for each sub-period is given by:

$$g_0^* = \frac{\widehat{\beta}_{10}}{1 - \widehat{\beta}_{30}}, \quad (4.47)$$

$$g_1^* = \frac{\widehat{\beta}_{10} + \widehat{\beta}_{11}}{1 - \widehat{\beta}_{30}}, \quad (4.48)$$

$$g_2^* = \frac{\widehat{\beta}_{10} + \widehat{\beta}_{12}}{1 - \widehat{\beta}_{30}}. \quad (4.49)$$

However, in the WoC CR category, since $\widehat{\beta}_{11} = 0$ and $\widehat{\beta}_{12} > 0$, the target level of RCV gearing only varies between the second and third sub-periods (i.e. $g_0^* = g_1^*$). Further, the equations for All WoC's and for the WoC NCR category indicate the target level of RCV gearing is the same in all three sub-periods since $\widehat{\beta}_{11} = \widehat{\beta}_{12} = 0$ (i.e. $g_0^* = g_1^* = g_2^*$).

Final estimates

The final estimates are set out in Table 4.14 and the PcGive outputs are given in appendix 4.H.3.

Diagnostic tests

The diagnostic tests applied to the final estimates are also shown in Table 4.14 and reveal more problems than the corresponding HCAV results. Again the most serious problem is heteroscedasticity but in these results the WoC CR category also fails both tests so that four of the six equations fail the test using the squares of the regressors and five equations fail the test based on the squares and the cross-products of the regressors. As before the t-statistics are based on robust standard errors to correct for this problem. Only the WaSC NCR equation accepts the heteroscedasticity tests. The equation for the WaSC CR category also fails the RESET. There was no evidence of serial correlation in the HCAV results but here the tests are rejected in the All WaSC's and WoC CR equations indicating the estimated coefficients in these equations are biased since the lagged dependent variable, D_{it-1}, is an explanatory variable. However, a Wald test decisively rejects the null hypothesis that all of the coefficients are zero in all equations.

Tests for cointegration

As before three approaches to testing for cointegration have been used.

The first simply applies ADF tests to the residuals, $\widehat{u}_{it}$, of the equations in Table 4.14 using the pooled data. As before a constant is included in the tests as none of the original equations contain a constant. Table 4.14 shows these tests reject the null hypothesis that the residuals from all equations are non-stationary at the 1% significance level. This suggests that it would be worthwhile conducting more sophisticated tests for cointegration.

The second approach uses Stage I of the two-stage procedure in Engle and Granger (1987) which estimates the long-run relationship between D_{it} and RCV_{it} and then tests whether the residuals are stationary. The results

Table 4.14: PAM results based on RCV

Equation		Variable RCV_{it}	$RCV_{it}T1_t$	$RCV_{it}T2_t$	D_{it-1}	Adjustmen factor α	Adjusted R^2	ADF t-test	Unit root t-test	Diagnostic tests rejected
WaSCs										
CR	Coefficient	0.068	0.030	0.106	0.898	0.102	0.974	-5.28 [1]	-1.02	N [1], H [1], HX [1], R [5]
	t-statistic	2.38	2.87	4.62	8.93					
NCR	Coefficient	0.088	0.065	0.060	0.715	0.285	0.988	-6.99 [1]	-11.1 [1]	N [1]
	t-statistic	9.86	7.59	4.83	27.80					
All WaSCs	Coefficient	0.076	0.044	0.052	0.832	0.168	0.977	-6.09 [1]	-2.93	A1 [5], N [1], HX [5]
	t-statistic	6.64	4.87	4.77	14.50					
WoCs										
CR	Coefficient	0.045	-	0.136	0.835	0.165	0.872	-5.79 [1]	-4.72 [5]	A2 [5], N [1], H [1], HX [1]
	t-statistic	2.40		2.49	23.90					
NCR	Coefficient	0.069	-	-	0.817	0.183	0.985	-7.61 [1]	-6.30 [1]	N [1], H [1], HX [1]
	t-statistic	6.29			28.10					
All WoCs	Coefficient	0.074	-	-	0.818	0.182	0.954	-5.90 [1]	-4.24 [1]	N [1], H [5], HX [5]
	t-statistic	5.28			19.00					

NOTES

t-statistic Calculated using robust standard errors from panel data models.

Adjusted R^2 Calculated from $1 - \text{Adj}R^2 = (1 - R^2)(n-1)/(n-k)$ where $1 - R^2 = RSS / \Sigma D_{it}^2$,
RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.

ADF t-test Augmented Dickey-Fuller test on t-statistic for the coefficient of residual_{t-1} with $\Delta\text{residual}_t$ as the regressand.
Critical values (for test including a constant) are from MacKinnon (1991).

Unit root t-test Test on t-statistic for the coefficient of D_{it-1} with ΔD_{it} as the regressand instead of D_{it}.
Critical values (for test with no deterministic components) are from Ericsson and MacKinnon (1999).

Diagnostic tests

		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	All the models reject the null that all the coefficients are zero at the 1% significance level.
	AR(1)	A1	Tests the null of no first order serial correlation.
	AR(2)	A2	Tests the null of no second order serial correlation.
Significance levels f	1%	[1]	
	5%	[5]	
	10%	[10]	

in Table 4.14 indicate the long-run relationship for all the WaSC categories should be estimated in the following form:

$$D_{it} = \widehat{b}_1 RCV_{it} + \widehat{b}_2 RCV_{it} T1_t + \widehat{b}_3 RCV_{it} T2_t + \widehat{e}_{it}, \tag{4.50}$$

where $\widehat{e}_{it}$ are the residuals. Similarly, for the WoC CR category the long-run relationship should be (4.50) with $\widehat{\beta}_2 = 0$ while that for All WoC's and the WoC NCR category should be (4.50) with $\widehat{\beta}_2 = \widehat{\beta}_3 = 0$. The Engle-Granger Stage I results are set out in Table 4.15. Again it is possible to add another observation and use all 13 observations for each company.

The ADF tests on the residuals of the equations in Table 4.15 have been applied in the same way as previously and again show that only the equations for All WaSC's and for the WaSC NCR category reject the null hypothesis of no cointegration but, in both cases, only at the 10% level.

As noted earlier the Engle-Granger approach imposes a common factor restriction on the dynamics of the relationship. Appendix 4.F, shows that in the case of the PAM this restriction has the effect of imposing the condition that:

$$\alpha = 1. \tag{4.51}$$

This is the limiting case of the PAM in which there is full adjustment to the long-run equilibrium in each period. In other words, applying the Engle-Granger procedure to a PAM assumes the SLRM applies. Clearly, this assumption is likely to be invalid.

The relatively large number of failures in the diagnostic tests shown in Table 4.15 again demonstrate that the estimates of the parameters obtained in the Stage I equations are likely to be biased.

The third approach uses a 'Unit root t-test' to test for cointegration. The PAM is transformed by using ΔD_{it} as the regressand instead of D_{it} which provides a direct estimate of the adjustment factor α together with a t-statistic which can be tested for significance and, thereby, for cointegration between the variables D_{it} and RCV_{it}. The test is applied in the same way as before and the results are given in Table 4.14. This shows that, unlike the results from the Engle-Granger approach, the equations for all of the WoC categories reject the null of no cointegration and it is not rejected by the All WaSC's equation. Only the WaSC NCR category rejects the null for both tests. Consequently, according to this test, four of the six equations demonstrate evidence

Table 4.15: Engle-Granger Stage I results based on RCV

Equation		Variable RCV_{it}	$RCV_{it}T1_t$	$RCV_{it}T2_t$	Adjusted R^2	ADF t-test	Diagnostic tests rejected
WaSCs							
CR	Coefficient	0.260	0.134	0.355	0.938	-4.26	N [1], H [1], HX [1]
	t-statistic	5.75	3.06	5.01			
NCR	Coefficient	0.155	0.198	0.317	0.960	-4.78 [10]	A1 [5], H [1], HX [1], R [1]
	t-statistic	7.02	7.53	11.60			
All WaSC s	Coefficient	0.183	0.180	0.331	0.940	-4.54 [10]	A1 [5], N [1], H [5], HX [5]
	t-statistic	7.80	7.48	11.30			
WoCs							
CR	Coefficient	0.276	-	0.134	0.745	-2.93	N [1], H [5], HX [5], R [1]
	t-statistic	3.48		1.61			
NCR	Coefficient	0.309	-	-	0.963	-2.86	H [1], HX [1], R [1]
	t-statistic	17.50					
All WoC s	Coefficient	0.311	-	-	0.910	-2.92	A1 [5], A2 [5], N [1], H [1], HX [1]
	t-statistic	17.70					

NOTES

t-statistic Calculated using robust standard errors from panel data models.

Adjusted R^2 Calculated from $1 - AdjR^2 = (1 - R^2)(n - 1)/(n - k)$ where $1 - R^2 = RSS / \Sigma D_{it}^2$,
RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.

ADF t-test Augmented Dickey-Fuller test on t-statistic for the coefficient of $residual_{t-1}$ with $\Delta residual_t$ as the regressand.
Critical values (for test including a constant) are from MacKinnon (1991).

Diagnostic tests

		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	All the models reject the null that all the coefficients are zero at the 1% significance level.
	AR(1)	A1	Tests the null of no first order serial correlation.
	AR(2)	A2	Tests the null of no second order serial correlation.

Significance levels	1%	[1]
	5%	[5]
	10%	[10]

of cointegration between D_{it} and RCV_{it}.

Adjustment factors

Direct estimates of the adjustment factors can be obtained from the estimated equations in Table 4.14 by using (4.46). They are constant throughout the period and the estimated factors for each category are set out in Table 4.14. Differences between the CR and the NCR categories have been tested for significance in the same way as for the HCAV results, that is, by applying slope dummy variables to the data for companies in the CR category and re-estimating the equations for All WaSC's and All WoC's. The results are shown in Table 4.16 (using the same format as Table 4.11).

Table 4.16: Differences between CR and NCR categories based on RCV

Equation		RCV_{it}	$RCV_{it}T1$	$RCV_{it}T2$	D_{it-1}
All WaSCs					
No CR dummy	Coefficient	0.088	0.065	0.060	0.715
	t-statistic	9.86	7.59	4.83	27.80
CR dummy	Coefficient	-0.020	-0.035	0.046	0.183
	t-statistic	-0.67	−2.64	1.75	1.76
WaSC CR	Coefficient	0.068	0.030	0.106	0.898
	t-statistic	2.38	2.87	4.62	8.93
All WoCs					
No CR dummy	Coefficient	0.069	-	-	0.817
	t-statistic	6.29	-	-	28.10
CR dummy	Coefficient	-0.024	-	0.136	0.018
	t-statistic	-1.09	-	2.49	0.41
WoC CR	Coefficient	0.045	-	0.136	0.835
	t-statistic	2.40	-	2.49	23.90

Table 4.16 shows that there is no significant difference between the coefficients of D_{it-1} and, therefore, in the adjustment factors for the CR and the NCR categories.

The adjustment factors for both the WaSCs and the WoCs are all within the range 0.10-0.29; the average being 0.18. As they are all constant throughout the period, differences between the other coefficients reflect differences in target gearing levels and these are considered next.

Target RCV gearing levels

The parameters of the SLRM can be obtained from the estimated equations in Table 4.14. In the three WaSC equations the coefficient of D_{it-1} is constant in all sub-periods and the only significant dummy variables are the slope dummies applied to $HCAV_{it}T1_t$ and $HCAV_{it}T2_t$. Consequently, from (4.45), (4.46), (4.47), (4.48) and (4.49), the long-run solution to the estimated PAM is:

$$\widehat{D^*}_{it} = \left(\frac{\widehat{\beta}_{10}}{1-\widehat{\beta}_{30}}\right) RCV_{it} + \left(\frac{\widehat{\beta}_{11}}{1-\widehat{\beta}_{30}}\right) RCV_{it}T1_t + \left(\frac{\widehat{\beta}_{12}}{1-\widehat{\beta}_{30}}\right) RCV_{it}T2_t. \tag{4.52}$$

Similar solutions can be derived for the three WoC equations.

The results for the equations in Table 4.14 are set out in Table 4.17.

Table 4.17: SLRM results based on RCV

Equation		Variable			Gearing		
		RCV_{it}	$RCV_{it}T1_t$	$RCV_{it}T2_t$	g_0^* %	g_1^* %	g_2^* %
WaSCs							
CR	Coefficient	0.665	0.288	1.039	66.5	95.4	170.4
	t-statistic	1.75	1.40	1.16			
NCR	Coefficient	0.309	0.227	0.212	30.9	53.7	52.1
	t-statistic	10.45	8.31	6.61			
All WaSC s	Coefficient	0.454	0.260	0.311	45.4	71.3	76.4
	t-statistic	4.59	4.81	2.56			
WoCs							
CR	Coefficient	0.275	-	0.827	27.5	27.5	110.3
	t-statistic	2.52		2.11			
NCR	Coefficient	0.377	-	-	37.7	37.7	37.7
	t-statistic	35.48					
All WoC s	Coefficient	0.406	-	-	40.6	40.6	40.6
	t-statistic	10.99					

The t-statistics for the WaSC CR equation are not significant and so the SLRM does not provide reliable estimates of the target levels of RCV gearing for this category. Indeed, the targets calculated from the estimated parameter values do not look plausible. However, the t-statistics are significant in the other equations. The estimates of the target level of RCV gearing for the WaSC NCR category increase significantly from 30.9% to 53.7% in the second sub-period but not in the third[23].The estimate of target RCV gearing for the WoC CR category in the first two sub-periods is unchanged at 27.5% as the variable $RCV_{it}T1_t$ is not significant. This is considerably lower than the estimated target for the WoC NCR category which is constant at 37.7% in all three sub-periods as the variables $RCV_{it}T1_t$ and $RCV_{it}T2_t$ are not significant. In the the third period the estimated target for the WoC CR category increases to much more 100% which is not plausible. Again this result is likely to be distorted because the third sub-period only covers three years and many of the companies in these categories only implemented the restructuring in 2002/03; the last year of the sub-period.

Supplementary results

The predicted values of the long-run equilibrium level of debt obtained from the SLRM results can also be used to estimate a PAM in the alternative form:

$$\Delta D_{it} = -\frac{1-\widehat{\beta}_{30}}{\widehat{\beta}_{30}} CI_{it} + \widehat{\nu}_{it}, \tag{4.53}$$

where:

$$CI_{it} = D_{it} - \widehat{D^*}_{it}, \tag{4.54}$$

and $\widehat{D^*}_{it}$ is calculated from (4.52).The estimated parameters of (4.53), therefore, provide further estimates of the adjustment factors. This approach is similar to Stage II of the Engle-Granger procedure which uses the predicted values from the long-run model in Stage I to estimate the PAM. The estimated form of the Stage II equation in this instance is, therefore:

$$\Delta D_{it} = -\frac{1-\widehat{\beta}_{30}}{\widehat{\beta}_{30}} R_{it} + \widehat{\nu}_{it}, \tag{4.55}$$

where R_{it} are the residuals ($= \widehat{e}_{it}$) calculated from (4.50).

The derivation of (4.53) and (4.55) and the results from estimating both equations are presented in appendix 4.I. As might be expected the results

[23] As before the difference between the target level of gearing in the second and third sub-periods was tested by reconfiguring the $T1_t$ dummy so that the coefficient on $RCV_{it}T2_t$ represented the marginal increase over that on $RCV_{it}T1_t$. The relevant t-statistic for the WaSC NCR category was -0.64 which is not significant.

are less satisfactory than those in Table 4.14. There are more failures in the diagnostic tests and in some equations the t-statistics are not significant. However, the adjustment factors estimated using (4.53) are very similar in absolute terms to those in Table 4.14 apart from the equation for All WoC's where the coefficient has the wrong sign and is not significant. The coefficients in the estimates of (4.55) all have the wrong sign.

4.6.4 Comparison of results based on HCAV and RCV

The previous discussion has already indicated that in many respects the estimated PAM's based on RCV data are less satisfactory than the estimated ECM's based on HCAV data. However, the two sets of models can be compared more formally by using encompassing tests. Three tests have been applied:

1. the Davidson and MacKinnon (1981) J-test,
2. a test based on the optimum combination of forecasts of D_{it} from each ECM and the corresponding PAM and
3. F-tests on a comprehensive model incorporating all the variables from each ECM and the corresponding PAM.

All three tests are concerned with testing the two non-nested hypotheses:

$$\begin{aligned} H_0 \quad &: \quad D_{it} = \beta_1 HCAV_{it} + \beta_2 HCAV_{it}T1_t + \beta_3 HCAV_{it}T2_t \\ &\qquad + \beta_4 HCAV_{it-1} + \beta_5 D_{it-1} + u_{0it}, \qquad (4.56) \\ H_1 \quad &: \quad D_{it} = \phi_1 RCV_{it} + \phi_2 RCV_{it}T1_t + \phi_3 RCV_{it}T2_t + \phi_5 D_{it-1} + u_{1it}. \qquad (4.57) \end{aligned}$$

With the appropriate restrictions on the parameters these hypotheses can be applied to each of the equations for the WaSC's and the WoC's. For simplicity the two hypotheses are written as:

$$H_0 \quad : \quad D_{it} = D_{it}^{HCAV} + u_{0it}, \qquad (4.58)$$

$$H_1 \quad : \quad D_{it} = D_{it}^{RCV} + u_{1it}, \qquad (4.59)$$

and the predicted values are respectively $\widehat{D}_{it}^{HCAV}$ and $\widehat{D}_{it}^{RCV}$.

The Davidson and MacKinnon J-test is a variance encompassing test which involves estimating the two equations:

$$
\begin{aligned}
D_{it} &= D_{it}^{HCAV} + \lambda \widehat{D}_{it}^{RCV} + \varepsilon_{0it}, && (4.60)\\
D_{it} &= D_{it}^{RCV} + \theta \widehat{D}_{it}^{HCAV} + \varepsilon_{1it}, && (4.61)
\end{aligned}
$$

and then testing the two null hypotheses $\lambda = 0$ and $\theta = 0$. If the former is not rejected then H_0 is not rejected by H_1 and if the latter is not rejected then H_1 is not rejected by H_0. It is, however, also possible for both H_0 and H_1 to be accepted or rejected by this test. The results of the test are set out in Table 4.18 [24].

Table 4.18: Davidson and MacKinnon J-test

	$H_0 : \lambda = 0$		$H_1 : \theta = 0$	
	λ	t-statistic	θ	t-statistic
WaSC CR	-1.584	-3.12	1.056	11.20
WaSC NCR	1.153	7.99	0.821	3.91
All WaSCs	0.084	0.20	0.997	11.70
WoC CR	0.523	0.88	0.986	10.00
WoC NCR	0.760	1.46	0.851	2.22
All WoCs	0.247	0.86	0.985	7.21

The Table shows that H_1 is rejected by H_0 and H_0 is not rejected by H_1 in the equations for All WaSC's, All WoC's and for the WoC CR and WoC NCR categories. The t-statistics for θ in these equations are all significant at the 1% level except for the WoC NCR equation where it is significant at the 5% level. This indicates that, in these categories the ECM's based on HCAV data are superior. However, the t-statistics for λ are also significant at the 1% level in the WaSC CR and WaSC NCR equations and so the test is inconclusive for these two categories as both H_0 and H_1 are rejected.

The second test uses the results from the two models to determine the optimum combination of forecasts by estimating:

$$D_{it} = (1 - \delta)\, \widehat{D}_{it}^{HCAV} + \delta \widehat{D}_{it}^{RCV} + \nu_{it}, \qquad (4.62)$$

[24] Where appropriate the t-statistics in this Table and the next have been adjusted for heteroscedasticity.

which can also be written as the two equations:

$$D_{it} - \widehat{D}_{it}^{HCAV} = \delta\left(\widehat{D}_{it}^{RCV} - \widehat{D}_{it}^{HCAV}\right) + \nu_{it}, \tag{4.63}$$

$$D_{it} - \widehat{D}_{it}^{RCV} = -(1-\delta)\left(\widehat{D}_{it}^{RCV} - \widehat{D}_{it}^{HCAV}\right) + \nu_{it}. \tag{4.64}$$

Estimating (4.63) and (4.64) makes it possible to test the two hypotheses $\delta = 0$ and $-(1-\delta) = 0$. If the former is rejected then H_1 explains D_{it} over and above H_0 and if the latter is rejected H_0 explains D_{it} over and above H_1. Again it is possible for both H_0 and H_1 to make a significant contribution to the explanation of D_{it}. The results of this test are given Table 4.19.

Table 4.19: Optimum combination of forecasts test

	$H_0 : \delta = 0$		$H_1 : -(1-\delta) = 0$	
	δ	t-statistic	$-(1-\delta)$	t-statistic
WaSC CR	-0.048	-0.52	-1.048	-11.50
WaSC NCR	0.192	0.96	-0.807	-4.00
All WaSCs	0.004	0.02	-0.996	-5.63
WoC CR	0.014	0.15	-0.986	-10.20
WoC NCR	0.227	0.98	-0.773	-3.33
All WoCs	0.016	0.21	-0.984	-12.30

The Table shows that in all the equations H_0 explains D_{it} over and above H_1 and that H_1 does not add anything to explaining D_{it} over H_0. The t-statistics for $-(1-\delta)$ are all significant at the 1% level. Consequently, according to this test, the ECM's based on HCAV data are superior to the PAM's based on RCV data in all cases.

In the third test the comprehensive model:

$$D_{it} = D_{it}^{HCAV} + D_{it}^{RCV} + \epsilon_{it}, \tag{4.65}$$

is estimated and F-tests, which are mean encompassing, are applied to the parameters of the variables in D_{it}^{HCAV} and D_{it}^{RCV} that are not common to both. In this instance D_{it-1} is the only common variable. Consequently, testing whether the coefficients of the non-overlapping variables in D_{it}^{HCAV} are significantly different from zero is a test of H_1 and, conversely, testing whether the coefficients of the non-overlapping variables in D_{it}^{RCV} are significantly different from zero is a test of H_0. Again it is possible for the tests to be inconclusive. The results of the tests are set out in Table 4.20 with the significance levels given in parentheses.

Table 4.20: F- test

	H_0 : F-test on D_{it}^{RCV} (exc D_{it-1})	H_1 : F-test on D_{it}^{HCAV} (exc D_{it-1})
WaSC CR	F(3,52)=5.206 [1]	F(4,52)=41.261 [1]
WaSC NCR	F(3,52)=1.534	F(4,52)=4.715 [1]
All WaSCs	F(3,112)=2.068	F(4,112)=36.954 [1]
WoC CR	F(2,66)=0.535	F(3,66)=33.324 [1]
WoC NCR	F(1,68)=3.156	F(2,68)=6.577 [1]
All WoCs	F(1,139)=0.618	F(3,139)=49.256 [1]

According to this test, therefore, the ECM's based on HCAV data are superior to the PAM's based on RCV data except in the WaSC CR category where the result is inconclusive.

The overall conclusion that can be drawn from the three sets of test results is that, generally, the ECM's based on HCAV data are superior to the PAM's based on RCV data although the results for the WaSC CR category are inconclusive for two of the three tests. The implication is that in the period under consideration the water companies considered HCAV gearing a more important measure of capital structure than that based on Ofwat's calculation of RCV.

4.7 The Results: Individual Companies

4.7.1 Approach

The ECM's based on HCAV data and the PAM's based on RCV data described in the previous section were also applied to the data on each of the 22 companies. The form of the equation that was estimated for each company corresponds to the model for the relevant category. As before the associated SLRM's were derived from the estimated equations. The detailed results are set out in appendix 4.J. As there are only 12 observations for each company the results are generally less satisfactory than those for the pooled data.

4.7.2 Results based on HCAV

In only six of the 22 estimated ECM equations based on HCAV data are all of the variables significant and there are no equations with no significant variables. Also there are ECM equations for two companies that do not converge to a long-run solution because the long-run adjustment factor, α, exceeds unity.

Diagnostic checks show that four of the ECM equations fail the RESET of which three are in CR categories. One equation fails a test for first order autocorrelation and one fails the AutoRegressive Conditional Heteroscedasticity (ARCH) test. The small number of observations prevent use of the test for heteroscedasticity based on the squares and cross-products of the regressors and the test for heteroscedasticity based on the squares of the regressors is limited to companies in the WoC NCR category but there are no failures. This suggests that the failures of the heteroscedasticity tests in the cross-section models were caused by the different sizes of the companies. The unit root t-test for cointegration between the variables is significant in only one equation.

4.7.3 Results based on RCV

The PAM equations based on RCV data again performed less well. In only one equation are all the variables significant and there are two equations in which no variables are significant. There are four companies where the PAM does not converge to a long-run solution and these include the two companies where the ECM does not have a long-run solution.

Diagnostic checks show that seven of the PAM equations fail the RESET, five of which are in the WoC CR category, and two of these also fail the ARCH test. Again the only available test for heteroscedasticity is that based on the squares of the regressors but it can be applied to all the WoC equations. The test is rejected in three cases also in the WoC CR category. In most cases where the ECM equation fails diagnostic tests then the PAM equation also fails. Again there is limited evidence of cointegration with the Unit root t-test being significant in two equations.

4.7.4 Adjustment factors

The estimated adjustment factors derived from the equations for each company are summarized in Table 4.21. Ranges are given, where possible, for each category of company and they are derived from parameter values which are significant in the estimated equations. Six ECM equations and seven PAM equations have been excluded because the parameter values are above unity and/or the equation fails the RESET.

Table 4.21: Adjustment factors - individual company estimates

	ECM				PAM
	γ_0	γ_1	γ_2	α	α
WaSC CR	0.54-0.89	0.53-0.94	0.64-0.78	0.36-0.41	0.26-0.40
WaSC NCR	0.39-0.64	0.46-0.69	0.46-0.76	0.09-0.32	0.26-0.35
WoC CR	0.51-0.97	-	0.69-0.96	0.34-0.39	0.45
WoC NCR	0.54-0.76	-	-	0.24-0.49	0.20-0.44

The ranges for the adjustment factors are generally in line with those estimated in the models using pooled data although the long-run adjustment factors, α, are somewhat higher.

4.7.5 Target gearing levels

As in the previous section estimates of target gearing levels can be obtained from the parameters of the SLRM's derived from the estimated ECM's and PAM's. The estimates are given in Table 4.22. Ranges are given, where possible, for each category of company and are based on parameter values which are significant in the SLRM's. Two equations from the ECM's do not have long-run solutions and the results from two other equations that fail the RESET are also excluded. Similarly, four of the PAM's do not have long-run solutions and three others that fail the RESET are excluded.

Table 4.22: Target gearing - individual company estimates

	SLRM from ECM			SLRM from PAM		
	g_0^* %	g_1^* %	g_2^* %	g_0^* %	g_1^* %	g_2^* %
WaSC CR	13-45	27-44	63-86	41-54	54-56	37-104
WaSC NCR	23	24-60	46-61	25-30	49-56	48-53
WoC CR	22-41	22-41	24-57	52	52	42
WoC NCR	22-50	22-50	22-50	19-37	19-37	19-37

The ranges for the targets derived from the ECM's are generally in line with those estimated in the cross-section and panel data models apart from the WoC CR category where the range for g_2^* is quite low. The ranges derived from the PAM's for the WaSC CR and WoC CR categories are lower than those for the cross-section and panel data models but this reflects the weakness of the

SLRM relating to the WaSC CR category where none of the parameters are significant and, as noted above, the diagnostic tests revealed major problems with five of the six equations in the WoC CR category.

4.8 Interpretation of Results

4.8.1 Comparing the theories of capital structure

Although the available data only covers a relatively short period of time, the results set out above provide reasonable evidence that water companies have behaved, at least when viewed collectively, as though they managed their finances with a target capital structure in mind. As explained in section 4.1, while this is consistent with the trade-off theory of capital structure, in a regulated environment it is also important to assess whether the companies have tried to exert a price-influence effect since it possible that their behaviour might otherwise have reflected the pecking order theory.

A price-influence effect might occur if a firm considers there is a benefit from increased gearing because it believes that the regulator is influenced by the risk of financial distress, and the associated risk of disruption to services, and would wish to reduce this risk by setting more favourable price limits. A regulated firm, therefore, might perceive that the costs of departing from the hierarchical approach to financing decisions inherent in the pecking-order theory are outweighed by the benefits of increasing gearing to a level that would induce the regulator to set higher price limits.

To reach a conclusion on which of the two theories is supported by results described above it is, therefore, important to assess whether there is any evidence of a price-influence effect in operation during the period under consideration. To make such an assessment it is necessary to consider:

- the principles used to set price limits in the water industry and, in particular, to understand the effect that gearing levels have on the regulator's decisions,
- whether there are indications that water companies have increased gearing in advance of a Periodic Review to levels that could be regarded as an attempt to put pressure on the regulator to set more favourable price limits.

4.8.2 Principles of setting price limits

The principles and methodologies that have been developed to set price limits in the water industry originate in the statutory duties of the regulator. Under the legislation that established the current regulatory framework the DGWS has a primary duty

> "to secure that companies holding appointments ... as relevant undertakers are able (in particular, by securing reasonable returns on their capital) to finance the proper carrying out of the functions of such undertakers."[25]

As can be seen from Ofwat (1993), Ofwat (1999) and Ofwat (2004b) this duty has led the DGWS to set price limits on the basis of two sets of financial considerations:

- an *economic approach* which is intended to ensure that an efficient company can expect to earn its cost of capital on the capital value of the business.
- a *financial approach* which aims to ensure that an efficient company has a projected financial profile that is acceptable to the capital markets, and especially the debt markets, so that it is able in practice to raise finance for new investment. These considerations are referred to as 'bankability' in Ofwat (1999) and 'financeability' in Ofwat (2004b).

Gearing and interest cover, which is inversely related to gearing, are two of the key financial indicators that Ofwat considers to be important in the financial approach. A consequence of this approach might, therefore, be to give companies an incentive to manipulate their finances and increase gearing in order to bring about a price-influence effect.

However, gearing is also a factor in the economic approach because it is explicitly taken into account in the regulator's assessment of the weighted average cost of capital. Indeed, as noted in section 4.1, there is a potential regulatory price-influence effect that could work in the opposite direction to the financial approach as the regulator will wish to ensure the assessed cost

[25] Water Industry Act 1991, Section 2. The Water Act 2003 retains this duty but also adds a new duty by giving the Authority a consumer objective to protect the interests of customers.

of capital is no higher than necessary. This suggests the regulator will have an incentive to support, at least implicitly, the trade-off theory and assume a level of gearing that will enable customers to receive the maximimum benefit from the tax shield on debt through lower prices.

It follows that a company would only succeed in exerting a price-influence effect if it could convince the regulator that its actual financial position at the time of a Periodic Review would make the price limits implied by the economic approach unacceptable from a financial perspective. This means the regulator would have to accept that:

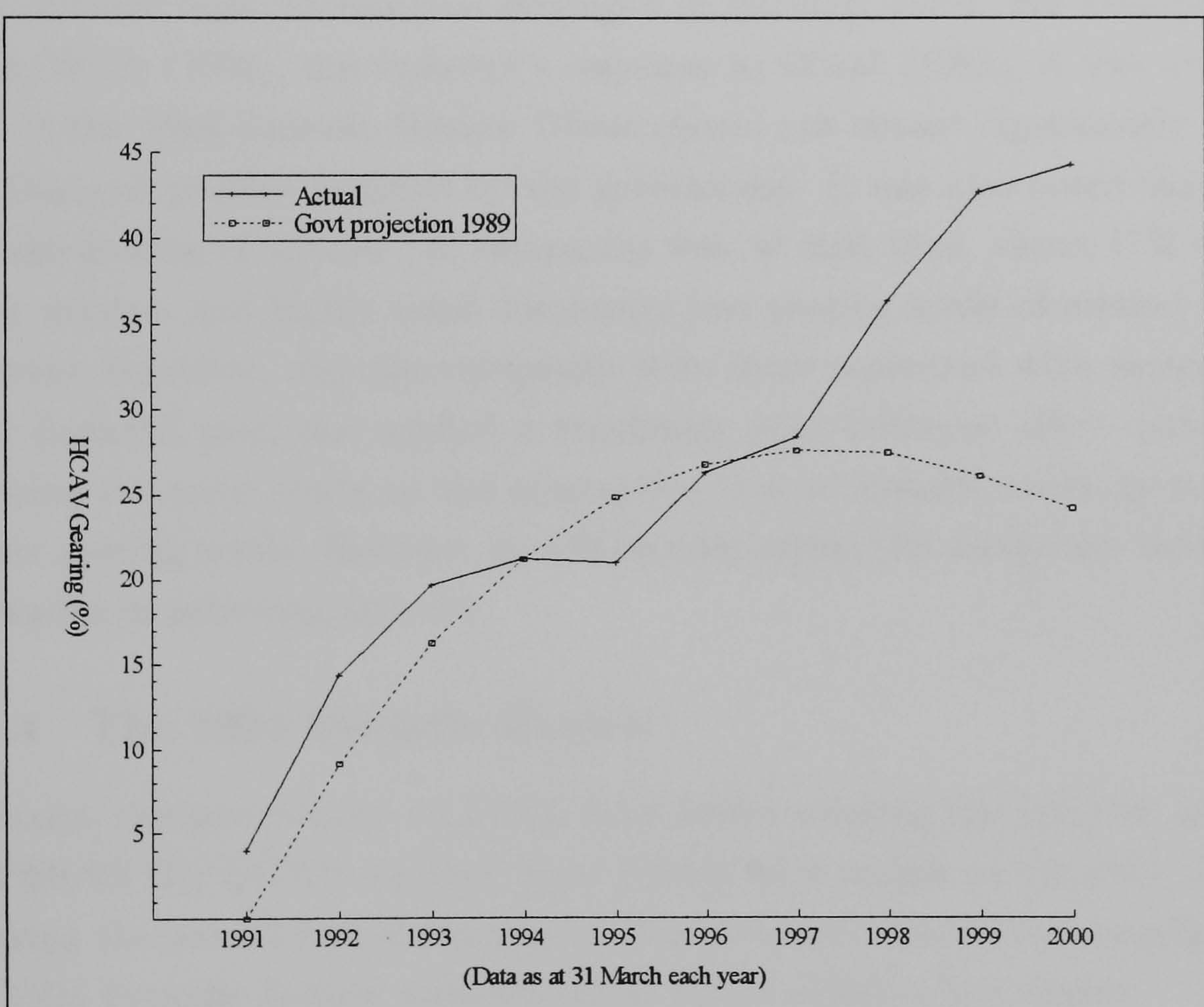
- the actual financial position of the company at the time a review takes place is reasonable and,
- the economic approach produces projected levels of gearing that would be too high and/or projections of interest cover that would be too low.

In other words, a successful price-influence effect requires the financial approach to dominate the economic approach. To assess whether this has happened in practice, the actions of water companies and the position taken by Ofwat on these issues need to be examined.

4.8.3 Initial setting of price limits in 1989

Ofwat (1991) makes clear that, compared with the financial approach, the economic approach had a relatively small impact on the initial price limits set by the government prior to flotation in 1989. The reason for this was that the methodology for calculating RCV's was only introduced in the 1994 Periodic Review. As explained in subsection 4.6.3 each company's RCV is, in part, determined by its initial market value in 1989. The government, therefore, did not have capital value figures for each company which could be projected on an annual basis so that price limits could be calculated for each of the ten years to 1999/00 in accordance with the economic approach. Instead the initial price limits were determined by evaluating the projected financial profiles of the companies. The most important key financial indicators at that time were considered to be interest cover, dividend cover, gearing and the return on capital; all calculated on an historical cost accounting basis. Ofwat (1991) states that the general criteria for an acceptable financial profile which were adopted by the government included a minimum interest cover of four times and gearing peaking at between 30% and 35% after a transitional period. As shown in section 4.4 the starting point for the WaSC's and the WoC's was very different. Nearly all the WaSC's started with positive net cash resources but with gearing projected to rise while the WoC's started with high gearing which was projected to decline progressively. Figure 4.5 shows the government's projections of HCAV gearing for the industry as a whole over the ten-year period to 1999/00 as set out in Ofwat (1991) and compares them with the actual level of industry gearing over the same period. The figures are, of course, dominated by the WaSC's as the WoC's only accounted for 4% of the industry's total HCAV over the five years to 1994/95.

Figure 4.5: Water industry HCAV gearing



Although actual gearing exceeded the government's projections for the first three years it coincides with the projection for 1993/94 and falls below the projection for the following year. The average HCAV gearing of the WaSC's had risen to 21.8% by 1994/95 while that of the WoC's had fallen from 42.9% to

26.9% over the five year period[26]. This pattern does not seem to be consistent with the companies generally trying to manipulate their financial positions to bring about a price-influence effect at the 1994 Periodic Review.

However, it does provide, at least in part, an explanation of why the estimate of the WaSC's target level of HCAV gearing for the period to 1994/95 shown in section 4.6 is relatively low compared to their subsequent targets and to that of the WoC's. The targets for both the WaSC's and the WoC's reflect their starting positions and were probably influenced by the outcome of the lengthy discussions with the government on the financial criteria that were to be used in setting the initial price limits. In addition, it was not clear at that time how the capital markets would assess the performance of the newly privatized companies and it is likely that their managements would have pursued cautious financial strategies in the early years. For example, in WSA/WCA (1991), the industry's response to Ofwat (1991), it was argued that in the 1994 Periodic Review Ofwat should not depart significantly from the financial profiles assumed by the government. It was also noted that the average gearing of quoted UK companies was, at that time, about 17% while other utilities and highly rated companies had gearing levels of around 30%. It seems, therefore, that the companies were more concerned with protecting their financial positions against a regulatory price-influence effect aimed at reducing the price limits on the assumption that companies could operate at higher gearing levels. However, as will be seen below, the companies were not successful in achieving this aim.

4.8.4 The 1994 Periodic Review

Although the government set initial price limits covering the ten year period to 1999/00 the DGWS decided there should be a review of the price limits covering the second half of the period. The financial criteria to be applied in the 1994 Periodic Review were set out in Ofwat (1993) which states:

> "The financial indicators of most relevance to lenders are interest cover (profits before interest and tax divided by interest payments) and, supporting this, gearing."

[26] The figures for the actual average HCAV gearing given in this and the following subsections are the unweighted mean values of HCAV gearing for the relevant type or category of company.

> "There is clear evidence that the markets will accept minimum interest covers well below the level of four assumed before flotation."
>
> "For individual companies, the maximum acceptable level of gearing will depend on interest cover. But there is certainly no reason why gearing levels could not substantially exceed current levels; the Director still considers that... levels of gearing (debt divided by debt plus equity) of 50% or more are unlikely to lead to financing difficulties." (p.38)

However, it also states that:

> "The main purpose of making detailed financial projections would be as a cross-check that the return on capital ensured viability."

Consequently, where the financial approach indicated that a company's ability to raise finance would be limited, the DGWS accepted some adjustment to the profile of price limits might be appropriate. However, he made it clear that if an adjustment was to be made:

> "...it would be necessary to take account of this at a subsequent Periodic Review; clearly charges to customers should only provide a reasonable return over the life of the assets. If higher retained profits are needed in the short term to meet financial ratio considerations, then charges in the longer term need only provide a lower return on the assets financed in that way." (p.39)

The DGWS appears to have been well aware that the financial approach might encourage companies to try and exert a price-influence effect. He took steps, therefore, to combat this by saying that even if the financial approach produced more favourable price limits in the short term a compensating adjustment would be made later.

The DGWS maintained this position in his final determination of price limits when the financial approach did result in the 'front-loading' of price limits for some companies. Ofwat (1994) attributes this to the fact that the expenditure allowed in price limits for these companies was projected to be higher in the first five years following the Periodic Review than subsequently; a factor which had adversely affected their financial profiles.

The 1994 Periodic Review clearly had a major impact on water company finances. As shown in subsection 4.4.3 and Figure 4.5, average HCAV gearing increased significantly after the 1994 Periodic Review. However, even by 1999/00 it was still below the figure of 50% that Ofwat had assumed in 1994. The average for the WaSC's had risen to 43.8% while the figure for the WoC's had fallen slightly to 22.2%.

The results in section 4.6 show there is an increase in the estimated target gearing levels of the WaSC's for the five year period to 1999/00 but only the WaSC NCR category has a target that was higher than Ofwat's assumption. The target for the WaSC NCR category is 65.4% as compared with 44.4% for the WaSC CR category although actual HCAV gearing in 1999/00 was similar in both categories. This reflects the faster rate of increase over the five years for the WaSC NCR category; average HCAV gearing in 1994/95 for this category being 16.3% compared with 27.3% for the WaSC CR category. It seems likely, therefore, that the financial criteria applied by Ofwat in the 1994 Periodic Review influenced both the increase in the actual HCAV gearing of the WaSC's and their target gearing levels.

The estimate of target gearing for the WoC NCR category in the period to 1999/00 remains stable at 47.8% which is also close to the Ofwat assumption. The relatively low figure of 15.4% for the WoC CR category reflects the lower starting figure of 34.0% in 1990/91 and a general downward trend over the ten year period to 11.7% in 1999/00. However, it should be noted, as shown in Table 4.4, that the WoC CR category has the highest variation in HCAV gearing and contains some small companies with positive net cash positions.

It seems reasonable to conclude there is little evidence of companies systematically attempting to exert a price-influence effect in the lead up to the 1999 Periodic Review.

4.8.5 The 1999 Periodic Review

The DGWS used tighter parameters for the economic approach in the 1999 Periodic Review. Price limits were based on a real, post-tax cost of capital for water companies of 4.75%, plus a premium to allow for the cost of companies' embedded debt which averaged around 0.25%. The real, post-tax cost of capital used in the 1994 review was in the range of 5-6%[27]. However, the

[27] In both reviews a 'small company' premium was also added to the cost of capital applied to the WoC's.

criteria applied in the financial approach were similar to those used in 1994. Ofwat (1999) states that:

> "The financial projections underpinning price limits assume that companies will achieve, on average, gearing levels of about 50% (measured as debt to total capital) over the period of the price limits." (p.130).
>
> "Consultation indicated that levels of gearing of about 50% (debt:debt plus equity) and accounting historic cost interest (EBIT) covers of about 2.0 times are consistent with maintaining a solid investment grade rating if coupled with acceptable cashflow profiles and ratios." (p.156)

However, as in 1994, the DGWS was concerned about the potential for price-influence effects from companies gearing up balance sheets. In particular, some parent companies had increased debt in their water subsidiaries to pay the windfall tax of 1997. Ofwat (1999) states:

> "The Director does not consider it appropriate for such actions to result in higher bills for customers than would otherwise be the case because of the impact on financial projections. Consequently, before considering the critical financial indicators, some adjustments have been made for a few companies ...[including] ...to write back special dividends (or other debt for equity swaps) into companies' balance sheets." (p.134)

Consequently, in the few cases where a price-influence effect might have occurred the DGWS took pre-emptive action to prevent this happening in accordance with his stated intentions during the consultation process for the review. The regulator's stance, therefore, seems to have provided a disincentive to the pursuit of price-influencing strategies by most companies, at least prior to the review.

However, at the time many commentators considered the 1999 Periodic Review to have been a very tough one for the water companies and, as explained in section 4.2, within three years half of the water companies had implemented some form of capital restructuring. Two-thirds of the companies that did so adopted enhanced financial structures that would enable their gearing to exceed 75%. The result was that average HCAV gearing in both the WaSC CR and the WoC CR categories reached 68.5% by 2002/03 while the WaSC NCR and WoC NCR categories had only increased to 52.2% and 42.3% respectively.

As Mayer (2003) observes, such restructurings hardly reflect the kind of mechanical funding response that is implied by the pecking order theory of capital structure. He suggests a better explanation is that companies increased gearing both to achieve a lower cost of capital and to obtain greater exit rights which would restrict the potential for further tightening of the regulatory contract. In other words, the rapid increase in gearing for some companies can be explained by the trade-off theory in conjunction with an intended price-influence effect at future Periodic Reviews that was motivated more by defensive considerations.

The attractions of restructuring might have been reinforced by the changes to capital allowances against corporation tax announced in 1996 and the abolition of the imputation system of taxation with the ending of the Advance Corporation Tax credits on dividends from 1999/00. These changes resulted in higher levels of business taxation which might have been regarded as increasing the attractiveness of debt finance[28].

In the case of companies which did not carry out capital restructurings, the analysis of the changes in ownership set out in section 4.3 indicates that such companies were unlikely to have attached a high value to the potential benefits of restructuring. In particular, the value of the benefits would be relatively low where the water subsidiary is considered strategically important to its parent's future growth prospects and the opportunity cost of reduced management flexibility is relatively high. The results in section 4.6 are consistent both with this interpretation and the trade-off theory as the estimated target HCAV gearing levels for the WaSC NCR and WoC NCR categories do not change materially after the 1999 Periodic Review. The estimated target levels of HCAV gearing for the WaSC CR and WoC CR categories are, of course, much higher and exceed 90%. However, for the reasons stated earlier, these high figures should be treated with caution.

[28] Group tax relief arrangements meant that the Advance Corporation Tax on dividend payments was only paid by parent companies. Consequently, it was the parent companies who had to decide whether to bring about an increase in the gearing of their water subsidiaries as a result of the abolition of the imputation system.

4.8.6 The 2004 Periodic Review

In the first two Periodic Reviews Ofwat and the companies focused on the HCAV gearing measure. However, as explained in section 4.4, attention moved to the RCV gearing measure in the 2004 Periodic Review. In 1999/00 actual RCV gearing for the industry as a whole was 43.2% and, following the capital restructurings, it increased to 56.9% in 2002/03. The restructurings led Ofwat to change its position on the level of gearing to be assumed in setting price limits. Ofwat (2003b) states that:

> "We have said that we do not believe that it would be appropriate to be guided simply by the most highly geared companies. However, we believe there may be some scope for assuming a slightly higher level of gearing than in 1999 without companies being forced into adopting capital structures that may carry more risk. This points to a range of 55-65% [for RCV gearing] as being sustainable over the period 2005-10 and beyond. This level of gearing is consistent with a credit rating that lies comfortably within the investment grade category." (p.67)

Although this range is below the RCV gearing of the companies that restructured their finances it is higher than the average of the companies which had not. In 2002/03 average RCV gearing in the WaSC and WoC NCR categories was 48.4% and 29.2% respectively. However, it does not appear that Ofwat's revised assumptions will result in a regulatory price-influence effect. Ofwat (2004b), which sets out the draft determinations of price limits for the review, states that they were based on a real, post-tax cost of capital of 5.1% with no embedded debt premium being allowed and this is slightly higher than the figure used in 1999[29].

The potential price-influence effects of the capital restructurings were still a matter of concern and Ofwat reinforced its price-setting methodology accordingly. Ofwat (2004b) also states that:

> "As in 1999, in our financial projections we have assumed an opening gearing level in 2005-06 consistent with the gearing assumption in the WACC [weighted average cost of capital], i.e. 55%, (gearing

[29] At the time of writing only the draft determinations of price limits had been published. The final determinations are due to be published on 2 December 2004.

measured as the ratio of net debt to RCV for all companies). We refer to this as the company's notional gearing. ... For a large number of companies we have therefore had to adjust their opening balance sheet position in 2002-03 by varying degress to reach this starting point." (p.195)

The only recognition of the capital restructurings that have taken place since 1999/00 was in the calculation of each company's expected tax liabilities because Ofwat (2004b) goes on to say:

> "Our approach assumes that price limits should only include a forecast of companies' expected tax liablilities rather than a notional liability linked to our assumptions on capital structure i.e. customers should only pay in their bills the actual level of tax faced by a company. Generally highly geared companies pay less tax because interest payments are deductible from taxable profits." (p.201)

Consequently, while Ofwat made a generic assumption about capital structure that was applied to all companies a different and rather inconsistent approach was taken in relation to tax. The reason for using a company-specific approach rather than assuming a generic tax wedge was given in Ofwat (2003a) where it says that to do so:

> "...would also be over-generous to those companies with highly geared structures which in practice will pay very little tax." (p.114)

The impact of these statements on any further capital restructurings in the water industry remains to be seen. Since Ofwat's approach effectively transfers the benefit of the tax shield on debt to consumers at Periodic Reviews then, according to the trade-off theory, this should create an incentive for companies to implement a restructuring immediately after a Periodic Review in order to maximize the period over which shareholders benefit. However, as the benefits can only be retained for at most five years it is possible that Ofwat's approach could deter many more restructurings.

Ofwat's position on gearing and tax issues also indicates that restructurings are unlikely to have much value as a defensive price-influence effect. The DGWS made this clear in a public letter to all water companies in January

2001 when the restructuring of Dyr Cymru, the first and most extreme example of the restructurings, was approved. The letter states, firstly, that:

> "Companies that choose to structure their business in ways other the equity-owned, vertically-integrated structure established at privatisation will receive no special or preferential treatment from Ofwat."

and, secondly, that in the event of a Special Adminstration Order being implemented, for example as result of insolvency, and the assets being transferred to a new owner:

> "There can be no assurance that the transfer .. could be achieved on terms that enabled creditors of the Appointee to recover amounts due to them in full"[30]

This policy was subsequently confirmed on a number of occasions including in Ofwat (2004b) which states:

> "The actual capital structure that companies choose is a matter for their management and the markets. This should not be at the expense of customers, however. ... We have not made any special allowances for companies' actual structures." (p.196)

Given these statements and Ofwat's approach to the prevention of price-influence effects at price reviews it is difficult to see why any management would expect to gain a significant benefit from trying to exert a price-influence effect, even of a defensive kind, from a capital restructuring. As observed in Stones (2001) this suggests the principal benefit of a capital restructuring from the perspective of management and shareholders was that predicted by the trade-off theory of capital structure. It provides the opportunity to obtain a substantial release of value to shareholders following the injection of a large amount of new debt finance and a reduction in the cost of capital to a level well below that assumed in price limits. Consequently, it seems probable that the companies concerned only regarded the potential price-influence effect of the restructuring as a second order benefit.

[30]Letter to Managing Directors, No. MD166 - The Regulatory Framework, 31 January 2001.

4.9 Conclusions

For the purposes of analysis the WaSC's and the WoC's have each been divided into two categories according to whether or not companies implemented a capital restructuring after 1999/00. The aim was to establish categories within which the behaviour of the companies is likely to be relatively homogeneous enabling separate models to be estimated for each category using pooled data. Econometric models of the relationship between debt and capital value have been estimated for each category of company and provide reasonable support for the proposition that water companies, at least when viewed collectively, have behaved as though they had target levels of gearing.

The models have been developed using a 'general-to-specific' model reduction procedure that starts with an unrestricted ADLM as the initial equation. When HCAV is used to measure capital value, the procedure shows that an ECM provides the best explanation and plausible estimates of the parameters viz. the target levels of HCAV gearing and the speed of response to both short-run changes in capital value and deviations from the long-run target.

The models satisfy a range of diagnostic tests, although in many cases there is evidence of heteroscedasticity. In the significance tests robust standard errors have, therefore, been used to adjust for this problem. A particular feature of this study is that it tests for cointegration between the variables to assess whether the results reflect a causal relationship and not merely stochastic time trends in the data. Although the available data only covers the 13 year period to 2002/03, which is a relatively short time period, half of the models accept one or more of these tests. This represents at least indicative evidence that the two variables are cointegrated and that the target gearing levels derived from the models are not the spurious result of stochastic time trends.

Models that use RCV as the measure of capital value have also been estimated. In these models the PAM provides the best explanation. However, the results of the diagnostic tests are less satisfactory and encompassing tests show that the ECM's based on HCAV are superior. This is to be expected as the water companies, Ofwat and, indeed, the capital markets all focused on the HCAV measure of gearing until attention moved to the RCV measure after the 1999 Periodic Review.

The overall conclusion of this case study is that the empirical evidence is more consistent with the trade-off theory of capital structure than the pecking order theory. It should be emphasized that the presence of target levels of gearing does not necessarily mean that a trade-off actually exists. The adjustment models on which this study has been based simply indicate that water companies appear to have behaved as though there is a trade-off. In order to validate the trade-off model it would be necessary to develop more extensive models where the target level of gearing is specified as a function of the explanatory variables that determine the costs and benefits of increasing gearing. Unfortunately, a number of those variables, for example, agency costs and the costs of financial distress, are extremely difficult to measure. However, adjustment models can provide evidence that the behaviour of firms is inconsistent with the pecking order theory since it predicts that firms do not have target gearing levels.

As the water companies are highly regulated it is important to assess whether they have increased gearing in order to exert a price-influence effect on regulatory decisions because it possible that their behaviour might otherwise have reflected the pecking order theory. There is, however, little indication that the water companies have generally tried to manipulate their financial positions to that end. Consequently, their behaviour does not appear to have been consistent with the pecking order theory.

There could be several reasons for the apparent absence of attempts to exert a price-influence effect. The potential for this kind of 'hidden action' or moral hazard problem is inherent in a regulatory environment and this was recognized by Ofwat from the outset. Ofwat, therefore, put mechanisms in place that would act as a deterrent to such behaviour. In addition, to be successful, a price-influence effect depends on increasing the risk of financial distress and a company which puts itself in such a position runs the risk of an adverse reaction from the capital markets. This would provide a further deterrent and especially for a company acting in isolation as, by definition, the adoption of such a strategy must remain hidden if it is to succeed. These considerations are likely to have been particularly important for the WaSC's in the early years following privatization.

The finding that water companies appear to have target levels of gearing should not be surprising. Each review of price limits is preceded by an extensive public consultation process lasting around two to three years during which all the operational and financial issues affecting the future prospects of the companies are examined in great detail. On each occasion large amounts of research and evidence on the cost of capital, the capital structure and the financial profile of water companies have been commissioned by the companies and by Ofwat. Further, such debates have not been confined to the water companies and similar debates have taken place during the reviews of price limits for other utilities in the UK. It is not unlikely, therefore, that the financial strategies of water companies have been influenced by the detailed discussion of these issues that has taken place.

When the initial price limits were set in 1989 the government needed to ensure that the financial profiles of the companies would be acceptable to the capital markets and, in particular, that the companies had the capacity to accommodate a significant increase in gearing. While this could have encouraged behaviour in line with the pecking order theory, this study indicates that, in the early years, the companies generally moved towards targets which are broadly consistent with the government's projection of the longer term position following the transitional period of the first five years.

In the 1994 and 1999 Periodic Reviews Ofwat decided that companies could operate at much higher levels of gearing than the government had assumed in 1989 and concluded that 50% gearing would represent an efficient capital structure. The evidence from this study indicates that after the 1994 Periodic Review the WaSC's target levels of gearing increased accordingly. However, the targets for the WoC's appear to have remained stable which probably reflects the fact they were mature companies that had been in private sector ownership for many years.

In addition, the pecking order theory does not appear to be compatible with the capital restructurings which followed so rapidly after the 1999 review. These restructurings seem to be more readily explainable in terms of the trade-off theory with some companies being driven to take a quite radical approach to reducing the cost of capital after a tight regulatory review. As would be expected the results of the study indicate that the target gearing levels for these companies have increased to well over 75%. Although the restructurings might also have reflected a defensive price-influence effect to protect the companies concerned against further tightening of the regulatory contract at the 2004 Periodic Review, this was probably a second order consideration. Ofwat already had a track record of putting mechanisms in place to avoid such effects and made its policy position quite clear when it approved the first restructuring in early 2001. The mechanisms have been reinforced for the 2004 review and this might act as a deterrent to many more restructurings. Further, many water companies did not implement a capital restructuring and the estimated target levels of gearing for these companies do not appear to have changed materially after the 1999 review. This is again consistent with the trade-off theory. These companies also seem to have certain common ownership characterstics which suggest the reduced management flexibility required by a restructuring might have been perceived as a costly limitation on their strategic options for future growth.

Ofwat has stated that it considers RCV gearing in the range 55-65% is sustainable over the period 2005-10 and beyond. It will be interesting to see what effect, if any, this has on the actual and target gearing ratios of water companies after the 2004 Periodic Review.

Appendix 4.A Data Sets

The data for net debt, HCAV and RCV are given in Tables 4.23, 4.24 and 4.25. The gearing ratios calculated from this data are given in Tables 4.26 and 4.27. The mean values of gearing for each type and category of company are given in Table 4.28. Graphical plots of the data for the WaSC's are given in Figure 4.6 and for the WoC's in Figure 4.7. The mean values of the data for each category and their standard deviations are given in Figures 4.8 and 4.9 repsectively.

To assist with this study Ofwat supplied the data contained in Table 19 of each water company's annual 'June Return' for each of the 13 years from 1990/91 to 2002/03. These Tables contain the HCA balance sheets for each company from which the data on net debt and HCAV have been obtained. By definition a company's HCAV is equal to the sum of its net debt and share capital and reserves and for convenience the data on HCAV was obtained by using this identity.

The Table 19 figures for net debt are generally consistent with those reported by Ofwat in its annual publication on the 'Financial performance and expenditure of the water companies in England and Wales'. Where there are inconsistencies the Table 19 data have been used in preference, except for NES in 1990/91 and 2000/01. Ofwat accepted that the 1990/91 data on net debt in Table 19 for NES was unreliable and so the total net debt of its three constituent companies (Northumbrian, North East and Essex and Suffolk) as reported in Ofwat's publication for 1994/95 has been used instead. The Table 19 figure for NES net debt in 2000/01 was adjusted by Ofwat in its publication for 2000/01 to exclude a loan note of £176m relating to the acquisition of Essex and Suffolk Water on 1 April 2000 and so the published figure has been used.

The Table 19 data on share capital and reserves for ANH in 2001/02 and 2002/03 have been adjusted to add back the capital restructuring dividend of £786m which was declared in 2000/01. This dividend was not paid and was eventually waived in 2002/03 when the capital restructuring was implemented by other means.

For these reasons the HCAV gearing ratios in Table 4.26 that have been calculated from this data are not always consistent with those published by Ofwat. In addition, Ofwat does not publish a figure for HCAV gearing when a company has positive net cash resources (i.e. negative net debt).

The Retail Price Index as at each financial year end has been used to adjust the data to a common price base and is given in Table 4.29. These are the figures that are used by Ofwat for such purposes.

Table 4.23: Net debt (at March 2003 prices)

	31-Mar-91	31-Mar-92	31-Mar-93	31-Mar-94	31-Mar-95	31-Mar-96	31-Mar-97	31-Mar-98	31-Mar-99	31-Mar-00	31-Mar-01	31-Mar-02	31-Mar-03
	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m
WaSCs													
CR													
ANH	259.6	391.0	475.5	594.8	623.4	882.3	989.9	1252.0	1300.8	1568.2	1654.4	2045.9	3307.5
WSH	-216.7	-43.7	58.1	103.4	144.4	225.3	357.6	731.9	869.8	914.6	1423.4	1925.0	2006.1
NES	155.1	240.9	360.7	372.7	307.0	437.5	518.2	665.6	701.0	791.5	974.3	1247.3	1358.5
SRN	408.5	493.0	528.5	537.2	482.6	405.9	541.1	629.2	810.3	978.8	1072.4	1239.8	1257.3
WSX	12.6	164.6	276.0	349.8	343.9	379.6	363.4	398.0	569.3	581.7	606.6	681.8	1028.4
	619.2	1245.8	1698.7	1958.0	1901.4	2330.6	2770.2	3676.7	4251.1	4834.7	5731.1	7139.8	8957.8
NCR													
SVT	-251.2	52.8	347.0	509.5	506.3	837.8	899.0	1444.7	1762.1	1984.5	2126.5	2122.3	2174.7
SWT	-307.8	-183.0	-6.6	138.6	252.2	285.7	345.2	475.7	613.3	564.4	613.9	794.8	931.9
TMS	117.9	422.0	619.1	710.9	709.0	685.3	745.5	1134.1	2055.4	2091.1	2270.9	2141.0	2260.5
UUW	-83.0	226.1	466.1	472.9	519.1	1090.1	1185.9	1638.1	1948.2	2205.8	2245.1	2322.0	2487.4
YKY	142.2	277.8	220.5	190.9	128.7	345.5	455.8	546.3	686.4	890.7	1003.7	1074.2	1170.5
	-382.0	795.8	1646.1	2022.8	2115.3	3244.3	3631.5	5239.0	7065.3	7736.4	8260.1	8454.4	9025.0
Total WaSCs	237.2	2041.6	3344.9	3980.8	4016.7	5574.9	6401.7	8915.7	11316.5	12571.1	13991.2	15594.2	17982.9
WoCs													
CR													
brl	57.7	68.3	58.2	64.7	67.9	60.3	50.3	55.1	72.9	71.1	65.4	73.5	74.8
dvw	4.2	3.3	0.6	-3.3	-6.7	-8.7	2.7	-2.8	-3.0	-5.6	-4.7	-3.8	21.8
mkt	14.9	16.2	25.6	31.5	26.0	20.9	24.4	43.4	38.8	36.0	39.2	56.4	127.6
prt	14.6	16.0	14.9	13.4	12.4	9.2	17.8	16.7	16.1	13.6	10.5	6.4	69.1
sst	29.9	29.9	26.9	23.8	16.7	11.7	16.2	18.2	16.5	13.6	16.9	23.7	96.3
ses	19.0	13.4	20.9	15.0	10.7	4.3	-0.6	-6.6	-5.0	4.1	47.6	48.5	53.3
	140.3	147.1	147.2	145.0	127.0	97.8	110.9	124.0	136.3	132.9	174.9	204.8	442.9
NCR													
bwh	18.0	15.0	13.9	8.8	8.1	6.7	10.0	14.2	18.3	16.6	15.2	18.6	22.3
cam	16.3	19.5	24.3	21.2	16.1	13.1	16.1	15.7	16.0	15.4	12.4	15.2	12.7
flk	4.1	4.2	4.8	5.6	6.3	4.6	9.5	9.2	12.1	9.4	8.0	13.3	15.7
mse	75.8	97.6	112.7	100.8	98.6	101.7	104.7	94.4	137.2	142.8	128.9	133.8	141.8
thd	5.5	10.2	12.6	10.7	8.6	6.7	7.5	8.9	8.5	8.9	11.9	10.4	10.5
tvn	98.3	127.5	145.1	119.0	101.6	107.4	117.0	137.7	134.5	131.3	149.0	169.4	185.6
	218.1	273.9	313.4	266.0	239.3	240.3	264.8	280.1	326.5	324.3	325.4	360.8	388.5
Total WoCs	358.4	420.9	460.5	411.0	366.3	338.1	375.7	404.1	462.8	457.2	500.4	565.5	831.5
Total	595.6	2462.5	3805.4	4391.8	4383.0	5913.0	6777.4	9319.7	11779.3	13028.3	14491.6	16159.7	18814.3

Table 4.24: Historical Cost Asset Value (at March 2003 prices)

	31-Mar-91	31-Mar-92	31-Mar-93	31-Mar-94	31-Mar-95	31-Mar-96	31-Mar-97	31-Mar-98	31-Mar-99	31-Mar-00	31-Mar-01	31-Mar-02	31-Mar-03
	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m
WaSCs													
CR													
ANH	1925.3	2121.3	2315.7	2464.2	2591.8	2747.1	2966.7	3247.2	3097.1	3333.7	3374.0	3853.5	4892.4
WSH	908.4	1064.5	1227.9	1296.0	1383.1	1495.8	1674.9	1851.7	2018.4	2107.3	2176.1	2579.7	2630.5
NES	787.0	901.7	1068.0	1156.5	1209.9	1326.8	1473.0	1694.2	1802.0	1950.3	1944.6	2086.2	2138.1
SRN	940.6	1031.6	1095.3	1153.3	1146.5	1135.6	1358.5	1452.6	1741.7	2005.0	1824.0	2074.8	2059.4
WSX	717.8	840.3	938.0	994.2	996.6	1048.3	1049.5	983.7	1193.5	1209.4	1244.3	1271.2	1384.8
	5279.1	5959.4	6644.8	7064.2	7327.9	7753.6	8522.6	9229.5	9852.7	10605.8	10563.0	11865.5	13105.1
NCR													
SVT	2246.0	2669.4	3066.3	3360.7	3418.1	3463.3	3506.5	3748.3	4113.3	4257.6	4425.6	4064.9	4050.9
SWT	615.6	778.2	1008.9	1192.6	1293.5	1368.8	1456.1	1472.0	1595.7	1644.9	1675.3	1761.0	1839.6
TMS	2111.4	2510.8	2851.9	3097.2	3233.6	3385.7	3596.8	3822.1	4062.4	4257.1	4368.7	3627.8	3770.7
UUW	2247.1	2660.2	3064.8	3235.3	2943.9	3647.0	3672.0	4019.3	4343.0	4696.5	4707.0	4579.1	4616.0
YKY	1568.0	1746.6	1765.7	1805.6	1715.1	1845.5	2068.5	2199.7	2426.2	2696.7	2710.3	2678.2	2740.4
	8788.2	10365.3	11757.6	12691.3	12604.1	13710.4	14300.0	15261.3	16540.6	17552.8	17886.9	16711.0	17017.5
Total WaSCs	14067.3	16324.7	18402.4	19755.5	19932.0	21463.9	22822.6	24490.8	26393.3	28158.6	28449.9	28576.5	30122.6
WoCs													
CR													
brl	100.4	109.1	117.1	125.1	130.1	126.6	121.6	131.3	150.5	153.6	150.5	149.4	139.7
dvw	23.3	23.8	21.9	20.4	18.5	16.8	23.5	22.3	5.3	7.5	10.4	1.8	28.6
mkt	72.5	74.7	85.5	93.2	90.7	90.0	91.4	94.4	98.3	101.6	106.3	114.3	158.6
prt	43.6	45.3	46.5	47.9	49.5	49.2	53.8	52.9	55.7	56.8	57.8	46.5	107.0
sst	61.6	67.2	69.3	70.2	70.6	69.8	78.7	83.9	86.4	88.1	93.2	99.0	108.1
ses	73.0	69.6	80.9	80.6	79.3	77.8	54.9	53.9	56.9	64.3	107.4	103.6	111.7
	374.5	389.8	421.2	437.3	438.7	430.2	423.8	438.9	453.1	472.0	525.6	514.7	653.7
NCR													
bwh	31.7	33.9	37.4	35.7	69.8	70.4	76.5	82.1	88.4	87.6	86.5	86.6	92.2
cam	29.6	38.2	45.2	45.1	41.2	40.7	40.9	42.9	44.9	45.3	43.0	36.3	33.2
flk	11.0	11.5	12.0	14.4	16.8	16.7	22.7	23.3	24.1	22.9	22.4	26.7	29.8
mse	120.8	154.6	189.4	198.1	216.7	235.7	266.1	278.8	282.5	308.3	309.3	306.1	320.3
thd	12.5	18.0	22.4	23.5	23.7	24.3	25.4	27.8	28.1	27.5	30.4	27.1	27.1
tvn	181.6	212.6	236.2	227.2	222.8	248.9	273.1	303.1	303.5	325.0	322.2	315.9	332.9
	387.1	468.8	542.7	543.9	590.9	636.7	704.6	758.0	771.6	816.6	813.8	798.6	835.5
Total WoCs	761.6	858.6	963.9	981.2	1029.7	1067.0	1128.5	1196.9	1224.7	1288.5	1339.5	1313.4	1489.2
Total	14828.9	17183.3	19366.3	20736.8	20961.7	22530.9	23951.1	25687.7	27617.9	29447.1	29789.4	29889.8	31611.9

Table 4.25: Regulatory Capital Value (at March 2003 prices)

	31-Mar-91	31-Mar-92	31-Mar-93	31-Mar-94	31-Mar-95	31-Mar-96	31-Mar-97	31-Mar-98	31-Mar-99	31-Mar-00	31-Mar-01	31-Mar-02	31-Mar-03
	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m	£m
WaSCs													
CR													
ANH	1756.8	1909.8	2073.2	2299.9	2537.5	2734.2	2969.6	3181.1	3358.3	3450.7	3813.4	3945.6	4032.3
WSH	591.6	730.2	890.9	1041.2	1166.8	1384.7	1530.1	1621.4	1742.1	1913.6	2133.9	2191.2	2362.3
NES	637.7	752.6	864.0	962.9	1047.0	1215.6	1361.6	1502.5	1632.1	1762.1	2115.0	2112.0	2171.1
SRN	757.4	866.2	929.3	1019.3	1170.9	1407.5	1567.7	1738.8	2004.9	2239.6	2186.5	2129.9	2191.8
WSX	517.8	607.8	669.2	740.4	818.5	871.2	942.0	1034.2	1124.0	1192.5	1309.8	1396.7	1474.4
	4261.3	4866.5	5426.6	6063.6	6740.6	7613.2	8370.9	9078.0	9861.4	10558.5	11558.6	11775.5	12231.8
NCR													
SVT	1725.3	2123.8	2452.4	2722.6	2947.7	3196.2	3439.9	3776.8	4086.8	4285.1	4275.0	4260.3	4397.0
SWT	286.9	441.5	646.4	869.3	1126.3	1239.6	1364.1	1438.5	1476.0	1558.2	1451.3	1523.4	1620.3
TMS	1993.0	2284.2	2475.0	2659.0	2871.4	3241.6	3614.0	3966.9	4283.3	4589.1	4645.2	4686.2	4777.6
UUW	1586.4	1909.5	2204.7	2627.2	3600.1	3939.6	4381.5	4725.4	4875.0	4900.8	4698.6	4873.2	5156.6
YKY	1088.8	1224.2	1340.3	1462.3	1595.4	1757.2	1953.7	2163.1	2367.9	2543.2	2724.2	2794.4	2957.1
	6680.3	7983.2	9118.8	10340.3	12140.9	13374.2	14753.1	16070.6	17089.0	17876.4	17794.3	18137.6	18908.6
Total WaSCs	10941.6	12849.7	14545.4	16404.0	18881.5	20987.4	23124.0	25148.7	26950.4	28434.9	29352.9	29913.1	31140.4
WoCs													
CR													
brl	90.5	97.6	104.0	112.6	122.1	124.7	129.7	135.7	139.4	143.9	167.2	173.7	183.1
dvw	31.3	33.8	34.8	36.9	38.0	39.8	41.7	43.4	45.3	46.6	43.3	43.2	44.5
mkt	77.6	87.0	91.5	96.7	99.4	109.2	116.1	122.9	129.2	133.7	148.8	157.8	166.3
prt	48.0	50.6	52.2	53.3	54.4	57.8	63.6	68.7	74.3	74.0	87.0	91.6	91.1
sst	79.4	85.6	90.6	93.6	99.7	107.4	115.4	120.6	122.2	128.3	127.8	134.7	146.4
ses	86.3	87.5	86.7	85.1	88.3	97.7	98.4	97.4	95.7	95.5	101.5	101.5	110.6
	413.1	442.2	459.8	478.2	501.9	536.7	564.8	588.6	606.2	622.0	675.7	702.5	742.1
NCR													
bwh	55.2	62.8	64.6	64.5	64.5	70.5	84.3	87.3	90.2	92.9	95.0	99.0	96.0
cam	25.4	30.8	37.5	40.7	38.5	39.4	40.6	41.7	42.2	42.4	41.5	41.9	41.9
flk	17.3	18.2	18.4	23.4	28.2	31.0	34.0	35.5	36.0	37.2	37.7	41.6	47.0
mse	183.6	214.2	229.2	243.0	253.8	285.8	312.6	338.0	362.6	386.7	413.3	421.9	434.8
thd	26.2	31.9	35.6	36.7	38.3	40.3	43.9	45.7	47.5	49.2	50.7	51.7	51.1
tvn	297.9	329.6	358.9	379.3	404.1	446.8	492.5	506.1	512.2	515.7	531.0	527.8	526.1
	605.7	687.4	744.2	787.5	827.4	913.8	1007.9	1054.2	1090.7	1124.2	1169.2	1183.9	1196.7
Total WoCs	1018.7	1129.6	1204.0	1265.7	1329.3	1450.5	1572.7	1642.8	1696.9	1746.2	1844.9	1886.4	1938.8
Total	11960.3	13979.3	15749.4	17669.7	20210.8	22438.0	24696.7	26791.5	28647.3	30181.1	31197.8	31799.5	33079.2

Table 4.26: HCAV gearing

	31-Mar-91	31-Mar-92	31-Mar-93	31-Mar-94	31-Mar-95	31-Mar-96	31-Mar-97	31-Mar-98	31-Mar-99	31-Mar-00	31-Mar-01	31-Mar-02	31-Mar-03
	%	%	%	%	%	%	%	%	%	%	%	%	%
WaSCs													
CR													
ANH	13.5	18.4	20.5	24.1	24.1	32.1	33.4	38.6	42.0	47.0	49.0	53.1	67.6
WSH	-23.9	-4.1	4.7	8.0	10.4	15.1	21.4	39.5	43.1	43.4	65.4	74.6	76.3
NES	19.7	26.7	33.8	32.2	25.4	33.0	35.2	39.3	38.9	40.6	50.1	59.8	63.5
SRN	43.4	47.8	48.2	46.6	42.1	35.7	39.8	43.3	46.5	48.8	58.8	59.8	61.1
WSX	1.8	19.6	29.4	35.2	34.5	36.2	34.6	40.5	47.7	48.1	48.7	53.6	74.3
	11.7	20.9	25.6	27.7	25.9	30.1	32.5	39.8	43.1	45.6	54.3	60.2	68.4
NCR													
SVT	-11.2	2.0	11.3	15.2	14.8	24.2	25.6	38.5	42.8	46.6	48.1	52.2	53.7
SWT	-50.0	-23.5	-0.7	11.6	19.5	20.9	23.7	32.3	38.4	34.3	36.6	45.1	50.7
TMS	5.6	16.8	21.7	23.0	21.9	20.2	20.7	29.7	50.6	49.1	52.0	59.0	59.9
UUW	-3.7	8.5	15.2	14.6	17.6	29.9	32.3	40.8	44.9	47.0	47.7	50.7	53.9
YKY	9.1	15.9	12.5	10.6	7.5	18.7	22.0	24.8	28.3	33.0	37.0	40.1	42.7
	-4.3	7.7	14.0	15.9	16.8	23.7	25.4	34.3	42.7	44.1	46.2	50.6	53.0
Average WaSCs	1.7	12.5	18.2	20.2	20.2	26.0	28.0	36.4	42.9	44.6	49.2	54.6	59.7
WoCs													
CR													
brl	57.5	62.6	49.7	51.7	52.2	47.6	41.4	41.9	48.4	46.3	43.5	49.2	53.5
dvw	17.8	13.8	2.7	-16.4	-36.0	-51.6	11.3	-12.5	-57.1	-74.0	-45.0	-203.5	76.1
mkt	20.6	21.6	29.9	33.8	28.7	23.2	26.7	45.9	39.5	35.4	36.8	49.4	80.5
prt	33.5	35.3	32.0	28.0	25.0	18.7	33.2	31.5	29.0	24.0	18.2	13.8	64.6
sst	48.6	44.5	38.9	33.9	23.6	16.8	20.6	21.7	19.1	15.5	18.1	23.9	89.1
ses	26.0	19.3	25.8	18.6	13.5	5.5	-1.1	-12.2	-8.9	6.3	44.4	46.8	47.8
	37.5	37.7	34.9	33.2	29.0	22.7	26.2	28.2	30.1	28.2	33.3	39.8	67.8
NCR													
bwh	56.9	44.2	37.0	24.6	11.5	9.6	13.0	17.3	20.7	18.9	17.6	21.4	24.2
cam	55.1	51.0	53.8	47.1	39.0	32.1	39.4	36.7	35.7	34.0	28.8	41.9	38.2
flk	37.4	36.3	39.5	39.0	37.8	27.9	42.0	39.4	50.1	41.1	35.7	49.9	52.8
mse	62.7	63.1	59.5	50.9	45.5	43.2	39.4	33.9	48.6	46.3	41.7	43.7	44.3
thd	44.3	56.5	56.3	45.4	36.4	27.7	29.4	31.9	30.1	32.3	39.3	38.5	38.8
tvn	54.2	59.9	61.4	52.4	45.6	43.2	42.8	45.4	44.3	40.4	46.2	53.6	55.7
	56.3	58.4	57.7	48.9	40.5	37.7	37.6	37.0	42.3	39.7	40.0	45.2	46.5
Average WoCs	47.1	49.0	47.8	41.9	35.6	31.7	33.3	33.8	37.8	35.5	37.4	43.1	55.8
Industry average	4.0	14.3	19.6	21.2	20.9	26.2	28.3	36.3	42.7	44.2	48.6	54.1	59.5

Table 4.27: RCV gearing

	31-Mar-91	31-Mar-92	31-Mar-93	31-Mar-94	31-Mar-95	31-Mar-96	31-Mar-97	31-Mar-98	31-Mar-99	31-Mar-00	31-Mar-01	31-Mar-02	31-Mar-03
	%	%	%	%	%	%	%	%	%	%	%	%	%
WaSCs													
CR													
ANH	14.8	20.5	22.9	25.9	24.6	32.3	33.3	39.4	38.7	45.4	43.4	51.9	82.0
WSH	-36.6	-6.0	6.5	9.9	12.4	16.3	23.4	45.1	49.9	47.8	66.7	87.9	84.9
NES	24.3	32.0	41.7	38.7	29.3	36.0	38.1	44.3	43.0	44.9	46.1	59.1	62.6
SRN	53.9	56.9	56.9	52.7	41.2	28.8	34.5	36.2	40.4	43.7	49.0	58.2	57.4
WSX	2.4	27.1	41.2	47.3	42.0	43.6	38.6	38.5	50.6	48.8	46.3	48.8	69.8
	14.5	25.6	31.3	32.3	28.2	30.6	33.1	40.5	43.1	45.8	49.6	60.6	73.2
NCR													
SVT	-14.6	2.5	14.2	18.7	17.2	26.2	26.1	38.3	43.1	46.3	49.7	49.8	49.5
SWT	-107.3	-41.4	-1.0	15.9	22.4	23.0	25.3	33.1	41.6	36.2	42.3	52.2	57.5
TMS	5.9	18.5	25.0	26.7	24.7	21.1	20.6	28.6	48.0	45.6	48.9	45.7	47.3
UUW	-5.2	11.8	21.1	18.0	14.4	27.7	27.1	34.7	40.0	45.0	47.8	47.6	48.2
YKY	13.1	22.7	16.4	13.1	8.1	19.7	23.3	25.3	29.0	35.0	36.8	38.4	39.6
	-5.7	10.0	18.1	19.6	17.4	24.3	24.6	32.6	41.3	43.3	46.4	46.6	47.7
Average WaSCs	2.2	15.9	23.0	24.3	21.3	26.6	27.7	35.5	42.0	44.2	47.7	52.1	57.7
WoCs													
CR													
brl	63.7	70.0	56.0	57.4	55.6	48.4	38.8	40.6	52.3	49.4	39.1	42.3	40.8
dvw	13.3	9.7	1.7	-9.1	-17.5	-21.8	6.4	-6.4	-6.7	-12.0	-10.8	-8.7	48.9
mkt	19.3	18.6	27.9	32.6	26.2	19.1	21.0	35.3	30.0	26.9	26.3	35.8	76.7
prt	30.4	31.6	28.5	25.2	22.8	16.0	28.1	24.3	21.7	18.4	12.1	7.0	75.9
sst	37.7	34.9	29.7	25.4	16.7	10.9	14.0	15.1	13.5	10.6	13.2	17.6	65.8
ses	22.0	15.4	24.1	17.6	12.1	4.4	-0.6	-6.8	-5.3	4.3	46.9	47.8	48.2
	34.0	33.3	32.0	30.3	25.3	18.2	19.6	21.1	22.5	21.4	25.9	29.1	59.7
NCR													
bwh	32.7	23.9	21.4	13.6	12.5	9.6	11.8	16.3	20.3	17.8	16.1	18.8	23.2
cam	64.3	63.3	65.0	52.2	41.7	33.2	39.7	37.8	38.0	36.3	29.8	36.3	30.2
flk	23.7	22.9	25.9	24.0	22.4	15.0	28.1	25.9	33.5	25.3	21.3	32.0	33.4
mse	41.3	45.6	49.2	41.5	38.8	35.6	33.5	27.9	37.8	36.9	31.2	31.7	32.6
thd	21.0	31.9	35.4	29.1	22.5	16.7	17.0	19.4	17.8	18.1	23.6	20.2	20.6
tvn	33.0	38.7	40.4	31.4	25.2	24.0	23.8	27.2	26.3	25.5	28.1	32.1	35.3
	36.0	39.8	42.1	33.8	28.9	26.3	26.3	26.6	29.9	28.9	27.8	30.5	32.5
Average WoCs	35.2	37.3	38.2	32.5	27.6	23.3	23.9	24.6	27.3	26.2	27.1	30.0	42.9
Industry average	5.0	17.6	24.2	24.9	21.7	26.4	27.4	34.8	41.1	43.2	46.5	50.8	56.9

Table 4.28: Mean values of HCAV and RCV gearing

	31-Mar-91	31-Mar-92	31-Mar-93	31-Mar-94	31-Mar-95	31-Mar-96	31-Mar-97	31-Mar-98	31-Mar-99	31-Mar-00	31-Mar-01	31-Mar-02	31-Mar-03
	%	%	%	%	%	%	%	%	%	%	%	%	%
HCAV gearing													
WaSCs													
CR	10.9	21.7	27.3	29.2	27.3	30.4	32.9	40.2	43.6	45.6	54.4	60.2	68.5
NCR	-10.0	3.9	12.0	15.0	16.3	22.8	24.9	33.2	41.0	42.0	44.3	49.4	52.2
	0.4	12.8	19.7	22.1	21.8	26.6	28.9	36.7	42.3	43.8	49.3	54.8	60.4
WoCs													
CR	34.0	32.8	29.9	24.9	17.8	10.0	22.0	19.4	11.7	8.9	19.3	-3.4	68.6
NCR	51.8	51.9	51.2	43.2	36.0	30.6	34.3	34.1	38.2	35.5	34.9	41.5	42.3
	42.9	42.3	40.6	34.1	26.9	20.3	28.2	26.7	25.0	22.2	27.1	19.1	55.5
Industry Mean	23.6	28.9	31.1	28.6	24.6	23.2	28.5	31.3	32.8	32.0	37.2	35.3	57.7
RCV gearing													
WaSCs													
CR	11.8	26.1	33.9	34.9	29.9	31.4	33.6	40.7	44.5	46.1	50.3	61.2	71.3
NCR	-21.6	2.8	15.1	18.5	17.3	23.5	24.5	32.0	40.3	41.6	45.1	46.8	48.4
	-4.9	14.5	24.5	26.7	23.6	27.5	29.0	36.3	42.4	43.9	47.7	54.0	59.9
WoCs													
CR	31.1	30.0	28.0	24.9	19.3	12.8	18.0	17.0	17.6	16.3	21.1	23.6	59.4
NCR	36.0	37.7	39.6	31.9	27.2	22.3	25.7	25.7	28.9	26.6	25.0	28.5	29.2
	33.5	33.9	33.8	28.4	23.3	17.6	21.8	21.4	23.3	21.5	23.1	26.1	44.3
Industry Mean	16.1	25.0	29.6	27.6	23.4	22.1	25.1	28.2	32.0	31.6	34.3	38.7	51.4

Table 4.29: Retail Price Index - Financial Year End

Year end	RPI
31-Mar-91	131.4
31-Mar-92	136.7
31-Mar-93	139.3
31-Mar-94	142.5
31-Mar-95	147.5
31-Mar-96	151.5
31-Mar-97	155.4
31-Mar-98	160.8
31-Mar-99	164.1
31-Mar-00	168.4
31-Mar-01	172.2
31-Mar-02	174.5
31-Mar-03	179.9

Figure 4.6: Net Debt, Historical Cost Asset Value and Regulatory Capital Value - Water and Sewerage Companies

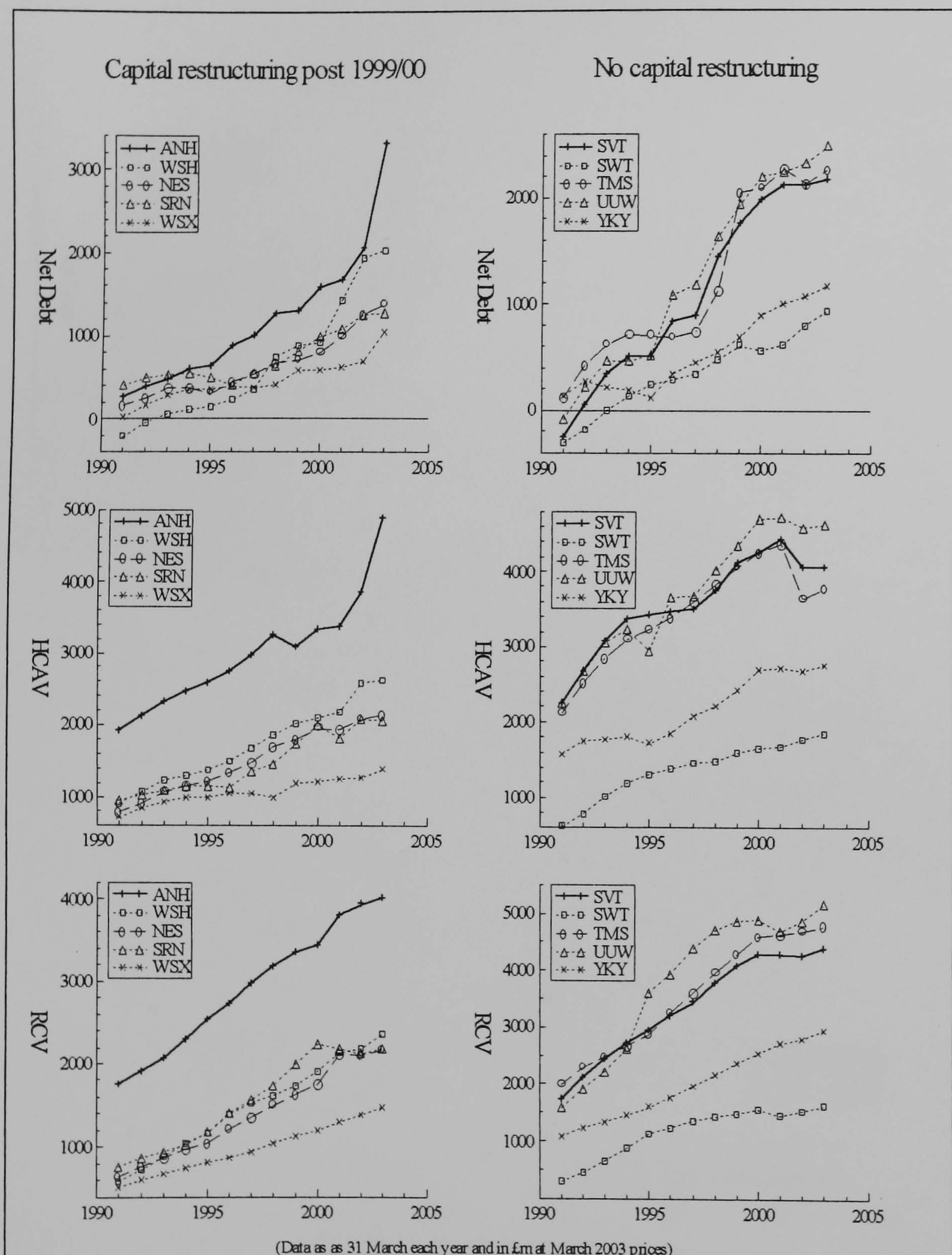


Figure 4.7: Net Debt, Historical Cost Asset Value and Regulatory Capital Value - Water only Companies

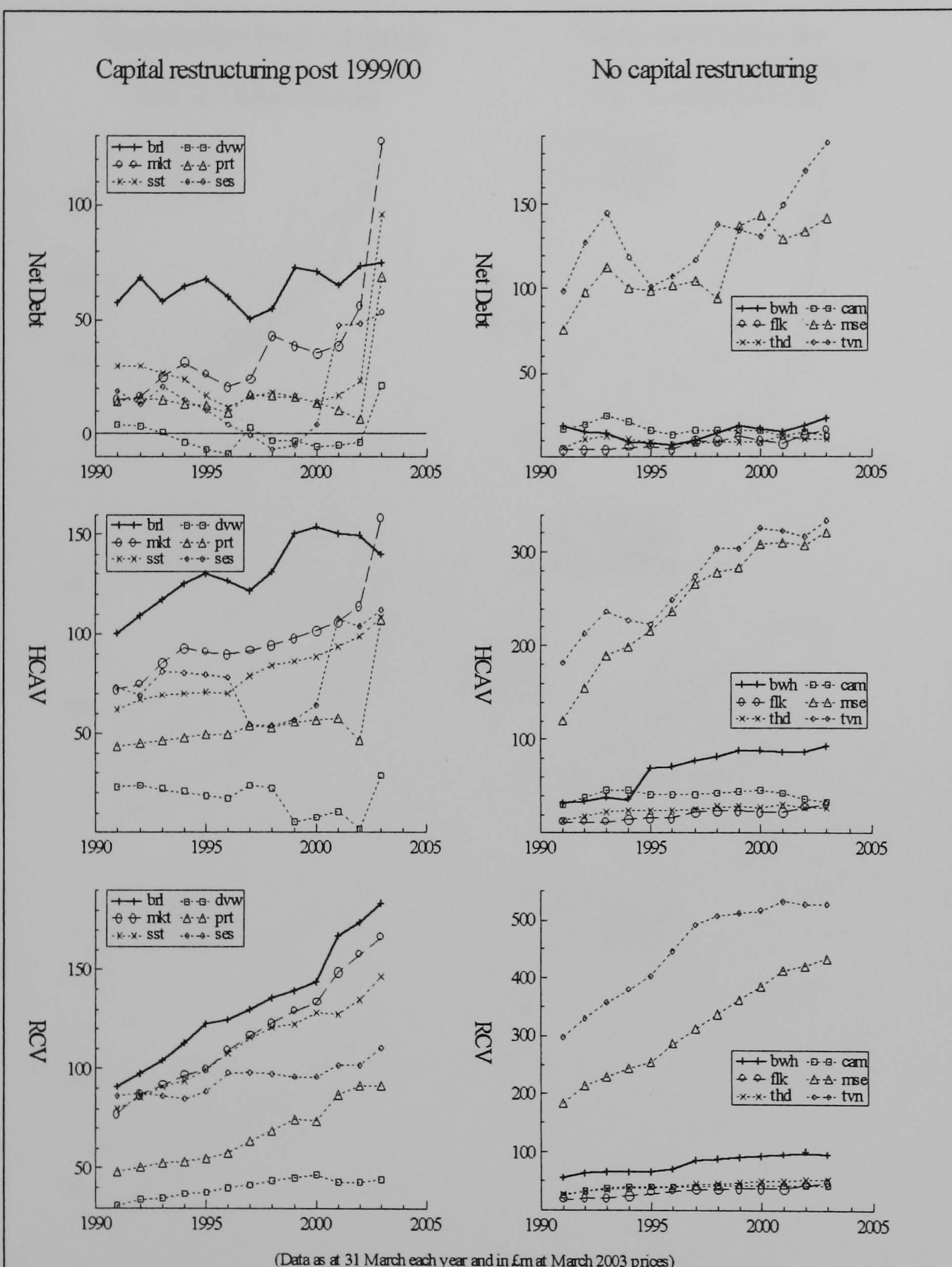


Figure 4.8: Mean Values of Net Debt, Historical Cost Asset Value and Regulatory Capital Value

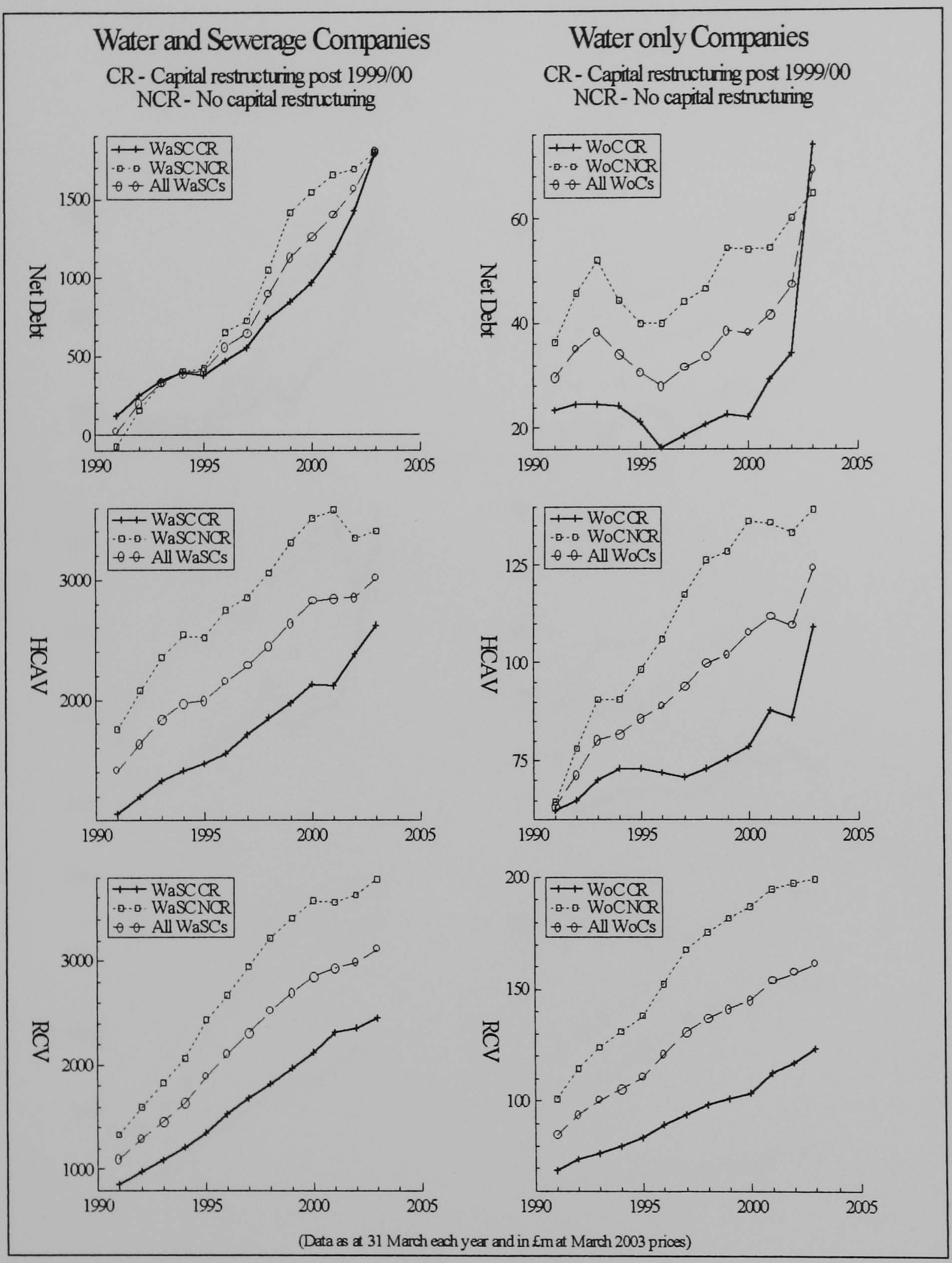
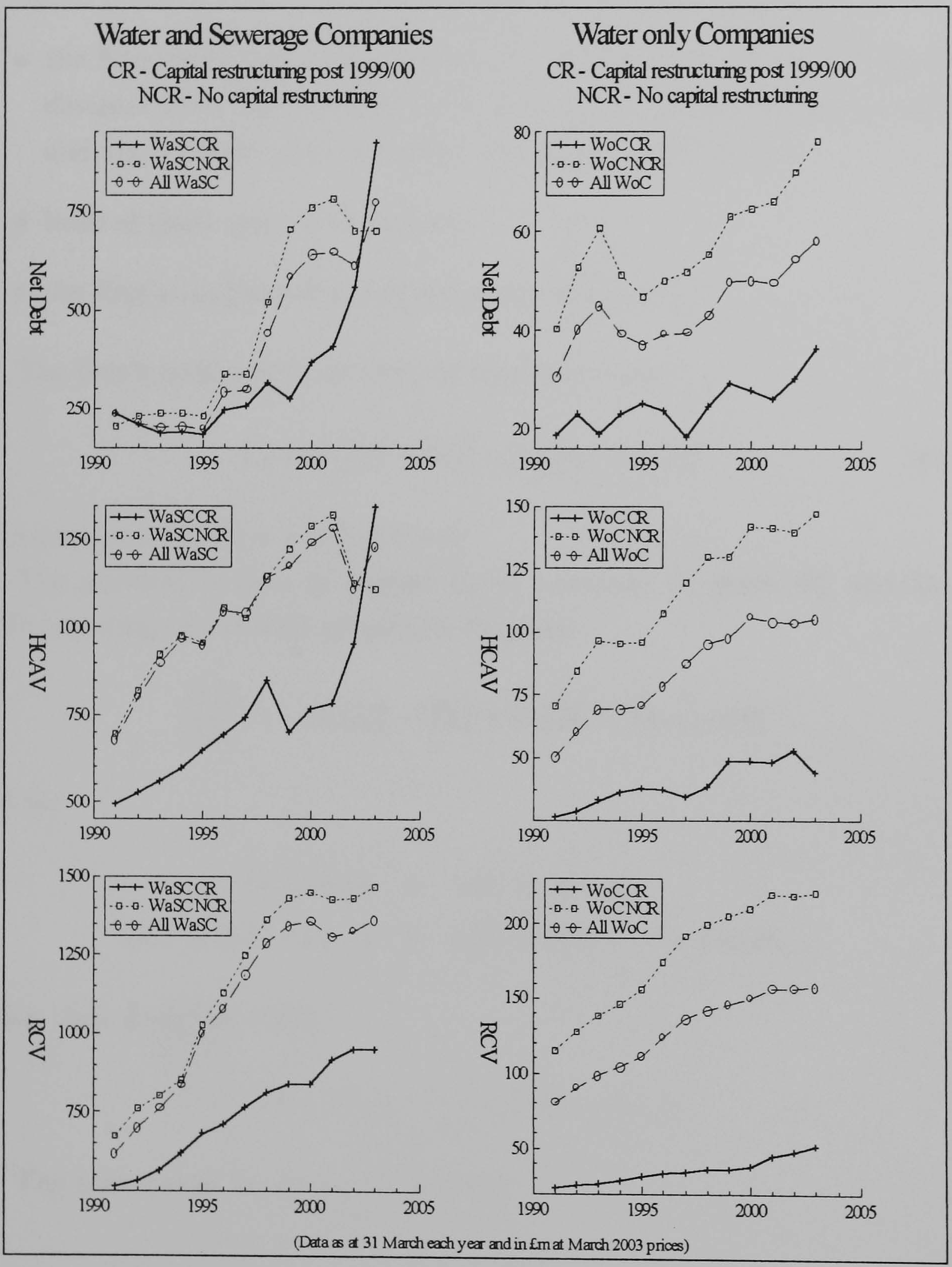


Figure 4.9: Standard Deviations of Net Debt, Historical Cost Asset Value and Regulatory Capital Value



Appendix 4.B Derivation of the Models

4.B.1 Partial Adjustment Model

An economic rationale for the PAM based on the highly simplified example in Griliches (1967) can be illustrated as follows. It is assumed that:

- the firm incurs two types of cost viz. a higher cost of capital if the firm deviates from D_t^*, the level of debt at its its optimal capital structure, and transactions costs in raising or repaying debt finance;
- both of these costs are quadratic;
- the firm's capital value is determined exogenously.

The firm's total costs can then be represented as:

$$C_t = a\left(D_t^* - D_t\right)^2 + b\left(D_t - D_{t-1}\right)^2 \tag{4.66}$$

with cost parameters $a > 0$ and $b > 0$.

The problem is then to choose D_t to minimize C_t given D_t^* and D_{t-1}. Differentiating (4.66) with respect to D_t gives:

$$\frac{\partial C_t}{\partial D_t} = -2a\left(D_t^* - D_t\right) + 2b\left(D_t - D_{t-1}\right) = 0,$$

and so:

$$\begin{aligned} (a+b)\,D_t &= aD_t^* + bD_{t-1}, \\ (a+b)\left(D_t - D_{t-1}\right) &= aD_t^* + bD_{t-1} - (a+b)\,D_{t-1}, \end{aligned}$$

which then gives the PAM:

$$D_t - D_{t-1} = \frac{a}{a+b}\left(D_t^* - D_{t-1}\right).$$

The adjustment factor, α, is, therefore:

$$\alpha = \frac{a}{a+b} \tag{4.67}$$

which depends on the relative size of the two types of cost.

4.B.2 Combined Partial Adjustment and Adaptive Expectations Model

The derivation of (4.12) can be shown as follows. This model is based on the three relationships in (4.5), (4.8) and (4.11) i.e.:

$$\begin{aligned} D_{it} - D_{it-1} &= \alpha(D^*_{it} - D_{it-1}) \\ V^*_{it} - V^*_{it-1} &= \lambda\left(V_{it} - V^*_{it-1}\right) \\ D^*_{it} &= g^* V^*_{it}. \end{aligned}$$

Substituting (4.11) and (4.8) into (4.5) gives:

$$D_{it} = \alpha g^* \left[\lambda V_{it} + (1-\lambda) V^*_{it-1}\right] + (1-\alpha) D_{it-1}.$$

However, substituting (4.11) into (4.5) and lagging by one period gives:

$$V^*_{it-1} = \frac{D_{it-1}}{\alpha g^*} - \frac{(1-\alpha) D_{it-2}}{\alpha g^*}.$$

Consequently, substituting for V^*_{it-1} and adding an error term gives (4.12), that is:

$$D_{it} = \alpha g^* \lambda V_{it} + (1 - \alpha + 1 - \lambda) D_{it-1} - (1-\alpha)(1-\lambda) D_{it-2} + u_{it}.$$

4.B.3 Error Correction Model

An economic rationale for the ECM can be derived as follows. It is assumed that:

- the firm incurs two types of cost viz. a higher cost of capital if the firm deviates from its optimal level of debt and transactions costs in raising or repaying debt finance;
- both of these costs are quadratic;
- the cost of deviating from the optimal level of debt has two components; the cost of deviating from D^*_{t-1} and the effect on that cost of moving from D^*_{t-1} to D^*_t because of a change in the firm's capital value V_t;
- the firm's capital value is determined exogenously.

The firm's total costs can then be represented as:

$$C_t = a\left[c\left(V_t - V_{t-1}\right) + \left(D^*_{t-1} - D_t\right)\right]^2 + b\left(D_t - D_{t-1}\right)^2 \tag{4.68}$$

with cost parameters $a > 0$, $b > 0$ and $c > 0$.

The problem is then to choose D_t to minimize C_t given D^*_t and D_{t-1}. Differentiating (4.68) with respect to D_t gives:

$$\frac{\partial C_t}{\partial D_t} = -2a\left[c\left(V_t - V_{t-1}\right) + \left(D^*_{t-1} - D_t\right)\right] + 2b\left(D_t - D_{t-1}\right) = 0,$$

and so:

$$\begin{aligned} ac\left(V_t - V_{t-1}\right) + aD^*_{t-1} &= (a+b)\,D_t - bD_{t-1}, \\ ac\left(V_t - V_{t-1}\right) + a\left(D^*_{t-1} - D_{t-1}\right) &= (a+b)\,D_t - (a+b)\,D_{t-1}, \end{aligned}$$

which then gives the ECM:

$$D_t - D_{t-1} = \frac{ac}{a+b}\left(V_t - V_{t-1}\right) + \frac{a}{a+b}\left(D^*_{t-1} - D_{t-1}\right).$$

The adjustment factors α and γ are, therefore:

$$\alpha = \frac{a}{a+b}, \tag{4.69}$$

$$\gamma = \frac{ac}{a+b}, \tag{4.70}$$

which shows that α depends on the relative size of a and b, and γ on the relative sizes of a, b and c.

It should also be noted that in the first part of the cost function:

$$\begin{aligned} c\left(V_t - V_{t-1}\right) + \left(D^*_{t-1} - D_t\right) &= \frac{c}{g^*}\left(D^*_t - D^*_{t-1}\right) + \left(D^*_{t-1} - D_t\right), \qquad (4.71) \\ &= \frac{c}{g^*}D^*_t + \left(1 - \frac{c}{g^*}\right)D^*_{t-1} - D_t. \end{aligned}$$

This shows that the cost of deviating from the optimal level of debt is based on the deviation from the weighted average of D^*_t and D^*_{t-1} where the weight attached to D^*_t is inversely related to the target level of gearing $g^*$and, conversely, the weight attached to D^*_{t-1} varies directly with g^*. Consequently, when the target level of gearing is high, a change in the optimal level of debt following a change in V_t has a smaller effect on costs. This is consistent with an assumption that the cost of debt rises with the target level of gearing and the loss from not being at the optimum capital structure is lower because the cost of debt is closer to the cost of equity.

Appendix 4.C Detailed Results based on HCAV

4.C.1 Initial equations

The OLS estimates of the initial equations for each type and category of company are numbered in this appendix as:

Equation (HCAV1-I): WaSC CR

Equation (HCAV2-I): WaSC NCR

Equation (HCAV3-I): All WaSC's

Equation (HCAV4-I): WoC CR

Equation (HCAV5-I): WoC NCR

Equation (HCAV6-I): All WoC's.

The outputs from PcGive for each equation are set out on the following three pages.

EQ(HCAV1-I) Modelling DEBT by OLS-CS (using WaSC CR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-18.4259	84.24	-0.219	0.828	0.0012
T1	-24.7028	97.89	-0.252	0.802	0.0016
T2	197.954	116.4	1.70	0.097	0.0674
HCAV	0.607709	0.6200	0.980	0.333	0.0235
HCAVT1	-0.0449099	0.6413	-0.0700	0.945	0.0001
HCAVT2	0.405112	0.6287	0.644	0.523	0.0103
HCAV-1	-0.623252	0.6607	-0.943	0.351	0.0218
HCAV-1T1	0.171235	0.6844	0.250	0.804	0.0016
HCAV-1T2	-0.148615	0.6770	-0.220	0.827	0.0012
DEBT-1	1.37040	0.7312	1.87	0.068	0.0807
DEBT-1T1	-0.578247	0.7588	-0.762	0.451	0.0143
DEBT-1T2	-0.267338	0.7508	-0.356	0.724	0.0032
DEBT-2	-0.395601	0.6615	-0.598	0.553	0.0089
DEBT-2T1	0.438416	0.6887	0.637	0.528	0.0100
DEBT-2T2	-0.339072	0.7208	-0.470	0.641	0.0055

sigma	87.134	RSS	303693.668
R^2	0.983806	F(14,40) =	173.6 [0.000]**
log-likelihood	-314.994	DW	2.34
no. of observations	55	no. of parameters	15
mean(DEBT)	822.731	var(DEBT)	340976

Normality test: Chi^2(2) = 13.182 [0.0014]**
hetero test: F(26,13) = 0.49689 [0.9374]
Hetero-X test: not enough observations
RESET test: F(1,39) = 3.3108 [0.0765]

EQ(HCAV2-I) Modelling DEBT by OLS-CS (using WaSC NCR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-15.7990	119.3	-0.132	0.895	0.0004
T1	-140.171	150.9	-0.929	0.359	0.0211
T2	110.773	191.2	0.579	0.566	0.0083
HCAV	0.202690	0.3872	0.524	0.603	0.0068
HCAVT1	0.464757	0.4369	1.06	0.294	0.0275
HCAVT2	0.109889	0.4232	0.260	0.796	0.0017
HCAV-1	-0.156250	0.3754	-0.416	0.679	0.0043
HCAV-1T1	-0.367282	0.4336	-0.847	0.402	0.0176
HCAV-1T2	-0.160631	0.4496	-0.357	0.723	0.0032
DEBT-1	1.03743	0.7463	1.39	0.172	0.0461
DEBT-1T1	-0.220856	0.7597	-0.291	0.773	0.0021
DEBT-1T2	-0.00631225	0.9844	-0.00641	0.995	0.0000
DEBT-2	-0.330679	0.6409	-0.516	0.609	0.0066
DEBT-2T1	0.312325	0.6715	0.465	0.644	0.0054
DEBT-2T2	0.308777	0.7785	0.397	0.694	0.0039

sigma	134.958	RSS	728551.623
R^2	0.975683	F(14,40) =	114.6 [0.000]**
log-likelihood	-339.057	DW	2.15
no. of observations	55	no. of parameters	15
mean(DEBT)	1062.55	var(DEBT)	544742

Normality test: Chi^2(2) = 33.725 [0.0000]**
hetero test: F(26,13) = 0.22194 [0.9995]
Hetero-X test: not enough observations
RESET test: F(1,39) =0.00031279 [0.9860]

EQ(HCAV3-I) Modelling DEBT by OLS-CS (using All WaSCs data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	20.4790	54.14	0.378	0.706	0.0015
T1	-94.4589	68.48	-1.38	0.171	0.0196
T2	38.1442	82.00	0.465	0.643	0.0023
HCAV	0.254540	0.2787	0.913	0.363	0.0087
HCAVT1	0.370169	0.3104	1.19	0.236	0.0148
HCAVT2	0.474102	0.2906	1.63	0.106	0.0272
HCAV-1	-0.243092	0.2742	-0.886	0.378	0.0082
HCAV-1T1	-0.272711	0.3110	-0.877	0.383	0.0080
HCAV-1T2	-0.440888	0.2902	-1.52	0.132	0.0237
DEBT-1	1.17353	0.4875	2.41	0.018	0.0575
DEBT-1T1	-0.355751	0.4998	-0.712	0.478	0.0053
DEBT-1T2	-0.00269857	0.5142	-0.00525	0.996	0.0000
DEBT-2	-0.321269	0.4411	-0.728	0.468	0.0056
DEBT-2T1	0.362110	0.4612	0.785	0.434	0.0064
DEBT-2T2	0.0893698	0.4726	0.189	0.850	0.0004

sigma	118.207	RSS	1327425.77
R^2	0.973608	F(14,95) =	250.3 [0.000]**
log-likelihood	-672.988	DW	2.18
no. of observations	110	no. of parameters	15
mean(DEBT)	942.641	var(DEBT)	457237

```
Normality test:   Chi^2(2) =   36.146 [0.0000]**
hetero test:      F(26,68) =  0.86254 [0.6543]
Hetero-X test: not enough observations
RESET test:       F(1,94)  =   1.3505 [0.2481]
```

EQ(HCAV4-I) Modelling DEBT by OLS-CS (using WoC CR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-4.69755	7.543	-0.623	0.536	0.0075
T1	2.23573	9.471	0.236	0.814	0.0011
T2	0.274732	9.997	0.0275	0.978	0.0000
HCAV	0.951309	0.6127	1.55	0.127	0.0451
HCAVT1	-0.376674	0.6640	-0.567	0.573	0.0063
HCAVT2	0.110151	0.6246	0.176	0.861	0.0006
HCAV-1	-0.874098	0.6858	-1.27	0.208	0.0309
HCAV-1T1	0.378323	0.7455	0.507	0.614	0.0050
HCAV-1T2	0.0324065	0.7109	0.0456	0.964	0.0000
DEBT-1	0.634351	0.4867	1.30	0.198	0.0322
DEBT-1T1	0.219863	0.5624	0.391	0.697	0.0030
DEBT-1T2	0.363788	0.5700	0.638	0.526	0.0079
DEBT-2	0.189184	0.4508	0.420	0.677	0.0034
DEBT-2T1	-0.230234	0.5365	-0.429	0.670	0.0036
DEBT-2T2	-0.492422	0.5003	-0.984	0.330	0.0186

sigma	9.79317	RSS	4891.21767
R^2	0.907916	F(14,51) =	35.92 [0.000]**
log-likelihood	-235.733	DW	2.13
no. of observations	66	no. of parameters	15
mean(DEBT)	27.9329	var(DEBT)	804.8

```
Normality test:   Chi^2(2) =   63.533 [0.0000]**
hetero test:      F(26,24) =  0.51901 [0.9474]
Hetero-X test: not enough observations
RESET test:       F(1,50)  =   4.6984 [0.0350]*
```

EQ(HCAV5-I) Modelling DEBT by OLS-CS (using WoC NCR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-1.84682	3.784	-0.488	0.628	0.0046
T1	-1.05227	4.453	-0.236	0.814	0.0011
T2	0.643652	4.873	0.132	0.895	0.0003
HCAV	0.481494	0.2022	2.38	0.021	0.1000
HCAVT1	-0.367915	0.3022	-1.22	0.229	0.0282
HCAVT2	-0.477840	0.3999	-1.20	0.238	0.0272
HCAV-1	-0.432644	0.6361	-0.680	0.499	0.0090
HCAV-1T1	0.488649	0.6757	0.723	0.473	0.0102
HCAV-1T2	0.509545	0.7237	0.704	0.485	0.0096
DEBT-1	1.13409	0.4578	2.48	0.017	0.1074
DEBT-1T1	-0.573753	0.4951	-1.16	0.252	0.0257
DEBT-1T2	0.130719	0.5393	0.242	0.809	0.0012
DEBT-2	-0.311111	0.4466	-0.697	0.489	0.0094
DEBT-2T1	0.429884	0.4757	0.904	0.370	0.0158
DEBT-2T2	-0.0755224	0.5647	-0.134	0.894	0.0004

sigma	7.83895	RSS	3133.90984
R^2	0.984823	F(14,51) =	236.4 [0.000]**
log-likelihood	-221.043	DW	2.28
no. of observations	66	no. of parameters	15
mean(DEBT)	50.4458	var(DEBT)	3128.57

```
Normality test:   Chi^2(2) =    40.254 [0.0000]**
hetero test:      F(26,24) =    3.2659 [0.0024]**
Hetero-X test: not enough observations
RESET test:       F(1,50)  =  0.65899 [0.4208]
```

EQ(HCAV6-I) Modelling DEBT by OLS-CS (using All WoCs data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-2.22241	2.970	-0.748	0.456	0.0048
T1	-1.00312	3.693	-0.272	0.786	0.0006
T2	1.75790	4.073	0.432	0.667	0.0016
HCAV	0.557183	0.1673	3.33	0.001	0.0866
HCAVT1	-0.179991	0.2341	-0.769	0.443	0.0050
HCAVT2	0.435448	0.1945	2.24	0.027	0.0411
HCAV-1	-0.506306	0.2002	-2.53	0.013	0.0518
HCAV-1T1	0.248699	0.2656	0.936	0.351	0.0074
HCAV-1T2	-0.326994	0.2378	-1.37	0.172	0.0159
DEBT-1	1.03530	0.1878	5.51	0.000	0.2062
DEBT-1T1	-0.326399	0.2452	-1.33	0.186	0.0149
DEBT-1T2	-0.000736656	0.2623	-0.00281	0.998	0.0000
DEBT-2	-0.208244	0.1851	-1.13	0.263	0.0107
DEBT-2T1	0.249532	0.2382	1.05	0.297	0.0093
DEBT-2T2	-0.135920	0.2523	-0.539	0.591	0.0025

sigma	8.90484	RSS	9277.66193
R^2	0.966425	F(14,117) =	240.6 [0.000]**
log-likelihood	-467.969	DW	2.05
no. of observations	132	no. of parameters	15
mean(DEBT)	39.1894	var(DEBT)	2093.39

```
Normality test:   Chi^2(2) =    55.650 [0.0000]**
hetero test:      F(26,90) =    1.2569 [0.2132]
Hetero-X test: not enough observations
RESET test:       F(1,116) =  0.90603 [0.3432]
```

4.C.2 Tests for serial correlation

Table 4.30 sets out the results of the first two tests for serial correlation based on the residuals $\widehat{u}_{it}$ from the six initial equations as described in subsection 4.6.2. Each test calculates an estimate ρ, the coefficient of $\widehat{u}_{it-1}$; the first by including $\widehat{u}_{it-1}$ as an additional regressor in the initial equation and the second by regressing $\widehat{u}_{it}$ on $\widehat{u}_{it-1}$. The t-statistics marked * are heteroscedasticity-robust t-statistics based on White (1980). None of the t-statistics are significant at the 5% level.

Table 4.30: Tests for serial correlation

Equation	Include $\widehat{u}_{it-1}$ as an additional regressor		Regression of $\widehat{u}_{it}$ on $\widehat{u}_{it-1}$	
	ρ	t-statistic	ρ	t-statistic
HCAV1-I: WaSC CR	-0.387883	-1.65	-0.211750	-1.44
HCAV2-I: WaSC NCR	-0.206623	-0.697	-0.0682388	-0.481
HCAV3-I: All WaSC's	-0.134548	-0.793	-0.0670618	-0.631
HCAV4-I: WoC CR	-0.435777	-1.07	-0.134411	-0.41438*
HCAV5-I: WoC NCR	-0.721456	-1.4157*	-0.145376	-0.69663*
HCAV6-I: All WoC's	-0.230694	-1.01	-0.0917538	-0.57645*

Table 4.31 gives the results of the third test for serial correlation described in subsection 4.6.2. This uses the residuals $\widehat{u}_{it}$ from the six initial equations to test for serial correlation by estimating ρ for each company separately. The t-statistics marked * are heteroscedasticity-robust t-statistics based on White (1980). The critical values of the t-test are 2.262 at the 5% level and 3.250 at the 1% level. Where the coefficient is significantly different from zero the significance level for the t-statistic is given in parentheses i.e. [5] or [1].

Table 4.31: Tests for serial correlation

Category	Company	Residuals $\widehat{u}_{it}$ from HCAV3-I & 6-I		Residuals $\widehat{u}_{it}$ from HCAV1-I, 2-I, 4-I & 5-I	
		ρ	t-statistic	ρ	t-statistic
WaSC CR	ANH	-0.481550	-0.871	-0.118627	-0.317
	WSH	-0.0229722	-0.0661	-0.326865	-1.02
	NES	-0.182230	-0.537	0.405146	1.29
	SRN	0.042014	0.114	-0.334939	-1.06
	WSX	0.126591	0.252	0.0693758	0.171
WaSC NCR	SVT	-0.638350	-2.50 [5]	-0.665724	-1.6111*
	SWT	0.0772960	0.223	0.330765	1.05
	TMS	0.0107160	0.0321	0.00964509	0.0290
	UUW	-0.218319	-0.673	-0.357898	-1.11
	YKY	0.588700	3.3465*[1]	0.106432	0.375
WoC CR	brl	0.0585079	0.178	-0.339937	-0.111
	dvw	-0.604096	-2.22	-0.374417	-1.22
	mkt	0.176661	0.371	-0.015584	-0.0372
	prt	-0.144748	-0.438	-0.295637	-0.882
	sst	-0.835291	-0.818	-0.892552	-0.986
	ses	0.437521	1.57	0.417120	1.30
WoC NCR	bwh	0.580751	1.81	0.641137	2.51 [5]
	cam	-0.220368	-1.0143*	-0.574619	-2.20
	flk	0.600759	2.31 [5]	0.394486	1.32
	mse	-0.279793	-0.830	-0.289309	-0.909
	thd	0.465946	1.76	-0.0825832	-0.257
	tvn	-0.188	0.622	-0.235752	-0.789

4.C.3 Model reduction

In the following Tables N is the number of observations and p is the number of parameters in the relevant equation. Variables deleted (or added) in the model reduction procedure are shown next to the first equation from which they have been eliminated (or to which they have been added).

Table 4.32: Model reduction - All WaSC's

Equation	N	Variable delete/add (−/+)	p	log-likelihood	SC	HQC	AIC
EQ(1)	110		15	-672.98818	12.877	12.658	12.509
EQ(2)	110	$-D_{it-1}T2_t$	14	-672.98820	12.834	12.630	12.491
EQ(3)	110	$-constant$	13	-673.07468	12.793	12.604	12.474
EQ(4)	110	$-D_{it-2}T2_t$	12	-673.22215	12.753	12.578	12.459
EQ(5)	110	$-HCAV_{it-1}T1_t$	11	-673.66058	12.718	12.558	12.448
EQ(6)	110	$-T2_t$	10	-674.20712	12.686	12.540	12.440
EQ(7)	110	$-D_{it-2}T1_t$	9	-675.55519	12.667	12.536	12.446
EQ(8)	110	$-D_{it-2}$	8	-676.16229	12.636	12.519	12.439
EQ(9)	110	$-D_{it-1}T1_t$	7	-676.63931	12.602	12.500	12.430
EQ(10)	110	$-HCAV_{it-1}T2_t$	6	-677.83786	12.581	12.493	12.433
EQ(11)	110	$-T1_t$	5	-679.37934	12.566	12.493	12.443

Table 4.33: Model reduction - WaSC CR

Equation	N	Variable delete/add (−/+)	p	log-likelihood	SC	HQC	AIC
EQ(1)	55		15	-314.99376	12.547	12.211	12.000
EQ(2)	55	$-HCAV_{it}T1_t$	14	-314.99714	12.474	12.161	11.964
EQ(3)	55	$-constant$	13	-314.99714	12.474	12.161	11.964
EQ(4)	55	$-D_{it-1}T2_t$	12	-315.11113	12.333	12.064	11.895
EQ(5)	55	$-HCAV_{it-1}T2_t$	11	-315.61290	12.278	12.032	11.877
EQ(6)	55	$-D_{it-2}T1_t$	10	-316.06952	12.222	11.998	11.857
EQ(7)	55	$-D_{it-2}$	9	-316.28247	12.157	11.955	11.828
EQ(8)	55	$-D_{it-1}T1_t$	8	-317.05466	12.112	11.933	11.820
EQ(9)	55	$-T1_t$	7	-317.76515	12.065	11.908	11.810
EQ(10)	55	$-T2_t$	6	-319.91966	12.071	11.936	11.852
EQ(11)	55	$-D_{it-2}T2_t$	5	-323.15389	12.115	12.003	11.933
EQ(12)	55	$-HCAV_{it-1}T1_t$ $+HCAV_{it}T1_t$	5	-323.60403	12.132	12.020	11.949

Table 4.34: Model reduction - WaSC NCR

Equation	N	Variable delete/add (−/+)	p	log-likelihood	SC	HQC	AIC
EQ(1)	55		15	-339.05734	13.422	13.087	12.875
EQ(2)	55	$-D_{it-1}T2_t$	14	-339.05736	13.349	13.036	12.838
EQ(3)	55	$-constant$	13	-339.07018	13.277	12.986	12.803
EQ(4)	55	$-HCAV_{it}T2_t$	12	-339.12907	13.206	12.938	12.768
EQ(5)	55	$-HCAV_{it-1}T2_t$	11	-339.18511	13.135	12.889	12.734
EQ(6)	55	$-D_{it-1}T1_t$	10	-339.22882	13.064	12.840	12.699
EQ(7)	55	$-D_{it-2}T1_t$	9	-339.37675	12.997	12.795	12.668
EQ(8)	55	$-D_{it-2}$	8	-339.60814	12.932	12.753	12.640
EQ(9)	55	$-T2_t$	7	-340.03048	12.875	12.718	12.619
EQ(10)	55	$-HCAV_{it-1}T1_t$	6	-340.51858	12.820	12.685	12.601
EQ(11)	55	$-T1_t$	5	-342.57588	12.822	12.710	12.639
EQ(12)	55	$-D_{it-2}T2_t$ $+HCAV_{it}T1_t$	5	-342.74656	12.828	12.716	12.645

Table 4.35: Model reduction - All WoC's

Equation	N	Variable delete/add (−/+)	p	log-likelihood	SC	HQC	AIC
EQ(1)	132		15	-467.96904	7.6453	7.4508	7.3177
EQ(2)	132	$-D_{it-1}T2_t$	14	-467.96904	7.6083	7.4268	7.3026
EQ(3)	132	$-T1_t$	13	-468.01248	7.5720	7.4034	7.2881
EQ(4)	132	$-D_{it-2}T2_t$	12	-468.23640	7.5384	7.3828	7.2763
EQ(5)	132	$-HCAV_{it}T1_t$	11	-468.53769	7.5060	7.3633	7.2657
EQ(6)	132	$-HCAV_{it-1}T1_t$	10	-468.56672	7.4694	7.3398	7.2510
EQ(7)	132	$-T2_t$	9	-469.20125	7.4420	7.3253	7.2455
EQ(8)	132	$-constant$	8	-470.32755	7.4221	7.3184	7.2474
EQ(9)	132	$-D_{it-1}T1_t$	7	-471.80894	7.4076	7.3168	7.2547
EQ(10)	132	$-D_{it-2}T1_t$	6	-472.61334	7.3828	7.3050	7.2517
EQ(11)	132	$-D_{it-2}$	5	-474.06264	7.3677	7.3029	7.2585
EQ(11)	144		5	-514.97832	7.3250	7.2638	7.2219
EQ(12)	144	$-HCAV_{it-1}T2_t$	4	-518.68906	7.3421	7.2931	7.2596

Table 4.36: Model reduction - WoC CR

Equation	N	Variable delete/add (−/+)	p	log-likelihood	SC	HQC	AIC
EQ(1)	66		15	-235.73282	8.0956	7.7946	7.5980
EQ(2)	66	$-T2_t$	14	-235.73331	8.0321	7.7512	7.5677
EQ(3)	66	$-HCAV_{it-1}T2_t$	13	-235.73574	7.9687	7.7079	7.5374
EQ(4)	66	$-T1_t$	12	-235.78849	7.9069	7.6661	7.5087
EQ(5)	66	$-D_{it-1}T1_t$	11	-235.86121	7.8456	7.6248	7.4806
EQ(6)	66	$-D_{it-2}$	10	-235.89542	7.7831	7.5825	7.4514
EQ(7)	66	$-D_{it-2}T1_t$	9	-235.91966	7.7204	7.5398	7.4218
EQ(8)	66	$-D_{it-1}T2_t$	8	-236.27971	7.6678	7.5073	7.4024
EQ(9)	66	$-constant$	7	-236.84425	7.6215	7.4810	7.3892
EQ(10)	66	$-HCAV_{it}T1_t$	6	-237.40057	7.5748	7.4544	7.3758
EQ(11)	66	$-HCAV_{it-1}T1_t$	5	-237.69631	7.5203	7.4200	7.3544
EQ(12)	66	$-D_{it-2}T2_t$	4	-238.91354	7.4937	7.4135	7.3610

Table 4.37: Model reduction - WoC NCR

Equation	N	Variable delete/add (−/+)	p	log-likelihood	SC	HQC	AIC
EQ(1)	66		15	-221.04255	7.6505	7.3494	7.1528
EQ(2)	66	$-D_{it-2}T2_t$	14	-221.05412	7.5873	7.3064	7.1229
EQ(3)	66	$-T1_t$	13	-221.07962	7.5246	7.2637	7.0933
EQ(4)	66	$-D_{it-1}T2_t$	12	-221.18760	7.4644	7.2236	7.0663
EQ(5)	66	$-T2_t$	11	-221.25962	7.4031	7.1824	7.0382
EQ(6)	66	$-HCAV_{it}T1_t$	10	-222.44693	7.3756	7.1749	7.0438
EQ(7)	66	$-HCAV_{it}T2_t$	9	-222.92446	7.3266	7.1460	7.0280
EQ(8)	66	$-HCAV_{it-1}T1_t$	8	-223.19989	7.2715	7.1109	7.0061
EQ(9)	66	$-HCAV_{it-1}$	7	-224.11682	7.2358	7.0953	7.0035
EQ(10)	66	$-HCAV_{it-1}T2_t$	6	-224.58448	7.1865	7.0661	6.9874
EQ(11)	66	$-D_{it-2}T1_t$	5	-229.05067	7.2583	7.1580	7.0924
EQ(12)	66	$-D_{it-1}T1_t$	4	-229.93036	7.2215	7.1412	7.0888
EQ(13)	66	$-D_{it-2}$	3	-231.87864	7.2171	7.1569	7.1175
EQ(14)	66	$-constant$	2	-233.11210	7.1910	7.1508	7.1246
All WoCs	72			-252.09469	7.2402	7.1641	7.1137
	72	$-HCAV_{it-1}T2_t$		-255.06311	7.2633	7.2062	7.1684

4.C.4 Final estimates

The final estimates of the equations for each type and category of company are numbered in this appendix as:

Equation (HCAV1-F): WaSC CR

Equation (HCAV2-F): WaSC NCR

Equation (HCAV3-F): All WaSC's

Equation (HCAV4-F): WoC CR

Equation (HCAV5-F): WoC NCR

Equation (HCAV6-F): All WoC's.

The outputs from PcGive for each equation are set out on the following three pages.

```
EQ(HCAV1-F) Modelling DEBT by DPD 1-step (using WaSC CR data)
                  ----   1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.849807    0.05800     14.7   0.000
HCAV                 0.717291    0.08330     8.61   0.000
HCAVT1              0.0451968   0.009129     4.95   0.000
HCAVT2               0.117944    0.02848     4.14   0.000
HCAV(-1)            -0.695859     0.1039    -6.70   0.000

sigma                87.61454  sigma^2             7676.307
R^2                 0.9793386
RSS              422196.91246  TSS             20434084.869
no. of observations        60  no. of parameters          5

Using robust standard errors

number of individuals       5 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(5) =2.623e+004 [0.000] **
AR(1) test:       N(0,1) =     0.1113 [0.911]
AR(2) test:       N(0,1) =     -1.553 [0.120]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   11.732 [0.0028]**
hetero test:      F(10,44) =   3.6724 [0.0013]**
hetero-X test:    F(17,37) =   2.3779 [0.0137]*
RESET test:       F(1,54)  =  0.47084 [0.4955]


EQ(HCAV2-F) Modelling DEBT by DPD 1-step (using WaSC NCR data)
                  ----   1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.861257    0.02513     34.3   0.000
HCAV                 0.418534    0.02382     17.6   0.000
HCAVT1              0.0579330   0.007086     8.18   0.000
HCAVT2              0.0611808   0.006382     9.59   0.000
HCAV(-1)            -0.385740    0.02833    -13.6   0.000

sigma                124.1088  sigma^2                15403
R^2                 0.9750227
RSS              847165.18798  TSS             33917339.459
no. of observations        60  no. of parameters          5

Using robust standard errors

number of individuals       5 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(5) =      9012. [0.000] **
AR(1) test:       N(0,1) =    -0.1255 [0.900]
AR(2) test:       N(0,1) =    -0.9123 [0.362]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   30.070 [0.0000]**
hetero test:      F(10,44) =  0.89600 [0.5445]
hetero-X test:    F(17,37) =  0.74110 [0.7423]
RESET test:       F(1,54)  =  0.33279 [0.5664]
```

```
EQ(HCAV3-F) Modelling DEBT by DPD 1-step (using All WaSCs data)
                  ----  1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.893932    0.02888     31.0   0.000
HCAV                 0.639570    0.09313     6.87   0.000
HCAVT1              0.0507238   0.009435     5.38   0.000
HCAVT2              0.0828719    0.01295     6.40   0.000
HCAV(-1)            -0.626875     0.1029    -6.09   0.000

sigma                 114.342  sigma^2              13074.1
R^2                 0.9730087
RSS            1503521.8264  TSS             55704025.479
no. of observations       120  no. of parameters          5

Using robust standard errors

number of individuals      10 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(5) =7.969e+004 [0.000] **
AR(1) test:        N(0,1) =   -0.4388 [0.661]
AR(2) test:        N(0,1) =    -1.065 [0.287]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   54.062 [0.0000]**
hetero test:      F(10,104)=   1.8932 [0.0542]
hetero-X test:    F(17,97) =   1.7839 [0.0410]*
RESET test:       F(1,114) = 0.057174 [0.8114]


EQ(HCAV4-F) Modelling DEBT by DPD 1-step (using WoC CR data.xls)

                  ----  1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.864012    0.02206     39.2   0.000
HCAV                 0.893743     0.1106     8.08   0.000
HCAVT2               0.113757    0.03395     3.35   0.001
HCAV(-1)            -0.872756     0.1108    -7.87   0.000

sigma                8.971958  sigma^2              80.49603
R^2                 0.9019792
RSS              5473.7300239  TSS             55842.560023
no. of observations        72  no. of parameters          4

Using robust standard errors

number of individuals       6 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(4) =6.846e+004 [0.000] **
AR(1) test:        N(0,1) =    -1.898 [0.058]
AR(2) test:        N(0,1) =    -1.766 [0.077]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   111.53 [0.0000]**
hetero test:      F(8,59)  =   1.2434 [0.2906]
hetero-X test:    F(13,54) =   1.5016 [0.1471]
RESET test:       F(1,67)  =   5.6595 [0.0202]*
```

```
EQ(HCAV5-F) Modelling DEBT by DPD 1-step (using WoC NCR data.xls)

                    ----  1-step estimation using DPD ----
                    Coefficient  Std.Error  t-value  t-prob
DEBT(-1)               0.821309     0.1065     7.71   0.000
HCAV                   0.391348    0.09783     4.00   0.000
HCAV(-1)              -0.306005    0.06949    -4.40   0.000

sigma                  8.541054  sigma^2           72.94961
R^2                   0.9771839
RSS                5033.5229362  TSS           220612.41213
no. of observations          72  no. of parameters        3

Using robust standard errors

number of individuals       6 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(3) =8.482e+004 [0.000] **
AR(1) test:        N(0,1) =    0.8663 [0.386]
AR(2) test:        N(0,1) =    -1.596 [0.111]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   17.346 [0.0002]**
hetero test:      F(6,62)  =   6.1910 [0.0000]**
hetero-X test:    F(9,59)  =   9.4965 [0.0000]**
RESET test:       F(1,68)  =   1.9566 [0.1664]


EQ(HCAV6-F) Modelling DEBT by DPD 1-step (using All WoCs data.xls)

                    ----  1-step estimation using DPD ----
                    Coefficient  Std.Error  t-value  t-prob
DEBT(-1)               0.809525    0.07686     10.5   0.000
HCAV                   0.805524     0.1005     8.01   0.000
HCAVT2                0.0700239    0.02193     3.19   0.002
HCAV(-1)              -0.757572     0.1074    -7.05   0.000

sigma                  8.999367  sigma^2           80.98861
R^2                   0.9615015
RSS                11338.405923  TSS           294515.66052
no. of observations         144  no. of parameters        4

Using robust standard errors

number of individuals      12 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(4) =1.012e+004 [0.000] **
AR(1) test:        N(0,1) =   -0.1158 [0.908]
AR(2) test:        N(0,1) =    -1.810 [0.070]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   89.661 [0.0000]**
hetero test:      F(8,131) =   2.5720 [0.0122]*
hetero-X test:    F(13,126)=   3.0591 [0.0006]**
RESET test:       F(1,139) =  0.66538 [0.4161]
```

Appendix 4.D ADF Tests on Debt, HCAV and RCV

The following Tables set out the results of the ADF tests on the variables Debt, HCAV and RCV. The ADF test of whether a variable y_t has a unit root is a test of the null hypothesis that $\rho = 1$ in the regression:

$$\Delta y_t = \alpha + \beta t + (\rho - 1) y_{t-1} + u_t \qquad u_t \backsim i.i.d\left(0, \sigma^2\right),$$

where t is a time trend. The 'constant/no trend' test assumes $\beta = 0$ and tests the null that y_t has a non-stationary or stochastic trend against the alternative that y_t is stationary around a constant mean. The constant term α is included to allow for a non-zero mean in the variable[31]. The 'constant/with trend' test includes the time trend t and tests the null that y_t has a quadratic stochastic trend against the alternative that y_t is stationary around a linear trend (i.e. when it is not valid to assume, as an alternative hypothesis, that the variable is stationary around a constant mean).

The tests are calculated for the pooled data on the variables for each type and category of company and also for the data on each company separately. Critical values for the t-statistics are given at the bottom of each Table. Where the coefficient $(\rho - 1)$ is significantly below zero (i.e. the null hypothesis of a unit root and hence non-stationarity is rejected) the significance level for the t-statistic is given in parentheses i.e. [5] or [1].

[31] The mean of a variable with a unit root is determined by its starting value. Also, under the alternative hypothesis of stationarity, if the constant term α is not included in the the test it is assumed that the variable has a zero mean. Consequently, a constant is included when it is not valid to assume that the mean of a series is zero.

Table 4.38: ADF tests - WaSC's and WoC's

		Category	constant/no trend		constant/with trend	
			$\rho - 1$	t-statistic	$\rho - 1$	t-statistic
Debt	WaSC's	CR	0.200	1.936	0.201	1.275
		NCR	-0.012	-0.403	0.004	0.077
		All	0.049	1.325	0.030	0.699
	WoC's	CR	0.008	0.093	-0.014	-0.178
		NCR	0.041	1.403	0.040	1.341
		All	0.026	1.000	0.020	0.683
HCAV	WaSC's	CR	0.093	1.691	0.102	1.767
		NCR	-0.030	-1.24	0.010	0.372
		All	0.008	0.363	0.023	1.158
	WoC's	CR	0.009	0.249	-0.004	-0.097
		NCR	0.040	3.019	0.047	3.704
		All	0.038	3.37	0.039	2.862
RCV	WaSC's	CR	0.023	1.697	0.042	2.922
		NCR	-0.002	-0.135	0.044	2.49
		All	0.017	1.71	0.044	4.25
	WoC's	CR	0.061	4.75	0.064	4.49
		NCR	0.039	3.78	0.044	4.811
		All	0.041	4.026	0.045	4.546
	Critical	5%		-3.148		-3.873
	values	1%		-4.137		-4.989

Table 4.39: ADF tests - Debt

	Company	constant/no trend		constant/with trend	
		$\rho - 1$	t-statistic	$\rho - 1$	t-statistic
WaSC's CR	ANH	0.391	2.761	1.626	2.070
	WSH	0.090	1.115	-0.236	-1.027
	NES	0.114	1.509	-0.140	-0.568
	SRN	0.071	0.751	-0.184	-1.008
	WSX	0.070	0.424	-0.713	-1.290
WaSC's NCR	SVT	-0.073	-1.248	-0.471	-1.347
	SWT	-0.057	-0.954	-0.586	-2.269
	TMS	-0.076	-0.698	-0.470	-1.636
	UUW	-0.049	-0.787	-0.579	-1.752
	YKY	0.057	0.677	-0.305	-1.470
WoC's CR	brl	-0.642	-2.063	-0.791	-2.372
	dvw	-0.857	-1.402	-0.389	-0.546
	mkt	0.949	2.072	0.731	0.782
	prt	-3.882	-3.102	-3.517	-2.462
	sst	0.251	0.231	2.327	2.528
	ses	-0.104	-0.428	-0.201	-0.880
WoC's NCR	bwh	-0.148	-0.628	-0.306	-1.665
	cam	-0.384	-1.405	-0.798	-2.810
	flk	-0.121	-0.488	-1.036	-2.822
	mse	-0.366	-1.700	-0.868	-2.738
	thd	-0.687	-2.778	-0.674	-2.538
	tvn	-0.136	-0.545	-0.399	-1.256
Critical values	5%		-3.148		-3.873
	1%		-4.137		-4.989

Table 4.40: ADF tests - HCAV

	Company	constant/no trend		constant/with trend	
		$\rho-1$	t-statistic	$\rho-1$	t-statistic
WaSC's CR	ANH	0.239	1.708	0.222	0.261
	WSH	0.013	0.213	-0.808	-2.407
	NES	-0.037	-0.892	-0.584	-1.671
	SRN	-0.037	-0.332	-0.657	-2.193
	WSX	-0.127	-0.995	-0.959	-3.136
WaSC's NCR	SVT	-0.233	-3.027	-0.325	-1.277
	SWT	-0.138	-4.048 [5]	-0.302	-2.453
	TMS	-0.258	-2.471	-0.256	-0.949
	UUW	-0.154	-1.651	-0.740	-2.042
	YKY	-0.33	-0.401	-0.377	-1.452
WoC's CR	brl	-0.247	-2.001	-0.407	-1.147
	dvw	-0.762	-2.311	-1.424	-2.613
	mkt	0.530	1.901	0.658	0.719
	prt	-1.341	-1.222	-4.739	-11.233 [1]
	sst	0.107	1.333	-0.205	-0.606
	ses	-0.205	-0.755	-0.291	-1.071
WoC's NCR	bwh	-0.148	-0.628	-0.489	-1.576
	cam	-0.587	-2.550	-0.419	-2.159
	flk	-0.236	-0.198	-0.700	-2.164
	mse	-0.141	-3.073	-0.336	-1.633
	thd	-0.390	-4.510 [1]	-0.520	-2.801
	tvn	-0.127	-1.380	-0.601	-1.990
Critical values	5%		-3.148		-3.873
	1%		-4.137		-4.989

Table 4.41: ADF tests - RCV

	Company	constant/no trend		constant/with trend	
		$\rho - 1$	t-statistic	$\rho - 1$	t-statistic
WaSC's CR	ANH	-0.019	-0.600	-1.164	-2.857
	WSH	-0.008	-0.309	-1.061	-3.180
	NES	-0.008	-0.160	-0.815	-2.562
	SRN	-0.056	-0.956	-0.218	-0.730
	WSX	0.021	1.184	-0.245	-1.011
WaSC's NCR	SVT	-0.110	-3.636 [5]	-0.041	-0.231
	SWT	-0.156	-3.358 [5]	-0.133	-0.978
	TMS	-0.053	-1.502	0.000	0.000
	UUW	-0.118	-2.025	-0.115	-0.624
	YKY	0.011	0.485	-0.377	-1.764
WoC's CR	brl	0.036	0.554	-0.461	-1.431
	dvw	-0.175	-2.114	-0.230	-0.982
	mkt	0.044	1.110	-0.304	-1.034
	prt	0.027	0.335	-0.515	-2.049
	sst	0.009	0.159	-0.703	-2.012
	ses	0.017	0.084	-0.699	-1.871
WoC's NCR	bwh	-0.098	-1.168	-0.495	-1.416
	cam	-0.424	-5.651 [1]	-0.454	-3.497
	flk	0.013	0.185	-0.420	-1.478
	mse	-0.023	-0.725	-0.451	-1.401
	thd	-0.157	-3.988 [5]	-0.420	-1.880
	tvn	-0.134	-3.006	0.040	0.232
Critical values	5%		-3.148		-3.873
	1%		-4.137		-4.989

Appendix 4.E Critical Values Tables

Table 4.42: MacKinnon (1991)

	No of variables	Test size %	β_8	β_1	β_2	Critical Values for sample size T= 12
Constant + no trend	1	1	-3.4336	-5.999	-29.25	-4.13664
		5	-2.8621	-2.738	-8.36	-3.14832
		10	-2.5671	-1.438	-4.48	-2.71804
Constant + no trend	2	1	-3.9001	-10.534	-30.03	-4.98648
		5	-3.3377	-5.967	-8.98	-3.89731
		10	-3.0462	-4.069	-5.73	-3.42508
Constant + no trend	3	1	-4.2981	-13.79	-46.37	-5.76928
		5	-3.7429	-8.352	-13.41	-4.53203
		10	-3.4518	-6.241	-2.79	-3.99126
Constant + no trend	4	1	-4.6493	-17.188	-59.2	-6.49274
		5	-4.1	-10.745	-21.57	-5.14521
		10	-3.811	-8.317	-5.19	-4.54013

Note:

$CV = \beta_8 + \beta_1/T + \beta_2/T^2$

Table 4.43: Ericsson and MacKinnon (1999)

	No of variables k	Test size %	β_∞	β_1	β_2	β_3	d	Critical Values for sample size N= 12
								T= 9
No constant	2	1	-3.2106	-4.69	-10.5	48	0	-3.79550
		5	-2.5937	-1.53	-0.8	-24		-2.80650
		10	-2.2643	-0.41	-0.5	-9		-2.32837
								T= 8
No constant	3	1	-3.6215	-6.14	-5.3	-67	0	-4.80214
		5	-3.0048	-2.11	2.1	-61		-3.44121
		10	-2.6744	-0.57	1.2	-44		-2.85962
								T= 5
No constant	4	1	-3.9433	-7.15	-3.1	-69	0	-6.04930
		5	-3.3268	-2.04	-6.4	19		-3.83880
		10	-2.9942	-0.21	-5.1	13		-3.13620

Note:

$T = N - (2k-1) - d$

$CV = \beta_\infty + \beta_1/T + \beta_2/T^2 + \beta_3/T^3$

Appendix 4.F Restrictions in the Engle-Granger Procedure

In this study the first stage of the Engle-Granger procedure is to estimate the long-run relationship:

$$D_{it} = g^* V_{it} + u_{it},$$

and then to use the residuals from the estimated relationship to test whether the error term, u_{it},is stationary.

Let:

$$\Delta u_{it} = a u_{it-1} + \varepsilon_{it},$$

where ε_{it} is an error term with zero mean and constant variance[32]. Consequently, if u has a unit root then $a = 0$ and u is non-stationary in which case D_{it} and V_{it} are not cointegrated. Conversely, if $a < 0$ then u is stationary and D_{it} and V_{it} are cointegrated.

It follows from the above that:

$$\begin{aligned} D_{it} &= g^* V_{it} + (1+a)\, u_{it-1} + \varepsilon_{it}, \\ D_{it} - (1+a)\,(D_{it-1} - g^* V_{it-1}) &= g^* V_{it} + \varepsilon_{it}, \\ D_{it}\,[1 - (1+a)\, L] &= g^* V_{it}\,[1 - (1+a)\, L] + \varepsilon_{it} \end{aligned}$$

where L is the lag operator. Consequently, the Engle-Granger procedure imposes a common factor restriction since $[1 - (1+a)\, L]$ is a factor that is common to both D_{it} and V_{it}. The effect of this restriction can be seen by noting that:

$$\begin{aligned} \Delta D_{it} &= g^* \Delta V_{it} + \Delta u_{it}, \\ \Delta D_{it} &= g^* \Delta V_{it} + a u_{it-1} + \varepsilon_{it}, \end{aligned}$$

and so:

$$\Delta D_{it} = g^* \Delta V_{it} + a\,(D_{it-1} - g^* V_{it-1}) + \varepsilon_{it}.$$

This is the ECM in (4.19) with the restriction (4.36):

$$\gamma = g^*,$$

[32] For these purposes the dummy variables have been excluded.

that is, the short-run adjustment factor is the same as the long run effect in equilibrium.

Note also that $-a = \alpha$, the long-run adjustment factor in (4.19).

The common factor restriction imposes a further significant assumption if the Engle-Granger procedure is applied to the PAM. It can be seen from (4.20) that the PAM is a special case of the ECM when $\gamma = \alpha g^*$, that is:

$$\Delta D_{it} = \alpha g^* \Delta V_{it} - \alpha \left(D_{it-1} - g^* V_{it-1} \right),$$

or:

$$D_{it} = \alpha g^* V_{it} + (1 - \alpha) D_{it-1}.$$

Consequently, in the PAM, the common factor restriction implies:

$$\alpha g^* = \gamma = g^*,$$

which also implies (4.51):

$$\alpha = 1.$$

This is the limiting case of the PAM in which there is full adjustment to the long-run equilibrium in each period. In other words, applying the Engle-Granger procedure to a PAM assumes the SLRM applies.

Appendix 4.G Adjustment Factors-Further Estimates based on HCAV

The following tables present the results from estimating an ECM in the form of:

- equation (4.42) using the results from the SLRM and
- equation (4.44) using the results from Stage I of the Engle-Granger procedure.

The short-run and long-run adjustment factors derived from these results are also given.

Table 4.44: ECM based on results from SLRM

Equation		Variable $\Delta HCAV_{it}$	$\Delta(HCAV_{it}T1_t)$	$\Delta(HCAV_{it}T2_t)$	CI_{it-1}	Adjusted R^2	Diagnostic tests rejected
WaSCs							
CR	Coefficient	0.751	0.038	0.123	-0.124	0.868	N [1], H [1], HX [1], R [5]
	t-statistic	17.70	2.25	5.50	-5.94		
NCR	Coefficient	0.431	0.039	0.026	-0.156	0.736	N [1], R [5]
	t-statistic	32.20	1.54	1.10	-6.55		
All WaSCs	Coefficient	0.646	0.041	0.058	-0.122	0.770	N [1], R [1]
	t-statistic	12.60	2.32	2.91	-6.05		
WoCs							
CR	Coefficient	0.976	-	0.025	-0.189	0.745	N [1], H [5], HX [5]
	t-statistic	9.48		2.87	-3.26		
NCR	Coefficient	0.391	-	-	-0.179	0.290	N [1], H [1], HX [1], R [1]
	t-statistic	4.01			1.99		
All WoCs	Coefficient	0.835	-	0.044	-0.214	0.579	N [1]
	t-statistic	7.89		1.83	-5.61		

NOTES

CI_{it} — CI_{it} is the the difference between the actual and predicted long run equilibrium value of D_{it} derived from the SLRM.

t-statistic — Calculated using robust standard errors from panel data models.

Adjusted R^2 — Calculated from $1 - AdjR^2 = (1 - R^2)(n-1)/(n-k)$ where $1 - R^2 = RSS / \Sigma\Delta D_{it}^2$,
RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.

Diagnostic tests

		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	All the models reject the null that all the coefficients are zero at the 1% significance level.
	AR(1)	A1	Tests the null of no first order serial correlation) All the models accept these tests.
	AR(2)	A2	Tests the null of no second order serial correlation)
Significance levels	1%	[1]	
	5%	[5]	

Table 4.45: ECM based on results from Engle-Granger Stage II

Equation		$\Delta HCAV_{it}$	$\Delta(HCAV_{it}T1_t)$	$\Delta(HCAV_{it}T2_t)$	R_{it-1}	Adjusted R^2	Diagnostic tests rejected
		Variable					
WaSCs							
CR	Coefficient	0.864	0.027	0.124	-0.135	0.850	H [1], HX [1], R [1]
	t-statistic	12.30	1.64	5.70	-1.73		
NCR	Coefficient	0.566	0.049	0.081	-0.233	0.606	N [1], R [1]
	t-statistic	20.80	2.14	4.21	-7.98		
All WaSCs	Coefficient	0.717	0.039	0.087	-0.192	0.696	N [1], H [1], HX [5], R [1]
	t-statistic	8.20	2.17	5.84	-3.46		
WoCs							
CR	Coefficient	1.019	-	-0.006	-0.279	0.673	N [1]
	t-statistic	8.08		-0.39	-3.29		
NCR	Coefficient	0.415	-	-	-0.183	0.289	N [1], H [1], HX [1], R [5]
	t-statistic	4.00			-1.80		
All WoCs	Coefficient	0.722	-	0.013	-0.238	0.489	N [1], R [5]
	t-statistic	6.13		0.50	-2.76		

NOTES

R_{it-1} — Residual from the E-G Stage I Models, i.e. the difference between the actual and predicted long-run equilibrium value of D_{it}.

t-statistic — Calculated using robust standard errors from panel data models.

Adjusted R^2 — Calculated from $1 - AdjR^2 = (1 - R^2)(n - 1) / (n - k)$ where $1 - R^2 = RSS / \Sigma\Delta D_{it}^2$, RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.

Diagnostic tests

		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	All the models reject the null that all the coefficients are zero at the 1% significance level.
	AR(1)	A1	Tests the null of no first order serial correlation) All the models accept these tests.
	AR(2)	A2	Tests the null of no second order serial correlation)
Significance levels	1%	[1]	
	5%	[5]	

Table 4.46: Adjustment factors based on SLRM

Equation	Short run adjustment γ	γ_1	γ_2	Long run adjustment α
WaSCs				
CR	0.751	0.789	0.874	0.124
NCR	0.431	0.469	0.457	0.156
All WaSCs	0.646	0.687	0.704	0.122
WoCs				
CR	0.976	0.976	1.002	0.189
NCR	0.391	0.391	0.391	0.179
All WoCs	0.835	0.835	0.879	0.214

Table 4.47: Adjustment factors based on Engle-Granger Stage II

Equation	Short run adjustment γ	γ_1	γ_2	Long run adjustment α
WaSCs				
CR	0.864	0.892	0.988	0.135
NCR	0.566	0.616	0.648	0.233
All WaSCs	0.717	0.756	0.804	0.192
WoCs				
CR	1.019	1.019	1.013	0.279
NCR	0.415	0.415	0.415	0.183
All WoCs	0.722	0.722	0.734	0.238

Appendix 4.H Detailed Results based on RCV

4.H.1 Initial equations

The OLS estimates of the initial equations for each type and category of company are numbered in this appendix as:

Equation (RCV1-I): WaSC CR

Equation (RCV2-I): WaSC NCR

Equation (RCV3-I): All WaSC's

Equation (RCV4-I): WoC CR

Equation (RCV5-I): WoC NCR

Equation (RCV6-I): All WoC's.

The outputs from PcGive for each equation are set out on the following three pages.

EQ(RCV1-I) Modelling DEBT by OLS-CS (using WaSC CR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-10.6598	181.0	-0.0589	0.953	0.0001
T1	73.1027	209.9	0.348	0.729	0.0030
T2	-131.364	225.5	-0.583	0.563	0.0084
RCV	-0.120158	1.731	-0.0694	0.945	0.0001
RCVT1	-0.347873	1.844	-0.189	0.851	0.0009
RCVT2	-0.150650	1.769	-0.0852	0.933	0.0002
RCV-1	0.158238	1.922	0.0823	0.935	0.0002
RCV-1T1	0.518125	2.041	0.254	0.801	0.0016
RCV-1T2	0.403010	1.961	0.206	0.838	0.0011
DEBT-1	1.58724	1.356	1.17	0.249	0.0331
DEBT-1T1	-0.916961	1.407	-0.652	0.518	0.0105
DEBT-1T2	-0.208982	1.398	-0.149	0.882	0.0006
DEBT-2	-0.690616	1.109	-0.623	0.537	0.0096
DEBT-2T1	0.643281	1.168	0.551	0.585	0.0075
DEBT-2T2	0.0268798	1.257	0.0214	0.983	0.0000

sigma	165.444	RSS	1094873.05
R^2	0.941618	F(14,40) =	46.08 [0.000]**
log-likelihood	-350.259	DW	1.98
no. of observations	55	no. of parameters	15
mean(DEBT)	822.731	var(DEBT)	340976

```
Normality test:   Chi^2(2) =   26.001 [0.0000]**
hetero test:      F(26,13) =   3.3369 [0.0133]*
Hetero-X test: not enough observations
RESET test:       F(1,39)  =   15.154 [0.0004]**
```

EQ(RCV2-I) Modelling DEBT by OLS-CS (using WaSC NCR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-27.3852	110.9	-0.247	0.806	0.0015
T1	-89.7461	137.9	-0.651	0.519	0.0105
T2	137.381	171.8	0.800	0.429	0.0157
RCV	0.0791597	0.2093	0.378	0.707	0.0036
RCVT1	-0.619683	0.4399	-1.41	0.167	0.0473
RCVT2	0.139852	0.3831	0.365	0.717	0.0033
RCV-1	-0.0256088	0.2834	-0.0904	0.928	0.0002
RCV-1T1	0.854974	0.5296	1.61	0.114	0.0612
RCV-1T2	-0.151272	0.4534	-0.334	0.740	0.0028
DEBT-1	1.26863	0.5958	2.13	0.039	0.1018
DEBT-1T1	-0.645125	0.6143	-1.05	0.300	0.0268
DEBT-1T2	-0.479179	0.7600	-0.630	0.532	0.0098
DEBT-2	-0.615434	0.3666	-1.68	0.101	0.0658
DEBT-2T1	0.520575	0.4314	1.21	0.235	0.0351
DEBT-2T2	0.714900	0.5130	1.39	0.171	0.0463

sigma	140.187	RSS	786101.221
R^2	0.973762	F(14,40) =	106 [0.000]**
log-likelihood	-341.148	DW	2.09
no. of observations	55	no. of parameters	15
mean(DEBT)	1062.55	var(DEBT)	544742

```
Normality test:   Chi^2(2) =   27.771 [0.0000]**
hetero test:      F(26,13) =  0.21735 [0.9995]
Hetero-X test: not enough observations
RESET test:       F(1,39)  =  0.99989 [0.3235]
```

EQ(RCV3-I) Modelling DEBT by OLS-CS (using All WaSCs data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	14.7221	73.22	0.201	0.841	0.0004
T1	-14.1841	93.90	-0.151	0.880	0.0002
T2	56.3169	112.9	0.499	0.619	0.0026
RCV	0.0806675	0.2302	0.350	0.727	0.0013
RCVT1	-0.445337	0.4100	-1.09	0.280	0.0123
RCVT2	0.161342	0.3379	0.478	0.634	0.0024
RCV-1	-0.0792231	0.2818	-0.281	0.779	0.0008
RCV-1T1	0.649833	0.4712	1.38	0.171	0.0196
RCV-1T2	-0.0960037	0.3784	-0.254	0.800	0.0007
DEBT-1	1.48860	0.5081	2.93	0.004	0.0829
DEBT-1T1	-0.820190	0.5306	-1.55	0.126	0.0245
DEBT-1T2	0.0821378	0.5486	0.150	0.881	0.0002
DEBT-2	-0.638950	0.3758	-1.70	0.092	0.0295
DEBT-2T1	0.650073	0.4212	1.54	0.126	0.0245
DEBT-2T2	-0.0815384	0.4605	-0.177	0.860	0.0003

sigma	161.778	RSS	2486364.35
R^2	0.950565	F(14,95) =	130.5 [0.000]**
log-likelihood	-707.505	DW	1.98
no. of observations	110	no. of parameters	15
mean(DEBT)	942.641	var(DEBT)	457237

```
Normality test:   Chi^2(2) =   58.461 [0.0000]**
hetero test:      F(26,68) =   1.3475 [0.1643]
Hetero-X test: not enough observations
RESET test:       F(1,94)  = 0.021400 [0.8840]
```

EQ(RCV4-I) Modelling DEBT by OLS-CS (using WoC CR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	-6.79633	12.91	-0.527	0.601	0.0054
T1	3.17897	16.23	0.196	0.845	0.0008
T2	-12.9229	18.02	-0.717	0.477	0.0100
RCV	0.566208	1.926	0.294	0.770	0.0017
RCVT1	-0.395882	2.150	-0.184	0.855	0.0007
RCVT2	-0.179954	2.054	-0.0876	0.931	0.0002
RCV-1	-0.473711	1.943	-0.244	0.808	0.0012
RCV-1T1	0.359758	2.171	0.166	0.869	0.0005
RCV-1T2	0.603310	2.076	0.291	0.773	0.0017
DEBT-1	0.695821	0.6523	1.07	0.291	0.0218
DEBT-1T1	0.331613	0.7585	0.437	0.664	0.0037
DEBT-1T2	0.145984	0.7355	0.198	0.843	0.0008
DEBT-2	0.171381	0.6975	0.246	0.807	0.0012
DEBT-2T1	-0.303983	0.8124	-0.374	0.710	0.0027
DEBT-2T2	-0.919162	0.7813	-1.18	0.245	0.0264

sigma	14.5039	RSS	10728.4761
R^2	0.798021	F(14,51) =	14.39 [0.000]**
log-likelihood	-261.653	DW	2.14
no. of observations	66	no. of parameters	15
mean(DEBT)	27.9329	var(DEBT)	804.8

```
Normality test:   Chi^2(2) =   14.439 [0.0007]**
hetero test:      F(26,24) =   1.6787 [0.1030]
Hetero-X test: not enough observations
RESET test:       F(1,50)  =   1.3507 [0.2507]
```

EQ(RCV5-I) Modelling DEBT by OLS-CS (using WoC NCR data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	1.14768	2.581	0.445	0.658	0.0039
T1	-1.64989	3.253	-0.507	0.614	0.0050
T2	-2.97410	3.723	-0.799	0.428	0.0124
RCV	1.17942	0.6048	1.95	0.057	0.0694
RCVT1	-0.982738	0.6265	-1.57	0.123	0.0460
RCVT2	-1.60545	0.6990	-2.30	0.026	0.0937
RCV-1	-1.24970	0.6712	-1.86	0.068	0.0636
RCV-1T1	1.10174	0.6905	1.60	0.117	0.0475
RCV-1T2	1.81332	0.7487	2.42	0.019	0.1032
DEBT-1	1.17769	0.1801	6.54	0.000	0.4560
DEBT-1T1	-0.401622	0.2429	-1.65	0.104	0.0509
DEBT-1T2	-0.432430	0.3541	-1.22	0.228	0.0284
DEBT-2	-0.268210	0.2313	-1.16	0.252	0.0257
DEBT-2T1	0.350202	0.2914	1.20	0.235	0.0275
DEBT-2T2	0.172960	0.3955	0.437	0.664	0.0037

sigma	7.75138	RSS	3064.28136
R^2	0.98516	F(14,51) =	241.8 [0.000]**
log-likelihood	-220.301	DW	2.36
no. of observations	66	no. of parameters	15
mean(ADEBT)	50.4458	var(ADEBT)	3128.57

```
Normality test:   Chi^2(2) =   28.712 [0.0000]**
hetero test:      F(26,24) =  0.88596 [0.6198]
Hetero-X test: not enough observations
RESET test:       F(1,50)  =   3.2445 [0.0777]
```

EQ(RCV6-I) Modelling ADEBT by OLS-CS (using All WoCs data)

	Coefficient	Std.Error	t-value	t-prob	Part.R^2
Constant	1.40397	3.058	0.459	0.647	0.0018
T1	-2.86863	3.791	-0.757	0.451	0.0049
T2	0.159703	4.562	0.0350	0.972	0.0000
RCV	1.02349	0.7014	1.46	0.147	0.0179
RCVT1	-0.821331	0.7362	-1.12	0.267	0.0105
RCVT2	-0.392174	0.7792	-0.503	0.616	0.0022
RCV-1	-1.06792	0.7371	-1.45	0.150	0.0176
RCV-1T1	0.901944	0.7721	1.17	0.245	0.0115
RCV-1T2	0.652217	0.8056	0.810	0.420	0.0056
DEBT-1	1.11302	0.2362	4.71	0.000	0.1595
DEBT-1T1	-0.224896	0.3039	-0.740	0.461	0.0047
DEBT-1T2	-0.0330067	0.3291	-0.100	0.920	0.0001
DEBT-2	-0.238479	0.2473	-0.964	0.337	0.0079
DEBT-2T1	0.256388	0.3218	0.797	0.427	0.0054
DEBT-2T2	-0.540597	0.3393	-1.59	0.114	0.0212

sigma	11.8617	RSS	16461.8329
R^2	0.940426	F(14,117) =	131.9 [0.000]**
log-likelihood	-505.816	DW	2.05
no. of observations	132	no. of parameters	15
mean(DEBT)	39.1894	var(DEBT)	2093.39

```
Normality test:   Chi^2(2) =   82.927 [0.0000]**
hetero test:      F(26,90) =   1.5458 [0.0685]
Hetero-X test: not enough observations
RESET test:       F(1,116) =   8.1229 [0.0052]**
```

4.H.2 Tests for serial correlation

Table 4.48 sets out the results of the first two tests for serial correlation based on the residuals $\widehat{u}_{it}$ from the six initial equations as described in subsection 4.6.3. Each test calculates an estimate ρ, the coefficient of $\widehat{u}_{it-1}$; the first by including $\widehat{u}_{it-1}$ as an additional regressor in the initial equation and the second by regressing $\widehat{u}_{it}$ on $\widehat{u}_{it-1}$. The t-statistics marked * are heteroscedasticity-robust t-statistics based on White (1980). In only one of the equations is the t-statistic significant at the 5% level with a critical value of 2.02 .

Table 4.48: Tests for serial correlation

Equation	Include $\widehat{u}_{it-1}$ as an additional regressor		Regression of $\widehat{u}_{it}$ on $\widehat{u}_{it-1}$	
	ρ	t-statistic	ρ	t-statistic
RCV1-I: WaSC CR	0.153154	0.233	0.0165040	0.084
RCV2-I: WaSC NCR	-0.158034	-0.489	-0.0406429	-0.285
RCV3-I: All WaSC's	0.344343	1.25	0.0860796	0.659
RCV4-I: WoC CR	-0.746798	-2.08 [5]	-0.239908	-0.71327*
RCV5-I: WoC NCR	-0.445646	-1.67	-0.203393	-0.84753*
RCV6-I: All WoC's	-0.530036	-1.6861*	-0.203981	-1.1617*

Table 4.49 gives the results of the third test for serial correlation described in subsection 4.6.3. This uses the residuals $\widehat{u}_{it}$ from the six initial equations to test for serial correlation by estimating ρ for each company separately. The t-statistics marked * are heteroscedasticity-robust t-statistics based on White (1980). The critical values of the t-test are 2.262 at the 5% level and 3.250 at the 1% level. Where the coefficient is significantly different from zero the significance level for the t-statistic is given in parentheses i.e. [5] or [1].

Table 4.49: Tests for serial correlation

Category	Company	Residuals $\widehat{u}_{it}$ from RCV3-I & 6-I		Residuals $\widehat{u}_{it}$ from RCV1-I, 2-I, 4-I & 5-I	
		ρ	t-statistic	ρ	t-statistic
WaSC CR	ANH	0.825213	0.60750*	-0.267508	-0.496
	WSH	0.202049	0.540	0.181643	0.525
	NES	-0.502263	-1.45	-0.0822472	-0.181
	SRN	-0.224795	-0.574	0.256682	0.676
	WSX	-0.210875	-0.382	0.220627	0.342
WaSC NCR	SVT	-0.0459407	-0.410	-0.0332185	-0.0995
	SWT	-0.0520932	-0.148	0.226459	0.664
	TMS	-0.0704462	-0.209	-0.00807595	-0.0243
	UUW	-0.0813406	-0.246	-0.225778	-0.689
	YKY	0.533866	2.04	-0.127372	-0.485
WoC CR	brl	0.0395038	0.122	0.0434322	0.119
	dvw	0.0121865	0.0334	-0.624364	-1.35
	mkt	0.284303	0.342	-0.283622	-0.487
	prt	-0.809307	-0.63669*	-0.989312	-0.93927*
	sst	-0.673088	-0.57360	0.0360716	0.047848*
	ses	-0.262975	-0.865	-0.310415	-0.926
WoC NCR	bwh	0.712256	2.61 [5]	0.0510999	0.150
	cam	-0.463746	-1.28	-0.455745	-1.52
	flk	0.231712	0.586	0.330051	0.947
	mse	-0.372309	-1.27	-0.267911	-0.67602*
	thd	0.698829	2.64 [5]	0.258714	0.779
	tvn	0.0195317	0.0611	-0.149880	-0.478

4.H.3 Final estimates

The final estimates of the equations for each type and category of company are numbered in this appendix as:

Equation (RCV1-F): WaSC CR

Equation (RCV2-F): WaSC NCR

Equation (RCV3-F): All WaSC's

Equation (RCV4-F): WoC CR

Equation (RCV5-F): WoC NCR

Equation (RCV6-F): All WoC's.

The outputs from PcGive for each equation are set out on the following three pages.

```
EQ(RCV1-F) Modelling DEBT by DPD 1-step (using WaSC CR data.xls)

                  ----  1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.897642     0.1005     8.93   0.000
RCV                 0.0680846    0.02864     2.38   0.021
RCVT1               0.0295181    0.01030     2.87   0.006
RCVT2                0.106359    0.02302     4.62   0.000

sigma                 155.563  sigma^2              24199.85
R^2                 0.9336799
RSS              1355191.5087  TSS              20434084.869
no. of observations        60  no. of parameters           4

Using robust standard errors

number of individuals       5 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(4) =2.953e+006 [0.000] **
AR(1) test:        N(0,1) =   -0.1517 [0.879]
AR(2) test:        N(0,1) =    -1.195 [0.232]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   30.340 [0.0000]**
hetero test:      F(8,47)  =   8.2634 [0.0000]**
hetero-X test:    F(11,44) =   18.267 [0.0000]**
RESET test:       F(1,55)  =   6.2889 [0.0151]*


EQ(RCV2-F) Modelling DEBT by DPD 1-step (using WaSC NCR data.xls)

                  ----  1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.714894    0.02568     27.8   0.000
RCV                 0.0882133   0.008945     9.86   0.000
RCVT1               0.0647764   0.008535     7.59   0.000
RCVT2               0.0604051    0.01250     4.83   0.000

sigma                137.6198  sigma^2               18939.2
R^2                   0.96873
RSS              1060595.1338  TSS              33917339.459
no. of observations        60  no. of parameters           4

Using robust standard errors

number of individuals       5 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(4) =8.249e+004 [0.000] **
AR(1) test:        N(0,1) =    0.9803 [0.327]
AR(2) test:        N(0,1) =   -0.7105 [0.477]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   30.861 [0.0000]**
hetero test:      F(8,47)  =   1.3244 [0.2551]
hetero-X test:    F(11,44) =   1.2563 [0.2810]
RESET test:       F(1,55)  =   1.1563 [0.2869]
```

```
EQ(RCV3-F) Modelling DEBT by DPD 1-step (using All WaSCs data.xls)

                  ----  1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.831847    0.05739     14.5   0.000
RCV                 0.0762582    0.01149     6.64   0.000
RCVT1               0.0436576   0.008972     4.87   0.000
RCVT2               0.0522781    0.01096     4.77   0.000

sigma                168.7876  sigma^2             28489.25
R^2                  0.940673
RSS              3304752.5214  TSS             55704025.479
no. of observations       120  no. of parameters          4

Using robust standard errors

number of individuals      10 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):     Chi^2(4) =3.236e+004 [0.000] **
AR(1) test:         N(0,1) =      2.072 [0.038] *
AR(2) test:         N(0,1) =     -1.002 [0.317]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   69.840 [0.0000]**
hetero test:      F(8,107) =   1.3460 [0.2290]
hetero-X test:    F(11,104)=   2.1277 [0.0244]*
RESET test:       F(1,115) =   2.1173 [0.1484]
```

```
EQ(RCV4-F) Modelling DEBT by DPD 1-step (using WoC CR data.xls)

                  ----  1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.835126    0.03491     23.9   0.000
RCV                 0.0454089    0.01893     2.40   0.019
RCVT2                0.136430    0.05488     2.49   0.015

sigma                14.01108  sigma^2             196.3104
R^2                 0.7574356
RSS              13545.419646  TSS             55842.560023
no. of observations        72  no. of parameters          3

Using robust standard errors

number of individuals       6 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):     Chi^2(3) =      1191. [0.000] **
AR(1) test:         N(0,1) =    -0.3271 [0.744]
AR(2) test:         N(0,1) =     -1.963 [0.050] *

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   45.728 [0.0000]**
hetero test:      F(6,62)  =   4.8583 [0.0004]**
hetero-X test:    F(8,60)  =   4.2322 [0.0005]**
RESET test:       F(1,68)  =   2.0503 [0.1568]
```

```
EQ(RCV5-F) Modelling DEBT by DPD 1-step (using WoC NCR data.xls)

                  ----   1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.816686    0.02911     28.1   0.000
RCV                 0.0691729    0.01101     6.29   0.000

sigma                9.056018  sigma^2              82.01146
R^2                 0.9739779
RSS              5740.8024216  TSS              220612.41213
no. of observations        72  no. of parameters           2

Using robust standard errors

number of individuals       6 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(2) =3.762e+004 [0.000] **
AR(1) test:        N(0,1) =     0.9437 [0.345]
AR(2) test:        N(0,1) =     -1.450 [0.147]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   26.416 [0.0000]**
hetero test:      F(4,65)  =   7.3330 [0.0001]**
hetero-X test:    F(5,64)  =   6.4988 [0.0001]**
RESET test:       F(1,69)  =  0.94393 [0.3347]


EQ(RCV6-F) Modelling DEBT by DPD 1-step (using All WoCs data.xls)

                  ----   1-step estimation using DPD ----
                  Coefficient  Std.Error  t-value  t-prob
DEBT(-1)             0.817718    0.04302     19.0   0.000
RCV                 0.0739380    0.01401     5.28   0.000

sigma                12.80639  sigma^2              164.0037
R^2                  0.920926
RSS               23288.52601  TSS               294515.66052
no. of observations       144  no. of parameters           2

Using robust standard errors

number of individuals      12 (derived from year)
longest time series        12 [1992 - 2003]
shortest time series       12 (balanced panel)

Wald (joint):    Chi^2(2) =      4356. [0.000] **
AR(1) test:        N(0,1) =      1.678 [0.093]
AR(2) test:        N(0,1) =     -1.519 [0.129]

Tests from modelling DEBT by OLS-CS
Normality test:   Chi^2(2) =   210.15 [0.0000]**
hetero test:      F(4,137) =   2.9219 [0.0234]*
hetero-X test:    F(5,136) =   2.3708 [0.0425]*
RESET test:       F(1,141) =   3.2833 [0.0721]
```

Appendix 4.I Adjustment Factors-Further Estimates based on RCV

Equation (4.53) can be derived as follows. The estimated PAM can be written as:

$$\Delta D_{it} = \alpha\left(\widehat{D^*}_{it} - D_{it-1}\right) + \widehat{u}_{it}$$

where $\widehat{D^*}_{it}$ is calculated from the estimated SLRM given by equation (4.52).

Let

$$CI_{it} = D_{it} - \widehat{D^*}_{it},$$

so:

$$\begin{aligned}
\Delta D_{it} &= \alpha\left(\widehat{D^*}_{it} - D_{it-1}\right) + \widehat{u}_{it} \\
&= \alpha\left(D_{it} - CI_{it} - D_{it-1}\right) + \widehat{u}_{it} \\
&= \alpha\Delta D_{it} - \alpha CI_{it} + \widehat{u}_{it} \\
\Delta D_{it} &= -\frac{\alpha}{1-\alpha}CI_{it} + \frac{\widehat{u}_{it}}{1-\alpha} \\
&= -\frac{\alpha}{1-\alpha}CI_{it} + \widehat{\nu}_{it}
\end{aligned}$$

Since $1 - \alpha = \widehat{\beta}_{30}$ in equation (4.45) then:

$$\Delta D_{it} = -\frac{\left(1 - \widehat{\beta}_{30}\right)}{\widehat{\beta}_{30}}CI_{it} + \widehat{\nu}_{it}.$$

Equation (4.55) can be derived in a similar way. In this instance $\widehat{D^*}_{it}$ is calculated from (4.50) in Stage I of the Engle-Granger procedure and the residuals are given by:

$$R_{it} = D_{it} - \widehat{D^*}_{it},$$

It follows from the above, therefore, that:

$$\Delta D_{it} = -\frac{\left(1 - \widehat{\beta}_{30}\right)}{\widehat{\beta}_{30}}R_{it} + \widehat{\nu}_{it}.$$

The following tables present the results from estimating a PAM in the form of:

- equation (4.53) using the results from the SLRM and

- equation (4.55) using the results from Stage II of the Engle-Granger procedure.

The adjustment factors derived from these results are also given.

Table 4.50: PAM based on results from SLRM

Equation		Variable CI_{it}	Adjustment factor α	Adjusted R^2	Diagnostic tests rejected
WaSCs					
CR	Coefficient	-0.104	0.094	0.468	W [1], N [1], H [1], HX [1]
	t-statistic	-8.06			
NCR	Coefficient	-0.299	0.230	0.375	W [1], N [1], R [5]
	t-statistic	-7.21			
All WaSC s	Coefficient	-0.154	0.134	0.282	W [1], N [1], H [1], HX [1]
	t-statistic	-15.50			
WoCs					
CR	Coefficient	-0.099	0.090	0.057	W [1], A2 [5], N [1]
	t-statistic	-2.42			
NCR	Coefficient	-0.021	0.021	-0.012	N [1], R [5]
	t-statistic	-0.463			
All WoC s	Coefficient	0.091	-0.100	0.015	N [1], H [1], HX [1], R [1]
	t-statistic	1.05			

NOTES

CI_{it}	CI_{it} is the the difference between the actual and predicted long run equilibrium value of D_{it} derived from the SLRM.		
t-statistic	Calculated using robust standard errors from panel data models.		
Adjusted R^2	Calculated from $1 - AdjR^2 = (1 - R^2)(n - 1) / (n - k)$ where $1 - R^2 = RSS / \Sigma\Delta D_{it}^2$, RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.		
Diagnostic tests			
		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	Tests the null that all the coefficients are zero.
	AR(1)	A1	Tests the null of no first order serial correlation.
Significance levels	1%	[1]	
	5%	[5]	

Table 4.51: PAM based on results from Engle-Granger Stage II

Equation		Variable R_{it}	Adjustment factor α	Adjusted R^2	Diagnostic tests rejected
WaSCs					
CR	Coefficient	0.367	-0.581	0.083	W [1], N [1], H [1], HX [1], R [1]
	t-statistic	3.59			
NCR	Coefficient	0.124	-0.142	-0.038	A1 [5], N [1], H [5], HX [5], R [1]
	t-statistic	0.90			
All WaSC s	Coefficient	0.314	-0.458	0.097	W [5], A1 [1], A2 [5],
	t-statistic	1.97			
WoCs					
CR	Coefficient	0.383	-0.620	0.188	W [1], A1 [5], A2 [5], N [1], H [1], HX [1], R [1]
	t-statistic	2.73			
NCR	Coefficient	0.246	-0.326	0.112	W [1], N [1], H [5], HX [5], R [1]
	t-statistic	2.82			
All WoC s	Coefficient	0.389	-0.635	0.252	W [1], A1 [5], N [1], H [1], HX [1], R [1]
	t-statistic	3.66			

NOTES

R_{it} — R_{it} is the difference between the actual and predicted long run equilibrium value of D_{it} from the E-G I Models.

t-statistic — Calculated using robust standard errors from panel data models.

Adjusted R^2 — Calculated from $1 - \text{Adj}R^2 = (1 - R^2)(n - 1) / (n - k)$ where $1 - R^2 = RSS / \Sigma \Delta D_{it}^2$, RSS is the Residual Sum of Squares, n is the number of observations and k is the number of regressors.

Diagnostic tests

		Abbrvn	
OLS models pooled data	Normality	N	Tests the null that the distribution of the residuals is normal.
	Hetero	H	Tests the null of homoscedasticity using squares of regressors.
	Hetero-X	HX	Tests the null of homoscedasticity using squares and cross-products of regressors.
	RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.
Panel data models	Wald (joint)	W	Tests the null that all the coefficients are zero.
	AR(1)	A1	Tests the null of no first order serial correlation.
	AR(2)	A2	Tests the null of no second order serial correlation.

Significance levels 1% [1]; 5% [5]

Appendix 4.J ECM and PAM Results for Individual Companies

The following Tables set out the results from applying ECM's and PAM's to the individual companies. The form of the equation that was estimated corresponds to the model for the relevant category. The SLRM's derived from these models are also given except where marked N/A. In these cases the estimated parameters of the ECM and/or PAM do not permit the model to converge to a long-run solution.

There were 12 observations for each company and the equations were estimated using PcGive 10.3 - OLS Single Equation Dynamic Modelling.

The diagnostic tests used in estimating the ECM's and PAM's are:

	Abbrvn	
AR 1-1	A	Tests the null of no first order autocorrelation
ARCH 1-1	AC	Tests the null of no first order autoregressive conditional heteroscedasticity using the squares of the residuals
Normality	N	Tests the null that the distribution of the residuals is normal
Hetero	H	Tests the null of homoscedasticity using the squares of the regressors. Only enough observations to apply the test to the WoC NCR companies in the ECM's and to the WoCs in the PAM's.
Hetero-X	HX	Test not available as not enough observations.
RESET	R	Tests the null that the model is correctly specified against omitting the square of the predicted value of the dependent variable.

The Wald test applied to the SLRM tests the null that all the coefficients are zero.

Significance levels are indicated as:

1% [1]

5% [5]

Table 4.52: ECM results using HCAV - WaSCs

		Variable					Short run adjustment			Long run adjustment	Adjusted	Unit root	Diagnostic tests
		$HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	$HCAV_{it-1}$	D_{it-1}	γ_0	γ_1	γ_2	α	R^2	t-test	rejected
WaSCs													
CR													
ANH	Coefficient	0.982	0.026	0.014	-1.041	1.133	0.982	1.008	0.996	-0.133	0.994	0.47	R [1]
	t-statistic	5.58	0.52	0.16	-4.98	4.00							
WSH	Coefficient	0.454	0.134	0.325	-0.430	0.595	0.454	0.588	0.779	0.405	0.990	-2.79	
	t-statistic	1.33	2.16	3.36	-1.16	4.09							
NES	Coefficient	0.886	0.053	0.196	-0.841	0.642	0.886	0.939	1.082	0.358	0.999	-5.06 [5]	
	t-statistic	7.12	4.11	9.62	-5.98	9.06							
SRN	Coefficient	0.535	-0.005	0.104	-0.267	0.404	0.535	0.529	0.639	0.596	0.996	-2.03	
	t-statistic	3.65	-0.17	2.60	-1.73	1.38							
WSX	Coefficient	0.945	-0.008	0.067	-0.919	0.966	0.945	0.937	1.012	0.034	0.980	-0.10	R [1]
	t-statistic	2.84	-0.11	0.67	-2.36	2.84							
NCR													
SVT	Coefficient	0.459	0.083	0.086	-0.428	0.810	0.459	0.542	0.545	0.190	0.994	-1.64	N [5]
	t-statistic	2.44	2.44	1.58	-2.07	6.97							
SWT	Coefficient	0.534	-0.007	0.037	-0.485	0.913	0.534	0.527	0.570	0.087	0.987	-0.53	
	t-statistic	1.29	-0.13	0.53	-1.01	5.49							
TMS	Coefficient	0.381	0.060	0.071	-0.341	0.849	0.381	0.441	0.452	0.151	0.967	-0.55	N [5]
	t-statistic	1.06	0.90	0.62	-0.84	3.12							
UUW	Coefficient	0.385	0.071	0.074	-0.337	0.793	0.385	0.456	0.460	0.207	0.997	-1.62	
	t-statistic	2.71	1.90	1.52	-2.14	6.18							
YKY	Coefficient	0.639	0.053	0.124	-0.617	0.684	0.639	0.692	0.763	0.316	0.997	-2.52	
	t-statistic	3.39	2.46	3.59	-3.23	5.46							

Table 4.53: ECM results using HCAV - WoCs

			Variable				Short run adjustment			Long run adjustment	Adjusted	Unit root	Diagnostic tests
		$HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	$HCAV_{it-1}$	D_{it-1}	γ_0	γ_1	γ_2	α	R^2	t-test	rejected
WoCs													
CR													
brl	Coefficient	0.887	-	0.054	-0.747	0.658	0.887	0.887	0.941	0.342	0.992	-1.21	
	t-statistic	3.03		1.33	-2.02	2.32							
dvw	Coefficient	0.305	-	0.470	-0.362	0.572	0.305	0.305	0.775	0.428	0.657	-1.29	
	t-statistic	1.32		1.78	-1.69	1.73							
mkt	Coefficient	1.577	-	0.066	-1.496	0.636	1.577	1.577	1.642	0.364	0.981	-1.14	N [5]
	t-statistic	5.97		1.15	5.73	1.99							
prt	Coefficient	0.969	-	-0.014	-0.746	0.137	0.969	0.969	0.956	0.863	0.986	-2.25	
	t-statistic	13.20		-0.27	-6.10	0.36							
sst	Coefficient	2.463	-	0.272	-2.698	1.400	2.463	2.463	2.735	-0.400	0.775	0.57	AC [5], R [1]
	t-statistic	1.35		1.91	-1.41	2.01							
ses	Coefficient	0.514	-	0.173	-0.484	0.606	0.514	0.514	0.688	0.394	0.973	-2.85	
	t-statistic	3.91		3.23	-3.45	4.38							
NCR													
bwh	Coefficient	0.035	-	-	0.038	0.673	0.035	0.035	0.035	0.327	0.970	-2.37	
	t-statistic	0.45			0.45	4.87							
cam	Coefficient	0.589	-	-	-0.401	0.507	0.589	0.589	0.589	0.493	0.980	-1.96	
	t-statistic	2.91			-2.31	2.02							
flk	Coefficient	0.948	-	-	-0.900	0.834	0.948	0.948	0.948	0.166	0.982	-0.44	R [5]
	t-statistic	4.32			-2.56	2.19							
mse	Coefficient	0.657	-	-	-0.421	0.437	0.657	0.657	0.657	0.563	0.986	-1.80	
	t-statistic	1.84			-1.35	1.40							
thd	Coefficient	0.757	-	-	-0.643	0.644	0.757	0.757	0.757	0.356	0.986	-2.08	A [5]
	t-statistic	5.09			-4.17	3.75							
tvn	Coefficient	0.543	-	-	-0.422	0.756	0.543	0.543	0.543	0.244	0.989	0.96	
	t-statistic	2.03			-1.38	2.99							

Table 4.54: SLRM results using HCAV - WaSCs

		Variable			Gearing			Wald test
		$HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	g_0^* %	g_1^* %	g_2^* %	
WaSCs								
CR								
ANH	Coefficient	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	t-statistic							
WSH	Coefficient	0.060	0.331	0.802	6.0	39.1	86.1	[1]
	t-statistic	0.46	2.70	5.54				
NES	Coefficient	0.127	0.147	0.547	12.7	27.4	67.4	[1]
	t-statistic	2.15	3.81	6.71				
SRN	Coefficient	0.450	-0.009	0.175	45.0	44.1	62.5	[1]
	t-statistic	11.30	-0.17	2.95				
WSX	Coefficient	0.774	-0.230	1.953	77.4	54.4	272.7	
	t-statistic	0.15	-0.06	0.12				
NCR								
SVT	Coefficient	0.158	0.438	0.453	15.8	59.6	61.1	[1]
	t-statistic	1.16	2.34	2.65				
SWT	Coefficient	0.555	-0.083	0.418	55.5	47.2	97.3	
	t-statistic	0.55	-0.11	0.58				
TMS	Coefficient	0.266	0.396	0.472	26.6	66.2	73.8	
	t-statistic	0.66	0.59	0.77				
UUW	Coefficient	0.234	0.340	0.359	23.4	57.5	59.4	[1]
	t-statistic	2.30	3.14	3.52				
YKY	Coefficient	0.071	0.168	0.393	7.1	23.9	46.4	[1]
	t-statistic	1.61	2.36	5.23				

Table 4.55: SLRM results using HCAV - WoCs

		Variable			Gearing			Wald test
		$HCAV_{it}$	$HCAV_{it}T1_t$	$HCAV_{it}T2_t$	g_0^* %	g_1^* %	g_2^* %	
WoCs								
CR								
brl	Coefficient	0.410	-	0.158	41.0	41.0	56.8	[1]
	t-statistic	3.98		0.76				
dvw	Coefficient	-0.131	-	1.097	-13.1	-13.1	96.6	
	t-statistic	-0.65		0.93				
mkt	Coefficient	0.223	-	0.181	22.3	22.3	40.3	[1]
	t-statistic	2.18		0.98				
prt	Coefficient	0.258	-	-0.016	25.8	25.8	24.3	[1]
	t-statistic	9.52		-0.29				
sst	Coefficient	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	t-statistic							
ses	Coefficient	0.077	-	0.440	7.7	7.7	51.6	[1]
	t-statistic	1.31		4.09				
NCR								
bwh	Coefficient	0.224	-	-	22.4	22.4	22.4	[1]
	t-statistic	5.69						
cam	Coefficient	0.382	-	-	38.2	38.2	38.2	[1]
	t-statistic	10.30						
flk	Coefficient	0.286	-	-	28.6	28.6	28.6	
	t-statistic	0.75						
mse	Coefficient	0.419	-	-	41.9	41.9	41.9	[1]
	t-statistic	9.97						
thd	Coefficient	0.322	-	-	32.2	32.2	32.2	[1]
	t-statistic	6.82						
tvn	Coefficient	0.497	-	-	49.7	49.7	49.7	[1]
	t-statistic	6.07						

Table 4.56: PAM results using RCV - WaSCs

		Variable				Adjustment factor	Adjusted	Unit root	Diagnostic tests
		RCV_{it}	$RCV_{it}T1_t$	$RCV_{it}T2_t$	D_{it-1}	α	R^2	t-test	rejected
WaSCs									
CR									
ANH	Coefficient	-0.119	-0.081	-0.087	1.796	-0.796	0.969	1.45	R [1]
	t-statistic	-0.95	-0.80	-0.56	3.27				
WSH	Coefficient	0.081	0.131	0.337	0.598	0.402	0.987	-2.86	
	t-statistic	1.33	1.61	2.96	4.23				
NES	Coefficient	0.143	0.043	0.108	0.656	0.344	0.994	-2.04	
	t-statistic	2.25	1.09	2.35	3.89				
SRN	Coefficient	0.141	0.004	0.033	0.739	0.261	0.991	-0.77	
	t-statistic	0.83	0.05	0.73	2.19				
WSX	Coefficient	0.259	-0.007	0.080	0.490	0.510	0.968	-1.26	R [5]
	t-statistic	1.86	-0.08	0.80	1.21				
NCR									
SVT	Coefficient	0.091	0.078	0.070	0.697	0.303	0.992	-2.14	
	t-statistic	3.27	1.79	1.07	4.93				
SWT	Coefficient	0.150	-0.034	0.041	0.744	0.256	0.986	-1.92	
	t-statistic	3.91	-0.57	0.53	5.57				
TMS	Coefficient	0.110	0.048	0.041	0.701	0.299	0.970	-1.11	N [5]
	t-statistic	1.49	0.72	0.42	2.60				
UUW	Coefficient	0.087	0.087	0.095	0.646	0.354	0.994	-2.52	
	t-statistic	2.90	2.34	1.68	4.61				
YKY	Coefficient	0.032	0.092	0.094	0.735	0.265	0.992	-1.30	
	t-statistic	0.85	3.12	1.90	3.61				

Table 4.57: PAM results using RCV - WoCs

		Variable				Adjustment factor	Adjusted	Unit root	Diagnostic tests
		RCV_{it}	$RCV_{it}T1_t$	$RCV_{it}T2_t$	D_{it-1}	α	R^2	t-test	rejected
WoCs									
CR									
brl	Coefficient	0.235	-	-0.047	0.550	0.450	0.985	-1.65	
	t-statistic	1.72		-1.06	2.02				
dvw	Coefficient	-0.049	-	0.203	0.454	0.546	0.062	-0.88	H [5], R [1]
	t-statistic	-0.70		1.59	0.74				
mkt	Coefficient	-0.112	-	0.165	1.531	-0.531	0.886	0.72	R [1]
	t-statistic	-0.59		1.92	2.07				
prt	Coefficient	0.743	-	-0.179	-2.161	3.161	0.637	-2.05	AC [1], H [5], R [1]
	t-statistic	2.00		-0.78	-1.40				
sst	Coefficient	-0.056	-	0.241	1.218	-0.218	0.748	0.33	AC [5], N [5], R [1]
	t-statistic	-0.42		2.43	1.86				
ses	Coefficient	0.035	-	0.332	0.337	0.663	0.925	-4.01 [5]	R [5]
	t-statistic	1.17		5.18	2.04				
NCR									
bwh	Coefficient	0.080	-	-	0.569	0.431	0.970	-2.24	
	t-statistic	2.40			2.96				
cam	Coefficient	0.072	-	-	0.804	0.196	0.966	-0.78	
	t-statistic	0.67			3.20				
flk	Coefficient	0.236	-	-	0.150	0.850	0.957	-2.51 [10]	
	t-statistic	2.86			0.45				
mse	Coefficient	0.159	-	-	0.571	0.429	0.985	-1.52	
	t-statistic	1.67			2.03				
thd	Coefficient	0.099	-	-	0.564	0.436	0.961	-1.67	H [5]
	t-statistic	1.76			2.15				
tvn	Coefficient	0.071	-	-	0.800	0.200	0.986	-0.87	
	t-statistic	1.10			3.45				

Table 4.58: SLRM results using RCV - WaSCs

		Variable			Gearing			Wald test
		RCV_{it}	$RCV_{it}T1_t$	$RCV_{it}T2_t$	g_0^* %	g_1^* %	g_2^* %	
WaSCs								
CR								
ANH	Coefficient	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	t-statistic							
WSH	Coefficient	0.202	0.326	0.838	20.2	52.8	104.0	[1]
	t-statistic	1.20	1.90	4.59				
NES	Coefficient	0.415	0.124	0.313	41.5	53.9	72.8	[1]
	t-statistic	3.78	1.04	2.32				
SRN	Coefficient	0.541	0.014	0.128	54.1	55.5	66.8	[1]
	t-statistic	3.27	0.05	0.56				
WSX	Coefficient	0.508	-0.014	0.158	50.8	49.4	66.6	[1]
	t-statistic	2.37	-0.08	1.01				
NCR								
SVT	Coefficient	0.300	0.257	0.231	30.0	55.7	53.0	[1]
	t-statistic	2.24	2.57	1.76				
SWT	Coefficient	0.587	-0.134	0.159	58.7	45.3	74.7	[1]
	t-statistic	1.64	-0.46	0.67				
TMS	Coefficient	0.366	0.160	0.135	36.6	52.5	50.1	[1]
	t-statistic	1.53	0.75	0.55				
UUW	Coefficient	0.245	0.245	0.270	24.5	49.0	51.5	[1]
	t-statistic	2.80	2.88	3.04				
YKY	Coefficient	0.122	0.348	0.353	12.2	47.0	47.5	[1]
	t-statistic	1.36	1.44	2.31				

Table 4.59: SLRM results using RCV - WoCs

		Variable			Gearing			Wald test
		RCV_{it}	$RCV_{it}T1_t$	$RCV_{it}T2_t$	g_0^* %	g_1^* %	g_2^* %	
WoCs								
CR								
brl	Coefficient	0.521	-	-0.104	52.1	52.1	41.7	[1]
	t-statistic	9.80		-1.30				
dvw	Coefficient	-0.089	-	0.371	-8.9	-8.9	28.2	
	t-statistic	-0.69		0.69				
mkt	Coefficient	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	t-statistic							
prt	Coefficient	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	t-statistic							
sst	Coefficient	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	t-statistic							
ses	Coefficient	0.053	-	0.501	5.3	5.3	55.5	[1]
	t-statistic	1.28		5.05				
NCR								
bwh	Coefficient	0.185	-	-	18.5	18.5	18.5	[1]
	t-statistic	7.87						
cam	Coefficient	0.368	-	-	36.8	36.8	36.8	[1]
	t-statistic	2.74						
flk	Coefficient	0.277	-	-	27.7	27.7	27.7	[1]
	t-statistic	10.90						
mse	Coefficient	0.370	-	-	37.0	37.0	37.0	[1]
	t-statistic	9.61						
thd	Coefficient	0.226	-	-	22.6	22.6	22.6	[1]
	t-statistic	6.99						
tvn	Coefficient	0.355	-	-	35.5	35.5	35.5	[1]
	t-statistic	3.33						

Chapter 5

Conclusions

5.1 Capital structure and the allocation of risk

5.1.1 The theoretical analysis

Chapters 2 and 3 of this thesis set out theoretical models that analyse the role of capital structure in a regulated firm, its relationship to the regulator's pricing decision and the allocation of risk between consumers and investors. Highly stylized models have been developed for this purpose and analyse the regulation of a monopolist that supplies a product which is fixed in quality and for which the demand is price inelastic. The models make reasonably realistic assumptions about the attitude of the various stakeholders towards risk. Consumers and shareholders are risk averse, managers are risk neutral up to a point, and debtholders are infinitely risk averse. A number of interesting results have been obtained from the analysis and they can be summarized as follows.

Firstly, the models demonstrate that a price-cap system, where prices are prices are fixed or vary only in exceptional circumstances, is almost certainly sub-optimal. If the regulator maximizes the welfare of consumers with a standard von Neumann-Morgenstern utility function, the optimal regulatory mechanism is such that consumers pay more in adverse economic conditions, except in the unlikely case that the managers' willingness to carry risk exceeds the inherent risk in the business. This is because consumers are willing to trade-off increased price variations against a lower expected price. Even if the regulator has complete information and there are no information asymmetries, as is assumed in the models, a fixed price-cap rule leads to welfare losses for the consumer.

Secondly, the models also indicate that the regulator should take a view on the capital structure of the regulated firm as this can affect the firm's cost of capital and, ultimately, the price paid by consumers. Even in the absence of corporate taxation, capital structure does matter because it determines the amount of equity finance and, in conjunction with the regulator's decision on price variations, the distribution of risks between consumers and shareholders. The model set out in chapter 2 only allows the regulator's decision on prices to influence the cost of equity indirectly through the regulator's choice of capital structure. Chapter 3 examines the more general case when the level of gearing and the regulator's decision on prices both have an independent and direct effect on the firm's cost of equity. In both cases there is a socially optimal capital structure that depends not only on consumers' aversion to the risk of price variations but also on the shareholders' trade-off between risk and returns.

Thirdly, when the firm's costs vary with fluctuations in the economy as a whole, the regulator's decision on price variations determines the degree to which systematic risks are carried by shareholders and, therefore, the cost of equity. Chapter 3 shows that it is open to the regulator to set prices so that shareholders' returns are either positively correlated, uncorrelated or even negatively correlated with the market return. This means it is not necessary for the shareholders' risks and rewards to be tied to the regulated firm's business risks and so its cost of equity can either be greater than, equal to or lower than the cost of debt. Consequently, although consumer prices should be higher when there are adverse economic conditions, it is not necessary for the shareholders' returns to be lower. Whether or not this is optimal depends on the consumers' and the shareholders' relative aversion to risk. For example, consumers might have such a low aversion to risk that prices should be set to provide shareholders with higher returns when economic conditions are unfavourable. Shareholder returns would then be negatively correlated with the market return providing shareholders with insurance against market risk. As result the cost of equity would be lower than the cost of debt leading to lower financing costs and a lower expected price for consumers.

Finally, chapter 3 explains how differences in the attitudes of consumers and shareholders towards risk determine the nature of the socially optimal capital structure. If the optimum for consumer prices is such that, at the margin, consumers and shareholders do not have the same aversion to risk then the social optimum is a capital structure with no debt. When consumers have relatively high risk aversion compared to shareholders then consumers prefer the lowest possible price variation even though this produces a higher expected price. Conversely, when consumers' risk aversion is relatively low, it is optimal to set prices so that the risks for shareholders are consistent with a cost of equity that is lower than the cost of debt in order to produce the lowest possible expected price. In either case, debt finance produces no benefit for consumers. However, if consumers and shareholders both have the same aversion to the risk of price variations at the margin, then there is only one very special set of conditions in the model where it is socially optimal for the regulated firm to be a 'not-for-profit' company which relies wholly on debt for its external finance; otherwise there should be a combination of equity and debt finance. For this to be the case the consumer optimum for prices must result in a rate of return on equity that is both equal to the cost of debt and just sufficient to satisfy shareholders.

5.1.2 Policy implications

These results raise a number of policy issues. In practice, even under price cap systems, prices do change in response to changes in the firm's costs. In the UK system there are often 'cost pass through' arrangements which allow price adjustments in specified circumstances and there is generally a complete reassessment of costs when a price cap is reviewed. However, such arrangements are typically designed to protect the regulated firm from material and unavoidable cost increases outside its control. For example, in the water industry, prices can be adjusted between price reviews if the government imposes costly new obligations to improve drinking and/or waste water quality. Firms are still expected to carry all normal business risks and, at price reviews, consumers receive the benefit of past efficiency savings. As a result little or no consideration is given to the possibility that consumers might prefer to carry some of the firm's normal business risks if this would lead to a lower expected price.

The various industry regulators in the UK pay considerable attention to the capital structures of regulated firms. At price reviews each regulator has usually stated explicitly the assumption that has been made about what constitutes an appropriate capital structure. Although there is no requirement that firms adjust their capital structures in line with the regulators' judgments, the models in chapters 2 and 3 show that they clearly have an incentive to adjust gearing levels to the extent that this reduces the cost of capital. This has recently become a significant policy issue. After the 1999 Periodic Review several water companies took action to increase leverage well above the level assumed by the regulator. 'Not-for-profit' companies that rely 100% on debt for external finance have also been created to replace privatized utilities which have encountered serious financial problems. Glas Cymru and Network Rail were both established on this basis and replaced, respectively, Dyr Cymru (Welsh Water) in May 2001 and Railtrack in October 2002.

However, as the models in chapters 2 and 3 demonstrate, there is no theoretical reason to suggest that a 100% debt financed company is socially optimal and, indeed, a unique set of conditions must apply for this to be the case. Further, if 100% debt financing produces too much variability in prices there is no equity buffer to absorb the risks that consumers do not wish to carry. This possibility seems to have been recognized in the design of 'not-for-profit' structures where a buffer is created, in the form of liquid reserves, to protect consumers and lenders from unexpected variations in costs. Even so, consumers pay for this protection and, in effect, take on the role of shareholders (but without the ownership rights) to the extent that these reserves have to be built up initially and then replenished out of revenues[1].

The use of 'not-for-profit' and highly leveraged structures remains controversial. In such restructurings the attitude of lenders towards risk and, therefore, the terms on which the new debt finance can be raised, has been a key consideration and it seems almost certain that the resulting risk profile for consumers will not be optimal. In Ofwat (2002) the water regulator expressed the view that capital structure is a matter for management and investors and that the assumptions about the cost of capital used to set prices should not pressure companies to adopt highly geared capital structures which would create undue risks for consumers. However, Ofwat's actions in the 2004 Periodic Review suggest a degree of concern about these developments on the part of the regulator. As explained in chapter 4, Ofwat reinforced the mechanisms that prevent firms from using high gearing levels to exert a price-influence

[1] In the case of Network Rail it could also be the taxpayer who provides this kind of insurance.

effect and effectively transferred the additional tax benefits of restructuring to consumers. This may well act as a deterrent to many more restructurings in the water industry.

5.1.3 Future research

The role of management in the models is relatively limited and they do not allow for the possible effects of capital structure on management incentives. This suggests the models might usefully be extended or others might be developed to look at such effects. Two examples are briefly discussed to illustrate issues that could be investigated.

The first example is related to agency costs. In the agency cost literature high levels of gearing are associated with high monitoring and bonding costs and with distortions to investment incentives. On the other hand a lower level of 'free cashflow' reduces the scope for unwise investments and produces a greater alignment of interests between internal and external shareholders. This leads to a trade-off and the familiar conclusion that there is an optimal capital structure. However, in the regulated firm, as has been seen, capital structure affects the allocation of risks between consumers and investors and, therefore, the firm's cost of capital. Although it is common to assume that a regulated firm's investment programme is determined exogenously, in practice there may be opportunities to invest to reduce future operating costs. Consequently, the effect of the regulator's pricing decision on the cost of capital might influence which cost saving investments are undertaken by management. Greater price variations and a lower cost of capital could lead to more cost saving investments.

Debt contracts, however, usually contain covenants to protect the interests of bondholders and to reduce bonding and monitoring costs. Typically, they include constraints on the levels of certain key financial ratios which, if contravened, allow bondholders to intervene or invoke default procedures. The ratios that are used for this purpose include interest cover and gearing. At high levels of gearing, therefore, managers might be more cautious about which discretionary cost saving investments are undertaken. This disincentive effect is likely to be reinforced by the absence of shareholders in a 'not-for-profit' company. Since efficiency savings create the opportunity for price reductions there is, therefore, a further trade-off for the regulator to consider; one which reflects the differing effects of capital structure on the incentives to increase efficiency. It may be possible to develop a model which examines the conditions under which a capital restructuring can lead to a welfare improvement though its effect on efficiency incentives.

The second example concerns the effect of cost pass through arrangements. The literature generally views this problem from the perspective of the firm. Armstrong, Cowan and Vickers (1994), for example, set out a simple model where there is a risk averse monopoly supplier and consumer demand is inelastic. In this model the optimal level of cost pass through is determined by a trade-off between incentives and insurance. While lower price variations provide a greater incentive to improve efficiency through increased effort, they also reduce the firm's insurance against risk. A risk averse management would, therefore, be less inclined to make that effort. Consequently, the greater the uncertainty in costs and the greater the management's aversion to risk then the higher should be the level of cost pass through. Their model explicitly assumes that consumers are risk neutral but the authors recognize that, if consumers are also risk averse, the possibility of risk sharing has to be considered. The optimal allocation of risk between consumers and the regulated firm is analysed in Cowan (2004) and, while he acknowledges the possibility of a relationship between the form of the price control and the cost of capital, he takes a different approach and also assumes that the firm is risk averse with a utility function that is solely dependent on the firm's profits. The models developed in chapters 2 and 3 might provide a framework for analysing the interaction between both sets of issues.

5.2 The water industry: an empirical study

5.2.1 Findings from the study

Chapter 4 considers the question of whether the behaviour of regulated firms is consistent with the trade-off or pecking order theories by taking the water industry over the period 1990/91 to 2002/03 as a case study.

For the purposes of analysis the WaSC's and the WoC's have each been divided into two categories according to whether or not the companies implemented a capital restructuring after 1999/00. The aim was to establish categories within which the behaviour of the companies is likely to be relatively homogeneous so that separate models could be estimated for each category using pooled data. Econometric models of the relationship between debt and capital value have been estimated for each category and provide reasonable support for the proposition that water companies, at least when viewed collectively, have behaved as though they had target levels of gearing.

The models have been developed using a 'general-to-specific' model reduction procedure that starts with an unrestricted ADLM as the initial equation. When HCAV is used to measure capital value the procedure shows that an ECM provides the best explanation of the relationship between debt and capital value. ECM's have been estimated for each category of company and they provide plausible estimates of the target levels of HCAV gearing and of the speed of response both to short-run changes in capital value and to deviations from the long-run target. A particular feature of this study is that it includes tests for cointegration between the variables to assess whether the results reflect a causal relationship and not merely stochastic time trends in the data. Although the available data only covers the 13 years to 2002/03, which is a relatively short time period, half of the models accept one or more of these tests. This represents at least indicative evidence that the variables are cointegrated and that the target gearing levels derived from the models are not the spurious result of stochastic time trends.

Models that use RCV as the measure of capital value have also been estimated. In these models the PAM provides the best explanation. However, the results of the diagnostic tests are less satisfactory and encompassing tests show that the ECM's based on HCAV are superior. This is to be expected as the water companies, Ofwat and, indeed, the capital markets all focused on the HCAV measure of gearing until attention moved to the RCV measure after the 1999 Periodic Review.

The overall conclusion of this case study is that the empirical evidence is more consistent with the trade-off theory of capital structure than the pecking order theory. It should be emphasized that the presence of target levels of gearing does not necessarily mean that a trade-off actually exists. The adjustment models on which this study has been based simply indicate that water companies appear to have behaved as though there is a trade-off. In order to validate the trade-off model it would be necessary to develop more extensive models where the target level of gearing is specified as a function of the explanatory variables that determine the costs and benefits of increasing gearing. Unfortunately, a number of those variables, for example, agency costs and the costs of financial distress, are extremely difficult to measure. However, adjustment models can provide evidence that the behaviour of firms is inconsistent with the pecking order theory since it predicts that firms do not have target gearing levels.

As the water companies are highly regulated it is important to assess whether they have increased gearing in order to exert a price-influence effect on regulatory decisions because it possible that their behaviour might otherwise have reflected the pecking order theory. There is, however, little indication that the water companies have generally tried to manipulate their financial positions to that end. Consequently, their behaviour does not appear to have been consistent with the pecking order theory.

There could be several reasons for the apparent absence of attempts to exert a price-influence effect. The potential for this kind of 'hidden action' or moral hazard problem is inherent in a regulatory environment and Ofwat put mechanisms in place that would act as a deterrent to such behaviour. In addition, the firm also runs the risk of an adverse reaction from the capital markets which would provide a further deterrent, especially for a company acting in isolation. This is likely to have been a particularly important consideration for the WaSC's in the early years following privatization.

This finding should not be surprising. At each review of price limits large amounts of research and evidence on the cost of capital, the capital structure and the financial profile of water companies have been commissioned by the companies and by Ofwat. Similar debates have also taken place when the price limits for other utilities in the UK have been reviewed. It is not unlikely, therefore, that the behaviour of water companies has been influenced by the detailed discussion of these issues that has taken place.

When the initial price limits were set in 1989 one of the government's aims was to ensure the financial profiles of the companies would be acceptable to the capital markets and, in particular, had the capacity to accommodate a significant increase in gearing.. Although this might have encouraged behaviour consistent with the pecking order theory the results of this study indicate that, in the early years, the companies generally moved towards targets which are broadly consistent with the projection of the longer term position that was made by the government.

In the 1994 and 1999 Periodic Reviews Ofwat decided that companies could operate at much higher levels of gearing than the government had assumed in 1989 and concluded that 50% gearing would represent an efficient capital structure. The evidence from this study indicates that, after the 1994 Periodic Review, the WaSC's target levels of gearing increased accordingly. However, the targets for the WoC's appear to have remained stable which probably reflects the fact they were mature companies that had been in private sector ownership for many years.

In addition, the pecking order theory does not appear to be compatible with the capital restructurings which followed so rapidly after the 1999 review. These restructurings seem to be more readily explainable in terms of the trade-off theory with some companies being driven to take a quite radical approach to reducing the cost of capital after a tight regulatory review. As would be expected the results of the study indicate that the target gearing levels for these companies have increased to well over 75%. The restructurings might also have reflected a defensive price-influence effect to protect the companies concerned against further tightening of the regulatory contract at the 2004 Periodic Review, but this was probably a second order consideration. Ofwat had previously put mechanisms in place to avoid such effects and these were reinforced for the 2004 review. Further, many water companies did not implement a capital restructuring and the estimated target levels of gearing for these companies do not appear to have changed materially after the 1999 review. This is also consistent with the trade-off theory. These companies seem to have certain common ownership characterstics which suggest the reduced management flexibility required by a restructuring might have been perceived as a costly limitation on their strategic options for future growth.

5.2.2 Future research

The finding that water companies in England and Wales appear to have target levels of gearing suggests two areas for further research.

The first concerns the mechanisms that water companies have used to move towards target gearing levels. The capital expenditure of water companies is almost entirely determined by the requirements of domestic and EU legislation. Consequently, if companies wish to move towards their target gearing levels more quickly than this allows, their only option is to return funds to shareholders; normally the relevant parent company. However, the data from water company June Returns shows that, prior to the capital restructurings that followed the 1999 Periodic Review, only four companies carried out share buybacks and these were all WoC's. The amounts involved were also quite small as a proportion of net assets. This raises the question of whether the dividend policies of the water companies have been influenced by their objectives regarding the achievement of target gearing levels.

The classic study of management behaviour in relation to dividend policy was carried out by Lintner (1956) who used a PAM to show that firms gradually adjust their dividend levels over time in order to achieve a target payout ratio. This has been confirmed in subsequent research and the surveys by Benartzi et al (1997) and Lease et al (2000) both conclude that Lintner's model remains the best available model of firm behaviour regarding dividend policy. However, preliminary estimates indicate that the PAM does not provide a good explanation of the data on dividends paid by water companies to their parent companies. This implies other factors need to be taken into account and the possible effect of decisions on capital structure could be investigated.

The second possible area for further research concerns the effect of the regulatory framework on capital structure decisions. It seems likely that the behaviour of water companies in this respect has been very much influenced by the incentives inherent in a price-cap system and the particular form of that system which has been adopted in the UK. This has encouraged both the regulator and the water companies to pay close attention to the issue of capital structure. The regulator's focus has been on the question of what represents an efficient and sustainable capital structure so that water prices are set at the lowest possible level consistent with maintaining the companies' financial viability. However, while the companies may be influenced by the regulator's views they do not have to accept them. Indeed, they have a clear incentive to find ways of improving financing efficiency and outperforming the assumptions which the regulator uses to set price limits. It seems probable that this was the main reason many companies decided to implement a major capital restructuring after the 1999 Periodic Review.

In the US, however, the system is closer to rate of return regulation and this issue seems to attract less attention. Most regulated firms in the US are long established and, typically, regulators take the capital structure as a given. Sidak and Spulber (1997) note that US regulators generally set the allowed rate of return as the weighted average of the cost of debt and equity, with weights given by the proportions of debt and equity finance, measured according to the firm's book value. It would, therefore, be interesting to investigate the capital structure decisions of companies in one of the US utiltity industries especially as, in some states, the regulators have moved towards incentive regulation with price caps.

Glossary

ADF Augmented Dickey-Fuller

ADLM Autoregressive Distributed Lag Model

AEM Adaptive Expectations Model

AIC Akaike information criterion

ARCH AutoRegressive Conditional Heteroscedasticity

CR Capital restructuring post 1999/00

DGWS Director General of Water Services

DWI Drinking Water Inspectorate

EA Environment Agency

ECM Error Correction Model

EU European Union

HCA Historical Cost Accounts

HCAV Historical Cost Asset Value

HQC Hanna-Quinn criterion

NCR No capital restructuring

Ofwat Office of Water Services

OLS Ordinary Least Squares

PAM Partial Adjustment Model

RCV Regulatory Capital Value

RESET Regression Specification Test

SC Schwarz criterion

SLRM Static Long Run Model

WaSC Water and Sewerage Company

WoC Water only Company

Water and Sewerage Companies

ANH Anglian

WSH Dyr Cymru

NES Northumbrian

SVT Severn Trent

SWT South West

SRN Southern

TMS Thames

UUW United Utilities

WSX Wessex

YKY Yorkshire

Water only Companies

bwh Bournemouth and West Hampshire

brl Bristol

cam Cambridge

dvw Dee Valley

flk Folkestone and Dover

mkt Mid Kent

prt Portsmouth

mse South East

sst South Staffordshire

ses Sutton and East Surrey

thd Tendring Hundred

tvn Three Valleys

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