Setting the regulatory WACC using Simulation and Loss Functions – The case for standardising procedures

by

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ABSTRACT

The level set for the weighted average cost of capital (*WACC*) for a regulated firm is a critical input in many regulatory determinations. A point estimate is typically used, although it is recognised that there is significant uncertainty concerning this estimate. Regulators often note that the welfare losses that might arise from errors in estimation may not be symmetric, and have often chosen, in particular applications, to use 'conservative' values for key variables when building up an estimate of *WACC* for the regulated firm. However, this approach continues to be decidedly *ad hoc*. This paper examines a simulation based approach to the choice of regulatory WACC. A standardised assessment of uncertainty and welfare loss using such a methodology would aid greater consistency in such determinations across the regulatory sector.

1. Introduction

A standard element of any regulatory review concerns the level to be set for the regulated firm's weighted average cost of capital (WACC). The value set for this variable has important implications for the level set for constraints on the firm (price caps for example). Whilst there has been extensive debate over the years concerning the merits of alternative ways of estimation of the WACC, and more specifically, components of the WACC, it remains the case that regulators typically adopt a point estimate, a value that then holds for the period through to the next regulatory review. Regulators recognise that there is significant uncertainty concerning the point estimate for the WACC[1] and that any error in setting the regulatory WACC rate may lead to welfare loss. For example, too low a WACC estimate will tend to result in price caps that are set 'too tight' and too high an estimate will result in price caps that are 'too loose'. If the welfare losses that arise from under-estimating the WACC outweigh those from over-estimation, one way of taking this into account is for the regulatory WACC determination to be set at a level above its expected value. It is common for regulators to accept there is such an asymmetry and to do precisely this (see for example, Ofcom [2005], BAA [2007], Competition Commission [2007]). However, the approach thus far remains decidedly *ad hoc*. That is, regulators tend to bias to some extent the values used for one or more of the key parameters in order to induce some uplift in the final WACC determination; the extent of the uplift and the rationale for it is often rather unclear.

The above described *ad hoc* adjustment processes are less than satisfactory. The aim of the present paper is to promote the use of a simple methodology for making such adjustments. The methodology proposed, Monte Carlo simulation, is well understood, is simple to implement, and facilitates a standardised approach to the assessment of uncertainty in the regulatory WACC. There is some precedent for this proposed use of *WACC* simulation as a methodology for the determination of the regulatory *WACC*. Robert Bowman has consistently advocated this approach in the context of Australia and New Zealand regulatory determinations (see e.g. Bowman [2004, 2005]), and it has been accepted by some regulators (e.g. NZCC [2004],

[1]See e.g. Fama and French [1997] for an assessment of the extent of the uncertainty in industry costs of equity.

ACCC [2005]). In the UK, regulators have at best looked at scenarios (upper and lower bounds for estimates), although very recently, the UK Competition Commission [2007] has made some use of simulation in its report on the BAA determination's for WACC for Heathrow and Gatwick airports.

The simulation approach has thus far been used merely to generate a distribution for the WACC.[2] Having done this, commentators have then argued that welfare loss asymmetries dictate that the regulatory WACC should be set at a percentile significantly above the median. For example, the New Zealand Commerce Commission (NZCC [2004]) adopted the 75th percentile in the context of a gas control enquiry, whilst an 80th percentile was used in a similar context by the Australian Independent Pricing and Regulatory Tribunal (IPART [2005]). Bowman [2004], in the context of that NZ gas control enquiry, argued for the use of the 90th or 95th percentile, largely on the grounds that these percentiles are commonly used for the assessment of confidence intervals in statistical inference; SFG [2005] suggested 'at least the 75th-80th percentile in the context of electricity network access, and Bowman [2005] argued for 1 standard deviation (84rd percentile from a normal distribution), in a Telecom context. The principal weakness in this literature concerns the 'extent of adjustment'. Clearly, an asymmetry in welfare losses associated with over- versus under-estimation motivates the choice of a percentile value above the 50th, but it says little about how far above the median constitutes an 'appropriate' adjustment. To put this another way, no special 'significance' can be attached to a particular percentile such as the 90th or 95th, without the specification of a welfare loss function.

The above discussion motivates focus on the use of a welfare loss function. Although there is a considerable literature bearing on information asymmetries in regulatory economics, to the author's knowledge, the only contribution that attempts an explicit assessment of the welfare loss function in the context of errors in WACC estimation is Wright et al [2003], although that analysis did not embed the loss function in a Monte

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[2] The only exception, to my knowledge, is the Competition Commission [2007] report, which came out after the first draft of the present paper had been written. It briefly examines how the choice of WACC can be related to welfare loss functions. The aim of the present paper is to develop and examine the pros and cons of this approach in more detail.

Carlo simulation (and the model used to 'determine' the extent of welfare loss is rather limited in other ways[3]). There is clearly more work that might be beneficially made concerning the determinants of the welfare loss function, given that, if a loss function can be determined, this then defines the extent of uplift that is appropriate. Given uncertainty concerning the structure of the loss function, the present paper adopts a 'parametric' approach. That is, a simple but reasonably flexible 2-parameter asymmetric power function is used to characterise welfare loss. This is then used to explore how the choice of WACC depends on the extent of welfare loss asymmetry. Inter alia, this also illustrates one of the strengths of the simulation approach; namely that it facilitates scenario and sensitivity analysis.

The analysis in any given case establishes a relatively simple link between the extent of asymmetry in welfare loss and the extent to which the regulatory WACC should be biased above the expected value of the WACC distribution. This can be used in two ways. Firstly, a judgement concerning the extent of loss asymmetry can be used to motivate the extent to which there should be an uplift in WACC. Secondly, for a given observed regulatory determination, it is also possible to use the simulation approach to identify the extent of loss asymmetry that would validate it.

The importance of improving consistency in shadow pricing has been emphasised by Sugden and Williams [1978, page 214]; they make the point that inconsistency necessarily entails economic inefficiency. When 'shadow pricing' the WACC, this is not to suggest that it should be the same across different firms and sectors – but that any variations across firms should be consistently related to the key underlying factors involved – and estimates for common components should be consistently set across sectors. Indeed, when the correct value for a shadow price is uncertain, and where it is set differently across different sectors, it can be shown that it is always welfare improving to reduce the dispersion in such prices (Dobbs [1985]).[4] Thus, from a policy perspective, there is a great deal of merit in not only systematising the approach to WACC estimation across regulatory sectors, but also in systematising and

[3] Discussed in more detail in section 3 below

[4] There is thus a prima facie case for coordination by regulators across industries, and in a European context, across countries.

improving consistency concerning the way in which regulators take account of the extent of uncertainty in the estimate, *and* the extent of welfare loss asymmetry, when setting the final determination for the regulatory WACC.

If a standard approach to uncertainty in WACC estimation is adopted, this should improve consistency. Clearly, if there is to be any hope for a standardised procedure to gain currency with practitioners (regulators and regulatees), the procedure needs to be reasonably straightforward to understand and implement. The extent of programming required to develop a simulation approach is really quite limited. Further, once established, the effort required to implement the process in subsequent applications is minimal; indeed, the approach lends itself to the use of a standardised program.[5] The use of a standardised simulation framework would also help to focus debate between interested parties on the assessment of key parameters and their distributions, and the extent of loss asymmetry in any given application

Section 2 outlines the basic simulation approach, section 3 discusses a simple but flexible form of loss function that may prove useful in this type of analysis. Section 4 examines, as a simple case study, the Ofcom [2005] regulatory determination of WACC for British Telecom and section 5 then draws conclusions and makes some suggestions for further work.

2. Overview of the Monte Carlo Simulation Approach

In essence, the Monte Carlo methodology involves assigning distributions/ranges for each key variable (risk free rate, *MRP*, beta etc.); following this, a drawing is taken from each distribution, and the *WACC* implied by these drawings computed; this process is repeated a large number of times, so as to build a frequency distribution for the *WACC*. Summary statistics for this *WACC* distribution can then be calculated (mean, median, and percentiles, for example). The approach allows a study of the distribution of the before tax/after tax *WACC*s - but also for other variables if desired (return on equity, return on debt etc.). The general approach is very flexible, and it is

[5] The program for the present simulation model can be made available at the author's website.

possible to select alternative distributional assumptions, to impose restrictions on the range of such variables, and to introduce correlations between variables where there is evidence for this. Finally, if a welfare loss function can be defined, it is possible to determine the best choice for the regulatory WACC given the distribution for 'true' WACC (that is, it is possible to determine the best choice of percentile to use).

The general approach can be applied whatever, the procedures used to estimate WACC and its components. Accordingly, given the focus on the use of simulation and loss functions in making a choice of regulatory WACC, discussion of arguments for and against different approaches to the estimation of the WACC and its components is omitted.[6] However, to illustrate the approach, for concreteness, it will be assumed that a 'build up' approach to the WACC is being adopted, based on the CAPM (the approach almost universally adopted now in the UK and in the EU generally). In this case the key components are

- the risk free rate
- the market (or equity) risk premium
- the firm's equity beta
- the debt premium
- the corporate tax rate
- the firm's level of gearing

The regulator, after consultation, takes a view concerning the central estimates for each of these variables. In the UK, regulators typically also consider ranges for some variables – notably the market risk premium and the equity beta, although the other variables are usually taken as simple point estimates.[7]

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[6] For example, concerning whether to use an effective or statutory tax rate; whether to include issue costs in the WACC or in the cash flows; whether to impose a fixed gearing level etc., whether to focus on a real or nominal WACC, a before tax or after tax WACC etc.; how to estimate the firm's equity beta. See e.g. Jenkinson [2006] for discussion of the issues involved.

[7] Taking the upper (resp. lower) values in the ranges for parameters generates an upper (resp. lower) value for the WACC. The interpretation of the ranges used is somewhat problematic, since they are not typically directly related to confidence intervals, and of course, taking a set of upper/lower values for such variables does not then identify an appropriate confidence interval for the WACC. Further as argued in what follows, variables such as the risk free rate and the debt premium are also properly interpreted as random variables. The Simulation approach resolves this problem by taking into account the interaction between different random variables.

To implement a simulation approach, it is further necessary to specify the joint distribution for these parameters. In the section 4 case study for example, the statuary tax rate is used and the gearing ratio is taken as a fixed number (a 'notional' gearing level). The other parameters are then taken to be distributed as independent normal variates. Thus a measure for standard deviation is required in each case, along with possibly a restriction on the range such variables might take (so as to be 'economically sensible' or for other reasons). It is straightforward to introduce correlations between such parameters, and indeed to make alternative distributional assumptions. Correlations might arise concerning the risk free rate, the debt premium, and the equity risk premium for example.

Over time, if the simulation approach became widely adopted, this would inevitably lead to improvement in best practice concerning estimation of the additional key elements - the choice of distributions and the estimation of standard deviations etc. – in a similar way to the way the central estimates for WACC components has now becoming increasingly systematised. Current regulatory determinations generally include extensive discussion of (the evidence for) central estimates of key parameters and may also consider a range for the market risk premium and the equity beta, but for other components there is typically little or no examination of the uncertainty underlying such estimates. Accordingly, a brief discussion of this is given below.

The distribution for the risk free rate

The *WACC* rate is a rate that applies to any project initiated in the period of the regulatory review. In fact, a firm expecting to initiate a project might be expected to raise debt finance of similar maturity to the expected life of the project. Further, the firm may be initiating investments on every day throughout the regulatory review period. For example, suppose the relevant bond maturity is 10 years. Then, for a project initiated today, today's point estimate of the risk free rate, based on gilts with this maturity, is the appropriate rate to use (since this rate can be locked in immediately). However what about decisions being take in 1 or 2 year's time? Is the rate that holds today necessarily the appropriate rate to use, given that this rate is likely to fluctuate over the regulatory review period. In the absence of defining triggers that allow the WACC to be adjusted following fluctuation in the risk free rate,[8] the rate to be used should be an estimate of the likely average rate[9] that will hold over the period and the standard deviation for this. Thus the value taken by the 'risk free rate' over the regulatory review period is properly viewed as a random variable, since the actual rate may fluctuate above or below the estimated average rate. This contrasts with UK current regulatory practice, which is to take the risk free rate as a simple point estimate in determining the WACC.

Debt Premium

Estimating the debt premium is usually regarded as reasonably straightforward; regulated companies will often have their own quoted debt, and it is usually possible to firm this up by looking at debt in comparator companies. As with the risk free rate, regulators typically use a single point estimate for the debt premium, despite the fact that the debt premium is likely to fluctuate over the regulatory review period. Thus debt premia should be viewed as random variables, where the observed historical volatility can be used as a guide to the appropriate standard deviation to use.

The market (equity) risk premium

Although there is scope for disagreement regarding the forecast for volatility over the regulatory window, the mean equity return for the UK is typically viewed as having a standard deviation of at least 2%. However, it can be argued that this may not be an appropriate estimate to represent the uncertainty that the regulator has concerning the ex ante expected return on the market. For example, some have argued that the volatility of the *expected return* should be less (e.g. Hathaway [2006] and Schaeffer [2007]). An alternative to looking at volatility manifest in historical data is to consider survey data; that is the level of uncertainty manifest in ex ante estimates of the risk premium reported by practitioners and financial economists. Surveys by Ivo Welch [2000, 2008] for example reveal as much uncertainty in this distribution as that arising from the assessment of historical returns. Although all survey work can be critiqued (hypothetical answers, issues associated with how the questions are framed

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[8] Just as airlines implement price adjustments based on a 'fuel price adjustment clause', it is possible to conceive of 'triggers' that adjust the WACC figure automatically contingent on events such as changes in the underlying level for the risk free rate of interest. See First Economics [2007] for a discussion of the pros and cons of such schemes. To date, such an approach has not found regulatory favour.

[9] Possibly a weighted average (to reflect the discounting effect on value).

etc.), it is interesting that the survey results are in line with the historically observed volatility. In the case study in section 4, a figure of 2% is adopted for the standard deviation.

Equity Beta

A standard error for Beta will normally be obtained as part of the beta-estimation process. It is also possible to examine its behaviour over time. The empirical evidence suggests that for many companies, the equity beta is significantly time varying. The standard error on beta is however, typically rather more stable, although it is worth studying its time series behaviour to verify this.

Further Observations

The above brief discussion of key parameters has ignored possible correlations. However, there maybe some evidence of correlation; for example, higher volatility in the market as a whole may tend to associate with increases in the MRP and also with debt premia and equity beta. This might prove a useful avenue for further research. The main point to make is that any improvements in estimation for the joint distribution for key parameters can always be subsequently and formally accommodated into the simulation of the WACC distribution.

3. The Welfare Costs of Mis-estimating the WACC

It appears that there is fairly limited explicit modelling of the likely structure of welfare loss arising out of WACC mis-estimation per se. Perhaps this is because a range of factors are likely to affect welfare loss, and the devil lies in the detail. Wright et al [2003] examine a simple 'one period' model in which the regulator makes an estimate of the WACC, imposes a price cap based on this, and the firm then uses the 'true WACC' (viewed as a random variable, as here) in deciding on whether and how much to invest in capacity. There is a tendency in this type of model for the firm to choose not to invest at all if the realised WACC is greater than that set by the regulator. Thus there tends to be a large welfare loss from setting a regulatory WACC that is too low, whilst the welfare losses arising from setting a regulatory WACC too high tends to be much smaller. Strictly, the above account really applies only to new ('now or never') investment in the regulatory review period. It does not apply to largely sunk investment already incorporated in the RAB. Thus the extent of asymmetry depends on the likely extent of new investment relative to that in the RAB. The asymmetry in welfare loss is also affected by the presence of irreversibility and real option effects. The most important of these is deferral option; the real option effect in this case tends to reduce the initial level of investment and to reduce the rate at which new investment is added (Pindyck [1988], Alleman and Rappaport [2002], Dobbs [2004]). One might think that real option effects mean higher welfare losses simply because there will be reduced investment compared to that which is socially optimal. However, this is not straightforward; in the case where there is a single period in which investment occurs or does not occur, the fact that investment is not rejected forever, but only 'unduly delayed', means the welfare loss may be less than in the one period case. Other factors may also be of importance; in emergent/innovative markets, investment may have positive intertemporal spillover effects – in that investment now may promote greater innovation in future service provision, new product development, and in future technical innovation reducing future production costs. Hausman [1979] has argued that, where these effects are important, the extent of welfare loss asymmetry can be substantial. It then follows that markets like telecoms are likely to feature greater welfare loss asymmetries than in more mature/static industries such as water supply. A final consideration on loss asymmetry concerns regulatory behaviour; the welfare loss asymmetry may be lessened in so far as observed non-investment due to regulatory error may be corrected or ameliorated through regulatory appeal, or through adjustments in subsequent reviews.

To sum up, the likely structure of welfare loss as a function of regulatory WACC is only 'qualitatively understood'. It seems largely accepted by regulators that there is an asymmetry in welfare loss arising from over- versus under-estimation of the WACC - but the extent of the asymmetry, and how it depends on a range of factors is at present only rather 'vaguely understood'. Rather than attempting to explicitly model the structure of welfare loss, in this paper, a simple parametric loss function is used. The loss function then links optimal choice for regulatory WACC to the extent of asymmetry in welfare loss.

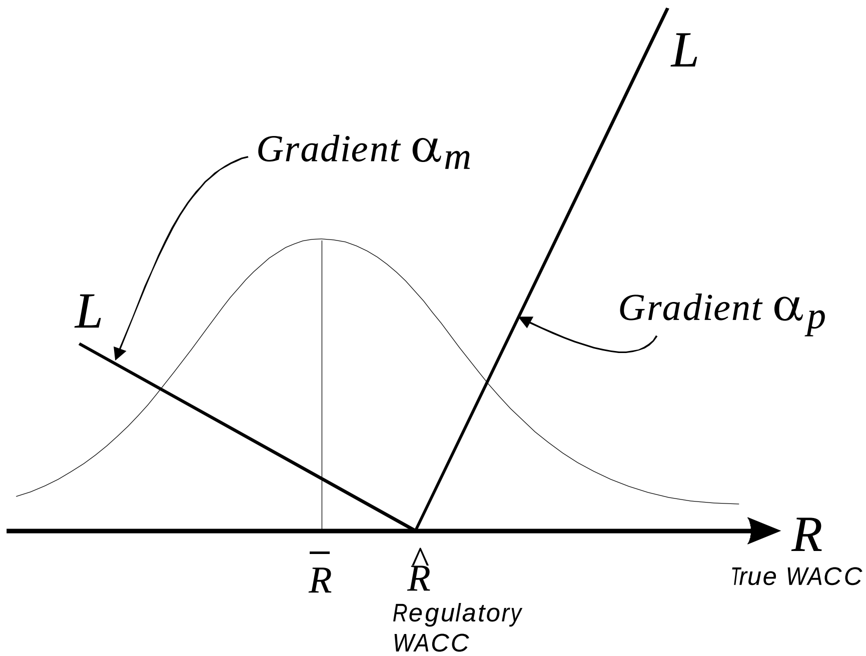
If the *WACC* is set 'just right', welfare loss is minimised. As the deviation between the set rate and the realised true value increases, so the welfare loss increases. In what follows, welfare loss is modelled by an 'asymmetric' power function defined by just 2 parameters. Let *L* denote the welfare loss arising from errors in estimation. Let *R* denote the true but unknown *WACC* rate; this is a random variable with density function $\phi(R)$ (the simulation model is used to estimate this density function for *R*). Suppose the regulator sets a *WACC* rate denoted $\hat{R}$. Welfare loss can then be viewed as a function $L(R,\hat{R})$ with $L(\hat{R},\hat{R})$ normalised to zero, $L(R,\hat{R})>0$ if $\hat{R}\neq R$ and with $L(R,\hat{R})$ strictly decreasing in *R* for $R<\hat{R}$ and increasing in *R* for $\hat{R}\neq R$. The power function representation takes the form

$$L(R)=\alpha_p(R-\hat{R})^{\lambda} \quad if \quad R\geq\hat{R}$$
$$L(R)=\alpha_m(\hat{R}-R)^{\lambda} \quad if \quad R<\hat{R} \qquad (1)$$

It can be argued that setting $\lambda=1$, giving a linear specification, will often be reasonable (since a linear function can always be used to approximate a non-linear function for small deviations). Given that the welfare loss that can arise from 'over-pricing' and the welfare loss that would arise if there were no investment at all are bounded, one might argue that if anything, the welfare loss function might be better approximated by setting $\lambda<1$ rather than $\lambda>1$. In the case study examined in section 4 below, sensitivity to alternative assumptions concerning the value of λ are explored.

If $\alpha_p=\alpha_m>0$, welfare losses from over- and under-estimation are symmetric. However, as explained in section 1, regulators generally accept there is asymmetry such that $\alpha_p>>\alpha_m>0$. Figure 1 illustrates the structure of the loss function, along with the density function which is centred on the expected value, $\overline{R}$ for the case where $\lambda=1$. With $\lambda>1$ the functions to left and right are convex, whilst for $0<\lambda<1$, they are concave. Notice that it is possible to normalise by setting $\alpha_m=1$. This means that once λ has been set, the single parameter α_p fully characterises the loss function. As α_p is increased above unity, it measures the number of times by which welfare loss from under-estimation is judged to exceed that from over-estimation.

Figure 1 The Loss Function with $\lambda = 1$



Suppose the random variable R has support $[R_L, R_U]$ (this is estimated in the simulation); then the expected loss is defined as

$$EL = \int_{R_L}^{R_U} L(R)\phi(R)dR$$
$$= \int_{R_L}^{\hat{R}} \alpha_m \left(\hat{R} - R\right)^{\lambda} \phi(R)dR + \int_{\hat{R}}^{R_U} \alpha_p \left(R - \hat{R}\right)^{\lambda} \phi(R)dR \qquad (2)$$

As the value selected for $\hat{R}$ is varied, expected welfare loss, *EL*, will reach a minimum value at some point to the right of $\bar{R}$. Denote this optimal solution for regulatory WACC as $\hat{R}*$.

Computationally, for given values for α_p, λ and a choice of $\hat{R}$, it is possible to run the simulation model; for each realisation for *R*, the loss *L* can be calculated from (1), and this repeated for all the drawings made in the simulation. The mean value (estimate for *EL*) for the loss *L* can then be calculated (an equivalent statistic would be the sum total value loss). Note that the loss figure calculated in this way is an index for welfare loss, not a monetary value. That is, if one choice for *WACC* results in a loss index value twice that for another choice of *WACC*, the welfare loss would be twice as great for the former as for the latter, although the absolute magnitude of the welfare loss is not defined. In the current implementation, the optimal solution $\hat{R}*$ is found by simply setting $\hat{R}$ to each of the 100 percentile values for the WACC distribution, repeating the computation of *EL* in each case, and then selecting the percentile, $perc(\hat{R}*)$, and associated regulatory WACC , $\hat{R}*$, that yields the smallest *EL* value. The simulation can then be run with different values for α_p and λ in order to explore the impact of asymmetry and non-linearity on optimal choice, $\hat{R}*$. The case study in section 4 illustrates how, as the asymmetry in welfare losses increases (as α_p increases), so the optimal choice for regulatory WACC climbs up through the percentiles.

4. An Illustrative Case Study – Ofcom's assessment of BT's WACC in 2005

This section illustrates the application of the Monte Carlo methodology to the assessment or BT's regulatory WACC in 2005. The original assessment and assessments for key parameters can be found in Ofcom [2005]; Ofcom's final determination for the regulatory WACC was disaggregated by line of business, with 10.0% for Access and 11.4% for 'Rest of BT' using a 40/60 weightings; this is thus equivalent to a 10.8% WACC determination for the business as a whole. Estimates at July 2005 for key parameters are given in Table 1. Rather than debate in detail the source and values for these parameters, this section focuses on illustrating how such estimates, along with the welfare loss function described in section 3, can be used in a Monte Carlo simulation in order to explore and inform the determination of regulatory WACC.

Table 1: Distributional assumptions for Variables/Parameters values at 7/2005

Parameter/Variable	**Distribution**	**Mean**	**S.Dev**	**Min**	**Max**
L=D/V		0.3	n/a	n/a	n/a
R_f *(nominal)*	Normal	4.6%	0.3%	2.6%	6.6%
MRP	Normal	4.0%	2%	1%	7%
Equity Beta	Normal	0.9	0.1	0	2
Tax Rate		0.3	n/a	n/a	n/a
Debt Premium	Normal	1.0	0.2	0	2%

The basic simulation involved taking *n*=1 million drawings from each of the above distributions, discarding those outwith the above specified ranges.[10] For each realisation, the WACC value is computed. This allows a frequency distribution to be developed and percentile values for the WACC determined. When a given value is set for the Regulatory WACC, each realisation for the 'true WACC' entails a welfare loss, from (1). It is thus possible to compute the expected loss (average loss over all the realised values for WACC) in (2). This computation can be repeated for different values set for the Regulatory WACC, and also for different values set for the key parameters of the loss function (α_p, λ). It is thus possible to explore how expected welfare loss varies with the choice of WACC, and to study the extent to which this is sensitive to alternative structures for the welfare loss function.[11]

[10] The number of runs, *n*, is chosen to ensure adequate precision in the estimation for the percentiles of the WACC. The percentiles in the tails are the least robust; the simulation approach can also be used to estimate the distribution of such statistics.

[11] As previously remarked, the program that does this is available from the author's website.

Table 2: BT's 2005 Pre-Tax WACC (%) by Percentile

Mean	9.88%
Percentile	
30	9.00%
40	9.43%
50	9.84%
55	10.04%
60	10.25%
65	10.46%
70	10.69%
75	10.93%
80	11.19%
85	11.49%
90	11.84%
95	12.34%
99	13.17%

Table 3: Expected Welfare Loss *EL* as a function of Percentile and α_p (with λ =1)

		α_p						
		1	2	3	4	5	10	20
Percentiles of the WACC Distribution	30	1.369	2.491	3.613	4.735	5.856	11.466	22.684
	40	1.241	2.086	2.931	3.776	4.621	8.845	17.294
	50	1.200	1.821	2.441	3.062	3.682	6.785	12.990
	55	1.210	1.734	2.257	2.781	3.305	5.923	11.159
	60	1.241	1.677	2.113	2.548	2.984	5.162	9.518
	65	1.295	1.650	2.005	2.361	2.716	4.492	8.044
	70	1.374	1.656	1.938	2.220	2.502	3.913	6.734
	75	1.481	1.698	1.915	2.131	2.348	3.431	5.597
	80	1.626	1.784	1.941	2.099	2.257	3.045	4.623
	85	1.819	1.925	2.031	2.137	2.243	2.774	3.834
	90	2.088	2.149	2.211	2.273	2.335	2.643	3.261
	95	2.510	2.535	2.561	2.587	2.612	2.740	2.995
	99	3.301	3.305	3.309	3.313	3.316	3.335	3.372

Table 2 gives a selection of percentile values for the WACC distribution generated by simulation. Table 3 then illustrates the fact that, for a given value for α_p and λ, there is a best choice for the percentile for the regulatory WACC, $perc(\hat{R}*)$ (equivalently, best choice for $\hat{R}*$) that minimises the expected welfare loss *EL* in (2). It indicates that a higher percentile figure should be chosen, the greater the extent of welfare loss asymmetry. For example, double weighting (α_p =2) in this case study implies that the optimal percentile is 65th, triple weighting, that it is 75th, quadruple weighting, the 80th percentile and so on. This suggests that if the regulator can take a view of the likely extent of welfare loss asymmetry, this can be used to support the choice of a particular percentile choice for regulatory WACC. Another way of utilising the simulation approach is to observe the actual regulatory determination and reflect on what level of loss-asymmetry would validate it. For the 2005 BT case, the regulator determined a WACC of 10.6%, and as Table 2 indicates, this corresponds to a choice of around the 73rd percentile if one assumes a linear loss function (λ =1). Referring to Table 3, that would in turn be validated if α_p lies between a 2 and 3 fold loss asymmetry.

As previously remarked, given uncertainty concerning the structure of the loss function, it is of interest to explore the sensitivity of results to variations in structure. Table 4 accordingly also reports how optimal regulatory WACC, $\hat{R}*$ is affected by reducing λ to 0.5.

Table 4: Optimal Regulatory WACC $\hat{R}*$ as a function of α_p and λ

	λ =0.5		λ =1	
α_p	$\hat{R}*$	$perc(\hat{R}*)$	$\hat{R}*$	$perc(\hat{R}*)$
1	9.80	49	9.84	50
2	10.98	76	10.55	67
3	11.55	86	10.93	75
4	11.92	91	11.19	80
5	12.11	93	11.36	83
10	12.64	97	11.93	91
20	13.17	99	12.34	95

As in table 3, the higher the value of α_p, the higher the best choice of regulatory WACC (the higher the best choice of percentile to use), and also as one would expect, the opposite is true for λ; that is, the lower the value of λ, the greater is the impact of loss-asymmetry. If it is accepted that, as argued in section 3, values of λ less than unity are likely to better approximate the true welfare loss function, then this suggests that the linear specification (λ =1) can be viewed as 'conservative' by the regulator (that is, less than generous to regulatees). When the extent of asymmetry is not too strong (α_p <2), the possible non-linearity in the welfare loss structure is of no great consequence. However, as might be expected, there is some sensitivity to the value chosen for λ when the asymmetry is stronger (α_p taking larger positive values).

Naturally, the simulation approach cannot generate 'something out of nothing'; conclusions concerning an appropriate regulatory WACC ultimately depend on judgements concerning (i) the extent of uncertainty in the WACC itself and (ii) the extent to which welfare losses arising from under-estimation of the WACC are likely to outweigh those from over-estimation. The simulation approach gives an assessment of the former, and in combination with a judgemental assessment concerning the extent of asymmetry in welfare loss (judgement concerning the value to be assigned for α_p), this give the regulatory WACC.

6. Conclusions

Inconsistent pricing necessarily leads to economic inefficiency. It follows that there is some merit in adopting a standard framework – across all regulated firms whatever their industry sector - when assessing the WACC for a regulated firm. Regulators recognise the WACC is properly viewed as a random variable – and that errors in setting the allowed rate may not be symmetric. For this reason, some upward adjustment to the estimate of regulatory WACC is typically made. However, such adjustments in the EU have thus far been largely 'numbers plucked from the air' and ad hoc in nature. The lack of a framework for judging this allowance is likely to increase the level of inconsistency across firms and industries. The present paper has suggested that the Monte Carlo simulation approach already making something of a showing in Australian and New Zealand regulatory determinations is a useful way forward in the quest for greater consistency in shadow pricing the WACC. It is worth emphasising that, whatever the details of the particular method used to construct an estimate for the WACC, it is possible to place this within the context of a Monte Carlo simulation assessment of the distribution of this inherently uncertain variable.

The chief drawback with the Antipodean approach is that it has thus far merely focused on simulation as a method for determining the percentiles of the WACC distribution. It does not go the extra mile of determining how this interacts with welfare loss asymmetries. The present paper has suggested the use of a simple loss function for this purpose, and illustrated how this can prove useful in analysing or making a regulatory determination.

Operationally the loss function approach merely requires a judgement concerning the relative magnitude of welfare loss associated with any given over/underestimate for the WACC. If they are judged to be of equal importance, then this implies a regulatory WACC close to the median of this distribution. As the extent of asymmetry in welfare losses from under-estimation *vis a vis* over-estimation increases (to twice, five times, ten times and so on), so the appropriate choice of percentile for the WACC increases. The analysis can also be reversed; following a given determination of WACC, it is also possible to ask the question; what level of loss asymmetry would validate that choice (and does that seem reasonable?).

The value that arises from standardising the framework for dealing with uncertainty concerning the WACC estimate lies not only in the potential increase in the level of consistency across sectors and firms per se; it also helps all parties concerned to debate clearly the issues that matter. That is, all the assumptions (concerning distributions, means, standard deviations, ranges etc.) involved in developing the WACC distribution and loss function can and should be detailed. One of the interesting features of the recent use of the Monte Carlo approach in Australian and New Zealand regulatory applications is that, in the 'debate' between the various participants, there is little criticism of the basic methodology – but rather criticisms with deficiencies in the way it has been implemented (see e.g. Hathaway [2006]). The benefit of an explicit modelling approach with transparent assumptions is that it allows the debate to concentrate on the relevant issues (whether the distributions and their moments have been appropriately selected). By contrast, in the absence of explicit modelling of the distribution for the *WACC*, it is difficult to assess or criticise the claim that the regulator has been 'generous' or not in its determinations.

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