Risk and Regulation in Water Utilities: a cross-country comparison of evidence from the CAPM

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Abstract

This paper addresses a core issue for the regulated utility: what are the risks taken by investors in organizations that supply a product whose supply is regulated? Prior research on returns of regulated water supply and distribution companies in the United Kingdom concluded that regulation interacts significantly with equity returns and that the systematic risk and hence required returns of water utilities equity were low and decreasing over time (Buckland and Fraser, 2001). The current research analyses the returns on securities issued by regulated water companies in the differently-regulated economies of the UK and the USA, using data from 1980 to 2010. Mirroring the results from the 1990s, the evidence suggests that UK regulators have chronically overestimated the systematic risks borne by investors in water utilities, resulting in lax pressure on permitted returns and higher prices than are needed to provoke efficient supply. The analysis also confirms that there are striking differences between the regulatory risks and patterns of returns for private sector water utilities in the USA and the UK.

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1. Introduction

US utilities are generally regulated by setting a permitted return on book equity during periodic rate cases. The permitted rate is intended to deliver a 'fair' return to investors for the risks of the activity which they finance. In contrast, UK utilities have generally been regulated by price caps based on the RPI-X principle (see, for example, Bernstein and Sappington, 1999). In establishing the level of X in the price cap, the regulator must assess what revenue stream is required to provide adequate compensation for the investment in the utility's assets, considering the time and the risk involved in financing the utility. In either system, determination of the cost of capital critically affects the size of utilities' customers' bills: in the case of water, it has been estimated that a 0.5 percentage point variation in the cost of capital might translate into a change of GBP10.00 in the average annual household bill (Ofwat, 2014: 2: there are some 28 million households in England and Wales).

In rate setting for utilities in the US, alternative models, primarily variants of the dividend growth model (DGM) and the capital asset pricing model (CAPM), are used to establish the acceptable level of return on regulated assets. Most recently, a GARCH-based modelling approach has been pioneered, the risk premium model (RPM) of Ahern (2011; 2013). In the UK, utilities regulation is historically by price cap rather than return, but again regulators' estimates are dominated by CAPM modelling. The flaws of the CAPM as a model of risk and as a tool for asset pricing and for regulation are well documented: see, for instance Fama and French (2005) and, in utilities, McDonald et al. (2010). The elegant logic of the CAPM as a model of expectations continues to lie behind many empirical analyses of risk factors. Whatever the merits or demerits of an expectations model in forecasting risk premia, outturn data can reveal how returns on utilities' issues of equity have been systematically related to other contemporary returns, establishing their levels of non-diversified risk. In this paper we use robust methods of estimating time-varying risk parameters to re-examine the levels of systematic risk in water utilities and to suggest that the estimates used by rate regulators could be significantly improved.

One of the characteristics of return and price cap regulation is the periodic re-setting of rates, thus introducing the likelihood that risk and regulation exhibit some level of endogeniety. Contemporary advances in estimation of time-varying risk and volatility afford us the potential for investigating such endogeniety: see Gort and Wall (1988) for an early commentary and Buckland and Fraser (2001) for an application to water utilities.

Three issues thus concern us in this paper. Firstly, does the recorded riskiness of investment in the water sector correspond to regulators' analyses? Secondly, does systematic risk vary over time, as has been found in prior research, and is any change over time endogenous with regulation itself? Thirdly, how does the risk of UK network utilities correspond to that of parallel utilities in the USA? We open with a review of the literature in section two, followed in section three by a discussion of our approach, which estimates the equity betas of UK and US listed companies in the water sector, using a robust, Recursive and Iteratively Reweighted Least Squares (RIWLS) model. Section four presents our results and analysis and section five concludes with the implications of our research and the prospectus of further work.

2. Background and Related Literature

"Our equity beta of 0.9 at the 57.5% notional level of gearing derives from an asset beta of 0.4."
Ofwat 2009, page 128

[TABLE 1]

In rate setting regulators will focus on their models of asset risk, while the data available to researchers from listed equities in utilities relates to equity risk, mediated by gearing levels, tax burdens and other impacts of capital structure (for example pensions). We are careful in this paper to consider whether our results might be affected by changes in the capital structure of companies, across firms and through time. We do not attempt to artificially construct series of asset betas from the traces of equiity betas, but we demonstrate the consistency of those equity betas, given the observable behaviour of firms' levels of and changes in gearing. In Table 1 we report the sample of firms in this study and some descriptive information from commercial data vendors, including estimates of the firms' beta and their debt to equity ratios. It is evident from the table that the commercial data vendors support very different equity beta estimates: indeed the same vendor (Thomson-Reuters) has provided two separate beta calculations (correlation and regression based): and there is some degree of variation in these estimates (see for instance Anglian Water, with a correlation beta of 0.098 and a regression beta of 0.425). More to be expected is the variation in betas between vendors, applying different estimation techniques. Where alternatives are available from vendors, for some UK firms, we see that estimates by Bloomberg and by Thomson-Reuters can diverge substantially.

The final six columns of Table 1 report quinquennial levels of the debt to equity ratios of firms in the sample. For US firms, debt to equity ratios congregate around 100 to 150%, equivalent to a capital gearing of approximately 50 to 75%. Across these listed firms the (unweighted) average gearing is around 137% in 1985, peaks at 150% in 1990, falling back steadily to some 118% by 2010. Thus in the US, water companies' gearing is steady and somewhat conservative for the utility sector. For UK companies, gearing levels were close to zero at the common time of privatization at the end of 1989, when the debt of the precursor public corporations was written off in the privatisation process; not surprisingly, ratios have risen aggressively over the intervening twenty years (encouraged by the regulator). By 2000 typical levels had reached 100%: but what is striking in the UK listed Water and Sewerage Companies (WASCs) is that gearing continues to rise, dramatically so by 2010, where the four remaining listed firms are exhibiting capital gearing in the balance sheet of debt at over 5 times equity. Thus by 2010 the surviving UK companies were exhibiting aggressive debt to equity ratios, substantially exceeding those in the USA. One would therefore expect that the equity betas of water utilities in England and Wales would also be markedly increasing over time, a feature which we discuss in the context of our results below.

The UK regulator's view of the risk of water companies is at odds with the estimates available from various major financial service data providers, see Table 1. This reflects longstanding dispute: throughout the period since privatization of the ten water companies supplying England and Wales there has been active and prolonged debate about the cost of capital. At privatization of the 10 WASCs in 1989, government set their cost of capital at 7%. By 1991 the regulator was arguing for a range of 5 to 6% after tax (Ofwat, 1991): this rate was used in determination of the new price cap for the 1994 Periodic Review (Ofwat, 1994). In the 1999 Periodic Review, the regulator again shifted the cost of capital downwards, to a range of 4.25 to 5.2% after taxes (Ofwat, 1997; 1999). In the 2004 and 2009 determinations, Ofwat settled upon 4.5% post-tax (Ofwat, 2004; 2009).

Estimation of the appropriate rate has been influenced by rival modeling strands of the DGM and CAPM. The former was the preferred approach by the UK water regulator in the early 1990s; latterly, the CAPM has gained ascendancy and has become institutionalized, through its use by consultants, by investigations of the Monopolies and Mergers Commission (later the Competition Commission and now the Competition and Markets Authority, hereafter CMA) and by the various regulators in their price determinations. Contemporary rival models, in particular the Arbitrage Pricing Theory or multi-factor models, have attracted speculative comment, but have gained no allegiance with the regulator.

The CAPM has itself predominantly been discussed in terms of a fixed-coefficients model, used in modeling a risk-adjusted periodic return. The debate has turned upon issues of (a) how systematically risky a utility company's regulated business is or will be; (b) what capital structure would be optimal for utilities (and how risk premia on utilities' corporate debt would behave under such structures); and (c) what the levels of returns on riskless assets and on the market portfolio will be over the period to be regulated (Cooper and Grout, 1993). Whether utilities' equity risk is appropriately modeled in turn determines whether shareholders' returns are excessive.

Our first question affects the validity of any estimation of risk parameters that underpin a regulated cost of capital and thus a price cap on the utility's regulated business. Is an estimate of a utility's beta, over a period during which the underlying beta is either cyclical or is trended upwards or downwards, a good or a poor basis for establishing the adequacy of returns to justify a price control? Critical academic commentary has been predicated upon well behaved and non-trended beta estimates, but risk measurement is increasingly recognized as problematic (Cooper and Grout, 1993, Robinson and Taylor, 1998, Cooper and Currie, 1999; or Morana and Sawkins, 2000; Buckland and Fraser, 2001; Antoniou et al., 2000; Grout and Zalewska, 2006; NERA, 2009).

The second question affects whether regulators are building into their models the risk of the business under regulated conditions, or rather the risk of such a business under the hypothetical conditions of competition. These concerns are first picked up by Dubin and Navarro (1982) and discussed further by Binder and Norton (1999). In other words, are investors to earn returns justified in the absence of the elements of market failure which itself necessitate regulation, or rather the returns appropriate to a particular, regulated state?

Third, that latter issue will in turn affect how the risks and returns that are experienced in other regulated regimes can be used as yardsticks within regulation elsewhere. For example, US utilities' beta estimates may be influenced by their regulation of returns rather than prices and by the typical short cycle of regulatory review; while estimates of beta across RPI-X regulatory systems may be affected by the maturity of any shift towards competitive product markets and by the duration and regularity of systems' review cycles.

Perfect competition (many suppliers, symmetric information, costless entry and exit) excludes suppliers from returns other than 'normal' profits. Price-taker producers deliver services efficiently and consumers benefit through price competition. Where natural monopoly precludes competition, regulators may aim to establish a regime that frequently and systematically claws back utilities' efficiency gains. Such gains would otherwise result in sustained 'abnormal' profits to an unregulated monopolist and to temporary 'abnormal' gains to a regulated utility, where price caps are binding and competitors are excluded. UK regulators typically deliver such gains to customers in periodic review of the price cap control. Thus regulators' regimes and behavior interact with utilities' riskiness. Such interaction may be asymmetric, with either a tendency to claw back the abnormal profits to deliver lower prices (arguably driving up utilities' cost of capital by skewing expected returns downward), or a tendency to regulatory capture, with utilities protected against variation in shareholders' returns by their ability to bank gains and pass any downside risk through to customers (driving the cost of capital downwards by skewing expected returns upward).

UK regulators have not explicitly considered interaction of regulation and beta estimation, despite recognition that estimates of low betas in US utilities may be affected by the rapid review cycle of capped returns there. In the context of US rate regulation, analytical and empirical attention to the interaction dates from the 1970s: see, for example, Breen and Lerner (1972), Leland (1974), Peltzman (1976), or Thomadakis (1976). Early analyses of the interdependence of regulatory intervention and returns variation were developed into models of risk-regulation linkages in the 1980s (see, for example, Thompson, 1979; Ahn and Thompson, 1989, Riddick, 1992, Llewellyn and Mauer, 1993; see also Bey, 1983; Bos and Newbold, 1984). Accepting the stochastic nature of asset betas, these studies suggested that rate regulation does reduce utilities' systematic risk by significant amounts. For example, Riddick suggests that '"average" systematic risk can be driven to zero; in essence, regulation makes beta a random variable with a near-zero mean' (Riddick, 1992: 151). Llewellyn and Mauer argue that stabilization mechanisms in incentive regulation (rules which allocate unexpected returns between utilities' shareholders and customers) will have similar impact on measured riskiness (Llewellyn and Mauer, 1993: 264). Structural linkage of risk and return in US rate regulation is also discussed by Marshall et al. (1981), Chen (1982), Prager (1989), Gombola and Kahl (1990) and Teisberg (1993).

In the UK Gandolfi et al. (1996) used the revealed volatility of equity returns, as impounded into traded options price movements, to test a model of cyclical behavior of beta for the shares of UK regulated utilities. Their contention is that beta will follow a saw-tooth cycle over periods of regulatory review, declining as review approaches, since in the review any systematically-variable excess returns generated during the cycle period are impounded into the revised price cap. As cycle periods and regulatory claw-back of excess returns accelerate, the measured (regulated) beta of the utility's equity declines in this framework, since product/service market risks are passed through to customers in the tightening or loosening of price caps in the evolution of the regulatory regime. Robinson and Taylor (1998)also drew attention to risk : regulation interaction in the UK, showing volatility of returns for UK electricity utilities to be time-varying. Dnes et al. (1998) find a 'minor contribution' of regulatory announcements to utility share values. Antoniou and Pescotto (1997) suggest that regulatory announcements impact upon the measured beta risk of a specific utility's equity, while Buckland and Fraser (2000; 2001) conclude that regulatory events are associated with changing systematic risk estimates both in electricity distribution and in water. Antoniou et al. (2000), using VAR and GARCH procedures in decomposing risk estimates during 1990 to 1995, conclude that regulatory uncertainty and unanticipated expectations revision are important in utilities' riskiness. Grout and Zalewska (2006) replicate this work and include comparison with experience in non-UK utilities sectors. This paper sets out to further improve our understanding of the links between regulation and the risks faced by the regulated.

The UK regime is well documented in Buckland and Fraser (2001). For the US, water regulation is clearly outlined in Beecher (2009) and will not be detailed further here. While the sector is more fragmented and diverse in structure and regulatory authorities than is the UK, there are common themes in the regulation of the (relatively few) private sector water utilities whose ownership is securitized and listed (ibid, p5).

The water industry in England and Wales was privatized in 1989, by converting the ten then nationalized, river basin boards into joint stock companies and selling their equity to the private sector through simultaneous initial public offerings on the London Stock Exchange. The value of and returns on the equity, or risk capital, investment in these companies is thus reflected in the behavior of the prices and yields of their shares as quoted on the London Stock Exchange. We assume here that the exchange operates under conditions of at worst semi-strong efficiency and that there are no issues of thin trading in the price and yield data on these major companies. After privatization, all WASCs have equities with closing prices and yields determined by market forces in the London Stock Exchange. This generates objective, secondary data on yields and returns. In the US, there are a multitude of water (and waste-water) utilities, some public/municipal, some private and unlisted, some private and listed. We focus on the latter group, which itself comprises companies ranging from single location to multi-state enterprises, with exchange-listed equities traded over substantial periods of time, but of varying length of listings.

In this paper, we construct our own robust estimates of the parameters of risk models. We use daily closing prices and dividend yields collected from Thomson Reuters DataStream database, converting this into daily returns for each company and also for the Financial Times Actuaries All-Share Index (representing the UK market) and the NYSE composite (representing the US market). We collect UK data from December 11th 1989, the common date of first dealings, until May 6th 2011, or the latest date available if the equity is delisted earlier, The data series for most of the UK privatized companies (Anglian Water, Northumbrian Water, North West Water, Southern Water, South West Water, Thames Water, Welsh Water, Wessex Water and Yorkshire Water) are affected by holding company changes over the sample period. [1] Both the multi-utilities are maintained within the sample, the latter until delisting in 2000. We note that, post-merger, their equity betas will reflect elements of (differently regulated) activity in electricity distribution and supply. The risk of the parents' equity is thereafter impacted by two major regulated activities and two regulators: Ofwat for North West Water and Welsh Water; Offer (later Ofgem) for the electricity supply and distribution activities of Norweb and Swalec. One might thus expect that the beta series for United Utilities and for Hyder will be more complex than for solely regulated water businesses. These shifts leave Severn Trent as the only ever-present, WASC-only listing, alongside Pennon and the relisted Northumbrian, plus the various abbreviated listings of the other WASCs.

[1] Anglian Water equity was delisted in December 2006, taken private by a private equity consortium, Osprey. Northumbrian Water was acquired by French concern Lyonnaise des Eaux in early 1996, then transferred to the Suez group, before the UK water interests were spun off into a consortium, prior to gaining a new London listing, again as Northumbrian Water Group, in September 2003. Southern Water was acquired by Scottish Power in 1997 and South West Water was renamed Pennon Group in 1998. Thames Water was acquired by the RWE multi-utility in 2001, then bought out in 2006 by Kemble Water Limited, managed by the private equity group Macquarie Capital. Wessex Water was acquired by the US Enron Corporation in July 1998, then bought by YTL Power International in May 2002. Yorkshire Water becomes the Kelda Group during 1999, being delisted in February 2008 when taken private by the infrastructure fund Saltaire Water. North West Water combined with regional electricity company (REC) Norweb to form United Utilities plc in 1996. A similar merger joined Welsh Water with the REC Swalec to form the multi-utility Hyder plc. In 2000, Hyder sold the electricity distribution business to British Energy and its water business to US firm Western Power Distribution: in 2000 the latter transferred the business as a mutual to Glas Cymru, a company limited by guarantee and unlisted.

Data on US listed water companies is similarly collected from the Thomson-Reuters database. Investigating the quality of the data, it is clear that the pre-1980 environment, prior to electronic trading, is characterised by frequent extended periods of no-trading, producing stale price data. While some trade-to-trade measurement of returns can be tolerated by the analysis, frequent and extended periods can frustrate and weaken the power of even sophisticated research algorithms. Thus we analyse the data available from the earliest date of January 2nd 1980 to May 6th 2011. We analyze and report data for the equity issued by the following US companies that have active listings within the period 1980 to 2011: American States Water, American Water Works, Aquarion, Aqua America, Artesian Resources, California Water, Connecticut Water, Consumers Water, Dominguez Resources, Middlesex Water, Pennichuck, San Jose Water (SJW), Southwest Water, United Water Resources and York Water. [2]

3. Data and Methodology

The theoretical foundation of the traditional Capital Asset Pricing Model (CAPM) of Sharpe (1964) and Lintner (1965) sees the return generating process on an asset as linear with respect to a market benchmark. It is a stylized fact of empirical finance that the intercept and slope coefficients, commonly referred to as betas (β), are not stable over time, with evidence on beta instability dating back to the early 1970s (Blume, 1971, 1975; Gonedes, 1973; Meyers, 1973; Baesel, 1974; Bos and Newbold, 1984; Black et al., 1992; and Gonzalez-Rivera, 1997). Additionally, there is evidence that betas are less stable for individual securities than they are for portfolios: and that as the size of the portfolio increases, betas' stability also increases, reflecting the effects of diversification (Alexander and Chervany, 1980).

In practice, numerous models have been used to estimate time-varying betas. These include short-term (usually five years) constant coefficient models; rolling regression and recursive regression models; and time-varying coefficient models which specifically model the time-varying characteristics of the betas (see Groenewold and Fraser (1999) for a review). Here we focus on a time-varying model and use the Kalman Filter procedure for the maximum likelihood estimation of parameters of interest. The Kalman Filter utilizes a state-space model to extract and incorporate information from the conditional variance of prior returns in modeling the evolution of model parameters. It is a dynamic and recursive algorithm, where time-varying parameters are allowed to be stochastic and which uses all available information in estimation, allowing for shocks to the weighting process. This procedure has been applied to US data by Fisher and Kamin (1985) and by Ahern et al. (2011), to UK data by Black et al. (1992) and Buckland and Fraser (2000), to Swedish data by Wells (1994) and to Australian data by Brooks et al. (1998) and Groenewold and Fraser (1999).

3.1. A Time Varying Coefficients Market Model

We utilize an autocorrelation and heteroskedasticity robust estimator, in the spirit of the realized volatility and covolatility literature: see, for instance, Barndorff-Nielsen et al. (2009). This utilizes a smoother to re-weight the historical data and an iteratively reweighted contemporaneous algorithm to account for non-normality and significant outliers. A similar approach is suggested in McDonald et al. (2010) that accounts for the leptokurtic properties of equity returns. The mechanisms that might generate skewness and excess kurtosis are complex and still not well understood. Realized measures of higher moments are a relatively recent addition to the financial econometricians toolbox: see, for instance, Buckle et al. (2014) for an overview in respect to high frequency returns. Our estimator combines the flexibility of least squares estimation, with the robust kernel approach of Barndorff-Nielsen et al. (2009) to generate beta estimates at the daily frequency. Higher frequency analysis is possible: however, investigation of the data indicates that

[2] Several US water companies also have complex listings histories during our sample period: American Water, bought by RWE ag in 2001 and spun off and relisted in 2008; Acquarion, bought by Suez sa in 2006; Consumers Water, bought by Vivendi sa in 1998; Dominguez Resources, acquired by California Water in 1998; United Water, bought by Suez sa in 2001. Data for one defunct listed utility company, Elizabethtown Water, taken over by Thames plc in 1999, is not available on the Thomson-Reuters DataStream database. Market data is published by Thomson Reuters DataStream for San Jose Water, but not accounts data.

the stale prices problem would be very acute, in particular for the US firms. Even at the daily frequency some stale prices are evident and techniques are needed and deployed to account for this lack of variation.

Consider the total return index $RI_{i,t}$ for the j^{th} asset from a complete market of n securities, with capitalization weighted total return index $RI_{m,t}$. A dynamic representation of the standard linear market model is

$$\Delta \log (RI_{j,t}) = \beta_{j,t} \Delta \log (RI_{m,t}) + \alpha_{j,t} + u_t \tag{1}$$

where $\alpha_{j,t}$ is the time varying expected excess return of asset j and $\beta_{j,t}$ is the systematic risk factor of asset j with respect to the market, for notational simplicity the parameters are collected into a vector $b_t = [\alpha_{j,t}, \beta_{j,t}]'$, for which the j asset indexation is presumed.

There are two main approaches for dealing with time varying coefficients models such as 1. First, one can treat the vector b_t as a vector stochastic process and implement a state-space type model. The simplest method is to assume a vector random walk without drift, i.e. $b_{t+1} = b_t + v_t$, where $v_t \sim \mathcal{N}(0, \Sigma)$ is a vector draw from a cross sectionally and serially uncorrelated normal random variable. The evolution of b_t may be estimated using a standard Kalman gain approach, maximizing the joint likelihood of the observed and unobserved state-space equations.

The motivation for the use of this estimator is that standard unscented Kalman filters have a tendency to over ascribe variation in the state-space to the constant, resulting in high levels of variation between the evolution of the estimates of the β coefficients for the cases when the intercept α is suppressed against the unrestricted model. In most applications to estimating dynamic market models restricting α to zero should not have a material impact on the β. A second issue is that sharp discontinuities in the slope and intercept coefficients are often ascribed to higher levels of variation in the state vector, implying a higher level of uncertainty in the results than is actually present.

To account for these issues we implement a robust alternative, which we have called recursive and iteratively re-weighted least squares (RIWLS). In this approach we treat b_t as an exogenous transmission function estimated by a rolling or recursive least squares approach with linear or exponential forgetting. Setting:

$$y_t = \Delta \log (RI_{i,t}), \quad x_t = \Delta \log (RI_{m,t}), \quad \tilde{x}_t = [1, x_t]' \tag{2}$$

we additionally implement an recursively and iterated weighted least squares, the procedure is as follows. For a rolling window:

$$\tilde{y}_t = [y_t]_{t-\tau}^{t}, \quad \tilde{X}_t = [\tilde{x}_t]_{t-\tau}^{t} \tag{3}$$

the objective is to estimate:

$$\tilde{y}_t = \hat{b}_t' \tilde{x}_t + \hat{u}_t, \tag{4}$$

subject to the assumption that the history of the system is contaminated by the past history of alternative $\beta_{j,t}$ and $\alpha_{j,t}$, i.e. that the transmission function is only locally stable. For an exponential forgetting factor $\hat{h}$, the temporally weighted historical data vector/matrix are as follows,

$$Y_t = \tilde{y}_t \circ \psi^y \Big| \hat{h}, \quad X_t = \tilde{X}_t \circ \Psi^x \Big| \hat{h} \tag{5}$$

where $\tau = \log(0.001) \log^{-1}(1 - \hat{h})$ is the lag order that covers the 99.9% mass of the exponential weighting. The OLS estimate of the transmission function is therefore:

$$\hat{b}_t^{ols} = (X_t' X_t)^{-1} X_t' Y_t \tag{6}$$

this is then reweighted in the standard manner, by collecting the raw residuals

$$\hat{e}_t^{ols} = Y_t - X_t \hat{b}_t^{ols} \tag{7}$$

then computing and inverting the diagonalized outer product of the residual vector with itself,

$$\hat{W}_t^{ols} = idiag \left(diag \left(\hat{e}_t^{ols} \hat{e}_t'^{ols} \right)^{-1} \right) \tag{8}$$

the weighting matrix is then inserted into the estimation system,

$$\hat{b}_{i=1,t} = \left(X_t' \hat{W}_t^{ols} X_t \right)^{-1} X_t' \hat{W}_t^{ols} Y_t \tag{9}$$

the process is repeated

$$\hat{b}_{i+1,t} = \left(X_t' \hat{W}_{i,t} X_t \right)^{-1} X_t' \hat{W}_{i,t} Y_t, \quad \hat{e}_{i,t} = y_t - X_t \hat{b}_{i,t} \tag{10}$$

until the norm difference between the updated coefficients converges beyond an arbitrary critical value,

$$\varsigma_{i+1} = \left| \hat{b}_{i+1,t} - \hat{b}_{i,t} \right|, \quad \hat{b}_t = \hat{b}_{i,t} \left| \varsigma_i < \varsigma^{crit} \right. \tag{11}$$

once the algorithm has computed estimates of b_t over the whole sample, the overall model residuals are computed,

$$\hat{u}_t = \tilde{y}_t - \hat{b}_t' \tilde{x}_t \tag{12}$$

and the cumulative square error $\lambda = \sum_{t=1}^{T} \hat{u}_t^2$ computed. The optimal bandwidth $\hat{h}$ is computed by finding the minimum cumulative squared error for pre-specified range of h. In this instance h is in effect a nuisance parameter with a limited range of permissible values. We restrict h to be within the range of 0.7 to 0.95, in keeping with the suggestion and results from Arvastson et al. (2000). In addition we have had to clean the daily data and construct a matched set of returns to the benchmark to account for stale prices, already noted as a particular issue with some of the US stock issuances. We utilize the Barndorff-Nielsen et al. (2009) approach to dealing with asynchronous updating of the quoted daily equity data.

4. Results and Analysis

Tables 2 and 3 present, for the UK and US respectively, the descriptive statistics of the daily returns for the water companies in the sample. The mean, median and standard deviations of returns have been annualized. In the case of the standard deviations the 'rule of 16' has been used to convert daily standard deviations into annualized standard deviations.

[TABLES 2 AND 3 HERE]

The Figures 1 to 52 in the internet appendix to the paper (Online Resource) plot the estimated time-varying beta, the alpha and the estimation standard errors of the water company equities over the relevant estimation period. Figures 1 to 10 are also displayed in the text below. Tables 4 and 5 summarize, for the UK and US respectively, the distributions of the time-varying parameters of our models for beta and alpha over the duration of these utilities' listing, ignoring the opening 'training' period of the estimation and any trailing period as data decays following suspension, acquisition or delisting of the stocks.

[TABLES 4 AND 5 HERE]

Mean and median estimated equity betas are substantially less than one across the companies, in both environments: for the UK firms, mean betas lie under 0.6 for all the listed firms; for US listed water utilities, betas are yet closer to zero: across the periods of listing, mean beta of 0.5 is approached only by Aqua America. Estimated levels of alpha are close to zero, the only possible exception being the pre-takeover history of Northumbrian in the UK (mean alpha 0.264, median 0.278). Critically, we find both parameters to be time-varying: and we report the features of their behavior over time in the following figures. We illustrate the results here in the text with exemplars. For the UK, taking the only ever-present WASC listing, that of Severn-Trent Water plc equity, two aspects are clear from the evidence, shown in Figure 1. First, the equity beta of this company lies below a level of 0.9 over almost the whole post-privatization period: indeed, for the majority of the time beta lies significantly below 0.7. Mean beta is 0.520 (standard deviation 0.202).

Second, Severn-Trent equity beta trends downwards throughout the period of the second price cap regime, from 1995-2000. This is consistent with the Gandolfi et al. (1996) argument that approaching review episodes will depress regulated companies' betas (see also Grout and Zalewska, 2006 and NERA, 2009, who argue for the 'decoupling' of regulated companies' beta from the market's risk as review approaches). However, after an initial rise in early 2000 the equity beta at Severn-Trent then continues to decline, to a level below 0.2 after the price review determination of 2000, before climbing in anticipation of the 2005 price review and climbing further and sharply in 2006 and 2007, prior to a halt at the onset of the credit crunch in 2007. While this rise is logical in light of the rapid increase in leverage at the company reported in Table 1, it confirms that the firm has been able to increase leverage because the underlying asset beta is seen and experienced to be low.

[FIGURE 1 HERE]

The standard error plot, in Figure 2, lends further, but only partial, support for the decoupling of systematic risk as regulatory review approaches: standard error climbs sharply in advance of the price cap reviews in 2000 and 2010: on the other hand, the regression gains explanatory power prior to the reviews of 1995 and especially of 2005. We can draw no firm conclusions from these results about regulatory influences.

[FIGURE 2 HERE]

The other UK listed WASCs offer similar evidence of the relatively low equity beta levels and of the interaction of risk and regulation over segments of the post-privatization period. The plots of beta and the regression intercept for Anglian (to end 2006), Welsh Water/Hyder (to 2000), for Yorkshire/Kelda (to the beginning of 2008) and Thames Water (to 2001) display similar behavior, of both coefficients and standard errors of regressions, as noted for Severn-Trent (all figures are made available in the Online Resource).

Turning to US companies, we apply the same methodology of estimating the parameters of regression of their returns as driven by the US market variability. Unlike the UK companies in this research, the history of listing and market data on US water companies' returns is more disparate, with data on several listings available from the early 1970s (American States Water, Aqua America, California Water, Middlesex, Southwest Water), others from later (Connecticut Water, York Water), or even around the turn of the century (Artesian Resources, Pennichuck); while American Water Works' listing delivers data only until 2001 and then again from 2008 onwards. San Jose Water delivers an extensive history of data, but for several other firms the data from the 1980s is patchy and trading can be erratic. Several US data series exhibit these problems of thin trading and stale prices, dealt with here by measuring returns trade to trade, eliminating occurrences of zero returns and then matching to index returns over the same intervals, using the Barndorff-Nielson et al. (2009) asynchronous returns approach, as discussed in the methodology section above.

The resulting estimates of beta and alpha (reported in full in the plots in the Online Resource) show a consistent pattern of very low betas through to the end of the century. For most water utilities, equity betas prior to 2000 are estimated at between zero and 0.2 (American States, Artesian Resources, California Water, Connecticut Water, Consumers Water, Dominguez Services, Middlesex Water, SJW, Southwest Water). The estimates are exemplified here in Fugures 3 and 4 within the text by American States Water: the mean estimated equity beta of 0.359 derives almost wholly from the post-2000 increase in levels of estimated beta.

[FIGURES 3 AND 4 HERE]

The plots for American States also exemplify the common post-2000 experience of betas in US listed water utilities (Figure 3). Estimated equity betas typically rise and for several listings they approach or exceed one by 2006, before falling back. The data suggests that markets rated US water utility stocks as systematically more risky in the first decade of the new century. The measures of leverage in water companies' accounts shows that this is not a reaction to more aggressive use of leverage, however: rather the break point of the late 1990s corresponds to a surge in merger and acquisitions activity in the US water sector, notably from the interest of international utilities groups, such as Vivendi, Suez, or RWE/Thames. The early years of the new century are marked in the US by this search for acquisitions by non-US companies, as well as by the acquisitive strategies of native US listed companies American Water Works and Aqua America.

In contrast, there was little change in the regulatory environment or outcomes for the sector in the US. Economic regulation remains driven by rate of return regulation in periodic rate cases: typical permitted rates of return on equity remain at levels around ten per cent per annum (Beecher and Buckland, 2011) and there is no dramatic change in typical capital structure (see Table 1: US listed water utilities' leverage is lower on average and less dispersed in 2010 than was the case in 1990 or 2000). With no change in business fundamentals, nor in the severity or mechanisms of economic regulation, it would appear that the post-2000 changes in estimated betas in the US arise from an acquisition bubble, marked not only by rising estimated betas, but by marked increases in price:earnings and market-to-book ratios across the sector (ibid).

Additionally, it must be remembered that these US company equities are subject to a variety of regulatory regimes (see Beecher, 2009). In one instance (Connecticut Water), the company avoided regulatory rate cases altogether for a 16 year period from 1992, finally having rates reset in a 2008 rate case (note, here, the sharp fall in estimated beta between 2006 and 2008: from beta estimated at 1.5 to beta marginally above zero after the rate case (see Figures 39 and 40 in the Online Resource). In several cases, US firms operate in multiple regulatory jurisdictions (an issue experienced in the UK context only in hybrid utilities such as United Utilities or Hyder). However, all these US firms are state-regulated (often, therefore, subject to several regulatory commissions' procedures, according to which states are served by their systems); and all are regulated by periodic-reset rate-of-return regulatory regimes.

The contrast with UK companies is stark: in the UK, a single regulator establishes a relatively long-term regulatory environment, directed to permissible price caps that are projected to enable delivery of financial viability and to incentivize operating and service efficiencies whose benefits can be arrogated by shareholders. The five-yearly review threatens to claw back cumulated efficiencies, deliver them to consumers in a revised price-cap and reincentivize companies to further efficiencies and innovative practices. In the US, by contrast, regulatees bid for a permitted rate and will return to reset their rate where they can argue that it restricts their delivery of service and of quality.

Consider, then, the beta history of Aqua America revealed by our analysis and approach, as in Figure 5 below. From 1984 through to 2000 the equity beta lies around 0.2, virtually decoupled from US market risks. After 2001 estimated beta climbs significantly, peaking at some 1.2 in 2007 before falling back to around 0.55. Mean beta across the listing history is estimated at 0.454, median 0.335.

[FIGURE 5 HERE]

[FIGURE 6 HERE]

Every US water equity in this investigation displays similar risk characteristics, particularly prior to 2007, as seen in the individual plots of estimated coefficients and their significance in the paper's Online Resource. For example, Californian Water imposes no systematic risk on its investors throughout the period; and neither do the equities of American States Water, Connecticut Water, Dominguez Resources, Middlesex, or San Jose Water. American States Water briefly ‘spikes’ to a beta of 0.2 in 1998, but this is barely significantly different from zero. Aquarion’s beta varies around 0.2 to 0.4 during its listing period; Artesian Resources’ beta rises above zero only in late 2006, although it then trends upwards to a level around 0.6 late in 2010. Such a late and significant trend towards positive beta in water equities is also evidenced by York Water. The listing histories of American Water and of United Water suggest levels of beta comparable to UK levels of the time: small but significantly positive, varying between 0.2 and 0.6.

We draw attention to two atypical cases. One company, Pennichuck, is notable for the erratic progress of the beta estimator over the period: moving between a low of less than -0.2 in 2002, to highs of over 0.4 in late 2000 and mid 2010 (see Figure 7). Pennichuck is particularly interesting because this variability coincides with a turbulent period of acquisition expectations. Initially in this period Pennichuck anticipated being taken over by Aqua America: but its host city, the City of Nashua in New Hampshire, baulked at this loss of local control and determined to municipalize the company, under the eminent domain procedure for condemning assets under public interest motivation. This triggered a decade-long legal dispute between the company and the City over the value of the assets of and control over Pennichuck. As the plots of beta and alpha estimates for Pennichuck show, the behavior of the estimates becomes erratic, even chaotic, over the period, in contrast to the other US water utilities, which themselves are either persistently acquisitive, or are chronically potential targets for takeover. For Pennichuck, as their defense against the City of Nashua’s takeover becomes less probable, estimated beta rises; as the threat of appropriation by Nashua increases, beta declines.

[FIGURES 7 and 8 HERE]

A further company, Southwest Water, displays a beta estimator that is insignificantly different from zero until 2007, before exploding upwards to over 1.5 (Figure 9). The rise here coincides with revelation of serious misstatements of earnings by the company, which resulted in Securities and Exchange Commission action and a series of substantial accounting restatements, prior to the firm being taken private and delisted in 2010.

[FIGURES 9 and 10 HERE]

We find, therefore, that the outturn levels of systematic risk in the equities of US listed water utilities are low and are consistent with the broad expectations of the paper: investors have experienced systematic risks that are appreciably lower than those used by US regulators in historic rate cases; and we find that they are lower than the betas estimated for UK water utilities over the same period. There is some evidence, however, that systematic risk experienced by US and by UK investors in water stocks has increased since 2000. There are special circumstances to explain such increases in estimated beta for some firms. One explanation may be the more febrile climate of anticipated acquisition activity, which was prominent both in the UK markets of the mid-1990s and particularly in the US listed water sector around/after the turn of the century. In the US there was significant attrition of listed firms in the years after 1998, both by consolidation amongst the US listings and by a surge of interest from overseas multi-utilities groups (RWE, Suez, Vivendi in particular): followed by a wave of interest, in both the UK and the US, from private equity groups.

The expectation of the effects of regulation on utilities’ beta is that regulation will attenuate systematic risks, by periodically capturing excess returns and sharing them in some manner with the consumer. As a corollary, the US system, with relatively frequent resetting of rates of return in firm-specific and periodic rate cases, is expected to deliver lower betas over time than the UK system, where prices are controlled in five-yearly reviews and where investors can in the interim capture returns from innovation or performance better than the expectations built into regulation. The comparative data of UK and US water utilities presented here suggests that this is indeed the case. Particularly in the period up to 2000, beta estimates for US water companies are less variable and closer to zero than is the case for the UK. Post-2000, the evidence is less strong, with some - but not all - US utilities displaying significantly positive systematic risk. In both countries, however, we find estimated betas that lie well below those built in to regulators' decisions about the cost of capital and permitted returns on equity.

5. Conclusions

This paper considers, first, whether water utilities' systematic risk is time-varying and, second, whether the observed variation can be explained in terms of regulatory factors. Our investigation significantly advances the modeling of the trace of beta and the regression intercept through time, employing a robust econometric approach. The RIWLS procedure built in to this analysis obviates the need for adjustments such as the Blume adjustments routinely applied by commercial suppliers of beta estimates. Using daily data over a sample period from 1980 through 2011 for the ten privatized water boards in the UK and for 14 US listed water utilities, we establish that these utilities' betas are not constant but are a function of time.

Implications of findings for water companies, for regulators and government

For the decade following privatization, WASC betas declined. While never exhibiting the levels close to unity utilized by the UK regulator, equity betas were significantly positive, although trending downwards towards zero. Over the same period, US water utility betas were firmly established at or just above zero, with little variation through time. This is consistent with the suggestion in the literature that frequent rate reset will result in lower systematic risk for utilities.

Since 2000, estimates of water companies' listed equity betas have increased in both the UK and the US, in some cases significantly. The remaining listed UK companies show equity betas of 0.5 (Northumbrian), 0.6 (Pennon) and 0.5 (Severn-Trent). The latter two are estimated to have peaked at around 0.8 in 2007 before falling back. This reflects the more aggressive leverage adopted by UK water utilities during the period, but betas remain substantially below those embedded in regulators' price-cap setting.

The parallel changes in US water betas have also been striking and stark: from levels around zero before 2000, the peak year of 2007 has seen betas of 1.5 (American States Water), 1.2 (Aqua America), 0.7 (Artesian Resources), 1.8 (California Water), 1.5 (Connecticut Water), 1.5 (Middlesex Water) and 1.7 (San Jose Water). This empirically robust phenomenon challenges conventional views and the use of risk modelling.

The reported results find support for the impact on systematic risk of regulatory review processes. However, these do not appear to be consistent with the standard explanation of a decoupling of utilities' beta as the regulator's review approaches (NERA, 2009). While betas fall as the price cap reviews of 2000 and 2010 approached, the opposite occurred prior to the 1995 and 2005 reviews. Further, betas continue to fall after 2000. Our analysis does confound the conclusion in earlier research that the betas of regulated water companies' equities were declining towards zero (Buckland and Fraser, 2001): instead, the equity betas of the remaining listed UK water utilities have risen, back to typical levels of 0.5 to 0.6, albeit alongside a very significant increase in leverage between 2005 and 2010. It might be that the low levels of beta around 2000 reflected a more general, but temporary, shift from systematic to idiosyncratic risk, which has since reversed, as noted by Black et al. (2002).

The findings of this paper suggest, also, that the systematic risk of UK water companies, under the regulatory process operated by Ofwat since privatization up to 2010, has stabilized into a pattern supporting presumption that systematic risk in the UK's regulated water industry produces equity betas significantly below 0.7. The estimates suggest, therefore, that the UK regulator's use of a range of 0.9 to 1.00 for the geared equity betas of the WASCs is significantly too high, with betas instead clustered between 0.4 and 0.6 over an extended period of time. We note that the RIWLS framework's robustness to non-normal distributions implies that there is no case for adjusting these beta estimates, a la Blume, or by other mechanisms. Thus the cost of equity capital used in the 2009 review determinations may again be seen to be overly generous to the sector, its shareholders and its management, giving scope for managerial slack, or for further significant excess returns on water companies' equities, over the review period 2010-2015. The observed upwards skew of returns distributions, as noted earlier, would accompany regulatory capture and lax allowable cost of capital, as opposed to tight regulation and clawback of gains for consumers.

A major innovation of this paper is the parallel investigation of the risk of US water utilities, subject to different, rate of return cap regulatory regimes. We have strongly confirmed that the outturn equity betas of US regulated water companies can be considered to be close to zero before 2000. The estimates from this robust modeling demonstrate very clearly that US investors in water utilities faced little or no systematic risk. This suggests, in turn, that the capital structures and cost of capital for the US water sector might be expected to differ substantially from those encountered in the UK.

However, there is also strong evidence that US water companies' betas have risen significantly above zero in the period since 2007. The evidence is shared across companies and deserves more sustained analysis in future years. It may reflect differences across states in the rate-setting processes in recent years, or the impact of sector consolidation and merger and acquisition activity, with uncertainties about acquisition premiums both dominating asset risks and associated closely with broader market volatility. Regulators need to be aware of the potential impact of takeover activity and speculation on equity markets and systematic risk measures.

Future work

While we show stark differences in risk between UK and US companies in the same business activity, for most water companies, the level of systematic risk borne by shareholders is very low. Our best estimates of betas confirm that water sector equities display significantly positive systematic risk, albeit UK regulators systematically and repeatedly overstate the systematic riskiness of the sector being regulated. The cost of capital has been presumed to be higher than is justified by the post-regulation risks borne by investors; and price caps are thus loose, transferring wealth from customer to investor. Further research is needed to disentangle the activity, financial, activity-diversification and taxation effects that underlie differences in beta for these essentially similar businesses. Further research is also needed to determine whether the patterns of cyclical, mean-reverting, regulatory, political and business risks are displayed by other utility sectors, where regulators, regulatory review procedures and cycles and regulatory objectives may be different.

Contrasts with US water firms have been very valuable, reinforcing the differentials observed in earlier research on the pre 2000 period (Grout and Zalewska, 2006). Given the disparate, state-based regulatory practices and the paucity of examples of listing for both US and UK based water utilities, a closer understanding of the regulator's procedures and practices is needed to untangle the reasons why investments in water in the US were essentially systematically riskless pre-2000, but were thereafter systematically relatively risky post-2000. The chaotic patterns of estimated beta for some US stocks - particularly that of Pennichuck - suggest strongly that risk measurement is disturbed by volatile expectations of returns from acquisition premia.

Finally, we would point out that the investigations and findings here, critical in establishing the basis for regulatory intervention, are dependent upon the continued existence of long runs of market data on the risky financial securities issued by regulated firms. Such market-generated data is hugely valuable in rate-setting activity and in benchmarking risk, returns and performance. This underlines the regulators' interest in the maintenance of listing and quotation for utilities' equities, whose returns are derived as closely as possible from the returns generated in the regulated activity. In the UK water industry, we are fortunate in the preservation of quotation of some of the privatized WASCs for two decades after their creation and privatization (albeit that several have since been absorbed into multi-utilities, others have been absorbed into foreign-owned and listed parent companies and others have been taken private by private equity groups, or, in the case of Welsh Water, mutualized). In the USA, virtually all water companies are unlisted, whether they are public enterprises or private companies (Beecher, 2009). When research turns in other papers to examination of the behavior of risk in other utilities, the degradation of market data by merger, acquisition and corporate diversification will become more problematic.

References

1. Ahern, P.M., Hanley, F.J. and Michelfelder, R.A. (2011). A New Approach to Measuring the Cost of Equity Capital for Public Utilities. Journal of Regulatory Economics, doi:10.1007/s11149-011-9160-5.
2. Ahern, P.M. (2013). Testimony before the New Jersey Board of Public Utilities on Behalf of United Water NJ, inc. Exhibit PT-7, Docket WR13. `http://www.unitedwater.com/uploadedFiles/Localized_Content/UW_New_Jersey/RB/UWNJ%20RATE%20CASE%20TESTIMONIES%20AND%20EXHIBITS.pdf`. Accessed 1 April 2014.
3. Ahn, C.M. and Thompson, C.E. (1989). An Analysis of Some Aspects of Regulatory Risk and the Required Rate of Return for Public Utilities. Journal of Regulatory Economics, 1(3), 241-257.
4. Alexander, G.J. and Chervany, N.L. (1980). On the Estimation and Stability of Beta. Journal of Financial and Quantitative Analysis, 15(1), 123-137.
5. Antoniou, A. and Pescotto, G. (1997). The Effect of Regulatory Announcements on the Cost of Equity Capital of British Telecom. Journal of Business Finance and Accounting, 24(1), 1-25.
6. Antoniou, A., Barr, D.G. and Priestley, R. (2000). Abnormal Stock Returns and Public Policy: the case of the UK privatised electricity and water utilities. International Journal of Finance and Economics, 5, 93-106.
7. Arvastson, L., Olsson, H. and Holst, J. (2000). Asymptotic Bias in Parameter Estimation of AR-processes using Recursive Least Squares with Exponential Forgetting. Scandinavian Journal of Statistics, 27(1), 177-192.
8. Baesel, J.B. (1974). On the Assessment of Risk: some further considerations. The Journal of Finance, 29(5), 1491-1494.
9. Barndorff-Nielsen, O.E., Hansen, P.R. Lunde, A. and Shephard, N. (2009). Realized Kernels in Rractice: trades and quotes. Econometrics Journal, 12(3), C1-C32.
10. Beecher, J. (2009). Water Pricing and the Cost of Service in the United States. Institute for Public Utilities, paper prepared for OECD, Michigan State University: Lansing, MI.
11. Beecher, J. and Buckland, R. (2011), Regulation and Risk: perceptions in the water business. Working Paper, University of Aberdeen Business School (mimeo).
12. Bernstein, J.I. and Sappington, D.E.M. (1999). Setting the X Factor in Price-Cap Regulation Plans. Journal of Regulatory Economics, 16(1), 5-26.
13. Bey, R.P. (1983). Market Model Stationarity of Individual Public Utilities. Journal of Financial and Quantitative Analysis, 18(1), 67-85.
14. Binder, J.J. and Norton, S.W. (1999). Regulation, Profit Variability and Beta. Journal of Regulatory Economics, 15(3), 249-266.
15. Black, A.J., Fraser, P. and Power, D. (1992). Unit Trust Performance 1980-1989: a passive time-varying approach. Journal of Banking and Finance, 16, 1015-1033.
16. Black, A.J., Buckland, R. and Fraser, P. (2002). Changing UK Stock Market Sector and Sub-sector Volatilities, 1968-2000. Managerial Finance, 28(8), 26-43.
17. Blume, M.E. (1971). On the Assessment of Risk. Journal of Finance, 26(1), 1-10.
18. Blume, M.E. (1975). Betas and Their Regression Tendencies. Journal of Finance, 30(3), 785-795.
19. Bos, T. and Newbold, P. (1984). An Empirical Investigation of the Possibility of Stochastic Systematic Risk in the Market Model. Journal of Business, 57, 34-41.
20. Breen, W.J. and Lerner, E.M. (1972). On the Use of β in Regulatory Hearings, Bell Journal of Economics, 3(2), 612-621.
21. Brooks, R.D., Faff, R.W. and McKenzie, M.D. (1998). Time-Varying Beta Risk of Australian Industry Portfolios: a comparison of modeling techniques. Australian Journal of Management, 23(1), 1-22.
22. Buckland, R. and Fraser, P. (2000). Political and Regulatory Risk: beta sensitivity in UK electricity distribution. Journal of Regulatory Economics, 19(1), 5-26.
23. Buckland, R. and Fraser, P. (2001). Political and Regulatory Risk in Water Utilities: beta sensitivity in the United Kingdom. Journal of Business Finance and Accounting, 28(7-8), 877-904.
24. Chen, C.R. (1979). Time-Series Analysis of Beta Stationarity and its Determinants: a case of public utilities. Financial Management, 11(3), 64-70.
25. Cooper, I. and Currie, D. (1999). The Cost of Capital for the UK Water Sector. Regulation Initiative Discussion Paper No. 28, London Business School, London, May.
26. Cooper, I. and Grout, P. (1993). The Cost of Capital in the Electricity Industry. London Business School, London: unpublished paper.
27. Dnes, A.W., Kodwani, D.G., Seaton, J.S. and Wood, D. (1998). The Regulation of the United Kingdom Electricity Industry: an event study of price-capping measures. Journal of Regulatory Economics, 13(3), 207-226.
28. Dubin, J.A. and Navarro, P. (1982). Regulatory Climate and the Cost of Capital, in M.A. Crew (Ed.), Regulatory Reform and Public Utilities. Lexington Mass: Lexington Books.

29. Fama, E.F. and French, K.R. (2004). The Capital Asset Pricing Model: theory and evidence. Journal of Economic perspectives, 18(3), 25-46.

30. Fisher, L. and Kamin, J.H. (1985). Forecasting Systematic Risk: estimates of 'Raw' beta that take account of the tendency of beta to change and the heteroskedasticity of residual returns. Journal of Financial and Quantitative Analysis, 20(2), 127-149.

31. Gandolfi, M., Jenkinson, T. and Mayer, C. (1996). Regulation and the Cost of Capital. School of Management Studies, University of Oxford.

32. Gombola, M.J. and Kahl, D.R. (1990). Time Series Processes of Utility Betas: implications for forecasting systematic risk. Financial Management, 19(3), 84-93.

33. Gonedes, N.J. (1973). Evidence on the Information Content of Accounting Numbers: accounting-based and market-based estimates of systematic risk. Journal of Financial and Quantitative Analysis, 8(3), 407-443.

34. Gonzalez-Rivera, G. (1997). The Pricing of Time-Varying Beta. Empirical Economics, 22(3), 345-363.

35. Gort, M and Wall, R. (1988). Foresight and Public Utility Regulation. Journal of Political Economy, Vol. 96, No. 1, pp. 177-188.

36. Groenewold, N. and Fraser, P. (1999). Time-Varying Estimates of CAPM Betas. Mathematics and Computers in Simulation, 48(4-6), 531-539.

37. Grout, P.A. and Zalewska, A. (2006). The Impact of Regulation on Market Risk. Journal of Financial Economics, 80(1), 149-184.

38. Joskow, P.R. and Schmalensee, R. (1986). Incentive Regulation for Electric Utilities. Yale Journal on Regulation, 4, 1-50.

39. Llewellen, W.G. and Mauer, D.C. (1993). Public Utility Valuation and Risk under Incentive Regulation. Journal of Regulatory Economics, 5(3), 263-287.

40. Leland, H.E. (1974). Regulation of Natural Monopoly and the Fair Rate of Return. Bell Journal of Economics, 5(1), 3-15.

41. Lintner, J. (1965). The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets. Review of Economics and Statistics, 47, 13-37.

42. McDonald, J., Michelfelder, R. and Theodossiou, P. (2010). The Robust Estimation with Flexible Parametric Distributions: estimation of utility stock betas. Quantitative Finance, 10.

43. Marshall, W.J., Yarritz, J.B. and Greenberg, E. (1981). Optimal Regulation under Uncertainty. Journal of Finance, 36(4), 909-922.

44. Meyers, S.C. (1973). The Stationarity Problem in the Use of the Market Model of Security Price Behavior. Accounting Review, 48(2), 318-322.

45. Morana, C. and Sawkins, J.W. (2000). Regulatory Uncertainty and Share Price Volatility: the water industry's periodic price review. Journal of Regulatory Economics, 17(1), 87-100.

46. NERA (2009). Cost of Capital for PR09: a final report for Water UK. Resource document. NERA Consulting, London. http://www.water.org.uk/home/policy/publications/archive/revised-cost-of-capital-nera-eport/090206-nera-water-uk-wacc-f pdf. Accessed 1 April 2014.

47. Offer (1999). Review of Public Electricity Suppliers 1998-2000. Distribution Price Control: consultation paper. Offer and Ofgas, Birmingham, UK, May. http://www.ofgem.gov.uk/Networks/ElecDist/PriceCntrls/Documents1/2695-dpcrmay99.pdf. Accessed 1 April 2014.

48. Ofwat (1991). Cost of Capital: a consultation paperr. Ofwat, Birmingham, UK, July. http://www.ofwat.gov.uk/legacy/aptrix/ofwat/publish.nsf/AttachmentsByTitle/costofcapitalv1_310701.pdf. Accessed 1 April 2014.

49. Ofwat (1994). Future Charges for Water and Sewerage Charges: the outcome of the periodic review. Ofwat, Birmingham, UK, July. http://www.ofwat.gov.uk/pricereview/det_pr_fd94.pdf. Accessed 1 April 2014.

50. Ofwat (1997). The Proposed Framework and Approach to the 1999 Periodic Review: a consultation paper. Ofwat, Birmingham, UK, June. http://www.ofwat.gov.uk/legacy/aptrix/ofwat/publish.nsf/Content/1999periodicreviewframework.html. Accessed 1 April 2014.

51. Ofwat (1999). Future Water and Sewerage Charges 2000-2005: final determinations. Ofwat, Birmingham, UK, July. http://www.ofwat.gov.uk/pricereview/pr99/det_pr_fd99.pdf. Accessed 1 April 2014.

52. Ofwat (2004). Future Water and Sewerage Charges 2005-2010: final determinations. Ofwat, Birmingham, UK, December. http://www.ofwat.gov.uk/pricereview/pr04/det_pr_fd04.pdf. Accessed 1 April 2014.

53. Ofwat (2009), Future Water and Sewerage Charges 2010-2015: final determinations. Ofwat, Birmingham, UK, November. http://www.ofwat.gov.uk/procereview/pr09phase3/det_pr09/final_fullpdf. Accessed 1 April 2014.

54. Ofwat (2014), Setting Price Controls for 2015-20 - risk and reward guidance. Ofwat, Birmingham, UK, January. http//www.ofwat.gov.uk/pricereview/pr14/gud_tec20140127riskreward.pdf. Accessed 1 April 2014.

55. Peltzman, S. (1976). Toward a More General Theory of Regulation. Journal of Law and Economics, 19, 211-246.

56. Riddick, L.A. (1992). The Effects of Regulation on Stochastic Systematic Risk. Journal of Regulatory Economics, 4(2), 139-157.

57. Sharpe, W.F. (1964). Capital Asset Prices: a theory of market equilibrium under conditions of risk. Journal of Finance, 19, 425-442.

58. Teisberg, E.O. (1993). Capital Investment Strategies Under Uncertain Regulation. Rand Journal of Economics, 24(4), 591-604.

59. Thomadakis, S.B. (1976). A Model of Market Power. Bell Journal of Economics, 7, 150-175.

60. Thompson, H.E. (1979). Estimating the Cost of Capital for Electricity Utilities. Bell Journal of Economics, 10(2), 619-637.

61. Wells, C. (1994). Variable Betas on the Stockholm Exchange. Applied Economics, 4, 74-92.

62. WSA (1991). The Cost of Capital in the Water Industry: a response to the Ofwat consultation paper, Volumes 1 to 3. Water Services Association and Water Companies Association, London, UK).

Figures and Tables

This is the complete annex of figures for the paper. The figures referenced specifically in the text above are to be included in the paper. The remaining figures are provided as a resource in an internet appendix.

Table 1: List of US and UK water companies in our sample with available historical data. Code represents the Thomson-Reuters company code. Sample start date represents the start of available data (including dividend adjustment information). End date is the final observation in our sample: for ongoing listed firms we censor at May 6, 2011, firms with end dates prior to this have been delisted. Correlation beta is the published historical beta as of March 3, 2012, computed using a long run correlation by Thomson Reuters. Regression beta presents the CAPM beta from an OLS regression of historical returns with the relevant market (FTSE All share for UK firms and the NYSE index for US firms). Bloomberg Beta presents the available betas from the Bloomberg data service, as of March 3, 2012; and finally the sub column under Debt to Equity reports the debt to equity ratio for each firm, calculated from their financial reports for every five years from 1985 to 2010. The following datapoints are estimated from approximate data: * debt to equity ratio relates to 2004 annual reports, during a period of delisting; ** debt to equity ratio relates to 1999 reports; *** San Jose data from online published annual accounts in the absence of Thomson-Reuters data; † debt to equity ratio from 2009; ‡ debt to equity ratio from 2009.

Company	Code	Sample Start Date	Sample End Date	Corr. Beta	Reg. Beta	Bloom. Beta	Debt to Equity Ratio					
							1985	1990	1995	2000	2005	2010
England and Wales												
Anglian	507523	December 11, 1989	December 21, 2006	0.098	0.425			3.06	8.35	74.91	275.56	
Hyder	904438	December 11, 1989	August 16, 2000	0.026	0.204			6.46	37.76	256.25		
Kelda	904486	December 11, 1989	December 20, 2007	0.311	0.815			7.13	34.12	85.32	109.21	
North. 1989-1996	506475	December 11, 1989	December 21, 1995					4.03	35.56			
North. 2003-2011	27057U	May 22, 2003	May 6, 2011	0.221	0.344	0.65					352.56	792.99
Pennon	904391	December 11, 1989	May 6, 2011	0.499	0.606	0.67		0.6	78.25	74.97	151.54	361.51
Severn Trent	904373	December 11, 1989	May 6, 2011	0.371	0.469	0.62		3.22	34.42	78.26	135.61	443.98
Southern	506484	December 11, 1989	October 10, 1996					3.9	33.6			
Thames	904393	December 11, 1989	February 15, 2001					8.99	40.78	86.98		
United	904367	December 11, 1989	May 6, 2011	0.464	0.58	0.61		7.42	37.53	116.01	160.47	525.45
Wessex	878048	December 11, 1989	November 17, 1998					1.07	16.81			
United States												
Am. States Water	906946	January 2, 1980	May 6, 2011	0.422	0.406		146.25	105.91	108.23	115.27	112.1	95.65
Am. Water Works	51922M	January 2, 1980	May 6, 2011	0.43	0.445		173.26	199.48	192.64	171.41	219.75*	138.28
Aqua America	923492	January 2, 1980	May 6, 2011	0.263	0.271		158.86	219.71	125.46	134.12	128.29	140.52
Aquarion	951519	January 2, 1980	July 1, 2000	0.14	0.489				100.00	104.08		
Artesian Resources	677833	April 3, 1998	May 6, 2011	0.565	0.409				226.02	170.35	165.85	143.38
Cal. Water Services	906833	January 2, 1980	May 6, 2011	0.362	0.29			91.83	99.04	102.89	93.65	116.02
Connecticut Water	981634	June 3, 1985	May 6, 2011	0.584	0.623		116.81	144.48	110.27	101.71	89.81	121.93
Consumers Water	@CONW	January 2, 1980	October 3, 1999				152.33	208.07	164.81			
Dominguez Resources	543773	January 1, 1991	May 24, 2000		0.250				54.25	73.5**		
Middlesex Water	981674	January 2, 1980	May 6, 2011	0.677	0.587		126.72	127.97	111.66	125.11	134.65	89.61
Pennichuck	517419	August 18, 1993	May 6, 2011	0.319	0.295				171.7	95.25	90.84	108.14
San Jose Water	916310	January 2, 1980	May 6, 2011								85.17***	115.96
Southwest Water	937831	January 2, 1980	May 6, 2011	0.289	0.579		52.48	57.77	99.82	107.11	87.78	134.24†
United Water	U:UWR	January 2, 1980	July 27, 2000	0.29	0.711		170.17	197.25	171.85	169.4‡		
York Water	938260	August 20, 1996	May 6, 2011	0.638	0.544					109.18	117.36	93.33

Table 2: Descriptive statistics of total returns (RI_t) for UK water companies. The first two columns present the annualized means and standard deviations computed from the daily returns, assuming 255 trading days in a year. The third column reports the median return (note that for all companies the median return is less than 0.1% therefore the returns are reported to be approximately zero). The fourth and fifth columns present the level of skewness and kurtosis relative to a normal distribution. The sixth and seventh columns present, respectively, the lowest and highest daily returns observed over the sample period.

	Mean $\Delta\log(RI_t)$	Stdev $\Delta\log(RI_t)$	Median $\Delta\log(RI_t)$	Skew $\Delta\log(RI_t)$	Kurt $\Delta\log(RI_t)$	Min $\Delta\log(RI_t)$	Max $\Delta\log(RI_t)$
Anglian	0.139	0.224	0.000	1.657	31.424	-0.143	0.216
Hyder	0.072	0.142	0.000	-0.515	15.007	-0.103	0.090
Kelda	0.047	0.203	0.000	5.781	204.746	-0.190	0.391
Northumbria 1989-1996	0.148	0.241	0.000	1.065	23.491	-0.172	0.197
Northumbria 2003-2011	0.088	0.120	0.000	9.158	244.818	-0.068	0.213
Pennon	0.198	0.244	0.000	0.533	7.928	-0.086	0.111
Severn Trent	0.151	0.253	0.000	-2.425	86.301	-0.394	0.179
Southern	0.139	0.240	0.000	0.489	12.157	-0.103	0.182
Thames	0.086	0.143	0.000	11.753	368.845	-0.040	0.323
United	0.104	0.178	0.000	2.876	65.616	-0.119	0.231
Wessex	0.119	0.236	0.000	0.754	15.507	-0.094	0.211

Table 3: Descriptive statistics of total returns (RI_t) for US water companies.

	Mean $\Delta\log(RI_t)$	Stdev $\Delta\log(RI_t)$	Median $\Delta\log(RI_t)$	Skew $\Delta\log(RI_t)$	Kurt $\Delta\log(RI_t)$	Min $\Delta\log(RI_t)$	Max $\Delta\log(RI_t)$
American States Water	0.112	0.252	0.000	-0.015	7.437	-0.102	0.102
American Water Works	0.157	0.249	0.000	0.454	14.710	-0.215	0.174
Aqua America	0.165	0.265	0.000	0.115	7.094	-0.111	0.123
Aquarion	0.128	0.216	0.000	0.251	8.454	-0.096	0.106
Artesian Resources	0.099	0.305	0.000	0.295	9.229	-0.122	0.133
California Water Services	0.119	0.276	0.000	0.127	7.099	-0.122	0.131
Connecticut Water	0.115	0.290	0.000	0.049	7.042	-0.140	0.134
Consumers Water	0.062	0.284	0.000	0.181	6.717	-0.112	0.116
Dominguez Services	0.171	0.358	0.000	0.344	5.896	-0.092	0.146
Middlesex Water	0.122	0.296	0.000	0.311	12.854	-0.210	0.283
Pennichuck	0.124	0.478	0.000	0.812	94.007	-0.569	0.643
San Jose Water	0.121	0.249	0.000	-0.331	19.554	-0.257	0.127
Southwest Water	0.119	0.524	0.000	-0.132	14.045	-0.448	0.384
United Water Resources	0.142	0.221	0.000	0.373	11.811	-0.130	0.123
York Water	0.109	0.316	0.000	0.132	8.038	-0.147	0.141

Table 4: Descriptive statistics of the computed β and α coefficients for UK water companies.

	Mean β_t	Mean α_t	Stdev β_t	Stdev α_t	Median β_t	Median α_t	Skew β_t	Skew α_t	Kurt β_t	Kurt α_t	Min β_t	Min α_t	Max β_t	Max α_t
Anglian	0.356	0.075	0.224	0.214	0.369	0.085	0.110	-0.365	1.891	2.650	-0.039	-0.722	0.806	0.514
Hyder	0.366	0.066	0.199	0.331	0.396	0.098	-0.095	-1.588	1.786	6.301	0.001	-1.194	0.760	0.552
Kelda	0.378	0.049	0.204	0.332	0.319	0.107	0.221	-1.468	1.806	5.373	-0.025	-1.333	0.812	0.546
North. 1989-1996	0.411	0.264	0.161	0.127	0.474	0.278	-0.696	-0.039	2.363	3.213	0.014	-0.148	0.667	0.620
North. 2003-2011	0.482	0.016	0.299	0.367	0.486	-0.017	-0.138	0.273	2.153	3.653	-0.126	-1.249	1.089	1.230
Pennon	0.346	0.130	0.204	0.222	0.336	0.164	0.238	-0.585	1.853	2.898	-0.012	-0.616	0.835	0.603
Severn Trent	0.520	0.083	0.202	0.217	0.488	0.101	-0.080	-0.691	2.711	3.625	-0.023	-0.689	1.001	0.588
Southern	0.474	0.101	0.164	0.241	0.516	0.065	-0.833	-0.210	2.778	1.905	0.001	-0.543	0.773	0.509
Thames	0.486	0.085	0.168	0.213	0.473	0.065	-0.430	-0.184	2.773	2.279	0.000	-0.623	0.776	0.545
United	0.579	0.098	0.169	0.197	0.586	0.116	0.045	-0.582	2.554	3.243	0.182	-0.656	0.988	0.468
Wessex	0.459	0.109	0.198	0.201	0.534	0.085	-0.908	0.063	2.517	1.974	0.000	-0.294	0.739	0.614

Table 5: Descriptive statistics of the computed β and α coefficients for US water companies.

	Mean β_t	Mean α_t	Stdev β_t	Stdev α_t	Median β_t	Median α_t	Skew β_t	Skew α_t	Kurt β_t	Kurt α_t	Min β_t	Min α_t	Max β_t	Max α_t
American States Water	0.359	0.047	0.421	0.118	0.193	0.000	1.386	0.333	4.221	2.548	-0.142	-0.281	1.754	0.379
American Water Works	0.338	0.035	0.143	0.135	0.318	0.041	0.263	-0.311	2.671	3.583	0.026	-0.383	0.711	0.434
Aqua America	0.454	0.073	0.308	0.154	0.335	0.089	0.945	-0.880	2.820	4.613	0.004	-0.558	1.269	0.463
Aquarion	0.227	0.009	0.115	0.149	0.229	0.008	-0.277	-0.170	2.683	3.294	-0.073	-0.447	0.481	0.443
Artesian Resources	0.158	0.035	0.224	0.169	0.122	0.024	1.163	0.074	4.425	2.867	-0.266	-0.468	0.852	0.494
California Water Services	0.360	0.032	0.475	0.118	0.167	0.002	1.645	-0.008	5.009	3.055	-0.193	-0.328	1.923	0.389
Connecticut Water	0.281	0.065	0.340	0.142	0.164	0.048	1.481	-0.293	4.757	3.365	-0.318	-0.405	1.497	0.422
Consumers Water	0.135	-0.038	0.191	0.164	0.060	0.000	0.841	-0.212	3.012	3.956	-0.387	-0.650	0.781	0.467
Dominguez Services	0.068	0.077	0.280	0.259	0.055	0.062	0.182	0.438	3.378	3.066	-0.713	-0.490	0.953	1.082
Middlesex Water	0.257	0.043	0.379	0.128	0.127	0.000	1.700	0.366	5.306	3.219	-0.327	-0.313	1.624	0.490
Pennichuck	0.083	0.001	0.158	0.165	0.034	0.000	0.595	-0.099	3.561	3.839	-0.339	-0.735	0.586	0.466
San Jose Water	0.326	0.028	0.499	0.114	0.094	0.014	1.694	-0.682	4.521	4.640	-0.082	-0.449	1.841	0.362
Southwest Water	0.361	0.018	0.529	0.205	0.205	0.000	1.009	-0.260	3.562	3.290	-0.688	-0.640	1.845	0.560
United Water Resources	0.266	0.038	0.142	0.170	0.253	0.031	-0.024	0.135	2.160	3.009	-0.048	-0.468	0.608	0.515
York Water	0.147	0.050	0.227	0.198	0.088	0.006	1.664	0.347	5.504	2.336	-0.236	-0.389	0.982	0.625

Figure 1: Time evolution of α and β for Severn Trent Water

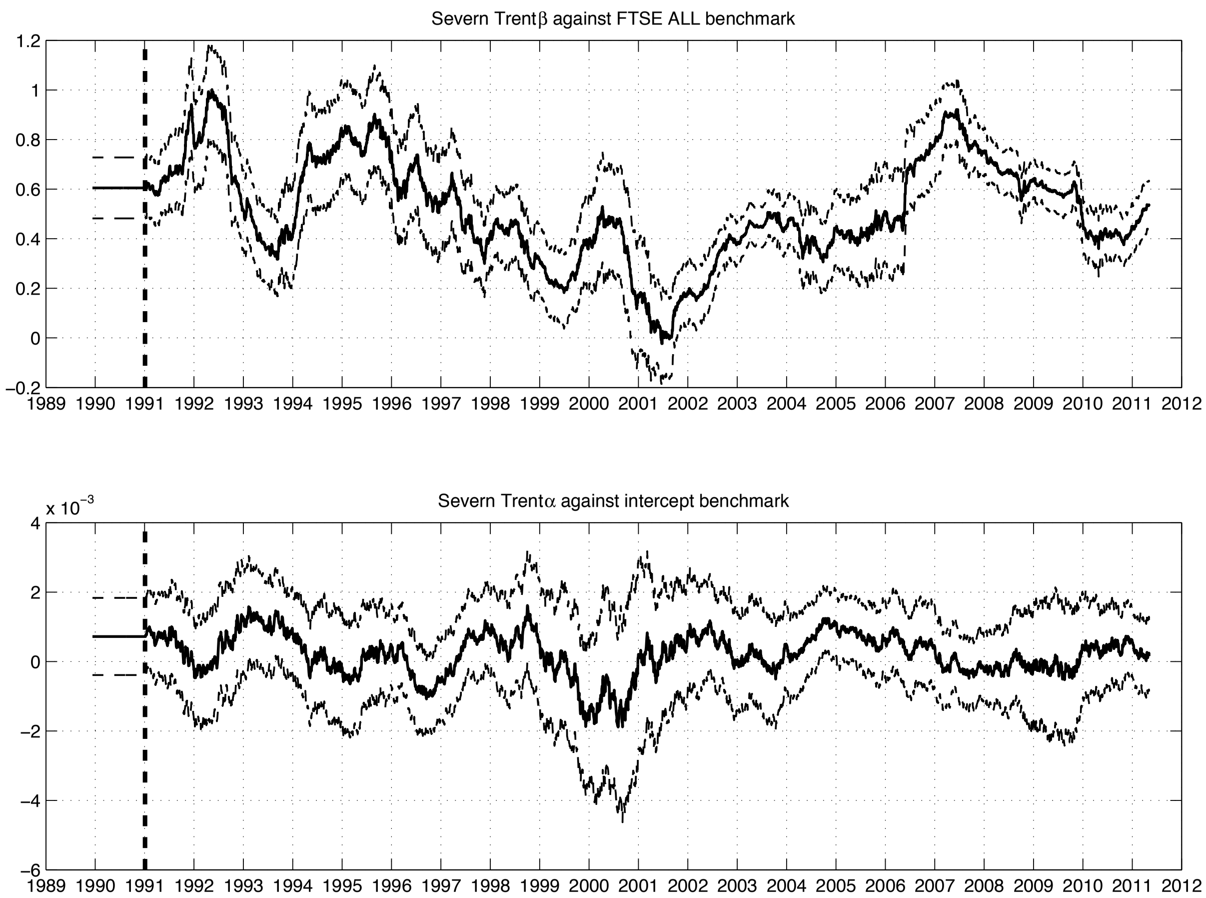


Figure 2: Time evolution of the recursive R^2 for Severn Trent Water

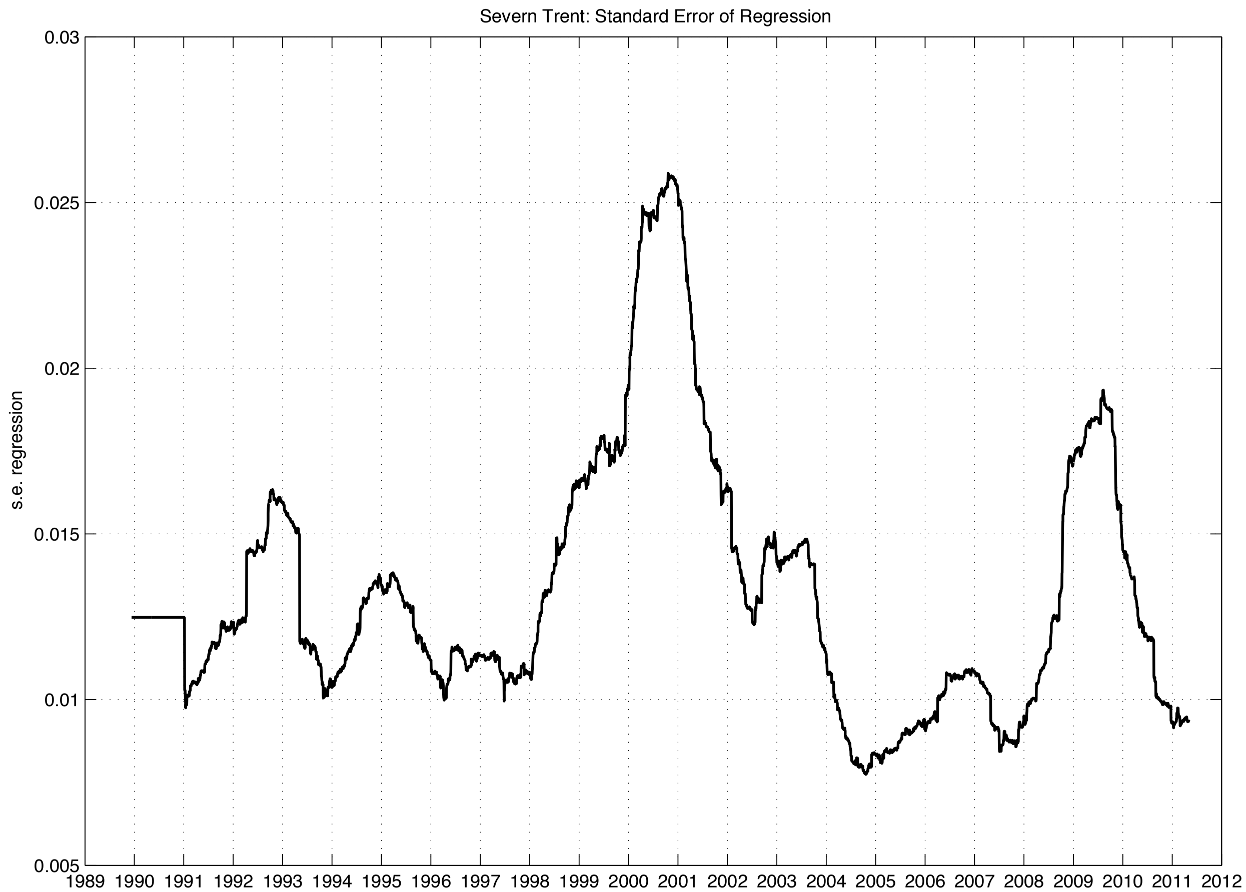


Figure 3: Time evolution of α and β for American States Water

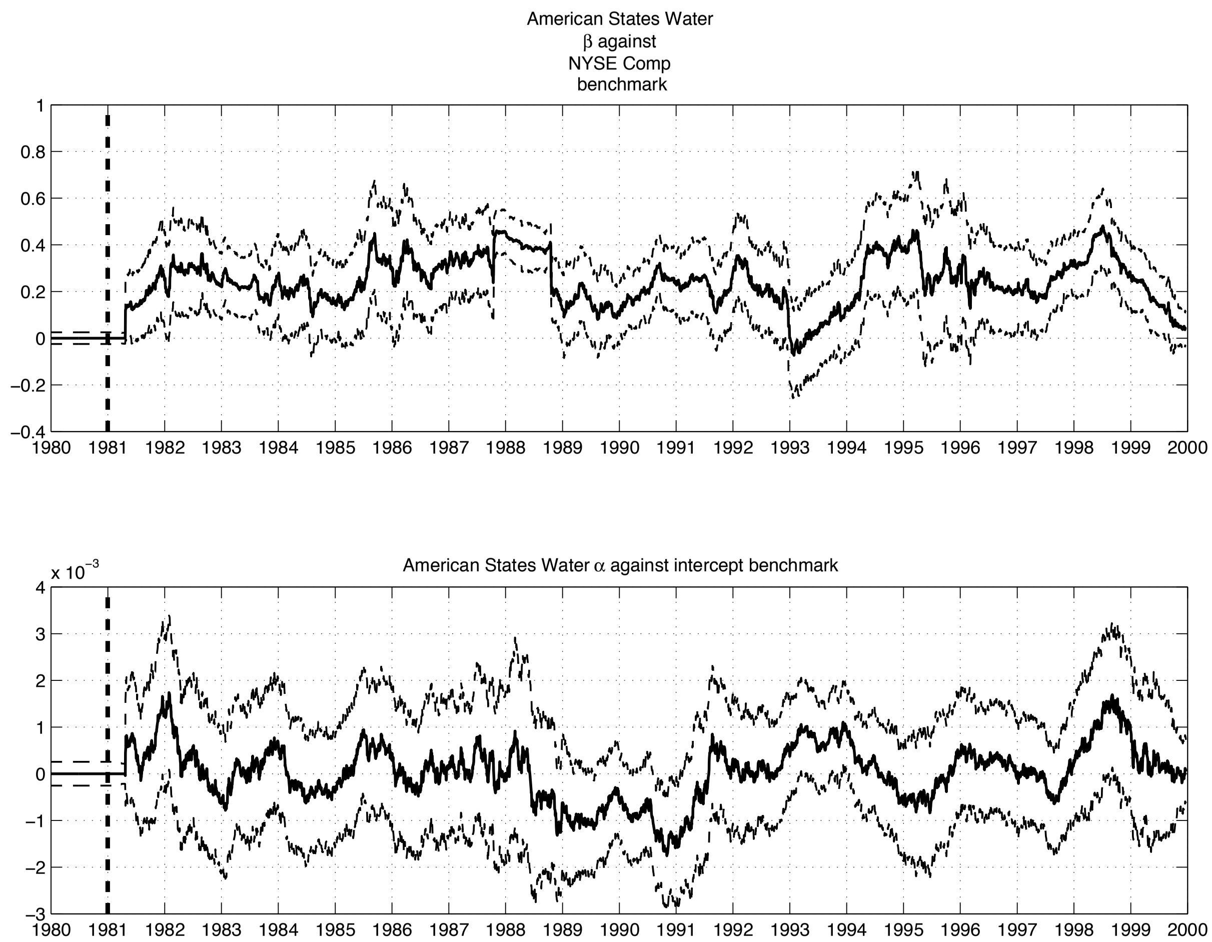


Figure 4: Time evolution of the recursive R^2 for American States Water

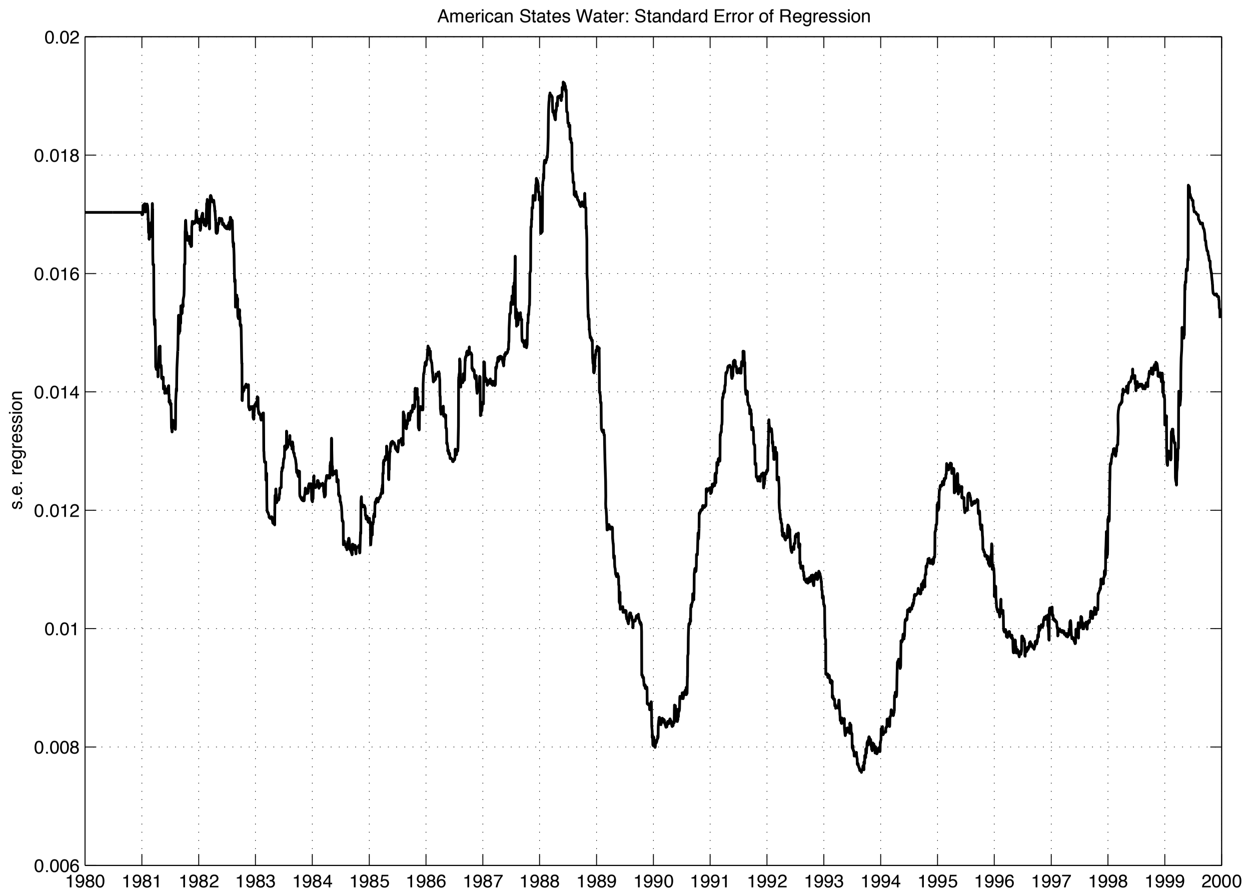


Figure 5: Time evolution of α and β for Aqua America

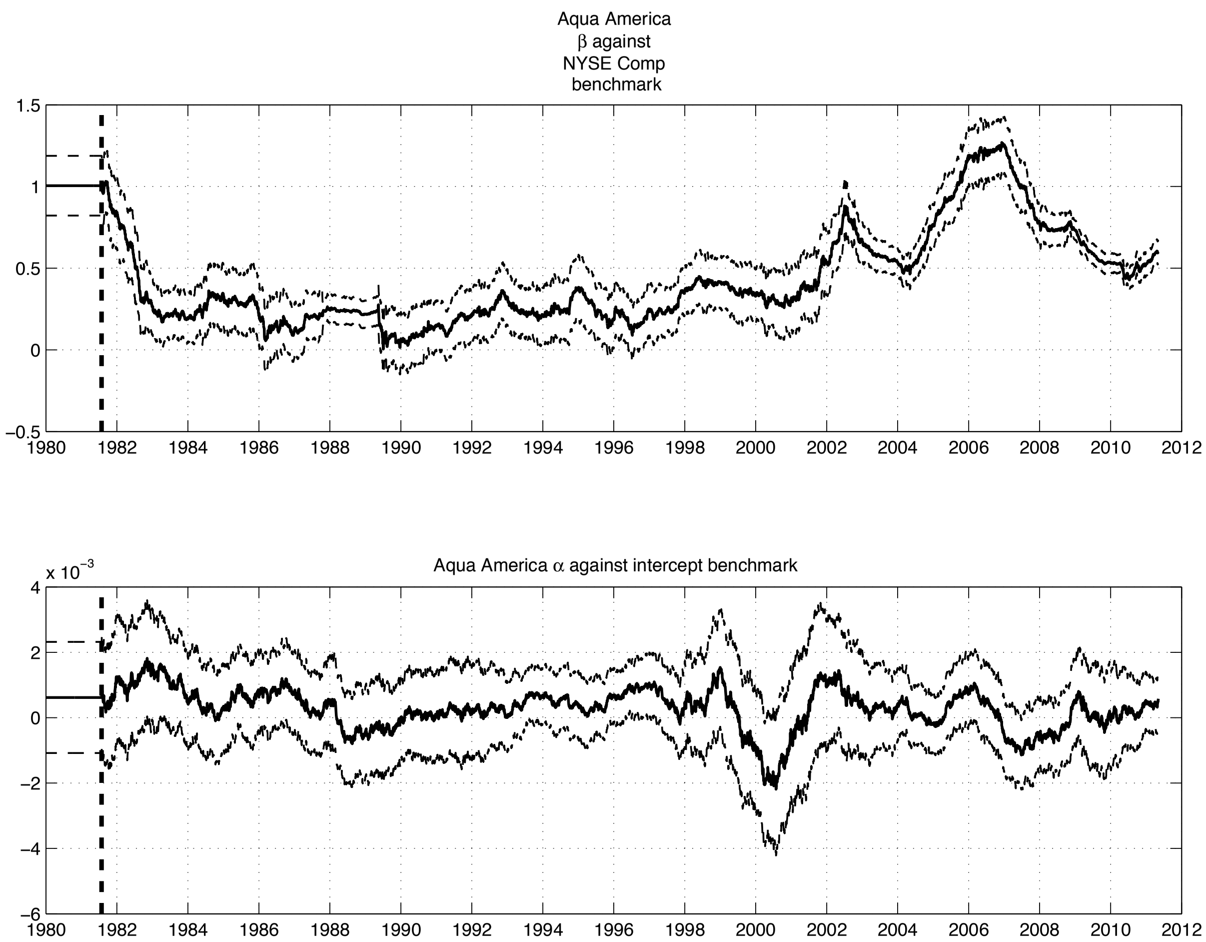


Figure 6: Time evolution of the recursive R^2 for Aqua America

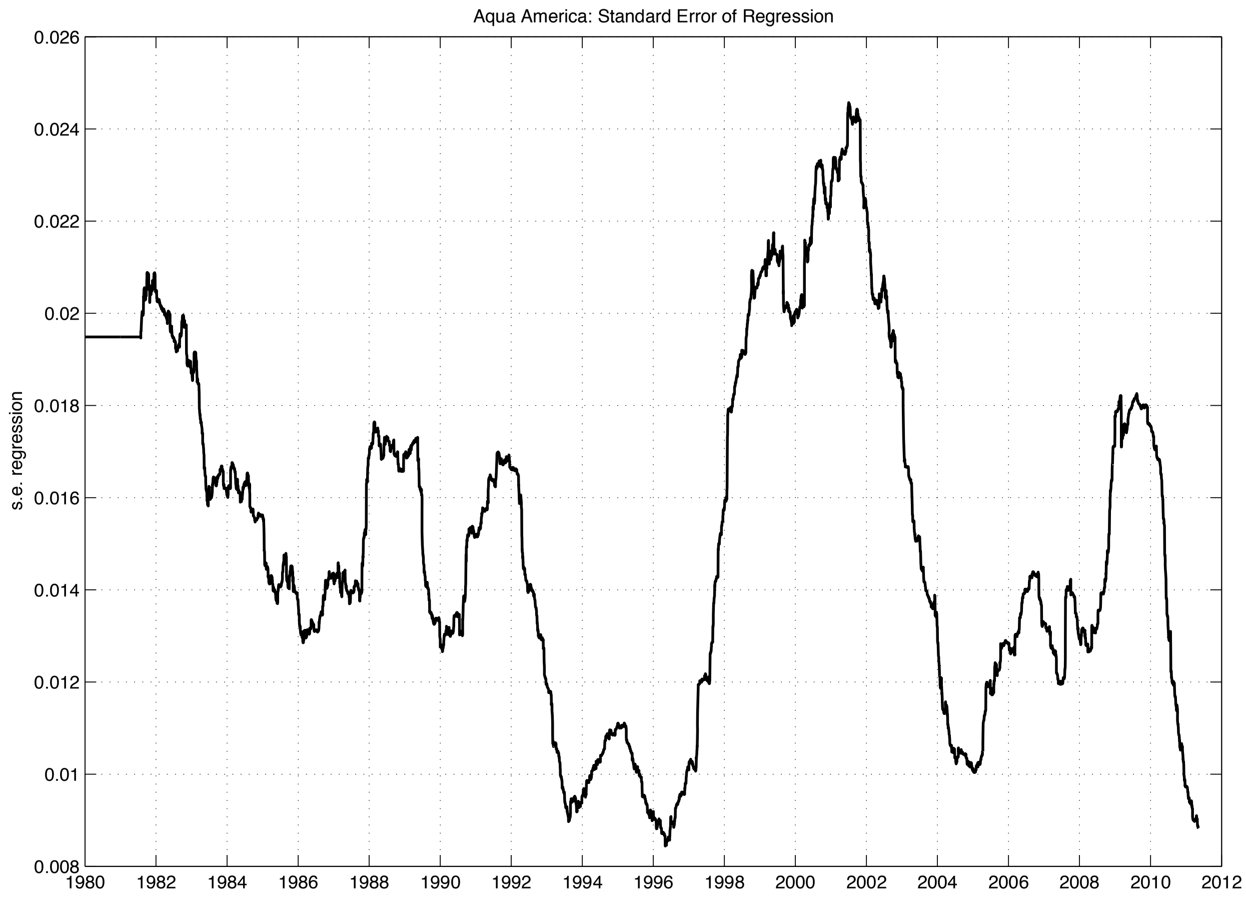
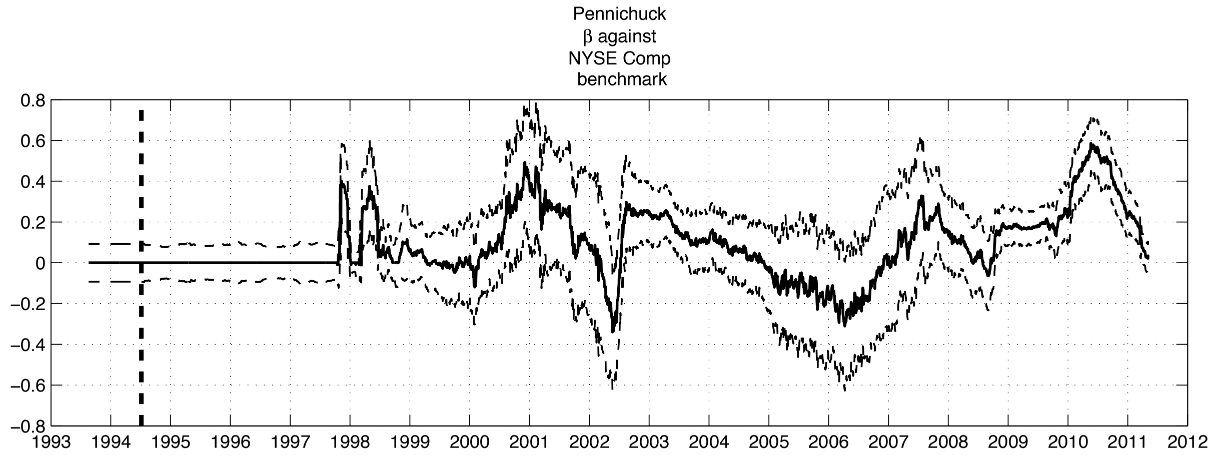


Figure 7: Time evolution of α and β for Pennichuck



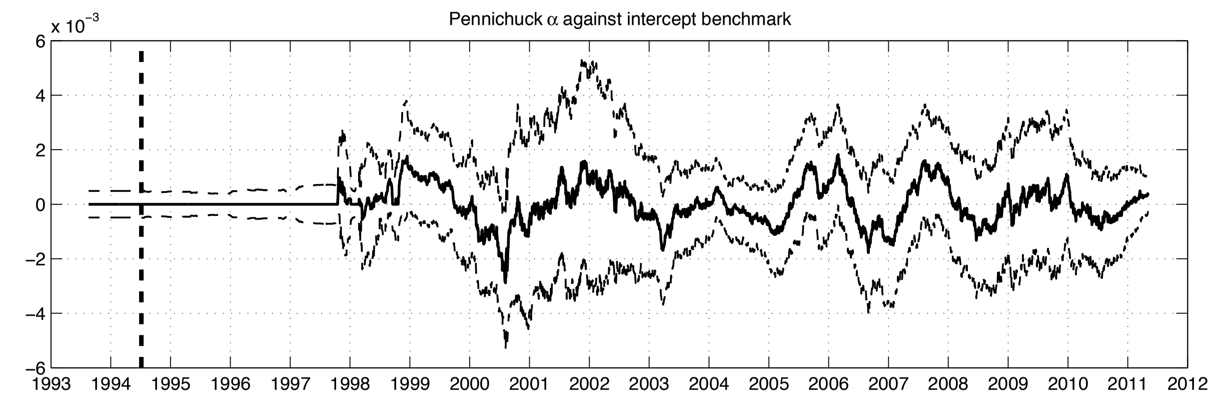


Figure 8: Time evolution of the recursive R^2 for Pennichuck

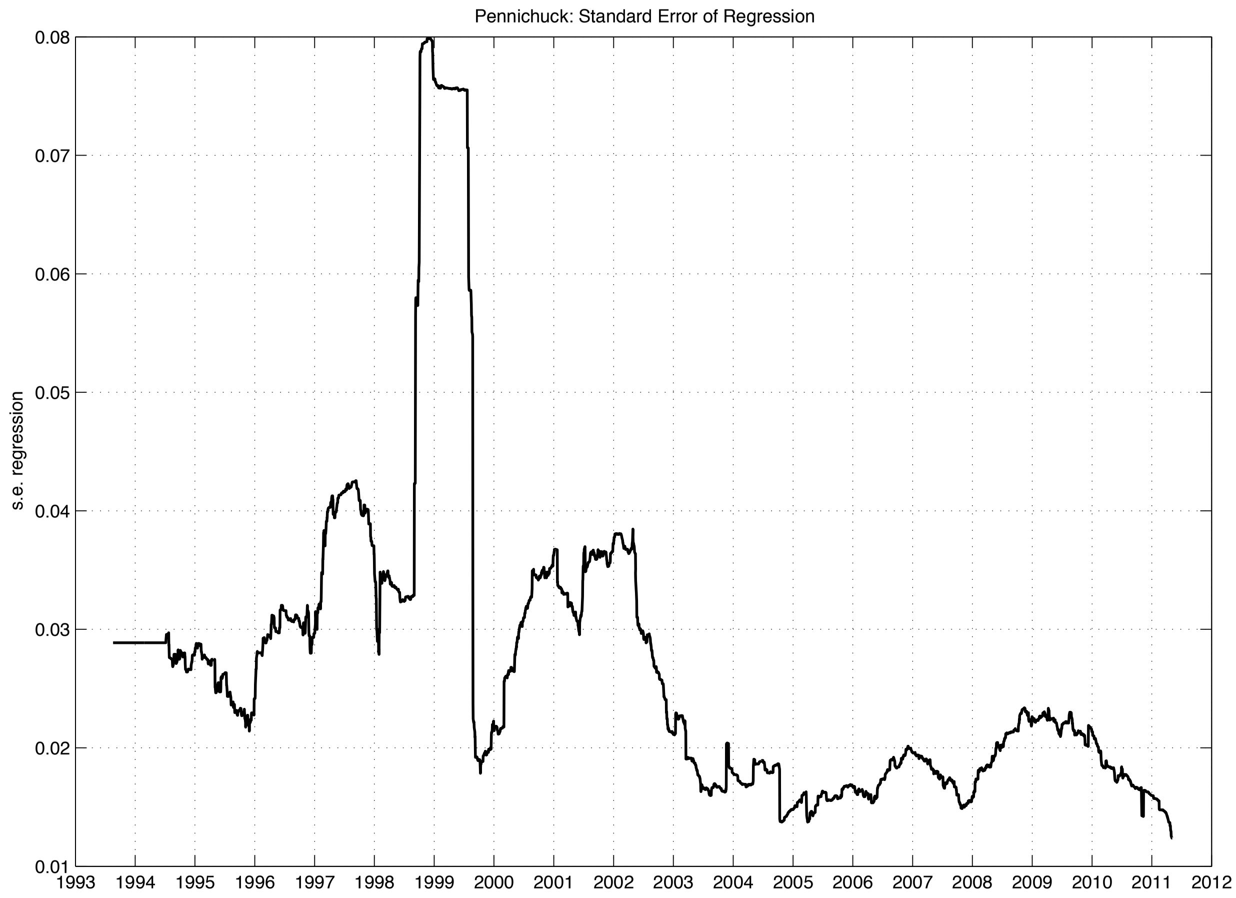


Figure 9: Time evolution of α and β for Southwest Water

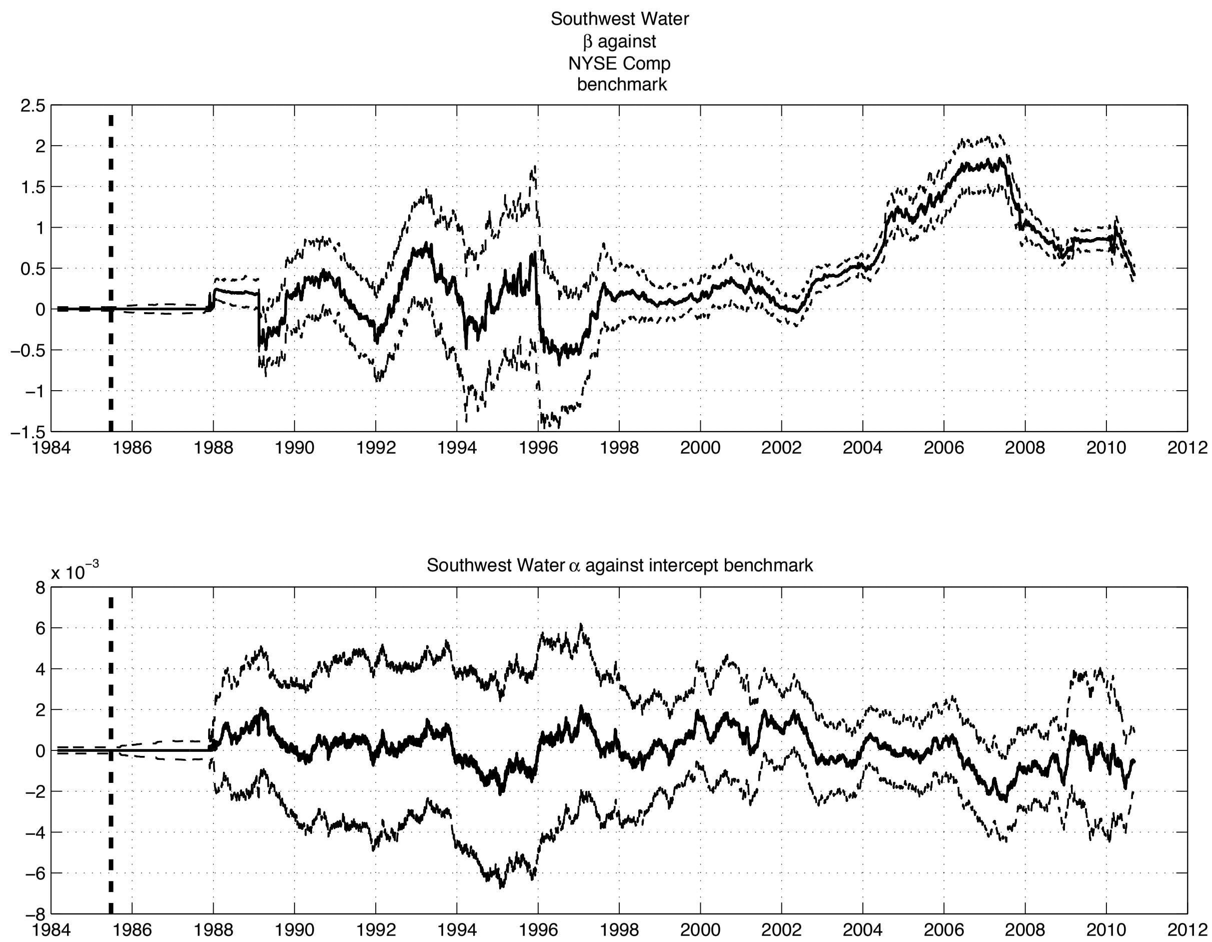


Figure 10: Time evolution of the recursive R^2 for Southwest Water