Is a Little Sunshine All We Need? On the Impact of Sunshine Regulation on profits, productivity and prices in the Dutch drinking water sector.[*]

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Abstract

This paper analyzes the conduct of publicly owned monopolistic utilities regulated by a voluntary sunshine regulatory model (i.e. publication of the performances of utilities). In particular, we examine the behaviour of Dutch drinking water utilities before and after the introduction of the sunshine regulation. As during the period 1992-2006 several alternative regulatory reforms including privatization, yardstick competition and profit regulation were also seriously considered, we examine how the discussion and possible implementation of these reforms influenced the behaviour of the utilities. By decomposing profit change into its economic drivers (quantity effect, price effect, operating efficiency, technical progress, scale, etc.), our results suggest that in an appropriate political and institutional context, sunshine regulation can be an effective and appropriate

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mean of insuring that publicly organised services are efficiently and profitably provided. In methodological terms, the profit decomposition is extended to robust (i.e. allowing for stochastic elements) and conditional (i.e. accounting for heterogeneity) non-parametric efficiency measures.

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JEL-classification: C14, L33, L51, L95

1 Introduction

The regulation of public and private utilities changed significantly over the last 20 years as new ideas and paradigms were developed and dismissed (Crew and Kleindorfer, 2002). However, privatisation and regulation with an appropriate form of incentive regulation is widely considered to be an appropriate policy response. For a particular sector, the transition from one regulatory model to another also involves heated discussions. These debates often create instability in the regulated sector which in turn influences profits, investments, performance and prices (Parker, 1999). In this paper, we therefore consider the case of the publicly owned Dutch drinking water sector, which between 1992 and 2006 has experienced several abortive regulatory initiatives. However, this regulatory reform process has ultimately resulted in the retention of public ownership and the implementation of light-handed sunshine regulation regime. Therefore, consideration of the performance of the Dutch drinking water sector over this period allows a useful example of performance change in a utility sector that has not followed the more conventional approach of privatisation and establishment of an incentive regulation regime (cfr. England and Wales).

The debate on reforming the Dutch drinking water utilities is part of a broader debate among both academics and practitioners (Bauer, 2005). The literature focuses especially on the privatization issue, regulatory problems (e.g. Ugaz and Price, 2003) or institutional structures (e.g. Spiller and Tommasi, 2004). Although connected to this branch of the literature, the focus of our analysis lies on the regulatory incentives which could arise from a (voluntary) publication of performances. In 1997, after several years of intense debate on the privatization of the Dutch drinking water sector resulting in a decision not to privatise, the Association of Dutch Water Companies (Vewin) started a sunshine regulation program with voluntary participation. In a sunshine regulatory model, the outcome of a benchmarking exercise (i.e. the comparison of utilities) is made publicly available so as to embarrass the least performing entities and to put the best performing entities into the limelight (for an extensive discussion of Dutch sunshine regulation, Wubben and Hulsink, 2003). Although sunshine regulation seems to result in significant efficiency gains (Dijkgraaf *et al.*, 2007; De Witte and Dijkgraaf, 2008), since 1992 the Dutch government also considered, but did not implement, several alternative regulatory approaches including privatization, yardstick competition (i.e. using the benchmark outcomes for determining maximum prices or revenues), profit regulation, and self-regulation of public companies. Furthermore, Dutch citizens, living in a country with a long history of public water management, are conscious of their role as indirect owners of the public drinking water utilities, and this results in edifying debates in the (financial and academic) press on the excessive profits, prices and returns on investment (e.g. van Damme and Mulder, 2006; NRC Handelsblad, 2007). Therefore, we can consider the Dutch drinking water sector as an interesting example where privatisation and the establishment of an incentive regulation regime were considered, but ultimately public ownership was maintained and an alternative sunshine regulation system was implemented. We therefore analyze this behavioral change using the non-parametric profit decomposition approach developed by Grifell-Tatjé and Lovell (1999, 2008). Inspired by their approach, we decompose profit change to identify its drivers (price, productivity, scale, etc.), and, in particular, to identify the conduct of the regional drinking water monopolists with respect to the regulatory changes.

This paper contributes to the literature by tackling six different issues. Firstly, we analyze the effectiveness of the voluntary sunshine regulatory model, in which (at first under the treat of privatization) firms committed themselves to publicize their performance. By comparing profits, quantity and price effects before and after the introduction of sunshine regulation and by pointing to different trends in the data, we shed light on the impact of the sunshine model on firm performance. Secondly, although the article does not intend to provide an exhaustive description of the Dutch drinking water sector (see Wubben and Hulsink, 2003; Kuks, 2006; Van Dijk *et al.*, 2007), it reviews the various debates on reform of the Dutch drinking water sector since 1992. Indeed, besides the introduction of sunshine regulation the sector faced discussion about privatization, yardstick competition, profit regulation, etc. Regulatory shifts and the preceding discussions are also found in other sectors (e.g. postal services, telecommunications, railway sector). However, the interesting characteristic of the Dutch drinking water sector is the extended time period (1992-2008) over which these debates have continued, and the ultimate retention of public ownership. Moreover, the wide ranging debate touched the very nature of drinking water provision by considering, private versus public water supply provision and how to design incentives for those private or public utilities. This analysis suggests that the regional drinking water monopolies anticipate potential regulatory changes and their resulting change in conduct subsequently delays or postpones the planned legislation. Our third contribution naturally follows, as we analyze the Dutch drinking water sector to investigate the behavior of the regional monopolists in this frequently changing regulatory environment. Monopolists can, in comparison to competitive firms, more easily seize the opportunity to increase prices and make excess profits. Thus, it is interesting to investigate how discussions on, e.g., a privatization, the incentive model or profits affect the behavior (in terms of profits, productivity, prices and activity) of regional monopolists. As a fourth contribution, an extensive panel data set (1992-2006) allows us to focus on overall efficiency by jointly considering the efficient use of both operating and capital costs. As such, the efficiency assessment in this paper is complementary to previous studies (e.g. Dijkgraaf *et al.*, 2007; De Witte and Dijkgraaf, 2008), which only consider operating cost efficiency. Fifthly, the paper directly responds to the current debate in the Dutch (financial and academic) press as to whether the recent profits in the drinking water sector are excessive, by closely examining the drivers of these profit changes. Following Grifell-Tatjé and Lovell (1999, 2008), we identify seven drivers for profit change: changes in (1) output prices (for both domestic and non-domestic customers), (2) input prices (for labor, capital and other inputs), (3) technical progress or regress, (4) catch-up by inefficient firms, (5) scale economies, (6) improved resource (i.e. input) mix and (7) improved product (i.e. output) mix. Moreover, given our panel data set, we are able to scrutinize the profit change and to determine the contribution of its seven drivers over the entire 1992-2006 period. To do so, the paper interprets the profit decomposition model of Grifell-Tatjé and Lovell (1999) with an input-orientation (i.e. for a given production of outputs, minimize input usage). As an input-oriented model is also natural for other industries with exogenous outputs (e.g. governmental services, health care, natural monopolies), our extension is not limited to the present application. Finally, we extend the basic efficiency evaluation model of Grifell-Tatjé and Lovell (1999, 2008) to a more advanced non-parametric model. In particular, we design a Data Envelopment Analysis (DEA) model which accounts for uncertainty in the sample (i.e. stochastic elements). These robust order-m efficiency estimates (Cazals *et al.*, 2002) allow for measurement errors, atypical observations and noise. By also employing the global DEA efficiencies proposed in Daraio and Simar (2007b) we incorporate heterogeneity in the efficiency analysis. As such, we account for the exogenous environment of the drinking water utilities. In addition, in a panel data set, we develop a non-parametric model which accounts for technical progress and regress.

The paper unfolds as follows. In the next section, we review the various debates on the regulatory model in the Dutch drinking water sector. Section 3 presents the input-oriented profit decomposition model while Section 4 outlines the methodology for estimating the unobserved quantities which are required for the profit decomposition. Section 5 discusses the particular application and its results. In the final section we offer our conclusions.

2 Regulatory discussions in the Dutch drinking water sector

The Dutch drinking water sector has experienced some remarkable discussions on its structure and the very nature of the regulatory model. Debates between advocates and opponents of privatization and strict regulation, have created several periods of instability in the Dutch drinking water sector. However, ultimately the sector has remained in public ownership and has come to be regulated with relatively light-handed sunshine regulation. Nevertheless, by analyzing several sector publications (mainly Waterspiegel published by the Association of Dutch Water Companies (Vewin), the annual accounts of the utilities and opinion articles in the Dutch financial press), we are able to distinguish four relatively distinct but nonetheless interrelated periods, which were characterized by somewhat different government policies and varying levels of instability. These findings are summarized on the time line in Figure 1. This section does not intend to exhaustively describe the history of the Dutch drinking water sector (see Kuks, 2006; Van Dijk *et al.*, 2007), but rather it summarizes changes in and debates about its structure and regulatory model.

**** The period 1992-1997 ****

Motivated by the Washington consensus and following the privatization waves in Western Europe, by the beginning of the 1990 the Dutch government implemented privatization and liberalization in several network sectors (e.g. telecommunication and energy sectors). Anticipating their own privatization, the Dutch drinking water utilities strove to increase their financial strength so as to be better prepared for the expected changes with respect to privatization and competition in the market (several annual accounts cite this). Indeed, if the government would decide to privatize the sector, the utilities realized that they would need to be 'attractive' to draw investments. As a result, profits were increased by raising water prices for both domestic and non-domestic customers, and these profits were justified as necessary to fund capital improvements. In addition, higher profits were deemed necessary to increase the capital ratio (i.e. shareholders' equity to liabilities) as it was anticipated that leverage levels would need to be lower under private ownership if private bank loans were to replace government debt as the primary source of debt funding. This resulted in a dramatic increase in economic profits. This increase is illustrated by the fact that in the sample of companies employed in our below empirical analysis, real (in 1995 prices) aggregate economic profits (calculated by total revenues minus total costs (detailed below) and differing from accounting profits reported by the utilities) increased dramatically from the equivalent of 4.3 million euros in 1992 to 177.4 million euros in 1996.

By the second half of the 1990s the Dutch drinking water sector had heavily debated its

1992	- Debate on the privatization of network industries
	- Large profits to increase attractiveness for investments
	- Significant increase in real drinking water price
1997	- Introduction of the voluntary benchmark by Vewin
	- Use of 1997 data for first public benchmark
1999	- Publication of 1997 benchmark
2000	- Use of 2000 data for second public benchmark
2001	- Publication of 2000 benchmark
	- Debate on the ownership in the drinking water sector (till 2003)
	- Debate on independent regulator and yardstick competition (till 2004)
	- Increasing product diversification and emphasize on innovations
2003	- Use of 2003 data for third public benchmark with a decreased participation
	- Moratorium on private investments: public sector by law
2004	- Publication of 2003 benchmark
	- Focus on environmental issues and innovations
2006	- Use of 2006 data for fourth public benchmark
	- Benchmarking is obligatory (in place in 2008)
	- Attention to ‘excessive’ profits and increased capital ratio
	- Investments are paid by cash flow (results in lower capital costs)
2007	- Publication of 2006 benchmark
	- Debate on dividend policy towards shareholders
Time	

Figure 1: Time line

monopolistic nature. A report for the Ministry of Housing, Spatial Planning and the Environment and the Ministry of Economic Affairs stated a clear relationship between monopolistic drinking water provision, which did not face price regulation, and the costs and prices for drinking water. The presence of a monopoly prevented any incentive to produce efficiently. Moreover, the reports authors argued that the introduction of incentive regulation would reduce water prices by at least 7% (Dijkgraaf *et al.*, 1997). However, despite this analysis, as well as the sector’s financial preparation for privatisation, there was in fact insufficient political support in the mid 1990s for the government to be able to actually implement privatisation of the sector. Given this political reality, policy makers sought a policy response that would allow for efficiency improvements while remaining public ownership, in at least the interim before future potential privatisation.

** The period 1997-2000 **

Initially, the Dutch drinking water sector organization Vewin was strongly opposed to any idea of strict incentive regulation. However, thanks to political pressures to increase transparency and efficiency in the sector and in order to avoid privatization which might become necessary without efficiency improvements (following the English and Welsh utilities), in 1997 Vewin started a voluntary benchmarking scheme which was used for sunshine regulation (Waterspiegel, 2001). As our results below suggest, this sunshine regulation was a landmark for the sector and dramatically altered the behaviour and performance of the water utilities.

Benchmarking is the comparison of utilities on one or several indicators and is applied in various regulatory regimes including those based on sunshine regulation and yardstick competition. The latter denotes the use of benchmarking results to determine maximum prices or revenues (as applied by the independent regulator in the privatized English and Welsh drinking water sector), the former uses benchmarking to 'embarrass' the least performing companies and to put the best performing in the limelight. The effectiveness of sunshine regulation depends on both internal and external carrots and sticks. In the Dutch drinking water sector, the internal incentives arrive from increased transparency, the diffusion of best practices by sector-specific workshops, improved knowledge of the priorities in the company and financial rewards for managers if they are able to improve the utility's position in the sunshine rankings. In addition, in their annual accounts the drinking water utilities explicitly set targets of their desired performance (e.g. a place in the top-three on all benchmarked issues). External incentives are driven by public interest in the water sector as the media heavily report the sunshine results. In addition, the water companies are owned by the provincial and municipal governments which in turn are elected by the citizens in the service area of the utility. As is common practice in the Netherlands, in the remainder of the text we will mix the terms of 'sunshine regulation' and 'benchmarking'.

The Vewin benchmark is implemented in a three year cycle by which in the first two years only costs are compared (these results are only internally published among the drinking water utilities) and in the third year an external 'benchmark' is generated which considers figures and ranking on quality, service, environmental issues and costs. The benchmark provides information at company level, process level (e.g. production, sales, distribution) and subprocess level (e.g. cost per km. mains). The first public benchmark considers 1997 data and was published in March 1999. Two years of internally benchmarking later, the second public benchmark analyses 2000 data and was published in November 2001. The third issue uses 2003 data (published November 2004) while the latest version considers 2006 information (published September 2007).

Considering operating cost efficiency, the few studies on the Dutch drinking water sector indicated some remarkable effects of the benchmark (Kuks, 2006; Dijkgraaf *et al.*, 2007;

De Witte and Dijkgraaf, 2008). Firstly, while water quality and service levels steadily increased, the sector experienced an efficiency increase of 23% between 1997 and 2006. In addition, triggered by the increased transparency and by the political pressures to create a drinking water company per province (because 100,000 connections was considered as a minimum size requirement and because of the strategic groundwater management duties of the 12 provinces) intensified merger activity arose from 1996 onwards. Thus, as a result, the number of drinking water companies halved between 1992 and 2007. However, especially the merged companies are evolving to even bigger companies due to additional mergers. Thus, of the 20 water companies in 1992, 6 utilities did not merge during the sample time period. Although the merging companies are claiming economies of scale, this is not found by recent empirical work (De Witte and Dijkgraaf, 2007). Conversely, by decreasing the number of reference observations in the benchmark, the mergers are reducing the potential effectiveness of benchmarking in identifying underperformance, a concern which is similar to that which has been observed in the privatized English and Welsh water industry.

** The period 2000-2003 **

After the introduction of sunshine regulation in 1997, the sector experienced a period of relative stability. Nevertheless, after two benchmarking reports with 1997 and 2000 data, in the period 2001-2003 the Ministry of Housing, Spatial Planning and the Environment again created uncertainty with regard to the status of the drinking water utilities by rediscussing ownership in the water sector (Eigendomswet). However, after two years of discussions (2001-2003), the apparent lack of political support for privatisation, and prompted by positive results from the sunshine regulation regime, by the end of 2003, the Dutch parliament reserved the drinking water sector as a public domain, which implied a moratorium on private investments. On balance, this policy decision was justified on the grounds that the sunshine benchmarking system was working to substantially improve efficiency, therefore making privatisation and formal incentive regulation unnecessary. The Dutch drinking water utilities therefore continue to be structured as Public Limited Companies (PLCs) in which the provinces and municipalities own the assets.[1] It is notable that the provinces are also responsible for regulating drinking water tariffs and, therefore, conflicts in interest may arise.

Linked with and started simultaneously with the ownership discussion, the government created additional instability in the monopolistic sector by proposing a new law which would have applied a form of yardstick competition to the sector. As such, the results of the benchmark (in the strict sense of the word) would no longer be used for light-handed sunshine regulation, but would instead be used for setting tariffs by an independent regulator.

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[1] As the sector has never experienced nationalization, part private ownership has been maintained in one firm as an historical legacy.

Moreover this regulator would carry out the (obligatory) benchmark instead of the sector organization Vewin. At this time, many drinking water utilities feared an over-emphasize on output prices and detailed these concerns in their annual accounts.

While the idea of establishing yardstick competition was (temporarily) buried by the beginning 2004 as a new Minister took office, it seems that the uncertainty relatively to the regulatory model undermined the willingness to participate in the voluntary benchmark. Whereas in 1997 and 2000, respectively, 78 and 71 percent of the companies participated, in 2003 this decreased to only two thirds of the utilities. Although all companies are officially in favor of benchmarking, in their annual accounts some companies commented on the imprecise methodology (e.g. measuring costs per m^3 or per connection could deliver significant different results). Others noted that they were merging or were about to merge and, therefore, 'had other priorities'. However, more likely than the cited reasons, the instability resulting from the potential change in regulatory model could have encouraged the companies to game the expected regulator by not publicizing cost information which could be used against them if maximum prices were set by an independant regulator (Jamasb *et al.*, 2003). Therefore, they did not participate the benchmark.

Although the benchmark was initially established as a voluntary project, given the relatively poor participation in the 2003 benchmark, the Dutch government decided in December 2006 to make the benchmark obligatory (with effect from 2008). This may have encouraged all the firms to voluntarily engage in the 2006 benchmark, but the government's decision to maintain the sunshine regulatory benchmark controlled by Vewin rather than establishing a yardstick regime administered by an independant regulator is also significant.

In 2001, several utilities' annual reports proudly mention the improved product diversification as they were increasingly delivering industrial water in various varieties. By using decentralized and customer tailored purification processes, the utility is able to boost production for industrial water customers and also reduce overall treatment costs. In the following years (up to 2006), product and process innovation becomes 'hot' as the government classifies the water sector as one of the key-innovation sectors to attain the EU Lisbon Strategy (i.e. the EU should become the most competitive and dynamic knowledge economy in the world by 2010).

** The period 2004-2006 **

During the period 2004-2005, the drinking water sector generally experienced a period of relative stability as the major debates were settled. This can to a certain extent be attributed to the responsible Minister who largely endorsed the viewpoints of the sector association Vewin and its administration of the sunshine benchmarking regime. Economic regulatory concerns are much less prominent during this period and environmental issues and innovative procedures and processes were therefore discussed more.

However at the beginning of 2004, for the first time and only very briefly, the discussion in the water sector focused on the absence of financial benefits, resulting from the benchmark, for the captive customers. The issue was initially dealt with by incorporating profit and capital ratios in the 2003 benchmark. More than two years later, after some critical articles in the press on 'excessive' profits and significantly increased capital ratios, public awareness increased again. Indeed, for the sample of firms in our below analysis, real (in 1995 prices) aggregate economic profits increased from 161.0 million euro in 2002 to 214.0 million euros in 2004 and 240.3 million euro in 2005. As a response, the sector gave increasing attention to drinking water prices in sector publications but, in contrast to the 2003 benchmark edition, the 2006 benchmark did not include any figures on profits or capital ratios. Nevertheless, in contrast to the preceding years aggregate real economic profits decreased to 208.8 million euro in 2006. In addition, the sector stressed that until 2000 drinking water prices increased more than the consumer price index (CPI), but from 2000 onwards drinking water prices increased less than CPI. However, given that economic profits in the industry remain very high relative to their level in the early 1990s, we would argue that these below inflation increases in water prices have not substantially eroded the high levels of economic profitability achieved in the sector.

Given the continued high profits in the industry, by 2006, the discussion shifted to the distribution of dividends. As drinking water companies are continuing to make large profits, debt levels have continued to decline. The public utilities point to the necessity and advantages of making (large) profits. Indeed, they argue that besides increasing the equity/debt ratio, profits are used to fund further capital investments. Therefore, investments are paid for by cash flow instead of borrowing money. This decreases the interest charges twice: on the one hand thanks to a lower interest rate (real interest rates decreased since 2001 in general and higher capital ratios further decreased the interest rate for particular utilities), on the other hand thanks to a lower borrowed sum. This in turn would decrease the drinking water tariffs in the long run.

For all utilities but one, the shareholders' meeting can decide on the payment of a dividend to the shareholders (i.e. mainly the provinces and municipalities). Some utilities decided not to return a dividend, whereas other opted for one percent point above the 10-year guild bond, still others return up to 57% of the profits to the shareholders. Interestingly, whereas the sector normally prefers self-regulation, several utilities have actually called for governmental regulation of dividend policies. However, the recent Drinking Water Law (2008) only states that the Minister and the sector will enter into an agreement. Thus, the issue of high profits in the industry and the appropriate distribution to government (shareholders) or water consumers through lower prices remains a highly relevant issue in the industry.

In sum, our brief review of the introduction of light-handed sunshine regulation and the various regulatory discussions over the past two decades suggests that the Dutch drinking water sector provides a somewhat unusual example that warrants careful analysis. This is the case, because the industry has undergone substantial mergers and adopted an alternative regulatory regime, despite the fact that it has not been privatised. Moreover, it has dramatically increased its profitability, which previous papers and general policy debate suggest may be attributable to improved efficiency/productivity and/or substantial increases in water prices for consumers. Given this, it is interesting to look behind the profit change by decomposing it into its underlying drivers. Moreover, by linking changes in profitability and its drivers to regulatory and structural changes that have occurred over the 1992-2006 period, we can better understand the drivers of performance in the Dutch drinking water industry. The two proceeding sections therefore develop a non-parametric model to do so.

3 Decomposing profit change

Consider n utilities which are using p heterogeneous and non-negative inputs x $(x_1, \ldots, x_p)$ to produce q heterogeneous and non-negative outputs y $(y_1, \ldots, y_q)$. The utilities buy inputs at input prices w $(w_1, \ldots, w_p)$ and sell outputs at output prices p $(p_1, \ldots, p_q)$, which could be either exogenously or endogenously determined. Economic profits π^t in time period t $(t = 1, \ldots, T)$ are determined as total revenues minus total costs:

$$\pi^t = \sum_{m=1}^{q} p_m^t y_m^t - \sum_{l=1}^{p} w_l^t x_l^t \tag{1}$$

where in the remainder of the article we will drop the subscripts and consider the variables as vectors. In their interesting contributions, Grifell-Tatjé and Lovell (1999, 2008) look at the change in economic profits between two time periods and decompose this profit change into its drivers. In particular, by rearranging the base period and comparison period units, Laspeyres (i.e. using units of the base period) and Paasche (i.e. using units of the comparison period) indices are obtained. Firstly, consider the decomposition of the profit change between period $t+1$ and period t into a quantity and a price effect:

$$\begin{aligned} \pi^{t+1} - \pi^t = \quad & \left[(y^{t+1} - y^t)p^t - (x^{t+1} - x^t)w^t\right] + \\ & \left[(p^{t+1} - p^t)y^{t+1} - (w^{t+1} - w^t)x^{t+1}\right]. \end{aligned} \tag{2}$$

The *quantity effect* (i.e. the first term in squared brackets) measures for constant base period prices the impact on profit change arising from the change in outputs relative to the change in inputs. As such, it measures the performance of the evaluated entity, while eliminating input and output price fluctuations. The *price effect* (i.e. the second term in squared brackets) estimates for a fixed reference basket the impact of input and output price fluctuations on the profit change between period t and $t+1$. The attractive feature of the Grifell-Tatjé and Lovell economic profit decompositions is that data from the annual accounts can be used without assuming profit maximization. In addition, the technique is fully non-parametric as it does not assume any *a priori* assumption on the production function.

To understand the latter, consider the two-dimensional Figure 2 with one input x on the horizontal axis (i.e. $p = 1$) and one output y on the vertical axis (i.e. $q = 1$). The production or technology set Ψ^t defines the set of all feasible input-output combinations in time period t:

$$\Psi^t = \left\{(x^t, y^t)|x^t \in \mathbb{R}^p_+, y^t \in \mathbb{R}^q_+, (x^t, y^t) \text{ is feasible}\right\}. \tag{3}$$

In a non-parametric setting, the production set is considered as a best practice frontier. Indeed, consider for example observation (x^t, y^t). All observations in the fourth quadrant relatively to (x^t, y^t) are, for at least the same output production y^t, using less inputs (e.g. observation x^A) and, thus, are dominating (x^t, y^t) in the input-orientation. Moreover, the observations in the fourth quadrant are, although using maximally the same amount of inputs x^t, producing more outputs (e.g. observation $x^{A'}$) and, thus, are dominating (x^t, y^t) in the output-orientation. Undominated observations constitute the best practice frontier and are defined as relative efficient. Dominated observations lie in the interior of the production set and are labeled as being relatively inefficient. We analyze the input and output-orientation more carefully.

Firstly, consider the input-orientation for which we define the input requirement set $C^t(y^t)$ as all input vectors which are able to produce output y^t with period's t technology: $C^t(y^t) = \left\{x^t \in \mathbb{R}^p_+|(x^t, y^t) \in \Psi^t\right\}$. Its efficient boundary or isoquant can be defined in radial terms as:

$$\partial C^t(y^t) = \left\{x^t|x^t \in C^t(y^t), \theta^t x^t \notin C^t(y^t), \forall \theta^t, 0 < \theta^t < 1\right\}. \tag{4}$$

If an observation is input-efficient it constitutes the input requirement set, i.e. $x^t \in \delta C^t(y^t)$. As suggested by Farrell (1957), for inefficient observations the distance θ^t to the $\partial C^t(y^t)$ can be radially measured as:

$$\theta^t(x^t, y^t) = \inf\left\{\theta^t|\theta^t x^t \in C^t(y^t)\right\} = \inf\left\{\theta^t|(\theta^t x^t, y^t) \in \Psi^t\right\}. \tag{5}$$

Input-efficient observations obtain an efficiency score $\theta^t = 1$, while inefficient observations should reduce inputs so that $\theta^t < 1$ (from (5) it can be seen that the efficient boundary is obtained by $\theta^t * x^t$). The next section develops a non-parametric model which allows us to compute the radial contraction by linear programming techniques.

Secondly, consider the output-orientation for which we define the output correspondence set $P^t(x^t)$ as all output vectors which are producible by the input x^t with period's t technology: $P^t(x^t) = \left\{y^t \in \mathbb{R}^q_+|(x^t, y^t) \in \Psi^t\right\}$. The efficient boundary is defined by:

$$\partial P^t(x^t) = \left\{ y^t | y^t \in P^t(x^t), \lambda^t y^t \notin P^t(x^t), \forall \lambda^t, \forall \lambda^t > 1 \right\}. \tag{6}$$

Output-efficient observations constitute the output correspondence set, i.e. $y^t \in \delta P^t(x^t)$, while for output-inefficient observations the inefficiency λ^t can be radially measured as:

$$\lambda^t(x^t, y^t) = \sup \left\{ \lambda^t | \lambda^t y^t \in P^t(x^t) \right\} = \sup \left\{ \lambda^t | (x^t, \lambda^t y^t) \in \Psi^t \right\}. \tag{7}$$

For output-inefficient observations $\lambda^t > 1$ equals the proportionate increase in outputs to achieve the efficient boundary (see, e.g., Daraio and Simar, 2007).

Thirdly, in the previous analysis both the evaluated observation and its reference observations, which potentially constitute the best practice frontier, are assumed to be from the same time period t. However, this could easily be extended to other assumptions. For example, $\theta^{t+1}(x^t, y^t)$ measures the input-efficiency for observation (x^t, y^t) with respect to the reference period $t+1$, for which the best practice corresponds in Figure 2 to observation x^B. Similarly, the radial distance from (x^{t+1}, y^{t+1}) to the best practice x^C in reference period $t+1$ corresponds to $\theta^{t+1}(x^{t+1}, y^{t+1})$. By technical progress or regress from the best practices, also the technology set Ψ can shift between two time periods. If observations are able to produce the same amount of outputs with less resources, technical progress occurs and the production set moves outwards (i.e. $\Psi^t \subset \Psi^{t+1}$). Similarly, technical regress occurs when observations need more inputs to produce a given set of outputs, so that the production set moves inwards (i.e. $\Psi^{t+1} \subset \Psi^t$). Having defined these concepts, we further decompose the profit change in Equation (2).

We enrich the profit decomposition by allowing for relative inefficiencies. Analyzing inefficiencies requires an assumption on the orientation. For the remainder of this article, we will focus on the input-orientation as this is the most natural in our empirical application. Indeed, drinking water utilities should try to reduce the consumed resources given exogenous drinking water production (i.e. by demand side management policy, drinking water utilities cannot promote consumption). Allowing for inefficiencies, the change in profits could be driven by increases in productivity or by improvements in the activity mix (all expressed in base period prices). This can be seen by further decomposing the quantity effect as follows:

$$\begin{aligned}(y^{t+1} - y^t)p^t - (x^{t+1} - x^t)w^t = \quad & [(x^t - x^A)w^t - (x^{t+1} - x^C)w^t + (x^A - x^B)w^t] \\ & + [(y^{t+1} - y^t)p^t - (x^C - x^B)w^t].\end{aligned} \tag{8}$$

The first term in squared brackets is referred to as the *productivity effect* and measures the sum of the impact on profit change resulting from (1) the evaluated entity's efficiency improvement relative to the best practice frontier (i.e. the difference between the first two terms) and (2) the overall technical progress (if $x^A - x^B > 0$) or technical regress (if $x^A - x^B <$

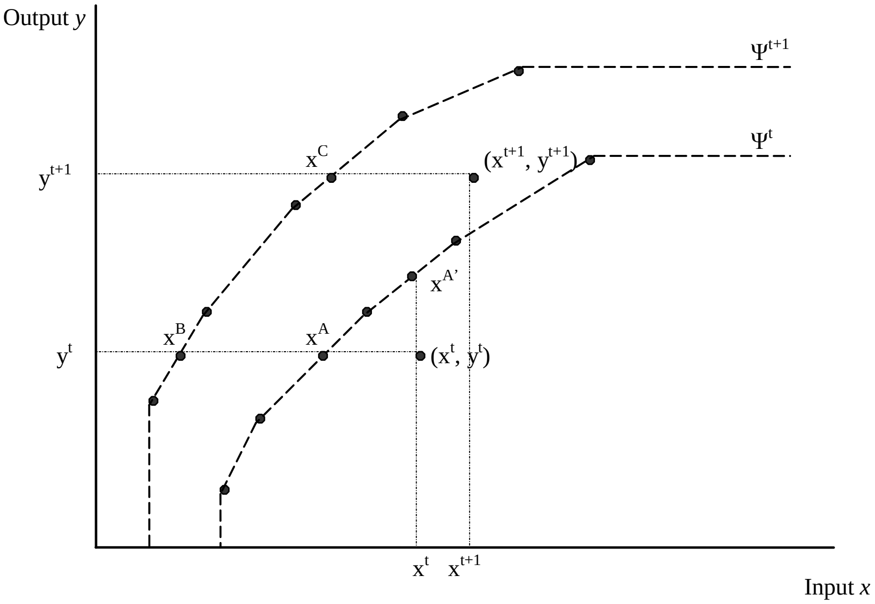

Figure 2: The production set in t and t+*1*

0) in the sector between period t and $t+1$. The former component is denoted as the *operating efficiency* (or *catch-up effect*), while the latter component is labeled as *technical change.* An increase in operating efficiency has a positive influence on profit change, as does technical progress. Using the input-oriented efficiency scores θ, which measure excessive input use for a given output set, we can deduce the unobserved inputs x^A, x^B and x^C as, respectively, $\theta^t(x^t, y^t) * x^t$, $\theta^{t+1}(x^t, y^t) * x^t$ and $\theta^{t+1}(x^{t+1}, y^{t+1}) * x^{t+1}$ (i.e. the radial projection of x^t and x^{t+1} on the respective frontier). The practical computation of θ is explored in the next section.

The second term in squared brackets evaluates the impact on profit change arising from the shift in activities. In particular, the *activity effect* measures for constant base period prices the changes in scale and scope between period t and $t+1$. To illustrate the activity effect more carefully, consider the two-dimensional Figure 3 with two input variables x_1 and x_2 on the axes. The above mentioned efficient input boundary $C^{t+1}(y^t)$ indicates the minimum input requirements to produce a given output level y^t by the best practice technology available in $t+1$. To produce efficiently the base period output level y^t in the reference period (note that this graph assumes technical progress as $C^t(y^t) \subset C^{t+1}(y^t)$ and thus less inputs are required to produce the same amount of outputs) x^B inputs are needed. Increasing the outputs, but holding the output mix similar to y^t, requires in the input-efficient situation x^D inputs. The difference between x^B and x^D reflects the *input scale effect.*

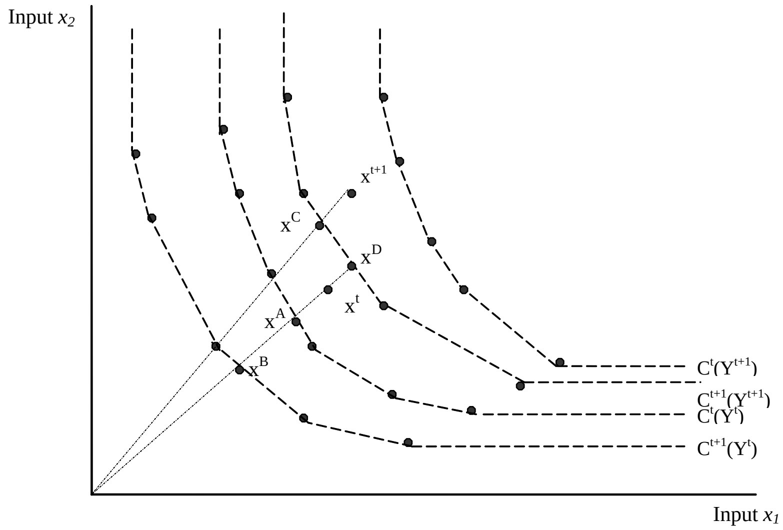

Figure 3: Input efficient boundaries

The output scale effect is visualized in the two-dimensional Figure 4 with two outputs y_1 and y_2 on the axes. The output correspondence set $P^{t+1}(x^B)$ measures the maximally obtainable outputs which are producible by the best practice technology in $t+1$ and the input level x^B. Increasing the inputs to the level of x^D, but holding the output mix constant to y^t, the *output scale effect* is measured as $y^E - y^t$ (again, technical progress is assumed in the graph).

From Figure 3, for a given production of outputs in reference period *t+1*, we can infer the shift in input use from base period t to reference period *t+1.* This is visualized by the difference between the efficient input level for producing y^{t+1} (but holding the input mix similar as in the base period) and the efficient input level x^C in *t+1.* The obtained difference $x^D - x^C$ is labelled as the *resource mix* effect. Similarly, we can deduce from Figure 4 the *product mix* effect as the shift in outputs from y^E to y^{t+1}.

Together, the resource mix (first term in Equation 9), product mix (second term) and scale effect (difference between the last two terms) constitute the activity effect:

$$\begin{aligned}&(y^{t+1} - y^t)p^t - (x^C - x^B)w^t = \\ &(x^D - x^C)w^t - (y^E - y^{t+1})p^t + (x^B - x^D)w^t - (y^t - y^E)p^t.\end{aligned} \tag{9}$$

The unobserved inputs x^D and outputs y^E can be obtained from, respectively, the inefficiency relatively to the efficient input requirement frontier $\theta^{t+1}(x^t, y^{t+1}) * x^t$ and the inefficiency relative to the efficient output correspondence frontier $\lambda^{t+1}(x^D, y^t) * y^t$. In the next section, we show how to estimate the inefficiencies without assuming any *a priori* assumption on the

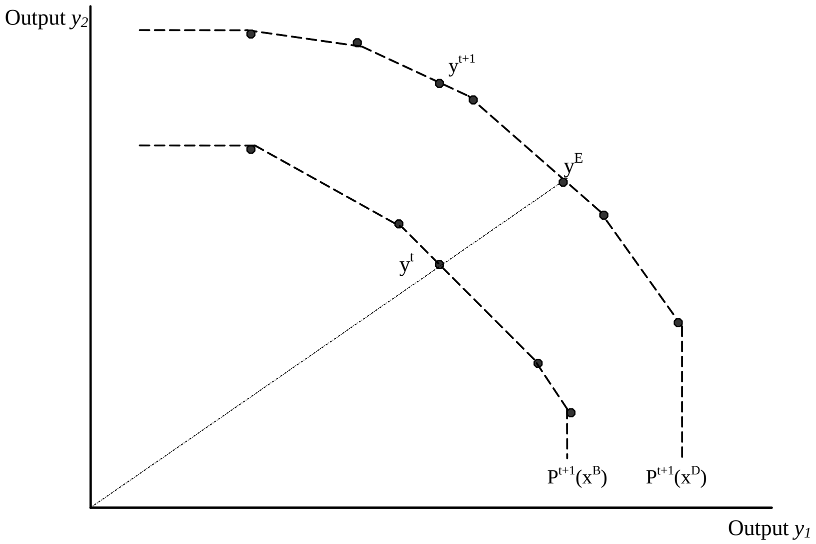

Figure 4: Output efficient boundaries

production technology, and while allowing for noise and heterogeneity in the data.

4 Non-parametrically estimating efficient quantities

To decompose the profit change into a technical change, operating efficiency, product mix, resource mix, scale and price effects, unobserved quantities x^A, x^B, x^C, x^D and y^E have to be deduced. As shown before, these can be obtained by linking the inefficiency estimates θ and λ to the observed quantities (x^t, y^t) and (x^{t+1}, y^{t+1}). To estimate the inefficiencies, Grifell-Tatjé and Lovell (1999, 2008) suggest a sequential Data Envelopment Analysis (DEA) model to recover the unobserved quantities from observed input-output combinations. We extend and improve their approach by developing a non-parametric DEA model (see Section 4.1) which allows for noise and uncertainty in the data (Section 4.2) and which takes into account heterogeneity in the sample (Section 4.3). The model is constructed step by step in the following subsections.

4.1 DEA in panel data

To evaluate the efficiency of entities, several techniques have been proposed. In this section, we concentrate on the popular Free Disposal Hull (FDH) (Deprins *et al.,* 1984) and Data Envelopment Analysis (DEA) (Charnes *et al.,* 1978) models which both estimate the inefficiency relative to a best practice frontier. Although both models do not assume any *a* *priori* specifications of the production function, they rely on, respectively, one and two presumptions which are easily defendable in the application under study. Both FDH and DEA assume free disposability of the inputs and outputs: $\forall (x^t, y^t) \in \Psi^t$, if $\widetilde{x^t} \geq x^t$ and $\widetilde{y^t} \leq y^t$ then $(\widetilde{x^t}, \widetilde{y^t}) \in \Psi^t$, or in words: if a particular input-output combination (x^t, y^t) is feasible, it should also be possible to produce y^t with more inputs and to produce less outputs with a given input set x^t. The corresponding best practice production set is defined as the set of undominated observations (undominated in both the input and output dimension):

$$\Psi^t_{FDH} = \left\{ (x^t, y^t) \in \mathbb{R}^{p+q}_{+} | x^t \geq x^t_i, y^t \leq y^t_i, i = 1, ..., n \right\}. \tag{10}$$

Having defined the step-wise best practice frontier, the FDH input and output-oriented efficiency score are obtained by, respectively, the minimal contraction (i.e. Equation (5)) and the maximal expansion (i.e. Equation (7)) to reach this non-parametric frontier.

Additionally to the free disposability assumption, DEA assumes a convex shape for the frontier: if $(x^t_1, y^t_1), (x^t_2, y^t_2) \in \Psi$, then $\forall \alpha \in [0, 1]$: $(x^t, y^t) = \alpha(x^t_1, y^t_1) + (1 - \alpha)(x^t_2, y^t_2) \in \Psi$. As such, the corresponding best practice production set is defined as a convex hull of the undominated input-output combinations:

$$\begin{aligned} \Psi^t_{DEA} = \quad & \left\{ (x^t, y^t) \in \mathbb{R}^{p+q}_{+} | x^t \geq \textstyle\sum_{i=1}^n \gamma_i x^t_i, y^t \leq \sum_{i=1}^n \gamma_i y^t_i, \text{for } (\gamma_1, ..., \gamma_n), \right. \\ & \left. s.t. \textstyle\sum_{i=1}^n \gamma_i = 1, \gamma_i \geq 0, i = 1, ..., n \right\}. \end{aligned} \tag{11}$$

The input and output-oriented efficiencies are obtained by plugging the convex production set, respectively, in Equation (5) and (7). Derived from the two previous assumptions and the production sets, it is worth noting that the DEA estimator can alternatively be obtained by convexifying the FDH efficient boundary. Therefore, we firstly determine the undominated FDH best practice observations and, secondly, convexify these points. The efficient FDH and DEA boundary is computed by the radial contraction of the inputs $\theta^t(x^t, y^t) * x^t$ or the radial expansion of the outputs $\lambda^t(x^t, y^t) * y^t$. Although the convexity assumption is not always easy to defend, it is natural when considering profits (Cherchye and Van Puyenbroeck, 2007).

In order to adapt the FDH and DEA estimators to a panel data set, we use a Window Analysis technique (e.g. Cooper *et al.,* 2004). A window analysis operates in a panel sample by the principle of moving averages so that an observation is evaluated against all entities in its 'window' (i.e. the reference set is enlarged to observations from different years). Obviously, the size of the window (and hence the reference set) will influence the results. Indeed, a too large window is unable to detect changes over time, while a too small window dramatically diminishes the discrimination in the results. By using window analysis we allow for both technical progress and regress (which is not the case in the sequential DEA analysis of Grifell-Tatjé and Lovell, 1999 and 2008). Remark that technical regress could arise from the introduction of costly technology processes (e.g. due to security reasons). In the current application, we assume a window size equal to 3 years and limit the scope of the window to the past. This corresponds to the evaluation of the reference period (i.e. t or $t+1$) and the two proceeding years. However, to test the robustness of this assumption, we experimented with other window sizes as well ($size = 1, \ldots, 6$) and found very similar results.

4.2 Allowing for noise in the data

A major disadvantage of the traditional FDH and DEA models lie in their deterministic nature as they assume that all observations (x_i^t, y_i^t) belong to the production set of size n, i.e. $\text{Prob}((x_i^t, y_i^t) \in \Psi^t) = 1$ for all $i = 1, \ldots, n$. As such, atypical or outlying observations (e.g. due to measurement errors) could bias the estimates as they dramatically influence the best practice frontier.

Firstly, consider the FDH efficiencies. To reduce the influence of atypical observations, Cazals *et al.* (2002) suggests estimating efficiency relative to a partial best practice frontier constituted from $m < n$ observations, instead of estimating the efficiency relative to the full best practice frontier constituted from all n observations. For the evaluated observation (x^t, y^t) this robust order-m approach draws for the input or output-orientation a sample of size m with replacement, respectively, among those x_i^t so that $y^t \leq y_i^t$ or among those y_i^t so that $x^t \geq x_i^t$. For the obtained sub-sample, the FDH model is computed. After repeating the sampling and efficiency evaluation B times, the *robust FDH* score $\theta^{t,m}(x^t, y^t)$ and $\lambda^{t,m}(x^t, y^t)$ is obtained by taking the arithmetic average of the B inefficiencies (notice that also sampling statistics can be computed). The partial frontier will shift inwards relatively to the full frontier (i.e. $\Psi^t \subset \Psi^{t,m}$) such that $\theta^{t,m} \geq \theta^t$ and $\lambda^{t,m} \leq \lambda^t$. Following Daraio and Simar (2007b), the size of the partial frontier m and the number of resamplings B is determined as the value for which the number of super-efficient observations decreases only marginally by further increasing m or B (i.e. the percentage of points outside Ψ^t is rather constant). In our analysis, we determined m or B equal to 50. However, simulations with other values of m (e.g. $m = 10,\ 20, \ldots, 70$) and B (e.g. $B = 25, 50, 100, 200$) delivered very similar results.

Secondly, consider the DEA estimates. Daraio and Simar (2007b) suggest a convenient approach that allows computation of robust efficiencies for the convex DEA model (which they describe as *global* DEA efficiency). In a first step, the robust FDH frontier is computed (by projecting all observations on the frontier, i.e. $\theta_i^{t,m}(x_i^t, y_i^t) * x_i^t$ for the input-orientation or $\lambda_i^{t,m}(x_i^t, y_i^t) * y_i^t$ for the output-orientation). In a second step, the robust FDH frontier is convexified and the DEA efficiencies are computed. The resulting DEA estimates are robust for noise and uncertainty in the data.

As the evaluated observation does not constitute its reference set in every of the B drawings, the robust FDH and DEA estimates can result in 'super-efficient' efficiency scores (i.e. $\theta^{t,m} > 1$ or $\lambda^{t,m} < 1$). However, as 'super-efficient' efficiency is inconsistent with the profit decomposition framework, these super-efficient observations could result in biased profit decomposition estimates. We therefore adopt the common practice in the traditional FDH or DEA framework, and treat any super-efficient observations as efficient (i.e. we set $\theta^{t,m} > 1$ or $\lambda^{t,m} < 1$ equal to 1).

The robust FDH and DEA estimates are attractive for several reasons. Firstly, they reduce the influence of atypical and outlying observations and, thus, allow for noise in the data. Secondly, by estimating efficiency relatively to a partial frontier ($m < n$), the robust estimation technique reduces the sample size bias (for a simulation, see De Witte and Marques, 2008). Indeed, Zhang and Bartels (1998) indicate that the individual and average efficiency of the observations in the data set decreases as the number of observations in the sample increases. This issue is mostly neglected in DEA applications. Finally, the order-m procedure can easily be extended to conditional efficiency measures which incorporate heterogeneity in the estimates (next subsection).

4.3 Taking into account heterogeneity

Up to now, we assumed that all observations are evaluated against the same frontier constructed from the overall best practices in the subsample of size m. However, this is a rather blunt approach as there might arise significant heterogeneity among the observations. Some observations could operate in a favorable (unfavorable) environment which acts as a substitutive input (output) and, thus, increases (decreases) the efficiency scores. To take into account the operational environment non-parametrically, Daraio and Simar (2005, 2007) propose to compare like with likes. This is implemented by conditioning on the environmental variable z_i^t by the use of a non-parametric Kernel function $K(.)$ (any Kernel with compact support delivers almost the same results, and in our application we have therefore opted for an Epanechnikov Kernel). The appropriate bandwidth h of the Kernel function is selected by the cross-validation principle (Daraio and Simar, 2005, 2007).

Firstly, consider the *robust conditional FDH* efficiencies which are obtained by adapting the previously outlined order-m sampling procedure as follows: for each of the B draws, the reference sample of size m is drawn with replacement and with a probability $K((z^t - z_i^t)/h)/\sum_{j=1}^{n} K((z^t - z_i^t)/h)$ among those x_i^t such that $y_i^t \geq y^t$ for the input-orientation, or among those y_i^t such that $x_i^t \leq x^t$ for the output-orientation. Relative to these environment-adjusted reference samples, we then proceed as discussed in the preceding sub-sections: we first estimate the input or output-oriented FDH model relatively to the reference sample; then re-do this B times; and finally average the B efficiency evaluations to obtain the robust conditional FDH efficiency estimate $\theta^{t,m}(x^t, y^t|z^t)$ and $\lambda^{t,m}(x^t, y^t|z^t)$.

Secondly, the *global robust and conditional DEA* efficiency score is (similarly as before) obtained by convexifying for every observation its robust conditional FDH frontier and estimating relative to this convex frontier the efficiency.

In the remainder of this article, we will focus on these robust conditional DEA estimates constructed in a window analysis. To compute by this model the unobserved quantities $x^A = \theta^{t,m}(x^t, y^t|z^t) * x^t$; $x^B = \theta^{t+1,m}(x^t, y^t|z^t) * x^t$; $x^C = \theta^{t+1,m}(x^{t+1}, y^{t+1}|z^{t+1}) * x^{t+1}$; $x^D = \theta^{t+1,m}(x^t, y^{t+1}|z^{t+1}) * x^t$ and $y^E = \lambda^{t+1,m}(x^D, y^t|z^t) * y^t$, both the evaluated observation and the period of its reference observations have to be adapted accordingly in the outlined model. This model modification is rather straightforward. In the next section, we apply the robust conditional efficiency estimates to compute the unobserved quantities in a profit decomposition of the Dutch drinking water utilities. As such, we try to explore the impact of sunshine regulation and regulatory discussions in the sector.

5 Profits and productivity in the Dutch drinking water sector

As is indicated in Section 2, the introduction of the sunshine regulation was a landmark in the reform of the Dutch drinking water sector. In addition to this benchmarking project, shifting ideas on the organization of the drinking water sector created several periods of relative instability. In this section, we empirically explore these movements by, using the previously outlined models, decomposing profit change into its drivers. We first describe the data and continue with the empirical results.

The panel data set consists of water only companies in the period 1992-2006 (there are no integrated water and sewerage companies in the Netherlands). All data are obtained from annual accounts, sector publications by Vewin and the periodic benchmark reports. To reduce the impact of inflation in the analysis, all monetary values are expressed in 1995 euro (in thousands and using the consumer price index of the Dutch Office for Statistics, Centraal Bureau voor Statistiek). Our sample consists of a set of 19 water utilities in 1992, and all these firms or the successor firms that resulted from mergers between them in subsequent years.[2] With the minor exception of the impact of the merger in 2003, comparison of aggregate data for our sample across time provides a consistent estimate of trends in the sector. Moreover, to investigate the underlying dynamics in the sector as well as possible, we did not exclude the mergers from the sample (as e.g. Grifell-Tatjé and Lovell (1999) did). To allow for mergers, we construct for the year of the merger t from the sub-utilities the 'merged' firm (i.e. the sum of the sub-utilities). By doing so, we can estimate the change in variables between year t (i.e. the merged utility composed from its sub-utilities) and $t + 1$ (when data from the

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[2] Thus, while the number of firms declines to only 10 in 2006, the geographic coverage of the firms represented in the sample remains the same, although we must note one minor exception to this as in 2003 a merger between a firm in our sample, and a firm not previously represented in the sample took place.

newly merged firm are available) without biasing profit change.[3] Aggregate statistics for our sample are provided in Table 1.

To calculate economic profits and, thus, profit change, total economic costs (operating costs and the opportunity cost of capital) are subtracted from turnover. Further decomposition in the determinants of profit change requires the revelation of unobserved quantities and prices by the outlined non-parametric model which uses input and output variables. As inputs, we decompose total costs into its capital, labor and 'other' component for which we construct prices and physical measures. Total costs are composed from the sum of operating expenditures (Opex), depreciation and capital costs. The former term, Opex, is in turn decomposable to wage costs and other costs. Firstly, the wage costs, as observed in the annual accounts, are decomposed into a physical proxy, i.e. the number of employees (in full time equivalents) and its resulting price proxy (i.e. wage costs divided by the number of employees). Secondly, as there is no appropriate price vector available for other costs, we proxy its price by the (material) construction price index as annually published by the Dutch Office for Statistics. The physical measure of other costs is computed by subtracting wage costs from Opex and dividing the outcome by the price proxy.[4] Thirdly, the total cost of capital consists of depreciation (from the annual accounts) and the opportunity cost of capital. The latter is computed by multiplying the real net assets by an assumed opportunity cost. Given the low risk of bankruptcy (thanks to both the monopolistic nature of the industry and its public ownership), we take the yield on the 10 year Dutch government bond as the opportunity cost of capital. The price of capital is then obtained by dividing the total cost of capital by mains

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[3] By construction with this approach the overall estimated individual profit change for a merged firm and its predecessor companies is unbiased. However, in the sample of 228 individual profit change decompositions underlying our aggregate results, there exists a theoretical potential for bias in a very small number (i.e. 8) of individual profit change decompositions for the years where mergers occurred. This further implies that there is a small potential for bias in the aggregate profit decomposition estimates reported for 1996, 1997, 1998, 2002, and 2006 as mergers occurred in these years.

However, sensitivity analysis (available from the authors upon request) shows that relative to firm size, the individual profit decompositions for the 8 potentially biased merger observations are in line with the individual results for the 220 unbiased companies. Trends in the aggregate profit decomposition components for the set of all companies reported here are also extremely consistent with aggregate trends for the sample of 228 firms excluding the 8 potentially biased individual observations. Moreover, as the focus of the paper lies on the influence of sunshine regulation on aggregate sector performance, we would strongly emphasize that any potential impact of mergers on estimated aggregate trends was vanishingly trivial before 2003. We are therefore extremely confident that any potential bias from the 8 merger observations does not influence our conclusion with regard to aggregate sector performance before and after the introduction of the sunshine regulatory model. While larger firm sizes imply that the mergers taking place from 2003 do have a larger impact on industry trends, the aggregate trends reported for the full sample still do not deviate significantly from those for the sample of firms that did not merge in this period.

[4] While it would be desirable to further decompose other costs into components such as energy costs, chemicals, and contracted out services, the necessary data to allow this are not available.

length (i.e. the physical proxy for capital).

The number of output variables is limited to two in order to avoid difficulties with the degrees of freedom in the non-parametric model (note that thanks to the use of panel data our analysis largely satisfies the rules of thumb concerning the minimum required number of observations, e.g. Cooper *et al.*, 2004) We opted for two consensual output variables related to production, i.e. production for domestic and non-domestic customers. However, robustness tests with different combinations of production and the number of connections (both aggregated and divided into domestic and non-domestic customers) delivered very similar results. Output prices are deduced from the annually Water Supply Statistics from Vewin and measure for domestic and non-domestic customers the average price (which corresponds to, respectively, the price for 130 m^3 and 25,000 m^3 of drinking water).

To account for heterogeneity in the data, we estimate the conditional efficiency measure for the non-parametric model described above. Given that population density is widely considered to be an important determinant of water utility input requirements, we consider the population density (computed by number of connections per squared kilometer of network length) as an environmental variable. Similar results are obtained with the number of connections, soil stability, drinking water quality measures and age of infrastructure (measured as book value over new value) as exogenous environmental factors.

The sample aggregate profit decompositions are summarized in Tables 2 and 3 and are visualized in Figures 5 to 7. Cumulative results for the different periods are presented in Table 4. As the current discussion in the Netherlands focuses on aggregate profits, we present graphs and tables in aggregate terms rather than in average terms. Additionally, this allows us to deal more easily with mergers.

Table 1: Aggregate statistics for the sample (real 1995 euro, thousands)

	1992	1993	1994	1995	1996	1997	1998	1999
Profit	4,320	20,746	42,394	163,772	177,361	179,627	179,460	200,785
Revenues	945,752	984,093	1,012,384	1,169,030	1,270,777	1,275,121	1,290,915	1,330,232
Production small customers	623,767	617,440	629,872	633,829	668,636	660,279	676,052	683,039
Av. price small customers	0.9720	1.0287	1.0355	1.1861	1.2458	1.2765	1.2796	1.3086
Production large customers	424,922	413,355	423,834	428,019	431,436	415,868	402,452	399,596
Av. price large customers	0.7988	0.8441	0.8497	0.9748	1.0148	1.0395	1.0582	1.0921
Total costs	941,432	963,347	969,989	1,005,258	1,093,415	1,095,493	1,111,455	1,129,447
Labour cost	231,327	239,629	240,967	242,616	254,297	273,284	289,690	292,856
Number of employees (fte)	6,797	6,783	6,719	6,587	6,715	7,198	7,307	7,155
Capital cost	413,088	373,965	399,159	411,230	415,097	400,154	383,183	398,685
Length of mains (km)	80,559	81,917	84,323	85,050	89,383	90,495	93,963	96,714
Other cost	297,017	349,754	329,863	351,411	424,022	422,056	438,582	437,907
Other costs (proxy, ths euro)	3,025	3,556	3,358	3,514	4,351	4,363	4,553	4,608
Number of utilities	19	19	19	19	18	17	16	16

	2000	2001	2002	2003	2004	2005	2006
Profit	183,887	164,091	160,985	192,247	214,073	240,318	208,775
Revenues	1,330,487	1,296,713	1,313,629	1,325,989	1,352,362	1,338,684	1,305,703
Production small customers	687,191	689,809	739,685	760,592	778,152	775,058	787,743
Av. price small customers	1.3050	1.2882	1.2461	1.2397	1.2407	1.2411	1.2033
Production large customers	394,369	387,090	397,201	396,550	403,959	395,074	388,679
Av. price large customers	1.0997	1.0542	0.9867	0.9660	0.9578	0.9536	0.9206
Total costs	1,146,601	1,132,622	1,152,644	1,133,742	1,138,288	1,098,365	1,096,928
Labour cost	288,018	286,426	262,314	246,299	253,964	249,324	212,870
Number of employees (fte)	6,825	6,540	5,943	5,804	5,445	5,257	5,132
Capital cost	439,844	398,563	406,278	387,237	393,063	369,445	363,794
Length of mains (km)	98,298	99,266	104,193	112,424	111,169	113,602	115,195
Other cost	418,739	447,633	484,052	500,205	491,261	479,597	520,265
Other costs (proxy, ths euro)	4,327	4,611	5,041	5,266	5,133	4,992	5,256
Number of utilities	16	16	13	13	13	13	10

**** Period 1992-1997 ****

In the period before the introduction of sunshine regulation, the utilities anticipated a potential privatization. Economic profits increased significantly (from 4.3 million 1995 euro in 1992 to 179.6 million 1995 euro in 1997). As Table 4 clearly illustrates, 149 percent of this 175.3 million euro increase in profitability was realized because of changes in output and input prices that benefited the companies. More specifically, output price increases for both domestic and non-domestic consumers contributed 284.1 million euro to increased profits (respectively, accounting for 65 and 35% of the output price increase). Contrarily, input prices increased such that capital, labor and other costs contribute negatively (22.6 million euro) to profit change. In contrast to the overall positive impact of the price effect on profits, the quantity effect contributed (in cumulative terms) negatively (i.e. -86.1 million euro). This negative effect can mainly be attributed to the negative productivity effect which decreased profits by -83.4 million euro between 1992 and 1997, with almost all of this effect being attributable to efficiency change (-83.4) and a small component being attributable to negative technical change (-6.6). Thus, while profits clearly increased because of price increases to consumers, there is substantial contradictory evidence to suggest that economic performance, as measured by the quantity effect, and more specifically operating efficiency, and technical change actually declined during the period before sunshine regulation was implemented. While it could be suggested that instability in the sector due to the government's intention to privatize the water industry resulted in a negative quantity effect, a more plausible explanation is that large output price increases, in the absence of any effective mechanism to incentivize improved performance, resulted in dramatically reduced performance as managers did not face any effective pressure to reduce costs. Thus, this result mirros the findings of Saal and Parker (2000, 2001) who found that privatisation did not improve performance in the English and Welsh water sector, until effective incentive regimes were implemented in 1995.

**** Period 1997-2006 ****

Our results suggest that the introduction of the sunshine regulatory model in 1997 significantly altered the behaviour of the utilities. Focusing first on aggregate profit change we see that for the entire 1997-2006 period profits increase by only 29.1 million euro, which was the result of even smaller aggregate profit increases for each of the 1997-2000, 2000-2003, and 2003-2006 periods. Relative to the pre sunshine period, profit growth was therefore relatively slow. When we further consider that for the entire 1997-2006 period, lower real output prices reduced profits by 103.9 million euro, lower input prices contributed a small positive effect of 10.1 million euro, and the quantity effect contributed 123.0 million euro, this reveals that after 1997 the sources of profit growth had dramatically altered. For example, over the period 1997-2006, positive profit growth was achieved despite considerable reductions in output prices and because of considerable increases in the underlying performance of the water utilities. Thus, contrary to the pre sunshine regulation period, when productivity growth and its components (technical change and operating efficiency) were all negative, productivity growth contributed 145.5 million euro to profit growth between 1997 and 2006, with 79 percent of this change attributable to technical change, and the remainder attributable to efficiency change.

These results suggest that after 1997 Dutch drinking water utilities operated in an environment in which profit change was primarily driven by productivity improvements, and consumers appear to have eventually received a substantial portion of the resulting cost reductions in reduced output prices. However, it is worthwhile to note that while a clear shift in underlying productivity performance is evident from the introduction of sunshine regulation in 1997 on (Figure 7) the pattern of the output price, quantity, and productivity effects suggest that consumer benefits, as well as underlying performance improvements, were most evident after 2000, and particularly in the 2000-2003 period. As benefits to consumers in reduced output prices are concentrated in the 2000-2003 and 2003-2006 periods, we would again note a parallel with the case of the English and Welsh water sector, where a similar pattern of performance improvements preceding consumer benefits is evident and accepted on the grounds that firms must retain the benefits of performance improvements for some period of time in order to provide appropriate incentives. The increasing focus in the media and in the Dutch academic journals on excessive profits in the water industry during this period clearly suggests that the water utilities and/or politicians responded to public opinion with large output price declines. Moreover, this could be seen as indicative of a system that is incapable of maintaining appropriate incentives in the face of political pressures from consumers. However we would again counter this with the observation that while output price reductions led to a 148.4 million euro reduction in economic profits between 2000 and 2006, economic profits actually increased form 183.0 to 208.8 million euro over the same period, suggesting that efficiency incentives had not been dampened. We would finally note that as the potential establishment of an independent regulator was debated during the 2000-2003 period it is plausible that the industry increased its performance under sunshine regulation during this period precisely because it sought to avoid the implementation of a more robust incentive regulation system, and not because sunshine regulation itself enhanced performance. However, while this is plausible, periodic in earnest discussion of the possible establishment of an independent regulator, cannot explain the continuing shift to positive productivity change in every year after 1997 when sunshine regulation was introduced. Moreover, we would also argue, that if the mere threat of movement to an alternative regulatory system from the preferred sunshine regulatory model is sufficient to improve company performance, this threat is always available to policymakers wishing to maintain the effectiveness of a sunshine regulation system.

Nevertheless, our models do suggest some negative evidence with regard to underlying company performance, as over 1997-2006 the activity effect resulted in profit change of -22.5 million euro. However, closer inspection of Table 4 reveals that in aggregate, this negative effect is driven by the resource mix effect (-142.7) which counteracted a relatively small positive scale effect (41.1) and the product mix effect (79.1), with the latter only being positive during the 2000-2003 and 2003-2006 periods. The scale effect result suggests that while on balance the industry benefited from increased scale, the magnitude of these benefits are quite small in comparison to productivity improvements. In contrast, the product mix effect suggests that the product diversification strategy of many drinking water utilities (i.e. increased non-domestic production by tailored solutions) and the impact on output structure caused by mergers had a much larger positive impact on utility performance. Unfortunately, these positive impacts of restructuring are countered by the large negative resource mix effect, which suggests that the net impact of the industry's move to a less labour intensive but more capital and other input intensive structure, has resulted in increased costs of production. This is not contradictory to the positive technical change, which implies that the industry is using a more productive technology, and to the positive efficiency effect, which implies that inefficient firms have eliminated technical efficiency. Stated differently, while the industry has seen substantial productivity improvements because it has reduced its input usage relative to outputs, its restructuring efforts have also, unfortunately, resulted in higher than economically efficient costs because of an increasing misalignment between input prices and the marginal rate of technical substitution between inputs. However, we would note at least part of this negative effect may be explained by the substantial increase in the mains network, which has been carried out to increase water supply security by allowing transfer of water resources between previously physically separated networks. As this increase in water supply security cannot be measured and is therefore not included as an output in the model, this could potentially result in an overstatement of the negative resource mix effect. We would also note that as the expansion of the mains network is certainly designed to allow for future demand, the substantial capital investment programme pursued in the past 15 years could result in 'excessive' capital usage, which is nonetheless appropriate if we allow for anticipated future demand expansion.

Table 2: Profit change decomposition (real 1995 euro, thousands)

	Profit change (1)+(2)	Quantity effect (1)=(1.1) +(1.2)	Productivity effect (1.1)=(1.1.1) +(1.1.2)	Technical change (1.1.1)	Operating efficiency (catch-up) (1.1.2)	Activity effect (1.2)=(1.2.1) +(1.2.2)+(1.2.3)	Product mix (1.2.1)	Resource mix (1.2.2)	Scale effect (1.2.3)
1992-1993	16,427	-32,491	-33,607	10,052	-43,658	1,116	-14,953	-359	16,427
1993-1994	21,648	21,339	10,773	7,360	3,413	10,566	15,386	1,293	-6,113
1994-1995	121,378	-1,774	4,304	-6,437	10,742	-6,078	3,078	-8,502	-654
1995-1996	13,589	-39,751	-28,368	282	-28,650	-11,383	47,933	-41,142	-18,174
1996-1997	2,266	-33,471	-36,529	-17,809	-18,720	3,058	-26,408	18,315	11,151
1997-1998	-167	-2,385	10,477	-1,001	11,478	-12,862	-2,951	-18,502	8,591
1998-1999	21,324	5,513	14,764	-5,972	20,736	-9,251	-3,581	-8,050	2,380
1999-2000	-16,898	28,772	16,817	23,212	-6,395	11,954	-6,887	17,330	1,511
2000-2001	-19,795	-1,654	13,979	-1,680	15,658	-15,633	-5,760	-14,864	4,990
2001-2002	-3,106	37,509	8,574	14,406	-5,832	28,935	70,855	-50,308	8,388
2002-2003	31,262	44,347	23,149	21,582	1,567	21,198	21,490	8,498	-8,790
2003-2004	21,826	4,774	10,458	14,627	-4,169	-5,685	26,743	-40,373	7,946
2004-2005	26,245	27,066	28,937	43,169	-14,232	-1,871	-22,046	-1,385	21,559
2005-2006	-31,543	-20,929	18,309	6,372	11,937	-39,238	1,243	-35,060	-5,421
$\sum$ 1992-2006	204,456	36,863	62,038	108,162	-46,124	-25,175	104,142	-173,110	43,793

Table 3: Price effect decomposition (real 1995 euro, thousands)

	Price effect (2)=(2.1) +(2.2)	Input price (2.1)=(2.1.1) +(2.12)+(2.23)	Price capital (2.1.1)	Price labour (2.1.2)	Price other (2.1.3)	Output price (2.2)=(2.2.1) +(2.2.2)	Domestic customers (2.2.1)	Non-domestic customers (2.2.2)
1992-1993	48,917	-3,254	5,321	-7,702	-873	52,172	35,799	16,373
1993-1994	309	-4,313	-1,009	-3,941	638	4,622	3,129	1,492
1994-1995	123,152	-25,864	-10,849	-5,534	-9,482	149,016	94,773	54,243
1995-1996	53,341	4,385	-4,008	-7,331	15,723	48,955	32,299	16,656
1996-1997	35,738	6,366	2,851	-801	4,316	29,372	19,157	10,214
1997-1998	2,218	-10,044	-1,244	-11,193	2,393	12,263	6,489	5,773
1998-1999	15,812	-17,922	-16,231	-9,388	7,697	33,733	21,819	11,914
1999-2000	-45,670	-44,180	-25,199	-9,024	-9,957	-1,490	-3,049	1,559
2000-2001	-18,141	11,635	23,539	-10,111	-1,793	-29,776	-10,735	-19,042
2001-2002	-40,615	15,988	13,069	-3,771	6,691	-56,604	-23,381	-33,223
2002-2003	-13,085	602	277	-6,187	6,512	-13,688	-5,093	-8,595
2003-2004	17,053	20,138	32,894	-8,327	-4,429	-3,085	79	-3,164
2004-2005	-820	2,136	8,714	-4,418	-2,159	-2,956	-1,396	-1,560
2005-2006	-10,614	31,697	19,109	30,461	-17,873	-42,311	-32,266	-10,045
$\sum$ 1992-2006	167,593	-12,630	47,234	-57,267	-2,596	180,223	137,625	42,597

Table 4: Cumulative effect (real 1995 euro, thousands)

	1992-1997	1997-2006	1997-2000	2000-2003	2003-2006
Profit change	175,308	29,148	4,259	8,360	16,528
Quantity effect	-86,148	123,011	31,899	80,202	10,910
Productivity	-83,426	145,464	42,058	45,702	57,704
Technical change	-6,553	114,715	16,240	34,308	64,167
Operating efficiency	-76,874	30,749	25,818	11,394	-6,463
Activity effect	-2,722	-22,453	-10,159	34,500	-46,794
Product mix	25,036	79,106	-13,419	86,585	5,940
Resource mix	-30,396	-142,714	-9,222	-56,673	-76,819
Scale effect	2,638	41,155	12,482	4,588	24,084
Price effect	261,456	-93,864	-27,640	-71,842	5,618
Input price	-22,680	10,050	-72,146	28,226	53,970
Output price	284,137	-103,914	44,506	-100,068	-48,352

6 Conclusion

This paper has analyzed the conduct of natural monopolies regulated by a sunshine regulatory model (i.e. publicizing the performances of utilities). In particular, we decompose the profit of publicly owned Dutch drinking water utilities into its drivers (price and quantity effects). We extend the decompositions of Grifell-Tatjé and Lovell (1999, 2008) by an advanced Data Envelopment Analysis (DEA) model which allows for uncertainty (resulting from noise, atypical observations, and measurement errors) and heterogeneity in the data (Daraio and Simar, 2007b).

Our results suggest that after the implementation of sunshine regulation in 1997 the productivity performance of the publicly owned Dutch drinking water utilities improved markedly (this in the absence of privatisation and without the establishment of a more robust incentive regulation system). Thus, while during the period 1992-1997, productivity declines caused an 83.4 million euro (in 1995 prices) reduction in economic profits, after 1997 productivity gains contributed 145.464 million euro of increased profitability in the industry. Moreover, while large increases in output prices in the 1992-1997 period contributed significantly to increased economic profits, output prices fell considerably after 2000. As economic profits, nonetheless increased between 2000 and 2006, our results strongly suggest that this consumer benefit did not accrue from inappropriate political interference, but was instead the result of passing past productivity improvements from producers to consumers. These results therefore suggest that 'naming and shaming' in a sunshine regulation system can induce publicly owned utilities to improve their productivity, and can also insure that

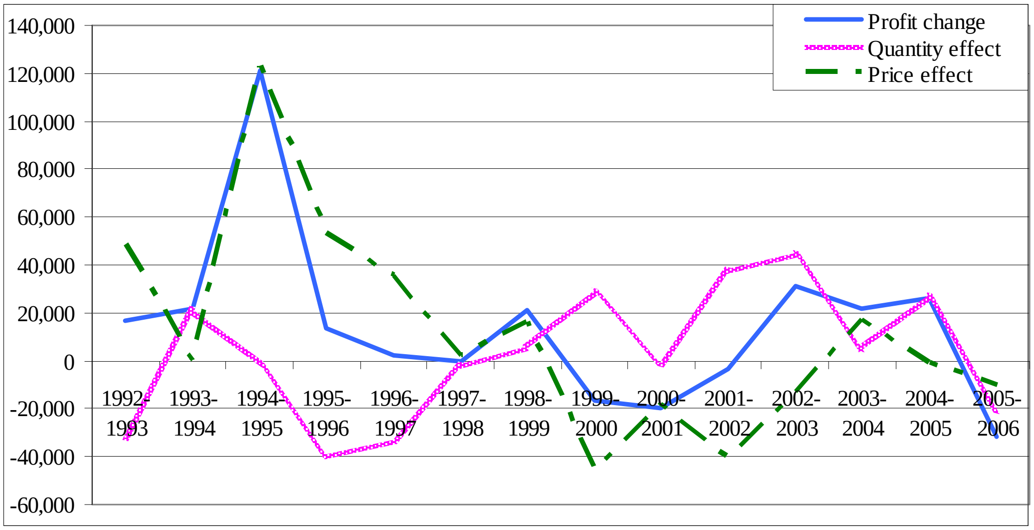

Figure 5: Profit change decomposition (real 1995 euro, thousands)

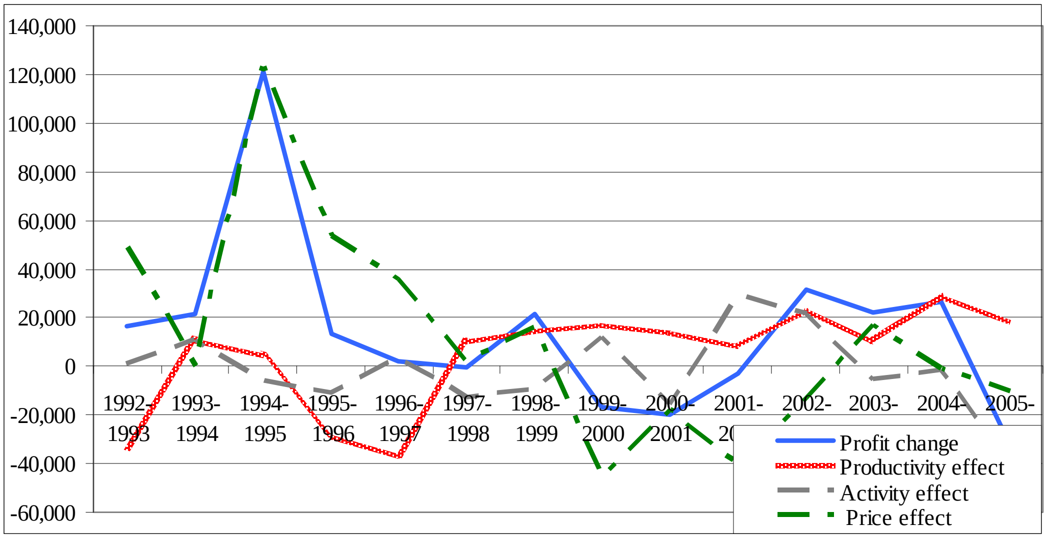

Figure 6: Quantity effect decomposition (real 1995 euro, thousands)

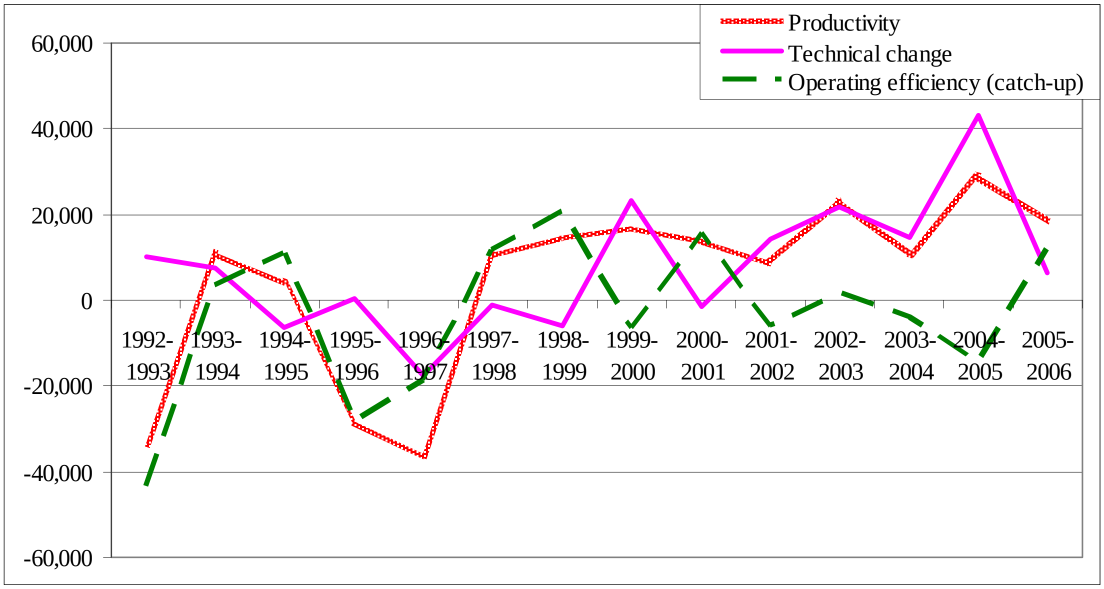

Figure 7: Productivity effect decomposition (real 1995 euro, thousands).

such productivity gains are eventually passed to consumers in lower prices. In sum, this paper suggests that in an appropriate political and institutional context, sunshine regulation can be an effective and appropriates means of insuring that publicly provided services are efficiently and profitably provided.

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