An Empirical Examination of the Theory and Practice of how to Set X

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Abstract:

This paper examines the setting of the X-factor in price cap regulation. While price caps date to 1982, there is still disagreement as to what X should be. We show the US-style *productivity-offset* X relies on assumptions that are unlikely to hold empirically. Adopting the productivity-offset X is likely to bias prices upwards relative to alternative definitions. We show that under the offset approach, using historical growth rates can to lead to price growth in line with cost of service regulation. We propose a more direct X, where X equals the forecast of TFP growth less the difference between industry input and consumer price growth.

Key words: Price caps, incentive regulation, productivity; JEL codes: L43, L51, L97

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1. INTRODUCTION

Price caps are perhaps one of the fundamental success stories of regulatory economics over the last 25 years. One of the particularly important developments of this form of incentive-based regulation was the recognition by economists that regulation could potentially mimic how competitive markets would pass on the majority of industry total factor productivity growth gains to consumers in the form of lower prices. Competition would compete efficiency gains away. Thus, in trying to design regulation that mimicked competition, economists generally agreed on the need to include a means of transferring efficiency gains to consumers, while still maintaining adequate incentives in the industry for investment and innovation.

The rate of relative price reductions, or transfer of efficiency gains, was settled upon as the so-called X factor. But on a global scale, this was perhaps all that was settled. X was first introduced in the UK price caps put in place after the Thatcher privatisations and quickly adopted in the US. The X factor is considered the 'efficiency factor' in UK price caps for regulated services such as water, gas, electricity, and telecoms. Somewhat differently, in the US the X factor is often referred to as a 'productivity offset', reflecting X's somewhat different definition in the US as something more complex than just efficiency.

The UK and the US approaches led to two different schools of thought on how to design or choose X, with the UK approach eschewing a rigorous mathematical derivation and relying instead on a combined 'judgement' approach. Crew and Kleindorfer (1996) preferred this method. The US, on the other hand, strongly influenced by groundbreaking work by Bernstein and Sappington (1999), relies on a solid definition of X as a productivity offset, a relative rate of total factor productivity growth and relative price changes. In spite of this, a number of commentators such as Crew and Kleindorfer (1996) expressed doubts about the productivity offset approach to X, seeing the offset approach as possibly increasing prices above what they might otherwise be.

Perhaps surprisingly, X can take on a number of definitions, often depending on the jurisdiction. It could be considered the measure of total factor productivity growth in its purest sense, or it could merely be considered a measure of how prices should change; or X could be considered a relative measure of productivity; or even a relative measure of productivity relative to price changes. The various definitions leave some lingering questions. Without a more rigorous definition of X there is room for confusion or criticism from industry: first as to what kind of productivity X should include, second as to how various price effects should be included, while maintaining transparency. Finally, is X a forecast, or is it a historical trend? If the former, how should we forecast X?

In the UK, due to the more judgmental approach to X, debate over what exactly X should be has likely led to regulatory uncertainty. In the US, because the offset is derived from a more rigorous setting, less debate over X has perhaps been replaced with debate over other parameters: consumer dividends, sharing factors, and accumulated inefficiencies. Even in the US, however, the dynamics of forecasting X have not been deeply studied. The result is remaining regulatory uncertainty surrounding X in the UK, the US, and jurisdictions having adopted the X approach. Regulatory uncertainty may increase the cost of capital, which may raise the cost of service in the long run--something every regulator wishes to avoid.

The importance of resolving certain issues with X is not just a problem in the UK and the US. Many of the EU, Eastern European, South American, and the Asian-Pacific countries have embarked on privatisation and deregulatory programmes that often draw on the experiences of the UK and the US. The combination of two competing views and unresolved issues with X no doubt leads to uncertainty and difficulty.

1.1 Critiques of the current approaches

While some have advocated for the UK approach to X (Crew and Kleindorfer 1996), the UK style has not been without its criticisms[1]. One of the major criticisms is a lack of transparency for X. While it is generally understood that X is some measure of the scope for efficiency improvement, it is not clear for a company facing their next price control review exactly what goes into X. The lack of transparency, it is argued, leads to things such as the possibility of over or double counting--for example, does X include input price changes? A more transparent X, it is argued, would address such questions. In addition, a transparent formula should be founded on sound economic theory and evidence that would allow open debate. For example, if X were defined[2] explicitly in terms of TFP growth, then how input prices would enter the price cap would become completely transparent, and debate might focus on what the proper forecast of TFP might be. Because of these concerns in the UK, regulated industry stakeholders have been calling for a more US-type definition of X[3].

We argue in this paper, however, that the productivity-offset X, as is used in the US, is not likely to be in regulators' interests. This is because the US-style productivity offset, while grounded in theory, does not reflect the empirical evidence. More precisely, the US-style productivity offset is based on a substitution that does not generally hold empirically.

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[1] See for example Williamson (2002).

[2] In general, there is no explicit formula for X in the UK price caps.

[3] See for example, the water industry's advocacy site at www.water.org.uk , and Water UK report The General Efficiency Assumption: Setting X in RPI-X, 2002.

2. PREVIOUS WORK ON X

2.1 Origins of X

The X in RPI[4] – X type price caps is by now a UK success story in terms of government policy in general, as well as in terms of regulatory economics. The introduction of X was originated by Littlechild and collaborators (Littlechild 2003) at the time of the first UK privatisations in the 1980s.

According to Littlechild, the original intentions were simple; X was to reflect how prices (for BT at the time) should fall relative to the economy as a whole, i.e., how real industry output prices should change over time. One of the more fundamental ideas of the price cap was also to avoid lengthy cost of service and rate of return regulation, which (in the view of the originators of X) had proved inefficient[5] in other jurisdictions such as the United States.

Apparently, more rigorous derivations of X were not investigated at the outset in the UK. This is not to say that the originators did not consider these things. Quite the contrary; they did. Their considerations were likely subsumed by practical matters of studying the actual effects of particular decisions for X on the companies' bottom line. What resulted was that the process of determining X in the UK was determined through consultations, both with the companies and outside experts and consultants. While this was perhaps the most reasonable way forward at the time, due in part to the lack of time series data, the process left embedded difficulties, such as the need to rely on company information for various

[4] RPI is the retail price index, the most common measure of general inflation in the UK. The corresponding fixed-weights consumer goods price index in other jurisdictions is the CPI.

[5] The main sources of the inefficiency are considered to be excess capacity, poor technology choices over time, failure to implement innovative organisational structures, and gold plating.

components of potential efficiency, and a lack of transparency as to what the definition of X should be.

Part of the difficulty with setting X in this more *ad hoc* way, rather than on the basis of a more rigorous definition, is that the companies invariably have better information about the scope for efficiency improvement than the regulator. These informational asymmetry problems were some of the problems that the price cap regulation was meant to avoid. The existence of informational problems seemed to become all too apparent, when according to many observers, the companies did the best out of the first round of X factors set immediately after privatisation (Saal and Parker 2001). Subsequent efforts at estimating efficiency scope for X partially addressed some of the informational problems from relying on the companies themselves for data by turning to comparator industry techniques, such as has been done by Ofwat in their more recent price reviews[6].

2.2 Work on X in other jurisdictions

The success of RPI- X type price caps is evident as the price cap form of regulatory price setting was quickly adopted in other jurisdictions. These include for example the Federal Communications Commission (FCC) in 1995 in their Common Carrier Bureau's Tariff Review Plan 1995, (setting the rates which the newly broken up AT&T companies would charge each other for various types of interconnection[7]). At about the same time, similar price caps were making their way into US States' regulatory pricing, which make up the

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6 See London Economics (2003), "PR04: Scope for efficiency study", Ofwat, at http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/AttachmentsByTitle/pr04_efficiencyrep_londonecon.pdf/$FILE/pr04_efficiencyrep_londonecon.pdf.pdf.

7 It is useful to note that productivity growth in US telecoms has been higher than in any other sector of the economy over a long run period such as the post war period, and over almost any business cycle. Total factor productivity growth rates exceeded 4%, versus 0-2% for many industries. 2% TFP growth in the US economy as a whole is considered strong.

bulk of the regulatory pricing in the US. Such examples include NYNEX[8] and the Boston Gas decisions of the Massachusetts DTE (Bodnar 1997). Similar decisions and uptake can be found in markets and jurisdictions outside the UK and the US, such as Canada[9] in their treatment of telecoms price regulation and Austria[10] in electricity.

There are some interesting similarities in most of the work in jurisdictions outside the UK. First, many of the regulators state the goal of the price cap is to be a "simulator" of competition, and also that it might be a bridge to a time when more competitive forces could gradually replace regulation. Second, in the FCC case, the Canadian telecoms case, the Boston Gas case and other cases regulators adopted a definition of X as a productivity 'offset' that was "relative" to other prices and "relative" to prices in the economy as a whole. This was the result of a well-known academic paper on the subject, and so we turn to this relative measure of X now.

2.3 Bernstein and Sappington

The predominant view outside the UK on the proper derivation of X in an RPI-X type price cap come[11] from a particularly important study, Bernstein and Sappington (1999) (B&S). B&S posit a regulator who must regulate an industry via an RPI – X type price cap. The regulator's goal is to keep prices in the industry as low as possible to ensure zero economic profits. Therefore, with the zero economic profits condition as the goal, the starting point

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8 MA DTE, NYNEX D.P.U. 94-50.

9 Bodnar, J. (1997), "Productivity input prices and price caps in telecommunications – the Canadian experience" 1997 ICFC June 24 - 27, 1997.

10 E-Control, (2003) "Incentive Regulation for the Austrian Electricity Transmission and Distribution Companies", Discussion paper. Vienna, 5th March, www.e-control.at.

11 Prior work, such as the working paper by B&S, notably predated the publication in the Journal of Regulatory Economics by a

for their analysis is an accounting identity--output price times quantity must equal input price times quantity. With output price, *P*, and an output quantity index *Y*, along with input price and quantity indices, *W* and *Q*, (superscript *i* to index the industry), the identity for the industry is given by equation (1) below:

$$P^i Y^i = W^i Q^i \tag{1}$$

Taking logarithmic time derivatives, equation (1) can be expressed in terms of growth rates. Using lowercase letters to indicate the natural log and a dot over a variable to denote the time derivative, the dynamic zero profits[12] condition is equal to:

$$\dot{p}_t^i + \dot{y}_t^i = \dot{w}_t^i + \dot{q}_t^i \tag{2}$$

Defining TFP as the ratio of total output to total input, Y/Q, the dynamic industry zero profits condition can be rearranged to yield two theoretically equivalent measures of TFP growth.

$$\dot{y}_t^i - \dot{q}_t^i = \dot{w}_t^i - \dot{p}_t^i \equiv T\dot{F}P_t^i \tag{3}$$

The first measure above is the quantity measure of TFP growth. The second is the dual, or price measure.

The regulator is interested in setting the rate of growth in output prices for the industry, so the dual dynamic zero profits condition can be rearranged in terms of TFP growth to solve for the rate of change in industry output prices:

number of years.

[12] Bernstein and Sappington (1999) show how to adjust the measure to allow for profits.

$$\dot{p}_t^i = \dot{w}_t^i - T\dot{F}P_t^i \tag{4}$$

This equation says that if zero profits are to be maintained, then the rate of growth of industry output price should equal industry input price growth less TFP growth. Of note is the fact that the rate of growth in output prices at the industry level is precisely the RPI – X type price cap. Therefore, we can write a general price cap definition as:

$$\dot{p}_t^i \equiv R\dot{P}I_t - \dot{X}_t^i \tag{5}$$

B&S then go on to derive what their view of what X should be. They start by defining (2) for the whole economy. Using the e superscript to denote an economy-wide variable, we can write the dynamic zero profits equation for the economy as a whole and derive economy TFP as:

$$\dot{y}_t^e - \dot{q}_t^e = \dot{w}_t^e - \dot{p}_t^e \equiv T\dot{F}P_t^e \tag{6}$$

Or, in terms of prices and TFP:

$$\dot{p}_t^e = \dot{w}_t^e - T\dot{F}P_t^e \tag{7}$$

Next, B&S recognise that RPI is, by definition, an estimate of the rate of growth in output prices in the economy on the whole; $\dot{p}_t^e \cong R\dot{P}I_t$. Therefore:

$$R\dot{P}I_t = \dot{w}_t^e - T\dot{F}P_t^e \tag{8}$$

Making the appropriate substitutions and rearranging the terms in the equation gives their X:

$$X_t = \left(T\dot{F}P_t^i - T\dot{F}P_t^e\right) - \left(\dot{w}_t^i - \dot{w}_t^e\right) \tag{9}$$

From here on, we will refer to the X given by equation (9) as the 'productivity-offset' X. What (9) says is the following. Given an RPI-X type price cap, then the X factor that ensures that the industry zero profits conditions holds a function of the difference between the rate by which TFP growth in the industry *exceeds* TFP growth for the economy as a whole, add the rate by which input price growth *exceeds* input price growth for the economy as a whole. Thus, according to B & S, the proper definition of the X factor is a differential of a differential.

3. PROBLEM WITH THE PRODUCTIVITY-OFFSET X

However, we contend that this view of X can lead to upward bias in the price cap[13]. This is because of the substitution of equation (8) into the price cap. Equation (8) is not likely to hold empirically. The rate of consumer price inflation is not likely to equal input price inflation less TFP growth for the economy and this is likely to upward bias the measure. First, let's rewrite the price cap as a function of the productivity offset X; this gives:

$$\dot{p}_t^i = R\dot{P}I_t - \left[\left(T\dot{F}P_t^i - T\dot{F}P_t^e\right) - \left(\dot{w}_t^i - \dot{w}_t^e\right)\right] \tag{10}$$

Notice that, if input prices grow at a rate that is similar between the industry and the economy as a whole, and if TFP growth in the economy is similar to the TFP growth in the industry, then prices in the industry under the price cap rise at exactly the rate of RPI. In other words, real prices remain constant. Notice that, under equation (10), TFP growth in the industry could be quite robust, input price growth could be nil (the two of which would imply strong unit cost reductions in a competitive industry), and the price cap could still

[13] As was foreseen by Crew and Kleindorfer (1996) but not substantially investigated.

require real prices to rise, if RPI was not falling. This seems counterintuitive if regulation is meant to mimic competition.

We thus assert that productivity-offset X is biased. To see the nature of the direction of bias, collect the economy and industry terms.

$$\dot{p}_t^i = R\dot{P}I_t + \left(T\dot{F}P_t^e - \dot{w}_t^e\right) - \left(T\dot{F}P_t^i - \dot{w}_t^i\right) \tag{11}$$

Next, define two RPIs (retail price index): the official RPI as measured by as national statistical agency such as the ONS[14] (call this *RPI*)*, and the RPI that would result from the whole economy TFP input price differential (Equation (8)); call this RPI^e. Making these substitutions, we find that:

$$\dot{p}_t^i = R\dot{P}I_t^* - \left(R\dot{P}I_t^e\right) - \left(T\dot{F}P_t^i - \dot{w}_t^i\right) \tag{12}$$

Notice that the official RPI, *RPI**, stays in the equation of the price cap and enters positively, while RPI^e, the RPI estimated difference between

TFP and input costs, enters the price cap negatively. Thus if *RPI** exceed RPI^e, then the price cap will be biased upwards. In other words, if the official RPI exceeds the theoretical RPI, actual economic profits will be expected to be positive under the price cap. Thus, the validity of the productivity-offset view of X depends on the validity of the substitution.

The validity of this substitution is something that therefore should be empirically tested. Fortunately, (12) contains variables that are regularly estimated by national statistics

[14] Office of National Statistics, the official data source for RPI in the UK.

agencies such as the UK's ONS. It is therefore possible to readily test the validity of the productivity-offset X.

3.1 Testing the productivity-offset view of X

In this section we report the results of our analysis using UK and US data. We start by reporting the results obtained with UK data and turn then to the results obtained with the US data. In this section we also address the issue of forecasting X.

3.1.1 UK data

The unbiasedness of the productivity-offset X factor depends critically on the validity of equation (8). To test the validity of (8), we obtained time series data on RPI, input prices, and TFP growth for the UK economy from ONS. We then calculated RPI – input price growth + TFP growth using the actual series over the years available for the series. A graphical depiction is shown below in Figure 1. We considered a variety of measures and series for general economy inflation and input price inflation. The results were qualitatively the same in all cases; the substitution did not hold. The X that resulted under the B&S derivation would have led to an under estimation of X and therefore a significant *increase* in prices over time *ceteris paribus*.

We first considered the following series: RPI, input prices as measured by the input PPI published by ONS, and TFP growth. The expression RPI – PPI + TFP shows over the period 1975 to 2000 an average annual (continuous) growth rate of 2.18%. Notice that the extent to which the value of this expression is positive is the extent to which the zero profits condition for the industry is violated, ignoring other factors for now.

To check the robustness of the result, alternative measures of output prices were used. On the output side, replacing RPI with: the GDP deflator gave result of 2.1%, and the domestic expenditure deflator gave 1.99%. Thus, the size of the bias in the price cap is estimated to be about 2%, and is evidently invariant across common definitions of output price inflation.

Next, we considered different definitions of input prices. First, we substituted for the PPI the ONS's unit labour cost index which yielded a bias of 2% and the ONS's materials and fuels input PPI, with similar results. Finally, we constructed our own input price indices for the UK economy as a whole to further check the robustness of our results. We obtained data from the ONS input-output accounts and the UK national accounts for the share of labour in total output: this share starts at about 57% and falls gradually throughout the sample period. Then, we constructed a measure of the cost of capital based on the user cost of capital approach developed by Jorgensen and co-authors. We used the ONS's national account data on total fixed capital formation and made the assumption that capital service flows were equal to the lagged value of the capital stock[15]. We then developed a measure of the user cost based on the methods of Jorgenson as detailed in Ball et. al. (1999). For this measure, a nominal real rate of return is needed and for this we used annual average yields on index-linked bonds from the Bank of England. We also needed an average depreciation rate and for this we used 0.04 per annum. Using each year's growth rate's appropriate weight, we calculated RPI - weighted average input growth + TFP growth. The result for this calculation over the 1979 – 2000[16] period was an average value of 1.8%.

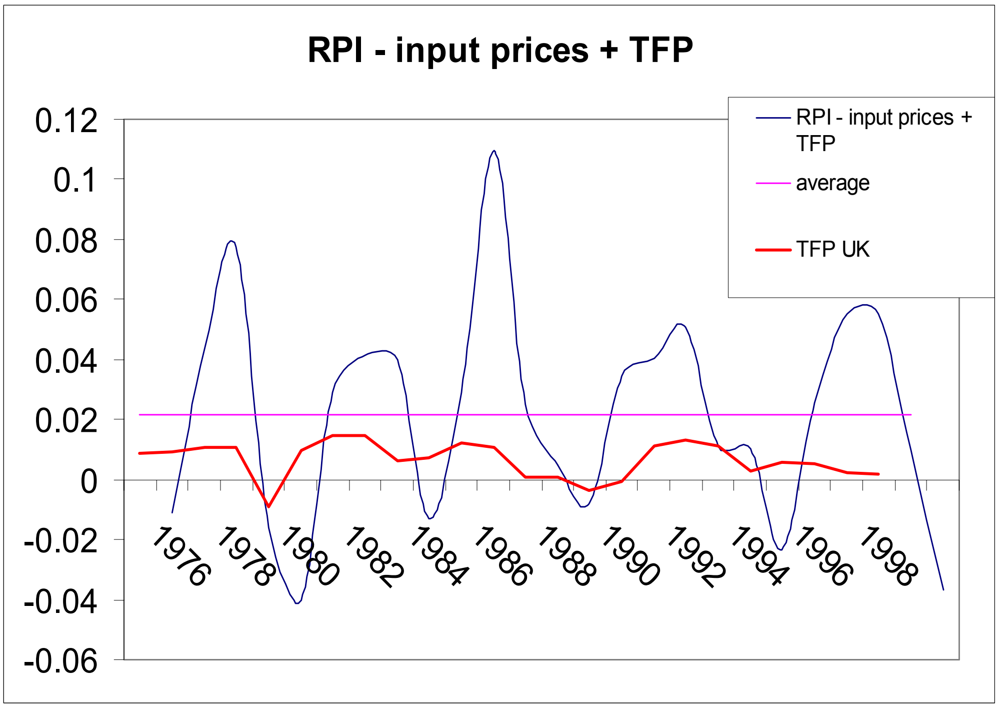
[15] This is a standard assumption used in the methodology for capital input measurement.

[16] A slightly shorter sample period was used due to limited data on the capital side.

Finally, a gross input price index was also constructed. For this, we used a weighted-average of the labour price index, the ONS materials and fuels inputs PPI, and the capital cost index based on the user cost measure described previously. We used 20% for the share of intermediate inputs in UK economy. In this case, the results were little changed; the average was 2.2% per annum. Thus for all UK series, the resulting price cap would be biased about 2% upwards by the productivity-offset view of X.

What is the reason for this evident bias in the price cap from the substitution? In the UK RPI averaged about 2.6% annual growth, while unit labour costs grew at only about 1.59%, similarly, other input prices grew at about 1.54%, while the cost of capital as measured by the user cost approach actually fell slightly –(1.2%), reflecting falling real interest rates and rising asset prices. At the same time, TFP growth was about 0.7% from 1976 to 2000. In addition, there seems to be a significant periodicity in the degree to which RPI exceeds TFP less input price growth in the economy overall as evidenced by the figure.

Figure 1: RPI – input prices + TFP



3.1.2 US data

Similar data were obtained and tested for the US economy with broadly similar results. The ? CPI growth, less hourly compensation growth, plus TFP growth (BLS data) for 1970 – 2000 yielded an average annual figure of 1.29%. For the US data using the PPI for finished goods, and the PPI for crude materials as a measure of input price inflation we obtained results of 0.7 and 0.76% per annum respectively. Results from using data for input price growth using other PPIs, such as the all commodities PPI were similar. We also were able to extend the time series for the US data back to 1948 using the BLS PPI data for input price growth. The results were similar; with the crude materials PPI (along with CPI and TFP data) yielding a result of 1.2%, and all commodities PPI yielding 0.92% as measures of the upward bias in a hypothetical price cap.

The result we have uncovered flows from an empirical regularity. Output prices do not grow in unison with input prices less TFP. The empirical regularity, that (8) does not hold, implies that the zero profits condition for the whole economy[17] does not hold (or that some other measurement error is occurring).

3.1.3 Forecasting X and the productivity offset view of X

A final point of testing the productivity-offset view of X concerns the trends in X given trends in the underlying series: output prices, input prices, and TFP. First, it is generally believed[18] X should be prospective, i.e., it should be forecasted X, since this is setting prices for the future regulatory period. Thus forecastability should impact our choice of a

[17] Bernstein and Sappington show how to adjust for industry profits, but not whole economy profits. Although a symmetric adjustment for economy-wide profit is conceivable, it would likely lead to quite a complicated X factor.

[18] See for example, London Economic (2003).

definition of X. Practitioners using the productivity-offset definition of X in the US have used average annual growth rates from the past to forecast the offset X.

However, we believe that the forecasting of X based on past trends using the productivity offset definition of X can lead to price caps that look like past cost of service regulation. We feel this is also indicative of the flaws in this particular formulation of X[19]. To see this, consider an X that reflects the average annual growth rate of the estimated underlying parameters over a previous time period, say 10 years growth, 1989-99. We can rewrite:

$$\dot{p}_t^i = R\dot{P}I_t - \left[\left(T\dot{F}P_{89-99}^i - T\dot{F}P_{89-99}^e\right) - \left(\dot{w}_{89-99}^i - \dot{w}_{89-99}^e\right)\right] \tag{13}$$

Substituting the dual or price definitions of TFP into the above gives:

$$\dot{p}_t^i = R\dot{P}I_t - \left[\left(\left[\dot{w}_{89-99}^i - \dot{p}_{89-99}^i\right] - \left[\dot{w}_{89-99}^e - \dot{p}_{89-99}^e\right]\right) - \left(\dot{w}_{89-99}^i - \dot{w}_{89-99}^e\right)\right] \tag{14}$$

Cancelling terms gives:

$$\dot{p}_t^i = R\dot{P}I_t - \dot{p}_{89-99}^e + \dot{p}_{89-99}^i \tag{15}$$

Now consider if inflation is stable and set according to a monetary authority target rate, such as the one set by the Bank of England[20], then forecast inflation is broadly expected to equal past inflation: $R\dot{P}I_t \cong \dot{p}_{89-99}^e$. If inflation is not expected to change, then it must be true that:

$$\dot{p}_t^i \cong \dot{p}_{89-99}^i \tag{16}$$

[19] A preferred technique would be to investigate fully the time series properties of whatever definition of X is preferred. This, although previously difficult due to lack of data, is becoming more feasible as more and more data become available over time.

Under the productivity-offset view of X, if one forecasts X based on past averages, then one runs the risk that prices in the industry will grow at the same rate as which they did in the past. Given that the regulator, especially when switching from cost of service regulation, was looking for some method that would improve upon the past, it seems that the productivity-offset X runs the risk of doing no better than the past in terms of output price growth. While this is partly due to the forecasting method chosen, this method has been used in a number of jurisdictions (e.g., Boston Gas, the FCC) and detailed investigations into the time series properties of X and its forecastability have generally not been undertaken to the best of our knowledge.

4. ALTERNATIVE DEFINITION OF X

In the simplest terms, X should be based on the zero economic profits condition. For practical purposes this is closely approximated by expected industry TFP growth (plus an input price differential or real input price change factor). To see this, using the same notation as previously: Start with $\dot{p}_t^i = \dot{w}_t^i - T\dot{F}P_t^i$ and $\dot{p}_t^i \equiv R\dot{P}I_t - \dot{X}_t^i$. Recall that the former is derived from the zero profits condition and the definition of TFP growth, while the latter is the definition of the price cap. Setting them equal and solving for X, gives:

$$\dot{X}_t^i = T\dot{F}P_t^i + \left(R\dot{P}I_t - \dot{w}_t^i\right) \tag{17}$$

Under this derivation, X is TFP growth for the industry over the period, plus the differential between RPI and input price growth. If RPI growth is close to input price growth (which it tends to be empirically), then X is just TFP growth (i.e., X ≅ TFP). Rewriting the price cap under our alternative definition gives:

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[20] Past UK inflation of 2-2.5% has been very close to the Bank of England target rate.

$$\dot{p}_t^i = R\dot{P}I_t - T\dot{F}P_t^i + \left(\dot{w}_t^i - R\dot{P}I_t\right) \tag{18}$$

Thus, the price cap says the X factor is just TFP less real input price growth. Then prices in the economy rise in nominal terms at the rate of general inflation, less TFP growth, plus real industry input price growth.

There are a number of benefits to this definition relative to productivity-offset X. First, it is simpler. It requires fewer estimates of underlying data series as well. Second, it is more likely to return a price cap that limits the industry to zero economic profits, since it does not rely on a substitution that evidently does not hold empirically. Also, since when TFP growth is properly measured, TFP growth maps directly into unit cost savings, *ceteris paribus,* the formula for X as proposed is easily seen to map into cost savings for the consumer that would be in-line with what a competitive industry would have generated. The formula, as proposed, does not wash out the impact of expected TFP growth in the industry with a differential between it and economy-wide TFP growth.

The proposed X is superior to the 'judgemental' approach to X practiced in the UK as well. Regulatory uncertainty is reduced and the accounting for input price changes is explicit. The impact of input price changes, and therefore also of measurement error in input prices, is likely to be small; our only concern here is whether input prices are differentially biased vis-à-vis RPI growth.

5. CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

This paper has discussed alternative definitions of X in standard price caps. While price caps are not new, issues in the actual implementation of price caps remain unresolved. The paper compared and contrasted the UK style efficiency judgement X with the productivity-offset X often found in the US. The UK approach to X has been criticised for lack of transparency. While the US-style productivity offset X is more transparent, we presented evidence that a critical substitution in the derivation of the productivity-offset X in general does not hold empirically. We also showed how this 'differential of a differential' X might lead to growth in output prices that exceeded the dynamic zero profits condition. Further, the way X has been forecast in various jurisdictions under the offset view of X is likely to lead to price growth that is similar to the past – when the objective of the price cap is to do better. Finally, we proposed a simpler X that is more likely to ensure the zero profits condition, that is transparent, and that maps TFP growth less real input price increases directly into the final output prices of the industry under the price cap.

This research raises some important directions for the future. For example, have regulators in the US compensated for bias in the productivity-offset X with 'consumer dividend' factors? Does a rigorous but upward biased productivity offset X, adjusted downward with a consumer dividend factor, reduce or increase regulatory uncertainty relative to a 'judgemental' approach? If so, is there evidence that one approach has been superior to the other? Another area of further interest is the time-series properties of X. We have proposed that X is properly seen as a forecast for the ensuing price control period. Once X is derived more rigorously, it is then an empirical question as to how to best forecast X. Research on forecasting differentials between input price indices for industry and the economy might also prove fruitful.

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