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Economic perspectives

A recommendation on how the method of setting water prices in Scotland should be changed: customer financed capital as a notional loan to the utility

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Introduction

It is difficult to over-estimate the importance of setting prices appropriately for a major utility like water, given that inappropriate pricing can cause unnecessary damage to the comparative competitiveness of a country's economy. In an earlier article in the Commentary, (Cuthbert and Cuthbert, 2007), we gave a critique of the current cost regulatory capital value (CCRCV) method of utility pricing: a method used, for example, in setting revenue limits, and so prices, in the water industry in Scotland and in England. While that article identified significant problems with the CCRCV approach, we did not make detailed recommendations about how these problems might be rectified. This paper makes a specific proposal about how CCRCV should be modified: our proposal is particularly well suited to the circumstances where, as in the case of Scottish Water, CCRCV pricing is being applied in a publicly owned utility. We argue that implementation of the proposed approach would have a number of advantages: in particular, it would lead to significantly lower water charges, while being fully sustainable well within current levels of public expenditure provision; it would reduce the likelihood of eventual privatisation of the water industry in Scotland; and there is the technical advantage of greatly reducing the cost to the Scottish Budget of the capital charge levied by the Treasury on the assets of the water industry in Scotland.

1. Background

1.1 Full details on the history and background of the CCRCV approach to utility pricing can be found in Cuthbert and Cuthbert, 2007. But to recapitulate briefly, the Regulatory Capital Value of a utility is an estimate of the total value of the capital value of the assets employed by the utility in performing its functions. We draw a basic distinction between applications which value the assets of the utility at historic prices, and those which value the assets in some form of current prices. We denote the latter approach as an application of current cost regulatory capital value, (CCRCV).

1.2 In a typical application of the CCRCV approach to utility price setting by a regulator, the CCRCV is rolled on from year to year by:

a. uprating for inflation
b. adding in the value of gross investment
c. deducting depreciation, as assessed in current cost terms.

The regulator then sets revenue caps for the industry, (that is, maximum allowable revenues, which therefore determine maximum allowable prices), as the sum of:

i. the level of current operating expenses the regulator is prepared to allow, (after adjusting, for example, for whatever level of efficiency savings the regulator judges is achievable);

ii. current cost depreciation;

iii. a capital charge, calculated as the product of an assumed rate of return times the estimated CCRCV.

1.3 A version of CCRCV utility pricing was initiated in the mid 1990s in England and Wales by the water regulator OFWAT, (see OFWAT 2004), to set the revenue caps for the water and sewerage companies, which had been privatised in 1989. The approach has subsequently been extended in the UK to the regulation of, for example, the electricity distribution network, airports, and the publicly owned water industry in Scotland, and is also proposed for the water industry in Northern Ireland.

1.4 There is, however, a major problem with the CCRCV approach. This can be seen by considering the simplest possible case, where the provision of capital assets is funded by borrowing. What the utility operator actually has to pay out to the market, to fully fund the provision of capital, is equal to depreciation and interest calculated at historic cost. But current cost depreciation and interest are normally greater than historic cost depreciation and interest, particularly where, as in the water industry, average asset lives are long: the CCRCV method thus leaves the operator with a financial surplus.

The implications of this were examined in detail in Cuthbert and Cuthbert, (2007). That paper set out the underlying algebra, and showed that, under CCRCV pricing, the utility operator will typically benefit from a windfall profit on any capital invested: this profit is a function of the rate of interest, the rate of inflation, and the length of asset life. The profit will commonly be very significant. For example, for an interest rate of 5%, with inflation running at 2.5%, and an asset with a thirty-year life, the operator will receive a windfall profit of over 40% of the value of the capital asset.

The probable consequences include:

- overcharging, and excess profits
- for a privatised utility, excess dividend payments;
- for a non-privatised utility, funding an undue proportion of capital from revenue;
- likely distortion of the capital investment programme, as capital investment itself becomes a profitable activity for the utility;
- unnecessary uncompetitiveness of water's business customers as they are over-charged for an important input.

For a public sector utility, the likelihood is that substantial cash surpluses would build up in due course: this is likely to make the utility a tempting target for eventual privatisation.

2. The proposed approach: treating capital financed from revenue as a notional loan

2.1 Is it possible to retain the key features of the CCRCV approach, (for example, the way that it smoothes the impact on present day charges of the accident of the timing of past investment decisions), while at the same time correcting the above problems? We argue that the modification proposed in this section achieves precisely this. The proposal put forward here is particularly relevant to the CCRCV method as applied in a publicly owned utility, where the financial surplus arising from the application of unmodified CCRCV pricing is likely to be used, in the first instance, to fund net new capital formation out of revenue.

2.2 In Cuthbert and Cuthbert 2007, we suggested that one route towards a more acceptable form of CCRCV would involve working out a proper decomposition of the current cost value of the capital assets of the utility into the components arising from different funding sources, that is, from borrowing, equity where appropriate, revenue raised from customers, inflation, etc. Once this was done, we argued that it should then be possible to find a more rational basis for determining how these different funding sources should be appropriately rewarded. What we are going to propose in this paper is in line with the spirit of this suggestion.

2.3 What is proposed is that the basis of CCRCV should be retained: but that where the CCRCV surplus, (the difference between what is charged to customers under CCRCV pricing and what is needed to cover historic cost depreciation and interest), is used to fund the creation of net new capital assets, then this should be regarded as customer-provided capital. More specifically, it is proposed that this customer-provided capital should be regarded as a notional loan from the consumer base to the company: a rebate would then be paid to the customer base, equal in amount to the value of historic cost depreciation and interest charges on the customers' loan.

(For the avoidance of doubt, we should make it clear that we do not propose that the calculation of notional debt would be carried out at the level of the individual customer. There would be an overall notional debt, owed to the customer base as a whole, on which an aggregate rebate would be calculated. This aggregate rebate would then need to be allocated to individual customers. This could be done in a variety of ways: e.g., as a flat percentage reduction in charges. This paper is not concerned with the precise detail of this last stage.)

2.4 The following quotation, taken from a reference book on utility regulation issued under the auspices of the World Bank, is relevant to this proposal:

> "The regulator may consider customer-provided capital to be an interest free loan to the operator, in which case the operator receives no return on that portion of its regulated assets, <u>or the regulator may impute to the operator an interest payment on the customer provided capital</u>, the effect of which is to lower the operator's regulated prices." (M.A. Jamison et al., 2004)

The underline in the above quotation is ours. It is clear that our proposed approach is entirely consistent with the principle embodied in this quotation.

3. Limiting behaviour in the steady state

3.1 We illustrate the implications of our proposal by considering what happens in a steady state model, where real investment is running at a constant amount each year. This is a not unreasonable description of, for example, a utility like Scottish Water: witness the following quotation from the then Water Industry Commissioner, giving evidence to the Scottish Parliament Finance Committee in December 2003:

> "… Scottish Water needs to make on-going investment in the industry at the present levels for the foreseeable future. There is no prospect of a diminishment in the investment spend of £400 million to £500 million a year. Every year for as long as I will be on the planet, Scottish Water will have to spend a similar sum of money…"

3.2 Specifically, we assume that gross investment is running at a constant real amount of 1 unit per annum. It is assumed that inflation is constant at r% per annum. The nominal interest rate is assumed to be i%, (which we assume is both the rate at which the utility can borrow from the National Loan Fund, and the rate used to assess the cost of capital in current cost pricing.) Each year, customers are charged an amount to cover the cost of the capital goods employed in the industry, where this amount is assessed using CCRCV charging. We assume that any surplus of customer charges over what is required to pay historic cost interest and depreciation is used to fund net new investment, and is regarded as a notional loan from the customer base. The customer base will in due course get a rebate, equal to historic cost interest and depreciation on this notional loan. Investment not funded from revenue is funded by borrowing from the NLF.

3.3 In the long run, the real, (as opposed to nominal), unrebated current cost charge to customers implied by the CCRCV approach will settle down to a limiting value, which we denote by cc: and the real historic cost interest and depreciation on the total annual investment of 1 will settle down to a constant amount, denoted by hc. (Note that hc is the historic cost interest and depreciation on the gross investment of 1: it is not affected by whether gross investment is funded in whole or part by borrowing from the NLF or the customer).

The limiting behaviour of the rebated payment system is entirely determined by cc and hc, as the following argument shows:

> Each year, the utility has to fund gross real investment of 1. The amount of free customer revenue which is available to fund this investment is what is left out of cc after paying hc historic cost interest and depreciation, (either to the NLF, or as a customer rebate): so the amount of gross investment funded from customer charges would be
>
> (cc – hc), if cc – hc $\leq$ 1:
> and 1, if cc – hc > 1.
>
> Hence, if φ is defined as min(cc – hc, 1), then the limiting proportion of gross investment funded out of customer charges will be φ.
>
> Clearly, φ is therefore also the limiting proportion of outstanding debt, (actual and notional), funded from customer charges: so φ also represents the limiting proportion of historic cost charges which will go back to the customer as a rebate.
>
> Therefore, in the limit, the real amount which customers pay after rebate is (cc - φhc).

3.4 This expression, (cc - φhc), in fact tells us a great deal about the limiting behaviour of the rebated system. As we will see, the way the system behaves depends critically on whether real interest rates are positive or negative, (which corresponds to whether hc > 1 or hc < 1): and on whether or not all capital expenditure is eventually funded direct from revenue, (which corresponds to whether φ < 1 or φ =1).

The following table shows how the amount customers pay after rebate, (denoted PAYS), depends on the different possible combinations of real interest rate and φ. The derivation of the relationships in the table is given in Annex 1.

Table 1: The rebated charge: PAYS

	$0 < \varphi < 1$	$\varphi = 1$
Real interest rate positive	1 < PAYS < hc	PAYS $\geq$ 1
Real interest rate zero	PAYS = 1	PAYS $\geq$ 1
Real interest rate negative	hc < PAYS < 1	PAYS $\geq$ 1

3.5 This table is interesting because it gives a fairly complete account of the possible relationships under the rebate model: but of course, not all the possibilities considered in the table are equally likely. If we regard as normality a situation where real interest rates are positive, (which is equivalent to the situation hc > 1), and if at the same time inflation is relatively low, then we would expect to be in the top left hand corner of the table. In this case, the rebated charge which customers will pay will actually be less than what customers would have paid if the utility had been operating historic cost pricing. If inflation rises, however, (with interest rates increasing so that real interest rates still remain positive), then we would find ourselves in the top right hand cell, with all of capital being funded from customer charges. In these circumstances, we could find ourselves back in the situation where a financial surplus is building up in the utility: however, the rate at which this surplus would accumulate would be much slower than under unmodified CCRCV pricing.

3.6 But how does this model translate into some potential real-life scenarios? First, we need to bring in one further parameter, which is the length of life of the capital assets. We assume that capital assets have a fixed life of n years. So, to summarise, we assume that we are operating a rebated model where we have fixed gross investment of 1 unit in real terms per annum: that inflation is r %: the nominal interest rate is i %: and that capital assets last for n years. The following tables show the limiting real values which will result for a number of different combinations of n, i, and r. In each case, we show:

- the CCRCV charge: that is, what customers would have been charged if full CCRCV pricing were in operation;
- the Historic Cost charge: that is, what customers would have been charged if historic cost pricing were in operation;
- the Rebated Charge: that is, the net amount customers would have been charged, after rebate, if the rebate system were in operation;
- the percentage of capital financed from customer revenues, if the rebate system were in operation;
- annual borrowing from the National Loan Fund.

The specific formulae used in deriving these figures are given in Annex 2.

3.7 The first point to note about Table 2 is that in all the cases considered, the rebated charge is a good deal less than the unrebated CCRCV charge: for example, in the case where asset life is 30 years, nominal interest rate 5%, and inflation 3%, the rebated charge is 62% of what the CCRCV charge would have been. Note too that the extent of the saving increases with asset life.

In most of the cases considered, the rebated charge is also less than the historic cost charge. The exceptions occur when there is a conjunction of long asset life with relatively high inflation: (for example, asset life 50 years, interest rate 8%, and inflation 5%, 6% or 7%). Under these, possibly relatively unlikely, scenarios, the rebate model would imply that substantial financial surpluses would still accrue within the utility, (though the extent of these surpluses would be much less than implied by unrebated CCRCV charging.)

In most of the cases considered, the rebated charge is in fact not much higher than 1, (which is what would be implied by funding all capital expenditure direct from revenue): typically, the rebated charge lies in the range 1.02 to 1.23. The exceptions occur with the conjunction of long asset life with high inflation, in which case the rebated charge is a good deal higher.

In most of the cases considered, the percentage of capital financed from revenue is substantial: (for example, for asset life 30 years, interest rate 5%, and inflation 3%, 54% of gross capital expenditure is financed from revenue). This percentage increases with asset life, and the rate of inflation.

The bottom row in each table gives the net amount of borrowing which would be required from the NLF. For example, for asset life 30 years, interest rate 5%, and inflation 3%, borrowing from the NLF each year would be 0.158, (as compared to a gross annual investment programme of 1.) To put this in context: if Scottish Water's investment programme is assumed to be around £600 million per annum in real terms, then this would imply an annual borrowing requirement of less than £100 million: this compares with a current public expenditure provision of around £180 million per annum for Scottish Water. (In most of the other cases illustrated in the above table, the borrowing requirement would be significantly less than for this particular example.)

3.8 As noted in the previous paragraph, the rebated charge in the steady state will very often be close to 1: that is, it will be close to what consumers would have paid if all capital investment had been funded direct from revenue

Table 2: Limiting values for customer rebate model (gross investment = 1 unit per annum

			Asset life in years	*30*
			Interest rate	*5%*
	Inflation rate	2%	3%	4%
CCRCV charge		1.78	1.78	1.78
Historic cost charge		1.38	1.23	1.11
Rebated charge		1.23	1.11	1.04
% of capital financed from rev		39.5%	54.4%	66.9%
Borrowing from NLF		0.153	0.158	0.14
			Asset life in years	*30*
			Interest rate	*8%*
	Inflation rate	5%	6%	7%
CCRCV charge		2.24	2.24	2.24
Historic cost charge		1.29	1.18	1.08
Rebated charge		1.02	1.06	1.16
% of capital financed from rev		94.7%	100%	100%
Borrowing from NLF		0.026	0	0
			Asset life in years	*10*
			Interest rate	*5%*
	Inflation rate	2%	3%	4%
CCRCV charge		1.28	1.28	1.28
Historic cost charge		1.15	1.1	1.05
Rebated charge		1.13	1.08	1.04
% of capital financed from rev		12.2%	17.7%	22.8%
Borrowing from NLF		0.089	0.121	0.146
			Asset life in years	*10*
			Interest rate	*8%*
	Inflation rate	5%	6%	7%
CCRCV charge		1.44	1.44	1.44
Historic cost charge		1.14	1.09	1.04
Rebated charge		1.1	1.06	1.03
% of capital financed from rev		30.3%	35.2%	39.7%
Borrowing from NLF		0.159	0.171	0.179
			Asset life in years	*50*
			Interest rate	*5%*
	Inflation rate	2%	3%	5%
CCRCV charge		2.28	2.28	2.28
Historic cost charge		1.56	1.32	1.14
Rebated charge		1.16	1.02	1.13
% of capital financed from rev		71.8%	95.1%	100.0%
Borrowing from NLF		0.105	0.024	0
			Asset life in years	*50*
			Interest rate	*8%*
	Inflation rate	5%	6%	7%
CCRCV charge		3.04	3.04	3.04
Historic cost charge		1.38	1.23	1.1
Rebated charge		1.66	1.81	1.194
% of capital financed from rev		100%	100%	100%
Borrowing from NLF		0	0	0

each year. This raises the question: why not move to the even simpler, and ultimately cheaper, system, where all capital expenditure is funded direct from revenue. In real life, however, while our assumption of constant real investment is likely to be reasonable as an average, the actual path of investment is likely to wobble around this average from year to year. The advantage of the rebated CCRCV approach is that it will smooth the impact of such wobbles on customer charges.

4. Dynamics of system in transitional phase

4.1 The preceding section looked at the limiting behaviour of the rebated system, under the assumption of steady state real investment. It would, however, take n years after the introduction of the rebate to reach this steady state, where n is the asset life. It is a question of great practical importance, therefore, to consider how charges would move in the early years following the introduction of the rebate system.

4.2 In this section we look at the dynamics of the transition from unmodified CCRCV pricing to rebated charging. It is assumed that, initially, traditional CCRCV charging is being operated: we assume that the system is operating in the limiting steady state, with unit real investment per annum: we assume that, initially, all gross investment is funded by borrowing from the NLF, with the CCRCV surplus over historic cost loan charges being removed from the system. Suppose that, at a given point in time, the rebated charging system is introduced. As before, we consider the three parameter model specified by asset life, interest rate, and inflation rate.

4.3 Chart 1 illustrates the resulting path of rebated charges, in the specific case of asset life 30 years, interest rate 5%, and inflation 3%.The following table shows the rebated charge as a percentage of the CCRCV charge, for each of the first 15 years after the introduction of the rebate system, for a number of different combinations of asset life, interest rate and inflation:-

What the Chart and Table 3 demonstrate is a pattern of a fairly rapid initial decline in the rebated charge, which then tapers off as the limiting value is approached after n years. Of the cases considered in the above table, the slowest rate of decline occurs in the left hand column, corresponding to asset life of 10 years, interest rate 5%, and inflation rate 3%. Even in this case, however, the rebated charges initially decline at a rate of 2% relative to CCRCV charges. In the other cases considered, (with longer asset lives which would be more typical of the water industry), the initial rate of decline lies between 2.5% and almost 5%. The implication is that substantial customer benefits are likely to accrue from a rebated charging system immediately from its date of introduction.

4.4 Finally, a note of caution is appropriate. If a rebated charging system were being introduced in real life, then the starting point would not be CCRCV charging operating in a steady state. For example, in the water industry in Scotland, while future real investment appears likely to be fairly steady on average, (witness the quotation in paragraph 3.1 above), past investment experienced a significant real uplift to around its present level, round about year 2000. This implies that the starting point, if rebated CCRCV charging were introduced now, would be different from the steady state CCRCV taken as the starting point in the above illustrations. To understand the actual dynamics of rebated CCRCV charging, introduced from the current starting point, would therefore require further modelling, which lies beyond our present scope. It is clear, however, even without detailed modelling, that a rebate system would produce rapid reductions in customer charges, relative to the profile of unrebated CCRCV charges.

5. Implications for the Treasury’s capital charge

5.1 In a 1995 White Paper, the then government at Westminster set out proposals for a new system of government accounting, called Resource Accounting and Budgeting, (RAB). RAB is a method of taking into account the full cost of assets consumed in the delivery of a government service. Essentially, in preparing their budgets, government departments count against their Departmental Expenditure Limit the cash costs of providing services, together with what are known as “non-cash” costs. These non-cash costs include an annual capital charge, related to the value of the capital assets controlled by the department. The capital charge is calculated as a rate of interest times the residual value, (having taken off depreciation), of the capital stock measured at today’s prices. Between 1997 and 2003 the rate of interest used by the government for the capital charge was 6% in real terms: this became 3.5% in real terms in 2003.

Since Scottish Water is a public corporation, the Scottish government has to account each year for a capital charge based on the value of Scottish Water’s capital assets.

5.2 The following quotation, from a Treasury document, describes the exact basis on which the capital charge is calculated:

> “The cost of capital charge is 3.5 per cent of the net assets (fixed capital and financial assets, net of financial liabilities and provisions) employed by each department.” (Treasury, 2007)

This quotation clearly states that the capital charge should be calculated on the basis of the current cost value of the capital assets employed, net of any financial liabilities. The introduction of a rebate scheme, as proposed here, would mean that Scottish Water, in addition to conventional NLF debt, would have a notional financial liability, equivalent to the notional historic cost debt on which the customer base earns its rebate. In the spirit of the above quotation, therefore, the capital charge on the Scottish Government

Chart 1: Real CCRCV charges historic cost charges and rebated charges: asset life 30 years

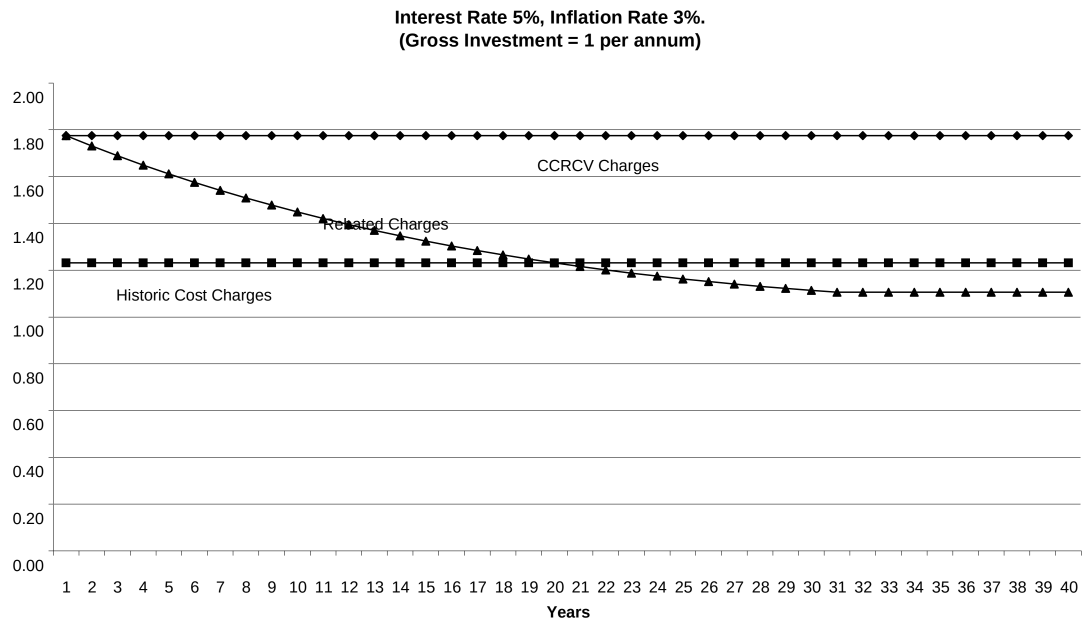

Table 3: Rebated charge as % CCRCV charge, by years since introduction of rebate

Asset Life		**10**		**30**		**50**	
Nominal Interest rate		**5%**	**8%**	**5%**	**8%**	**5%**	**8%**
Inflation rate		**3%**	**5%**	**3%**	**5%**	**3%**	**5%**
Year	1	100.0	100.0	100.0	100.0	100.0	100.0
	2	98.0	96.4	97.5	95.4	97.2	96.9
	3	96.1	93.1	95.2	91.2	94.4	93.9
	4	94.3	90.1	92.9	87.2	91.8	91.2
	5	92.6	87.4	90.8	83.6	89.3	88.6
	6	91.1	85.0	88.8	80.2	87.0	86.2
	7	89.6	82.8	86.8	77.0	84.7	83.9
	8	88.3	80.8	85.0	74.1	82.5	81.8
	9	87.0	79.0	83.3	71.4	80.4	79.8
	10	85.8	77.5	81.6	68.9	78.4	78.0
	11	84.8	76.1	80.1	66.6	76.5	76.3
	12	84.8	76.1	78.6	64.4	74.7	74.6
	13	84.8	76.1	77.2	62.4	73.0	73.1
	14	84.8	76.1	75.9	60.6	71.4	71.7
	15	84.8	76.1	74.6	58.9	69.8	70.4
	Limit	84.8	76.1	62.3	45.3	44.6	54.6

for the assets of Scottish Water should be calculated on the basis of net assets reduced by this liability: so the rebated system should result in a significant reduction in the capital charge on the Scottish Government.

5.3 In fact, we would go further than this: a strong case could be made that that portion of the capital stock which has been funded from customer charges had never represented a burden on public expenditure resources, and should therefore be exempt from the capital charge: that is, the entire portion of CCRCV which was financed from revenue should be exempt from the capital charge. As the relevant figures in Table 2 above indicate, the percentages of capital financed from revenue are typically high: so the savings to the Scottish Government from this would be very significant.

6. Conclusion

6.1 To recapitulate, the modification to CCRCV pricing proposed in this paper has the following advantages:

It would lead to a rapid decrease in water charges, relative to charges under unmodified CCRCV pricing: this would be of direct benefit to consumers, and bestow a significant comparative advantage on industry in Scotland, relative to, for example, England, (where unmodified CCRCV remains in operation.)

The proposed approach is fully sustainable, both in the sense that all sources of finance are appropriately rewarded, and also in the sense that the residual public expenditure requirement is well within the level of real borrowing provision for water currently in the Scottish budget.

It should significantly reduce the burden on the Scottish Budget of the Treasury’s capital charge for water.
It prevents the build-up of a financial surplus within Scottish Water. In addition, it will be very clear to consumers in general exactly what proportion of the capital stock has been funded directly by consumers, so increasing the feeling that consumers own, and benefit from, a stake in the industry. Both of these factors should reduce the likelihood of eventual privatisation.

The proposal is entirely consistent with the World Bank principles of how customer funded capital might be rewarded: and it retains the smoothing benefits of the CCRCV approach.

6.2 In the light of the above, we suggest that the proposal should be given active consideration by the Scottish Government.

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Treasury, (2007): “Public Expenditure Statistical Analysis 2007”, Annex C.

Annex 1: Derivation of relationships in Table 1

Recall that PAYS = (cc - φhc).

First of all, suppose $\varphi < 1$:

If hc > 1, then (cc - φhc) = (cc – hc) + (1 - φ)hc > (cc – hc) + (1 - φ) = 1.

If hc = 1, then (cc - φhc) = (cc – φ) = hc = 1.

If hc < 1, then (cc - φhc) = (cc – hc) + (1 - φ)hc < (cc – hc) + (1 - φ) = 1.

Moreover, (cc - φhc) > hc

if and only if (cc – hc) > (cc – hc)hc

if and only if 1 > hc, (since (cc – hc) > 0).

Secondly, if $\varphi = 1$, then

(cc - φhc) = cc – hc $\geq$ 1.

Annex 2: Formulae used

The specific values quoted in the paper were calculated using the following formulae. The model assumes that there is a steady state real level of gross investment of 1 unit per annum. There are three input parameters: interest rate, i, inflation rate, r, and length of asset life. The model assumes that, up to year n, pure CCRCV pricing has been in operation, with the CCRCV surplus, (that is, the excess of CCRCV charges over historic cost interest and depreciation), removed from the system. From year (n+1), the surplus is used to fund investment, and regarded as a notional loan from customers, on which they will then get a rebate, equal to the historic cost depreciation and interest charges on this loan. The model then models the transition to the new steady state. The formulae used are as follows: (note that in these formulae, r and i are expressed as fractions). Note that the values calculated are in nominal terms, whereas those given in the text have been deflated to be in real terms:-

Gross investment in year t = $(1+r)^t$

Current cost depreciation in year t = $CCD_t = (1+r)^t$

Current cost asset value in year t = $CCRCV_t = 0.5(n+1)(1+r)^t$

Current cost interest in year t = $CCI_t = 0.5i(n+1)(1+r)^t$

Historic cost depreciation in year t $= HCD_t = \frac{1}{n}\sum_{k=1}^{n}(1+r)^{t-k}$

Historic cost interest in year t = $HCI_t = \sum_{k=1}^{n} i(1+r)^{t-k}\frac{(n+1-k)}{n}$

Self financed investment in year t = SFI_t

= 0, for $t \leq n$,

= min(($CCD_t + CCI_t - HCD_t - HCI_t$), $(1+r)^t$),

for $t \geq (n+1)$.

Depreciation element of rebate in year t = $RD_t = \frac{1}{n}\sum_{k=1}^{n} SFI_{t-k}$

Interest element of rebate in year t = $RI_t = \sum_{k=1}^{n} iSFI_{t-k}\frac{(n+1-k)}{n}$

Net borrowing from NLF in year t = $(1+r)^t - SFI_t - HCD_t + RD_t$