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# OPEX-risk as a source of CAPEX-bias in monopoly regulation

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*Abstract*: This paper shows with a formal model that under monopoly regulation, OPEX-risk can be a source for a CAPEX-bias. If OPEX and CAPEX are substitutes, the regulated firm can reduce the risk of the firm and thereby reduce the true cost of capital by rebalancing OPEX and CAPEX. If the allowed rate-of-return on capital is not influenced by the firm's actions, this creates a margin between the allowed rate-of-return and the true cost of capital. We examine two remedies: first, fixed-OPEX-CAPEX-share (FOCS) which is a variation of TOTEX-regulation and second, OPEX-mark-up. FOCS internalizes the CAPEX-bias and can be implemented easily. The OPEX-mark-up is effective, but it will be challenging to reach the optimum.

*Keyword*: Capex-bias, Opex-risk, regulated monopoly

*JEL-classification*: K23, L12, L51, L9

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## 1. Introduction

There has been a renewed interest in the OPEX-CAPEX-incentive bias, also known as the CAPEX-bias (cf. Smith et al, 2019); OPEX stands for operating expenditures and CAPEX for capital expenditures. A CAPEX-bias is similar to the "gold plating" effect, developed by Averch and Johnson in their seminal 1962 work (cf. eg. Borrmann & Finsinger, 1999). The topic was put on the regulatory agenda again by the UK water regulator Ofwat in 2010. Ofwat, and somewhat later the UK energy regulator Ofgem, subsequently changed the regulatory system to address the CAPEX-bias and implemented a variation of TOTEX regulation. Meanwhile, we observe similar discussions in other countries, like the US, Australia, Germany; we will provide a brief overview of the current debate further below.

With this article, we study one potential source of a CAPEX-bias under monopoly regulation: OPEX-risk. With this we mean the additional risk for the firm caused by an OPEX-activity, as opposed to a CAPEX-activity. To the best of our knowledge, OPEX-risk as a source for CAPEX-bias has not been studied in the academic literature. Extending the formal framework of Averch & Johnson (1962), we develop a regulatory model, which allows that a firm's operating decision influences the firm's risk profile. In the case that OPEX and CAPEX are substitutes, the firm can rebalance OPEX and CAPEX to change the overall level of risk. If regulation relates the regulated rate-of-return to the capital base, then rebalancing OPEX and CAPEX (reducing risk to an inefficient low level) creates a margin between the true cost of capital and the regulated rate-of-return; at the same time, an inefficient high level of CAPEX (and thus inefficiently high cost) is recouped as a cost-pass-through of the regulation. This leads to a CAPEX-bias.

Based on this, we explore two remedies: 1) a so-called fixed-OPEX-CAPEX-share (FOCS), which is a variation of TOTEX-regulation and 2) an OPEX-mark-up. As we will discuss, especially the fixed-OPEX-CAPEX-share seems promising to address the CAPEX-bias.

We note explicitly that this is problem of regulation. In an unregulated market environment, OPEX-risk would not lead to a CAPEX-bias. Furthermore, we note that this problem is not a problem of regulatory risk; it is a market risk, which has an effect because of the regulatory regime.

The structure of the paper is as follows. Section 2 provides definitions and a brief overview of the relevant literature. Section 3 provides the formal approach and shows the CAPEX-bias. Section 4 discusses the two potential remedies: first, the so-called fixed-OPEX-CAPEX-share, which is a variation of TOTEX-regulation and second, the OPEX-mark-up. Section 5 concludes.

## 2. OPEX-risk and regulation: background and literature

### 2.1. OPEX-risk

OPEX is short-lived, i.e. the operational expenditures are expenses on short-lived assets or otherwise items, which are fully used up within the accounting year. Therefore, OPEX is not depreciated and does not incur cost of capital. In contrast, an investment in a long-lived asset, which requires a certain capital expenditure (CAPEX), will take a long time before the investment is paid back. Thus, in contrast to OPEX, CAPEX requires binding capital for a longer period.

OPEX-risk is hardly mentioned in the finance literature in general. We only find hints on OPEX-risk in practical literature concerning the regulation of monopolies, as for example the consultancy firm ECA (2011, p. 2), the reports of the European energy regulatory agency ACER (2014, p. 9), or more recently, for Australian regulation (ENA, 2018).

We define OPEX-risk as the marginal risk for the firm caused by an OPEX-related activity. This is opposed to CAPEX-risk. Usually, and especially for practitioners, the difference is not very important; investors are interested in the risk of the entire firm, not in its source. If, however, OPEX and CAPEX are substitutes and we are interested in OPEX-CAPEX-incentive-biases, then the difference is important. Therefore, two examples illustrate what we mean by OPEX-risk.

First, an example from a competitive market, the insurance industry. As costs are incurred when the insured event occurs, they are considered OPEX and are risky by definition (although often capped). However, this OPEX uncertainty is not immediately passed through to revenues; rather, insurance policies rely on long-term contracts in which tariffs and other charges are clearly defined. The uncertainty, therefore, is actually a risk for insurance companies. We note explicitly, however, that OPEX-risk in an unregulated market environment does not lead to a CAPEX-bias; the CAPEX-bias following OPEX-risk, as we will argue below, is related to regulation.

Second, an example for the regulated network industries: replacement versus maintenance. As the network gets older, reliability decreases and the probability of breakdowns increases. The company has two options. First, it can replace the asset, which requires CAPEX. Second, it can maintain the asset and repair if it breaks down. This requires OPEX. Because the occurrence of a breakdown is uncertain, this is an OPEX-risk. To be precise, as we will set out below, the OPEX-risk is due to the regulatory lag in regulation.

## 2.2. OPEX-risk and the relation to monopoly regulation

We deal with OPEX-risk in the context of monopoly regulation of revenues or profits. In the debate on a CAPEX-bias in the regulated water industry in the UK, ECA (2011, p. 2) notes: "the main sources of systematic risk are likely to be in OPEX markets and in periodic review processes." The classical distinction in regulation is between cost-pass-through and price-based regulation. The most prominent example of the former is rate-of-return regulation and examples of the latter are RPI-X, price-cap and revenue-cap regulation (cf. Beesley and Littlechild, 1989; Sappington and Weisman, 2010). They have two important aspects in common: first, the regulatory lag within a regulatory period and second, the regulatory review. Figure 1 illustrates the regulation timeline.

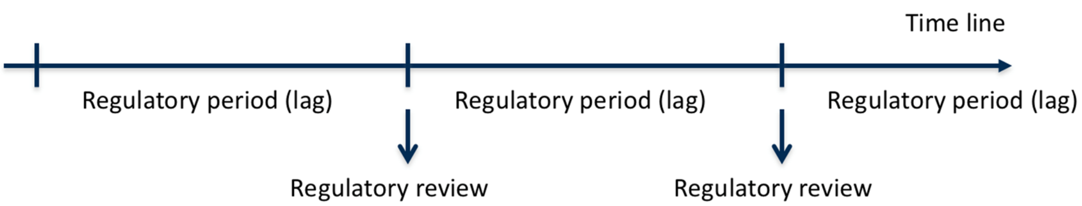


*Figure 1: The regulation timeline.*

During the regulatory lag, the development of allowed revenues is exogenously given by the regulation; the development is determined by the regulatory formula. During the regulatory lag, the revenues are delinked from underlying costs. If the firm decreases its costs during the regulatory lag, it will increase profits; on the other hand, if costs go up, those costs cannot be recouped. Hence, within this context, OPEX may be risky: if OPEX change during the regulatory lag, these changes are not passed through into revenues. Consequently, the firm bears the risk. The connection between revenues and underlying costs is restored at the regulatory review. The regulator adjusts the starting revenues for the next regulatory period to the firm's costs at that moment, after which the next regulatory period starts. At the regulatory review, the regulator determines a "fair and reasonable" rate-of-return on capital, which creates the potential incentives for a CAPEX-bias.

As Joskow (1989 and 2014) points out, in practice the different types of regulation may actually be quite similar. In cost-based approaches, the regulatory lag is endogenous and relatively short; in price-based approaches, the regulatory period is exogenous and relatively long, mostly 4 or 5 years. Cost-based models tend to emphasize the regulatory review and price-based models the regulatory period. In fact, however, all types of regulation include both aspects to some extent.

The combination of a regulatory lag and regulatory review sets our problem. The regulatory lag, during which revenues and costs are delinked, allows OPEX-risk. The regulatory review links revenues and costs and opens up potential for strategic behavior.

## 2.3. The CAPEX-bias in the literature

In their seminal contribution, Averch and Johnson (1962) showed the so-called gold-plating effect. They argue that regulation by means of an allowed rate-of-return on capital incentivizes a bias towards CAPEX and away from OPEX, if the allowed rate-of-return ("s") is higher than the cost of capital ("r"). The UK water regulator Ofwat (2011, p. 15) picks up precisely this point, where it states: "But in some cases, the regulator may – when assessing its duties in the short and long run – 'aim up' on the cost of capital to secure that efficient companies can finance their functions." Whereas the Averch-Johnson effect is often cited and well understood, the empirical relevance is ambiguous (cf. Borrmann and Finsinger, 1999, p. 353). Law (2014) conducts a meta-study on existing literature dealing with the overcapitalization in the regulated industries while distinguishing the different types of regulation as well as by separating theoretical and empirical conducted studies. He concludes that there is only little empirical evidence for an Averch-Johnson-effect in regulated utilities. Buranabunyut and Peoples (2012, pp. 182-186) provide an empirical study of the CAPEX-OPEX bias under regulation in telecommunications, which finds no bias under price-cap regulation, but does find a bias under rate-of-return regulation. However, in practice, we find hybrid forms of regulations, such that the conclusion on the existence of a CAPEX-bias is ambiguous.

Generally, we can distinguish three groups of causes of the CAPEX-bias:

1. CAPEX-advantage; in particular, if the regulated rate-of-return on capital is larger than the actual cost of capital. This is the case Averch and Johnson (1962) had in mind.
2. The details of the regulation may create a CAPEX-bias, especially due to *asymmetric* regulation of CAPEX and OPEX (cf. AER, 2014) or by details in the benchmarking (cf. Smith et.al., 2019).
3. OPEX-disadvantage; one example is that OPEX-risk (vis-à-vis CAPEX-risk) is not fully captured under the regulation. This is the topic we address in this paper.

In practice, this topic received renewed attention in recent years (cf. Smith et al., 2019). The UK water regulator, Ofwat (2011, pp. 15-18), discussed the issue in detail and provides a long list with possible drivers of the CAPEX-bias; we should note though that not all these drivers are equally convincing. NERA (2016) analysed the problem especially in the context of smart electricity grids. The European association for electricity distribution system operators EDSO (2017, p. 4) draws attention to a CAPEX-bias for electricity distribution networks. Bade (2016, p. 10) refers to the state regulator in New York claiming a CAPEX-bias; discussing the same developments in New York, Makholm (2016) is more critical towards a CAPEX-bias. The energy regulator in Australia, AER (2014) stresses balanced and symmetrical CAPEX- and OPEX-treatment to avoid a CAPEX-bias. Frontier Economics (2018) deals with an analysis of TOTEX for Australian energy regulation that was triggered by the existing CAPEX-bias of the former regulatory design. The energy regulator in Germany found that the new incentive regulation, in effect since 2019, which treats CAPEX and OPEX asymmetrically, induce a CAPEX-bias (Consentec and Frontier Economics, 2019, p. 105).

One of the most promising solutions for the CAPEX-bias is a variation of TOTEX-regulation; it has been implemented in the UK for the regulation of water and energy networks (cf. Ofwat, 2011; Oxera, 2014; Ofgem, 2017, pp. 14/15; Smith et al, 2019; and Oxera, 2019). We call this a "fixed-OPEX-CAPEX-share (short: FOCS)". The idea is straightforward. Under FOCS, all expenditures, whether for capital goods (CAPEX) or operational measures (OPEX), are treated equally as TOTEX. A fixed share, the capitalization rate of this TOTEX, is then "capitalized" (quasi-CAPEX) and the remaining part is volatilized as quasi-OPEX ("pay-as-you-go"). This capitalization rate is given: fixed-OPEX-CAPEX-share. In the regulation, the resulting quasi-CAPEX and quasi-OPEX are treated in exactly the same way as the CAPEX and OPEX in the normal system. The quasi-CAPEX go into the regulatory capital base and generate depreciation and interest. The quasi-OPEX are booked within the book year. This way, cet. par. the firm is actually indifferent between CAPEX and OPEX and thus the CAPEX-bias is internalized. We will discuss the fixed-OPEX-CAPEX-share in more detail in section 4 below.

In what follows, we analyse one specific source of a CAPEX-bias: OPEX risk. To the best of our knowledge, this has not been done in the literature so far.

# 3. OPEX-risk and the CAPEX-bias: the model

## 3.1. Preliminaries and assumptions

### Production factors OPEX and CAPEX

To model the OPEX-risk in a regulatory setting with the aim to show the CAPEX-bias, we rely on the well-known Averch-Johnson (1962) framework and the exposition of this model in Braeutigam (1981) and in the textbook by Borrmann and Finsinger (1999). We follow the notation of these sources.

For OPEX we take the cost of labor, $wL$, where $L$ is the amount of labor and $w$ is the price of labor. Obviously, $wL$ can be replaced by any source of OPEX. For CAPEX we take the cost of capital $(r + \beta)K$, where $K$ is the amount of capital and $(r + \beta)$ is the risk-adjusted price of capital; $r$ is the risk-free interest rate and $\beta$ is the risk-premium. In our approach, we take $w$ and $r$ as given; these are market prices and cannot be influenced by either the company or the regulator. Hence, the variables for OPEX and CAPEX, which are under the control of the firm, are the quantities *L* and *K*. Importantly, we focus exclusively on the case where OPEX and CAPEX are substitutes.[3]

## Setting the regulatory constraints

The OPEX-risk is part of the cost of capital: the investors on the capital market only charge for providing capital, which includes the overall risk, independent of whether it is CAPEX- or OPEX-risk. Similarly, the risk-beta, as estimated by the CAPM-models, represents the overall risk of the company, irrespective of the source of the risk. We assume that the same is reflected in the regulation constraint: the regulation is a constraint on the rate-of-return on capital, which reflects the overall risk, but does not distinguish between OPEX- and CAPEX-risk.

In our base model, following Averch-Johnson (1962), the regulatory constraint is the allowed rate-of-return on capital, denoted by $s$. But how is $s$ determined? Importantly, the regulator cannot determine this from the regulated company's data; i.e. the regulator cannot simply look at the capital costs of the company and then derive $s$ from this. Alternatively, as is common regulatory practice, $s$ is determined *externally*. A common way of doing this is to apply the CAPM-approach (cf. eg. Brealey, Myers and Allen, 2017, 12th ed.) to determine the comparative risk-adjusted cost of capital ($r + \beta$). Usually, regulators use historic data of national or international peer firms (in the same or a similar industry) and estimate an average for a prespecified number of years, depending on the considered investment horizon. The consequence of the notion that $s$ is determined externally is that company does not affect $s$ if it balances OPEX and CAPEX. Thus, whereas the company can affect its risk by balancing OPEX and CAPEX, it does not affect the regulatory constraint $s$.

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[3] In practice, in many cases, OPEX and CAPEX are complements or are simply unrelated; these cases are irrelevant if the topic is the bias of production factors. Therefore, we restrict our attention to the set of cases where OPEX and CAPEX are substitutes, such that the firm has to make a choice between OPEX and CAPEX.

## Risk-$\beta$ as a function of $K$ and $L$

Define $\beta(.)$ as the risk factor in the cost of capital, defined as $\beta_i = \frac{Cov(r_i;r_M)}{{\sigma_M}^2}$. This beta value is a measure for the systematic risk, that cannot be diversified away by the market. It includes elements affected by operational business that vary over time and cannot be passed through in terms of their costs but also the usual financing costs of equity investors. For expository convenience, we assume a fully equity-financed firm. This allows us to set the cost of capital equal to the equity costs.[4]

We assume that the overall risk of the firm is a function of OPEX and CAPEX, expressed with the variables $L$ and $K$: $\beta(L, K)$. Furthermore, for the purpose of this paper, we assume that risk increases in $L$ and decreases in $K$: $\beta_L = \frac{\partial \beta}{\partial L} > 0$ and $\beta_K = \frac{\partial \beta}{\partial K} < 0$.[5,6] Recall that we assume that OPEX and CAPEX are substitutes. The background is that $\beta(.)$ is a function of the OPEX-risk and the share of operational expenditures compared to total expenditures, as well as the CAPEX-risk and the according share of capital expenditures compared to total expenditures. If $L$ increases, this has two implications for the risk per unit of capital. First, the overall risk-$\beta$ increases, as a larger part of production costs is OPEX resulting in higher absolute OPEX-risk. Second, the consequently higher risk is spread over a smaller capital base, increasing the risk per unit of capital.

More intuitively, this means that both OPEX and CAPEX can create risk at a different degree. The firm can substitute or balance OPEX ($L$) and CAPEX ($K$) to optimize the degree of risk. If regulation relates the regulated rate-of-return to $K$, then rebalancing between $L$ and $K$ (reducing risk to an inefficient low level) creates a margin between the true cost of capital and the regulated rate-of-return. The inefficiently low $L$ and inefficiently high $K$ result in inefficiently high costs, which, however, are passed-through into the regulated revenues. In sum, as we will show below, a CAPEX-bias results.

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[4] This implies further that existing trade-offs with the optimal capital structure will not be addressed in this article.

[5] Note on formulation: Subscripts always denote first-order derivatives.

[6] To be precise, whether the first-order effect of $K$ on $\beta$ is positive or negative is not at all that important for our model. In contrast, the assumption that the first-order effect of $L$ on $\beta$ is positive is important.

## 3.2. The model

The revenue ($R$) is a function of the production function $f(L,K)$: $R(f(L,K))$, with the derivative $R_f > 0$. The production function $f(L,K)$ is twice differentiable:

$$f_L = \frac{\partial f}{\partial L} > 0, \qquad f_K = \frac{\partial f}{\partial K} > 0, \qquad f_{LL} = \frac{\partial^2 f}{\partial L^2} < 0, \qquad f_{KK} = \frac{\partial^2 f}{\partial K^2} < 0.$$

Define the costs of the firm as:

$$C(L,K) = wL + (r + \beta(L,K))K \tag{1}$$

As explained above, the factor price $w$ is the price for labor $L$; the term in brackets constitutes the capital cost composed of the risk-free rate $r$ and the risk premium $\beta$. The profit is then given by:

$$\pi(L,K) = R(f(L,K)) - C(L,K) \tag{2}$$

and the regulatory constraint:

$$R(f(L,K)) - wL \leq sK \tag{3}$$

Here, $s$ is the regulated risk-adjusted rate-of-return on capital. It contains a measure of the overall risk of the company and does not differentiate between CAPEX- and OPEX-risk.

Forming the Lagrangian:

$$\begin{aligned} \mathcal{L}(L,K,\lambda) = R(f(L,K)) - wL - \big(r + \beta(L,K)\big)K \\ - \lambda[R(f(L,K)) - wL - sK] \end{aligned} \tag{4}$$

Taking first-order conditions:

$$\begin{aligned} \mathcal{L}_L &= R_f f_L - w - \beta_L K - \lambda\big[R_f f_L - w\big] = 0 \\ \mathcal{L}_K &= R_f f_K - (r + \beta) - \beta_K K - \lambda\big[R_f f_K - s\big] = 0 \\ \mathcal{L}_\lambda &= R(f(L,K)) - wL - sK = 0 \end{aligned} \tag{5}$$

After rearranging terms, and dividing $f_K$ by $f_L$, it follows:

$$\frac{f_k}{f_L} = \frac{(r+\beta) + \left(\frac{1}{1-\lambda}\right)\beta_K K - \left(\frac{\lambda}{1-\lambda}\right)\left(s-(r+\beta)\right)}{w + \left(\frac{1}{1-\lambda}\right)\beta_L K} \tag{6}$$

Note that the terms $\beta_K K$ and $\beta_L K$ express the marginal effects of $L$ and $K$ on risk. To compare, the reader may note that the usual well-known Averch-Johnson-equation appears if we would assume $\beta_L = \beta_K = 0$, as should be. Our contribution is to analyze the effect of $L$ and $K$ on the risk-$\beta$, which is not included in the basic Averch-Johnson-framework. Therefore, if we would assume $\beta_L = \beta_K = 0$, we should expect the familiar Averch-Johnson-effect. With these preliminaries, we can now turn to our main result.

### 3.3. Result: the CAPEX bias

As a reference, we first derive the undistorted equilibrium, denoted with asterisk (*), which results if we optimize the use of production factors without regulation. Of course, this would result in a monopoly outcome with inefficiently low output, but there would be no bias in production factors, which means that a given output would be produced at least costs. This is equivalent to a regulation that is not binding, which technically means $\lambda = 0$. Hence, we end up with:

$$\frac{f_K^*}{f_L^*} = \frac{(r+\beta^*) + \beta_K^* K^*}{w + \beta_L^* K^*} \tag{7}$$

The undistorted equilibrium implies that the ratio of marginal values of production factors should equal the ratio of marginal costs of these production factors. Here, due to our formulation, this reflects the marginal impact of $K$ and $L$ on risk.

Based on this, we derive the long-run ratio of production factors under regulation; we denote the distorted outcome with superscript “D”. We assume that in the long-run equilibrium, regulation recovers total costs: $s = r + \beta$. Recall, in general, the regulator does not differentiate between OPEX- and CAPEX-risk explicitly, but includes all risk implicitly in the rate-of-return on capital. Substituting the assumptions gives:[7]

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[7] Strictly speaking, the value of the regulatory constraint λ also changes and should have a superscript. As we do not explicitly use this, for ease of notation, we refrain from a superscript for λ.

$$\frac{f_K^D}{f_L^D} = \frac{(r+\beta^D) + \left(\frac{1}{1-\lambda}\right)\beta_K^D K^D}{w + \left(\frac{1}{1-\lambda}\right)\beta_L^D K^D} \tag{8}$$

**Proposition:** In the long-run equilibrium (given the regulation as specified in the regulatory constraint), OPEX-risk leads to a systematic CAPEX-bias:

$$\frac{f_K^D}{f_L^D} < \frac{f_K^*}{f_L^*} \qquad \text{and thus} \qquad \frac{K^D}{L^D} > \frac{K^*}{L^*} \tag{9}$$

If instead no long-run equilibrium exists, we end up with a corner-solution with very large $K$.

**Proof**: Denote the right-hand-side of equation (7) as function $g(K)$ and the right-hand-side of equation (8) as function $h(K)$. For $0 < \lambda < 1$, it follows unambiguously, that $h(K) \leq g(K)$ for any $K$. Since $f_K/f_L$ is downward sloping in $K$ and $h(K) = g(K)$ for $K = 0$, it must be the case that $K^D > K^*$ and thus ceteris paribus $L^D < L^*$. **QED**

The figure below illustrates this graphically. The equilibrium is given by $g(K) = f_K/f_L$ and $h(K) = f_K/f_L$, respectively.

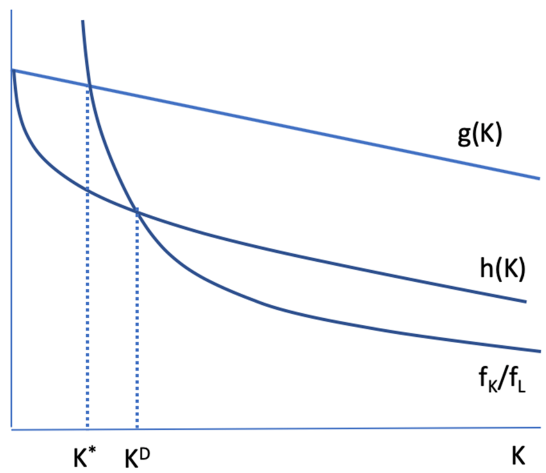


*Figure 2: illustration of the proof of the position.*

There is an intuitive way to see that the opposite cannot work. Suppose $h(K) > g(K)$ (which actually requires $\lambda < 0$) the long-run equilibrium would imply $K^D < K^*$. This situation implies that the firm decreases $K$ and increases $L$ (i.e. an OPEX-bias) as compared to the undistorted outcome. However, under our assumptions, this means that *both* the risk and the costs have increased. This runs counter to the regulation, because $(r + \beta) > s$. What happens is that the regulation gets more binding and, formally, $\lambda$ rapidly increases and goes to 1, bringing $h(K)$ down, such that $h(K) \leq g(K)$.

Lastly, depending on the assumptions of the second-order derivatives of $\beta(L,K)$, an equilibrium may not exist. This can happen if for example the effects of $K$ and $L$ on risk are strong and increasing. In this case, $h(K)$ may go down faster than $f_K/f_L$, such that there is no point of intersection at all, as $h(K)$ always lies well below $f_K/f_L$. In this case, a corner-solution results with very large $K$. As we hold this case for not empirically relevant and do not explore this case further.

What is the intuition behind this distortion? The firm can influence the regulation at the regulatory review. At this moment, the parameters for the next regulatory period are determined. Firstly, the starting revenues are based upon real costs – hence, at that moment, the firm's costs are passed through. Secondly, the allowed rate-of-return on capital $s$ is determined. As we explained above, this is not determined by the data of the firm itself, but it is determined externally relying on other companies. Hence, for the firm, $s$ is a benchmark, which it does not influence. The firm can influence the regulation by reducing its risk at the expense of higher costs. By targeting an inefficient high level of CAPEX (and inefficiently little OPEX), the firm reduces risk and thus $(r+\beta)$, while $s$ stays at the same (externally determined) level. As a result, $s > (r+\beta)$, creating a margin for excess profits. This risk-rebalancing comes at the expense of higher costs (due to inefficient production), but at the regulatory review these are passed through. In one sentence: regulated companies can have an incentive to shy away from risky OPEX.

The reader should note that the result above only applies to cases of regulation; it does not apply to a general competitive market context. It is precisely the regulatory review which distinguishes a regulated business from a market business: the market will adjust revenues to the cost of the entire industry, but not to the cost of an individual firm.

## 4. Two potential remedies

In this section, we discuss two potential remedies: first, the so-called fixed-OPEX-CAPEX-share (FOCS), which is a variation of TOTEX-regulation and second, the OPEX-mark-up. We will show below that especially the fixed-OPEX-CAPEX-share is very promising to address the CAPEX-bias.

### 4.1. TOTEX-regulation: fixed-OPEX-CAPEX-share (FOCS)

Recall that the regulatory problem is that the risk-adjusted rate-of-return is based on $K$. By rebalancing $L$ and $K$, the firm can lower the true cost of capital under the regulated rate-of-return, and so create a profit margin. If this is the problem, the intuitive answer would be a mark-up on total costs (TOTEX)[8], instead of on just one of the production factors.

TOTEX-regulation is well established in the literature, especially by Braeutigam (1981) and Finsinger and Kraft (1984), who call this approach mark-up regulation. Recently, a new variation of TOTEX-regulation was implemented exactly to address the CAPEX-bias in water and energy regulation in the UK (Ofwat, 2011; Ofgem, 2017, pp. 14/15; cf. oxera, 2019). Under FOCS, all expenditures, whether for capital goods (CAPEX) or operational measures (OPEX), are treated equally as TOTEX. A fixed share, the capitalization rate (here "$\alpha$"), of this TOTEX is then "capitalized" (quasi-CAPEX) and the remaining part (here: "1-$\alpha$") is volatilized as quasi-OPEX ("pay-as-you-go"). The capitalization rate is given and set by the regulator: the fixed-OPEX-CAPEX-share. In the regulation, the resulting quasi-CAPEX and quasi-OPEX are treated in exactly the same way as the CAPEX and OPEX in the normal system. The quasi-CAPEX go into the regulatory capital base and generate depreciation and interest. The quasi-OPEX are booked within the fiscal year. Below, we will model the fixed-OPEX-CAPEX-share (FOCS) and show that it actually internalizes the CAPEX-bias.

Profits are as described above in eq. (2). The regulatory constraint is somewhat different from the above. Define total costs as in eq. (1):

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[8] Strictly speaking, TOTEX and total costs are not the same, because the former is expenditure and the latter are depreciated costs. We ignore this difference here. In practical implementation in the UK, TOTEX (total expenditure) is used.

$$C(L,K) = wL + (r + \beta(L,K))K \tag{10}$$

With

$$\frac{\partial C}{\partial L} = w + \beta_L K \tag{11}$$

$$\frac{\partial C}{\partial K} = (r + \beta) + \beta_K K \tag{12}$$

The FOCS-mechanism collects all expenses into total costs and then splits the total costs in quasi-OPEX and quasi-CAPEX, following a predetermined capitalization rate, $\alpha$:

$$C(L,K) = (wL)^F + \big((r + \beta)K\big)^F = (1 - \alpha)C(L,K) + \alpha C(L,K) \tag{13}$$

Where the superscript "F" stands for FOCS. The regulatory constraint sets a mark-up, $\mu$, on quasi-CAPEX; this corresponds to the usual regulated rate-of-return on capital (as "s" above), but specified in a slightly different way.

$$R(f(L,K)) \leq (1 - \alpha)C(L,K) + \mu\alpha C(L,K) = (1 - \alpha + \mu\alpha)C(L,K) \tag{14}$$

Forming the Lagrangian:

$$\begin{aligned} \mathcal{L}(L,K,\lambda) = R(f(L,K)) - wL - \big(r + \beta(L,K)\big)K - \\ \lambda[R(f(L,K)) - (1 - \alpha + \mu\alpha)C(L,K)] \end{aligned} \tag{15}$$

The reader may note that the term $(1 - \alpha + \mu\alpha)$ is a construct of constant parameters, set by the regulator. It is then immediately obvious that this mechanism boils down to the well-known TOTEX-mark up, as in Braeutigam (1981).

Taking first-order conditions:

$$\begin{aligned} \mathcal{L}_L &= R_f f_L - (w + \beta_L K) - \lambda\big[R_f f_L - (1 - \alpha + \mu\alpha)(w + \beta_L K)\big] = 0 \\ \mathcal{L}_K &= R_f f_K - ((r + \beta) + \beta_K K) - \lambda\big[R_f f_K - (1 - \alpha + \mu\alpha)\big((r + \beta) + \beta_K K\big)\big] \\ &= 0 \\ \mathcal{L}_\lambda &= R(f(L,K)) - (1 - \alpha + \mu\alpha)C(L,K) = 0 \end{aligned} \tag{16}$$

Working out and rearranging terms, yields:

$$\frac{f_K^F}{f_L^F} = \frac{(r + \beta^F) + \beta_K^F K^F}{w + \beta_L^F K^F} \tag{17}$$

where the equilibrium values are denoted with superscript "F" (standing for FOCS). This is exactly the undistorted outcome as specified further above in eq. (7): the fixed-OPEX-CAPEX-share (FOCS) results in an optimal factor balance.

Note that we have shown that FOCS internalizes the CAPEX-bias resulting from OPEX-risk. But this is in fact a special case; more generally, FOCS internalizes the CAPEX-bias (or OPEX-bias for that matter) irrespective of the source of the bias.[9]

For practical implementation of the fixed-OPEX-CAPEX-share, several important details need to be cleared (cf. oxera, 2019). In particular, the capitalization rate needs to be set. Furthermore, for sufficiently high capitalization rate, part of OPEX is actually transferred into quasi-CAPEX and is treated as such: for this, a deprecation rate needs to be determined. It goes beyond the scope of this paper to go into detail. For here, it suffices to say that FOCS can actually be implemented quite easily.

### 4.2. OPEX mark-up

Another potential remedy would be to increase profitability of OPEX and reduce proportionally the profitability of CAPEX. For this, we define a regulatory OPEX mark-up $\gamma$. As there is a regulated rate-of-return on capital, this needs to be adjusted if there also is an OPEX mark-up. Thus, we denote the so adjusted rate-of-return on capital as $\sigma$.

Our approach is similar to the approach in Braeutigam (1981, p. 19, type 2), where the approach, similar to the OPEX-mark-up, is called "regulation of the operating ratio". Braeutigam defines a mark-up on operating costs above real costs, while there is no rate-of-return for CAPEX; not surprisingly, an OPEX-bias results, which is a "reversed" Averch-Johnson-effect. Yet, we have taken a slightly more refined approach, such that the OPEX mark-up and subsequent CAPEX-deduction can be balanced to find the optimal factor balance. The main effect of the OPEX mark-up is the same as in Braeutigam: it reduces or eliminates the CAPEX-bias.

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[9] As FOCS seems to provide a rate-of-return on capital to OPEX, whereas OPEX does not incur cost of capital, it seems as if it is similar to an OPEX-mark-up. This is not the case. The mechanism transfers OPEX into quasi-CAPEX, after which it is actually depreciated over a longer time and these quasi-CAPEX do actually incur capital costs, which are remunerated by the regulated rate-of-return.

The regulatory constraint is:

$$R(f(L,K)) \leq \gamma L + \sigma K \tag{18}$$

Forming the Lagrangian:

$$\mathcal{L}(L,K,\lambda) = R(f(L,K)) - wL - \big(r + \beta(L,K)\big)K - \\ \lambda[R(f(L,K)) - \gamma L - \sigma K] \tag{19}$$

Taking first-order derivatives gives:

$$\begin{aligned} \mathcal{L}_L &= R_f f_L - w - \beta_L K - \lambda\big[R_f f_L - \gamma\big] = 0 \\ \mathcal{L}_K &= R_f f_K - (r + \beta) - \beta_K K - \lambda\big[R_f f_K - \sigma\big] = 0 \\ \mathcal{L}_\lambda &= R(f(L,K)) - \gamma L - \sigma K = 0 \end{aligned} \tag{20}$$

Below we denote equilibrium values with superscript "OM" (meaning OPEX-mark-up). Rearranging gives:

$$\frac{f_K^{OM}}{f_L^{OM}} = \frac{(r + \beta^{OM}) + \left(\frac{1}{1-\lambda}\right)\beta_K^{OM}K^{OM} - \left(\frac{\lambda}{1-\lambda}\right)\left(\sigma - (r + \beta^{OM})\right)}{w + \left(\frac{1}{1-\lambda}\right)\beta_L^{OM}K^{OM} - \left(\frac{\lambda}{1-\lambda}\right)(\gamma - w)} \tag{21}$$

We can rewrite this more conveniently, using the identity:

$$\left(\frac{1}{1-\lambda}\right) = \left(\frac{1-\lambda}{1-\lambda}\right) + \left(\frac{\lambda}{1-\lambda}\right) \tag{22}$$

Equation (21) can thus be rewritten as:

$$\frac{f_K^{OM}}{f_L^{OM}} = \frac{(r + \beta^{OM}) + \beta_K^{OM}K^{OM} - \left(\frac{\lambda}{1-\lambda}\right)\left(\left(\sigma - (r + \beta^{OM})\right) - \beta_K^{OM}K^{OM}\right)}{w + \beta_L^{OM}K^{OM} - \left(\frac{\lambda}{1-\lambda}\right)\left((\gamma - w) - \beta_L^{OM}K^{OM}\right)} \tag{23}$$

The first part is precisely the undistorted equilibrium. From this, it follows that the OPEX mark-up reaches the optimal undistorted equilibrium if the following two conditions are met:

$$\left(\sigma - (r + \beta^{OM})\right) - \beta_K^{OM}K^{OM} = 0 \tag{24}$$

*and*

$$(\gamma - w) - \beta_L^{OM}K^{OM} = 0 \tag{25}$$

With $\gamma > w$ and $\sigma < r + \beta$ and $\beta_L = \frac{\partial \beta}{\partial L} > 0$ and $\beta_K = \frac{\partial \beta}{\partial K} < 0$, it can easily be shown that these conditions can both be met. This means that the OPEX mark-up ($\gamma > w$) should be in line with the marginal effect of OPEX on risk ($\beta_L = \frac{\partial \beta}{\partial L} > 0$) *and* similarly, the corresponding CAPEX-deduction ($\sigma < r + \beta$) should reflect the marginal effect of CAPEX on risk ($\beta_K = \frac{\partial \beta}{\partial K} < 0$). From this, it follows that if $\gamma > w$ (OPEX mark-up) and $\sigma < r + \beta$ (CAPEX deduction), the CAPEX-bias, as established in the proposition, gets smaller. In fact, if the OPEX mark-up becomes too large, regulation might overshoot which reverses the situation and leads to an OPEX-bias.

Hence, the OPEX mark-up can reduce the CAPEX-bias effectively. However, reaching the optimal undistorted outcome will be challenging and seems coincidental. The regulator will have to set optimal values for the OPEX mark-up and the CAPEX deduction, which rely on the marginal impacts of OPEX and CAPEX on risk. It is not clear whether such information would be available.

Notwithstanding the difficulties mentioned above, the OPEX mark-up seems effective and focused. It can quickly and pointedly address urgent problems. A selective, transitory OPEX mark-up for demarcated selected fields, where the regulator feels that something needs to be done urgently, the OPEX mark-up will certainly promote activities. It is a very pragmatic approach and does not aim for academic precision.

## 5. Conclusions

In this paper, we show that under monopoly regulation, OPEX-risk can be a source of CAPEX-bias. With OPEX-risk we mean the additional risk for the firm caused by an OPEX-activity, as opposed to a CAPEX-activity. Importantly, we restrict attention to cases where OPEX and CAPEX are substitutes. Our formal model extends the classical approach by Averch and Johnson (1962).

The argument developed in this article is as follows. The firm can influence the regulatory parameters for the next regulatory period at the regulatory review. For the firm, the allowed rate-of-return on capital is an external benchmark, which it cannot influence. Under the regulation, the strategic incentive for the regulated firm is to reduce overall risk at the expense of higher costs. By using inefficiently much CAPEX (and inefficiently little OPEX), the firm reduces risk, while the allowed rate-of-return on capital stays at the same (externally determined) level. As a result, the allowed rate-of-return on capital is higher than the true cost of capital, creating a margin for excess profits. This risk-rebalancing comes at the expense of higher costs (due to inefficient production), but these are passed through in the regulated revenue. This establishes the CAPEX-bias.

We discuss two potential remedies: 1) the so-called fixed-OPEX-CAPEX-share (FOCS), which is a variation of TOTEX-regulation and 2) an OPEX-mark-up. Especially FOCS is very promising to address the CAPEX-bias. It effectively internalizes the CAPEX-bias and can easily be implemented. The OPEX mark-up is effective to reduce the CAPEX-bias and to promote OPEX, but it will be challenging to reach the optimum.

We note the following issue for further research. We have not provided empirical support for our claims. To the best of our knowledge, sufficient data are not available as yet. Nevertheless, we do acknowledge the importance of empirical evidence, but leave this now for further research.

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