Regulating natural gas retail prices in France: the absence of a magic indexation formula and other implementation issues*

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Executive Summary

The EU has progressively implemented a policy of liberalization of the natural gas markets. Following the transposition of EC directives at the national level, the opening of the French retail natural gas market to competition has been completed. Yet, the retail domestic segment is still highly regulated (86% of domestic customers currently buy natural gas under regulated tariffs[1]).

Regulated tariffs are supposed to evolve so as to mirror the evolution of the price of petroleum products which determine the supply cost of the gas utility in the context of its long-term supply contracts with foreign producers mainly in Norway, the Netherlands, Algeria and Russia[2]. To do so, regulated tariffs are set through an indexation formula taking into consideration the evolution of the prices of these petroleum products as well as of the USD/€ exchange rate.

The appropriateness of the formula and of the regulatory process has been much debated, the gas utility periodically arguing that it was not truly reflecting its costs[3], while on the other hand consumers were arguing that prices were set too high and that the utility was benefiting from an undue regulatory rent[4]. The formula has periodically been amended, and has not been systematically applied at a preset frequency.

Recently, following a 5.2% increase in tariffs on 1st April 2011, the French government has decided to freeze any price increase for at least a year, while prices were supposed to be increased by around 7% in July 2011[5].

As shown by the French example, if the choice is made to maintain regulated retail tariffs, it is crucial to assess the possible regulatory designs and to discuss the challenges associated with their implementation. This is the aim of this paper.

From an economic standpoint, natural gas retail tariff regulation must fulfil 4 main functions. First, it should allow the regulated company to recover its cost[6], while at the same time preventing it to capture an undue regulatory rent. Second, regulated prices should send good signals to the demand and supply sides. Third, it should incentivise

[1] CRE (2010) - Observatoire des marchés de l'électricité et du gaz T4 2010 - www.cre.fr/fr/content/download/10571/.../2010Observatoire4emeTrim.pdf

[2] `http://www.insee.fr/fr/themes/tableau.asp$?reg_id=0\&ref_id=NATTEF11314$`

[3] 'Comptes sociaux publics' of GDF give figures relative to the financial impact on its results of tariff adjustments that it claims to be insufficient. The cumulated negative impact for the years 2004 to 2008 would reach 1.6 billion euro.

[4] See for instance: UFC-Que Choisir (2011), "Hausse du prix du gaz: après la trêve, un nouveau coup de massue injustifié!" - Press release - 22 February 2011

[5] `http://www.cre.fr/fr/content/download/$10684/178036/file/110405$CP-Decisions_concernant_les_prix_de_l_energie.pdf`, `http://www.lesechos.fr/entreprises-secteurs/energie-environnement/actu/0201281264033.htm`

[6] Let us note here that cost recovery is not a difficult task for fixed and predictable costs. Therefore, we focus in this paper on the cost of the commodity, which, whether purchased on the spot market or through long-term contracts can vary significantly.

the regulated company to make efficiency gains and reduce its costs. Finally, it should appropriately allocate risks between economic agents (the regulated company and its consumers in particular). The regulator must adopt the appropriate regulatory instrument fulfilling these functions. Any regulatory instrument has imperfection, and the more complex the regulatory framework is, the larger the economic challenges and the regulatory imperfections are likely to be. Besides, any regulatory mechanism is usually not able to fulfil all functions required to reach a first best solution, and the regulator will likely need to make some trade-off between these objectives.

The two most popular (theoretical) regulatory instruments, cost-plus and fixed price cap, can be assessed in terms of their ability to fulfil the above mentioned functions. A cost-plus regulation adjusted to cost is likely to allow the gas company to recover its cost but is unlikely to give the good incentives to both the company and the consumers. On the contrary, a fixed retail price, without *ex-post* adjustment, may only meet the objective to incentivize the company to reduce its costs. Although there is still a demand response in both cases, signals to consumers are not optimal because they are not based on cost-reflective prices. In terms of risk allocation, with a price cap, any price fluctuation risk would be borne by the regulated company, while with a cost-plus regulation they would entirely be transferred to consumers.

Table 1 summarizes the economic properties of these two 'extreme' regulatory instruments.

	Regulatory instrument		
	[1]	[2]	[3]
Objective	Cost plus	(ex ante) Fixed tariff	Ex ante indexation formula
Adequate cost recovery and no rent	++	−	++
Incentive to reduce cost	−	++	++
Signal to consumers	+	+	Depends on formula parameters and tariff adjustment frequency
|Risk allocation	Consumers	Regulated company	Depends on formula parameters

Table 1: Economic properties of the regulatory instruments

Setting the tariff via an indexation formula, defined *ex-ante*, and reflecting the evolution of the underlying costs that the company cannot directly control, is an alternative which a priori enables to fulfil the 4 main functions of tariff regulation.

However, in practice, the regulator who opts for a 'formula' faces many challenges when designing and implementing such a regulatory mechanism. To illustrate these complexities, we build a simple model in which a single natural gas (retail supply) company purchases gas on long-term contracts from three different suppliers and supplies the entire French domestic customers' demand.

In the context of this model, we simulate the work of the regulator who wants to regulate retail prices with a formula. Therefore, we simulate the estimation of the price setting formula by the regulator, in a context of information asymmetry and of uncertainty, and then we assess the performances of the formula by building performance indicators reflecting the level of accuracy and bias of the formula as well as the frequency of price adjustment. The accuracy is linked to the ability to give price signals to consumers, while the bias of the formula is linked to the cost-recovery objective. Finally, the frequency of adjustment is linked to the price variability risk sharing between the utility and the consumers.

We show that even in this simple setting, the inaccuracy and the bias of the formula can be significant as soon as the periods and dates of the retail price adjustment with the formula are not exactly the same and/or are not matching the review periods and dates of the different long-term contracts. These errors are mainly estimation errors coming from the lack of flexibility of the formula and its inability to account for the variations of the series of cost that it is aiming to proxy.

Moreover, because of an unclear and undecided regulatory decision process - as it has been the case in France over the past decade - and because of political pressure notably, the regulator may have incentives or may be forced to delay price adjustments, or to change (most likely to increase) the price adjustment period. This can further enhance the mismatch between the price set by the formula and the supply cost of the gas company.

A price which is not cost-reflective can create an unjustified regulatory rent for the company - at the expense of the customer - if the price is higher than the supply cost. On the contrary, if the price is too low, the gas company will not be able to recover its costs. An imperfect formula can therefore fall short of the objective of enabling the company to recover its costs.

More generally, an imperfect formula, coupled with an unstable institutional framework or simply with the inability of the regulator to commit not to modify *ex-post* the prices adjustment period or the formula itself will not allow to fulfil the 4 main functions of the tariff regulation.

These problems are likely to be even more pronounced in a real setting with several gas companies, each having several long-term contracts with various producers and potentially performing a different arbitrage on the wholesale spot market which we have not included here[7]. The diversity of contractual arrangements with producers and wholesalers, with their own indexation on petroleum products and potentially on natural gas spot prices and with their own clauses such as 'take-or-pay' is another source of variation and imperfection.

Theoretically, using an *ex-ante* formula to set the tariff is a good regulatory option which fulfils the functions expected from the regulation. Yet, through a simulation of the work of the regulator, we have shown that there are significant imperfections and inaccuracies.

Some imperfections are inherent to the structure of the formula and therefore cannot be prevented whatever the decision process. The lack of flexibility of the formula - which is supposed to aggregate all supply contracts of the utility which have different indexation coefficients and adjustment periods - indeed leads to imprecision and potential biases. However, some inaccuracies and biases arising from the use of the formula to set tariffs are linked to the regulatory process and mechanism, and more precisely, to the improper implementation of rules set at the beginning of the regulatory period. Inherent inaccuracies and biases are worsened when price adjustment is either not performed with the initially set periodicity or is delayed.

Stakeholders must be aware of the inherent inaccuracies. If they are not, they could be tempted to try to renegotiate the formula or the regulatory process as soon as there is a small deviation (positive or negative) between the tariff and the supply cost of the utility. While updating the formula when supply contracts are modified could make sense, changing or blocking the adjustment schedule without changing the formula will most likely worsen any inaccuracy or bias.

Moreover, stakeholders, especially the government and the regulator, must acknowledge the fundamental necessity to stick to initial rules, even if imperfect, in order to reach a second best regulation and limit further imperfections. If they do not stick to rules set *ex-ante*, this could lead to further inaccuracies, which in turn would trigger attempts of renegotiation, which if they successfully delay or change the periodicity of the tariff adjustment, would worsen the situation.

The inability to create a stable regulatory environment, without political interference is probably at the core of the problem in France. While the whole debate has focused on

[7]For simplicity, we are not including the wholesale spot market in the portfolios in this version of the paper. In a future version, we will see that adding arbitrage on the wholesale market does not affect our findings and conclusions.

getting the presupposed accurate formula, we argue that the main problem is the lack of commitment to the rules.

Therefore, we recommend transferring all price-setting power to the independent energy regulator, and *de facto* to remove the discretionary power of the government on this matter. This is actually no more than what is required by European Commission directives. Then, the regulator should set stable rules (periodicity, decision process, ...) of tariff adjustment using a tariff-adjustment formula and should stick to these rules throughout a pre-determined regulatory period. Only once this has been completed, should the regulator estimate the tariff setting formula, which would eventually be re-evaluated at the end of the regulatory period.

Unless such measures are taken, the same issues and debates will arise again and again over the coming years.

1 Introduction

The European Union has progressively implemented a policy of liberalization of the natural gas markets. Several European directives have been issued with the aim of creating a unified European natural gas market[8]. The transposition of these directives at the national level has led to the opening-up of the retail market to competition. This process, however, has experienced different national dynamics and there are currently several European countries where natural gas retail segments (mainly domestics and small professional consumers) continue to be highly regulated[9].

France is a typical example where the natural gas retail domestic segment is still highly regulated. While the opening of the French retail natural gas market to competition has been complete - meaning that all customers are now eligible to choose their retailer, there is coexistence on the retail market of a system of liberalized prices and of a system of regulated prices[10]. Regulated retail tariffs[11] are only offered by the historic suppliers (GDF-Suez and Tegaz (Total Energie Gaz)) and the 22 local distribution companies on their respective geographical areas. Today, GDF Suez regulated tariff remains the main option on the domestic retail segment. Customers under regulated tariff account for more than 88% of domestic sites and 92.8% of all domestic customers are still GDF Suez customers[12].

The choice to maintain regulated tariffs on a liberalized retail market raises a certain number of challenges notably concerning the level of these tariffs, their appropriateness, and their adjustment to the evolution of the underlying supply costs of the retailer. This is particularly true for the part of the regulated tariff related to the gas molecule purchased to the producer or the wholesaler[13]. In 2008, the cost of the molecule accounted for 56% of the total cost to be covered by regulated tariff for GDF Suez[14]. Natural gas supply cost is still the most variable component of the regulated tariff since it depends strongly on several factors (oil and oil derivatives prices, total gas demand, exchange rates, etc...) characterized by volatile patterns, and this paper will only deal with the part of the tariff related to this supply cost.

[8] European directives aiming at creating a unified natural gas market: 1998/30/CE; 2003/55/CE; and 2009/73/EC.

[9] See: ERGEG (2010): Status review of end-user price regulation as of 1 January 2010 or Swartenbroekx, C. (2010): Implications of liberalisation for methods of setting retail gas prices in Belgium. National Bank of Belgium, Economic Review, December 2010.

[10] The coexistence of regulated and non-regulated tariffs could be explained by the dual objective of the French government. On the one hand, the French authorities had to comply with the necessity to open-up markets to competition. On the other hand, the will to preserve a 'public service' of energy supply has led them to keep the regulated tariffs as a way to ensure an 'acceptable' level of natural gas prices for domestic customers. Although it is an important question, discussing the legitimacy of the regulation of natural gas retails prices is not in the scope of our paper.

[11] Regulated tariffs are set by an 'arrêté ministériel', and are applicable for the selling of natural gas to domestic customers as well as other clients who, although they are eligible, have not 'exerced' their eligibility.

[12] CRE (2011)-Observatoire des marches de l'électricité et du gaz T4 2010

[13] The other component of the cost include infrastructure costs (such as regasification terminals, storage), transportation, distribution and commercialization.

[14] Author's calculations based on GDF Suez data.

In France, 98% of the natural gas consumed is imported and 92% are through long-term supply contracts[15]. In these long-term contracts, the purchasing price to the foreign producer is set, and these contracts usually have duration of between 10 and 25 years[16]. In general, these contracts have contractual prices which are independent of spot prices but are instead indexed on oil products prices[17], principally domestic (light) and heavy fuel oil. These indexations clauses are called 'net back' contracts, according to which the selling price to the final consumer is set at a competitive level with respect to the price of petroleum products. Adjustments of the contractual price are performed periodically (every 3 or 6 months) and are based on mean indices of petroleum products prices. These indices are calculated so as to allow for a smoothing of long-term contract prices[18].

Each contract has its own indexation formula (along with some specific other contractual clauses), and precise information on the parameters of the indexation clauses is strictly confidential and not observed by the regulator. However, natural gas retail companies are required to give the French Energy Regulatory Commission[19] (CRE) and the Ministry in charge of Energy, a tariff indexation formula which should reflect, as accurately as possible, the variation of their average natural gas supply cost. This formula should to some extent aggregate the indexation formulas of their respective portfolios of contracts. The regulatory process is represented schematically in the diagram of Figure 1.

The formula is used to estimate the evolution of the supply cost of the utility following a variation in the level of the indexation variables (petroleum products prices, USD/€ exchange rate notably). Then, this estimate is used to set a new retail tariff. This tariff adjustment procedure however depends on some pre-set modalities (Is there a fixed frequency for tariff adjustment? / Who proposes a tariff adjustment? / Who decides over the effective level of this adjustment? / How do parties interact in the decision process? etc . . .)

[15] `http://www.economie.gouv.fr/discours-presse/discours-communiques_finances.php?type=discours&id=801`

[16] Neumann, A. and C. V. Hirschhausen (2004): Less Gas to Europe? An Empirical Assessment of Long-term Contracts for European Energy Supply. Zeitschrift für Energiewirtschaft, Vol. 28, No.3, 175-18.

[17] Long-term contracts usually stipulate that the importer bears volumes risks by committing to buy a contractually set volume of natural gas whatever its actual consumption (take-or-pay contract) while the producer bears the price risk by guarantying an indexed price for the total duration of the contract. These 'price' and 'volume' risks have historically been shared by the producers (Gazprom, Sonatrach, etc..) and the former import natural monopolies given that natural gas is a substitutable source of energy and that its transportation notably requires large upfront investments. The take-or-pay clauses give the insurance to the producer that its gas will be bought so that he can recover the large investments made to develop production fields, while buyers have an insurance regarding the evolution of the natural gas price thanks to their indexation on the spot price of petroleum products.
Recently, as the spot price has been lower than the long term contracts price, utilities such as GDF Suez have started to renegotiate their long term contracts with their suppliers in order to include market prices in these contracts.

[18] CRE (2006). Rapport d'activité 2006, La régulation du marché du gaz naturel, page 22.

[19] Commission de Régulation de l'Energie (CRE).

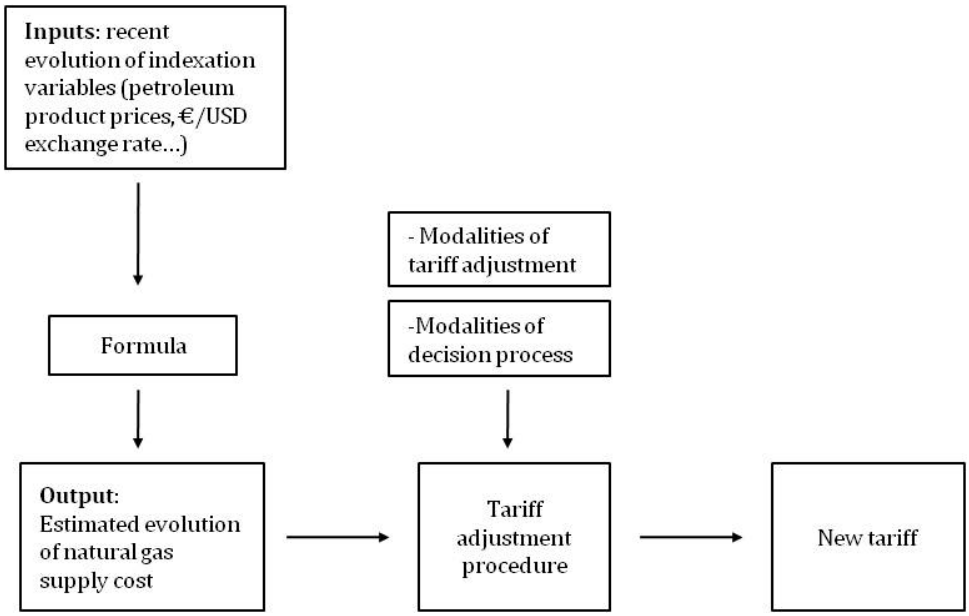


Figure 1: Retail tariff regulatory process

The indexation formula currently in effect has the following structure[20]:

$$\begin{aligned}\Delta Tariff[e/MWh] = coef_{d/e}.\Delta I_{d/e} + coef_{DFO}.\Delta I_{DFO} \\ + coef_{HFO}.\Delta I_{HFO} + coef_B.I_B + coef_{NG}.\Delta I_{NG}\end{aligned} \tag{1}$$

Where :

- ΔTariff is the evolution of the natural gas retail price between two adjustment periods
- ΔI_i is the evolution of the index I_i between two adjustment periods
- The index I_i is the average monthly value of the variable i calculated over the 6-month period preceding the adjustment period with a 1-month delay
- $I_{d/e}$ is the index for the USD/€ exchange rate
- I_{DFO} is the index for the domestic fuel oil (Gasoil 0.1% in sulfure) (in €/ton)
- I_{HFO} is the index for the heavy fuel oil (BTS, 1% in sulfure) (in €/ton)
- I_B is the index for the brent dated (€/barel)
- I_{NG} is the index for the trimestrial TTF (Q+1) natural gas price (in €/MWh)

The values of the coefficients of this indexation formula are given in Table 2.

[20]Source: CRE. `http://www.cre.fr/fr/marches/marche_du_gaz_naturel/marche_de_detail`

Coefficient	Value
$coef_{d/e}$	1.33269
$coef_{DFO}$	0.01642
$coef_{HFO}$	0.02244
$coef_{B}$	0.05384
$coef_{NG}$	0.09478

Source: CRE (2011)

Table 2: Coefficients of the indexation formula as per January 2011.

Since 2001, the formula has been modified several times[21]. From 2001 to 2005, the formula was the formula of tariff evolution set in the 'State-Company contract 2001-2003', a public service contract signed between the French State and GDF Suez in the spring of 2001 and which included a set of clear and stable rules and mutual contractual obligations. Between 2001 and 2005, the formula was indexed on the price of heavy fuel oil and on the USD/€ exchange rate, and it was not made public. In 2006, the formula was still not released publicly, but its determinants also included the price of domestic fuel oil. In a publication of July 2008, the Energy Regulatory Commission (CRE) published a new indexation formula which then included the price of heavy and domestic/light fuel oil, the price of brent and the USD/€ exchange rate. More recently, to reflect the renegotiation by the regulated utility of part of its supply contracts - renegotiation which aimed at indexing them partly on the natural gas spot price, which is currently lower than the price of its long-term contracts - a new formula has been adopted and includes, as an indexation variable, the quarterly natural gas future price.

The factors included in the formula can experience substantial variations overtime. This can be seen on Figure 2 which reports the evolution of the prices of the oil or oil derivative products included in this indexation formula. This is also the case for the exchange rate and the natural gas spot price.

[21] A summary of this evolution is given in appendix.

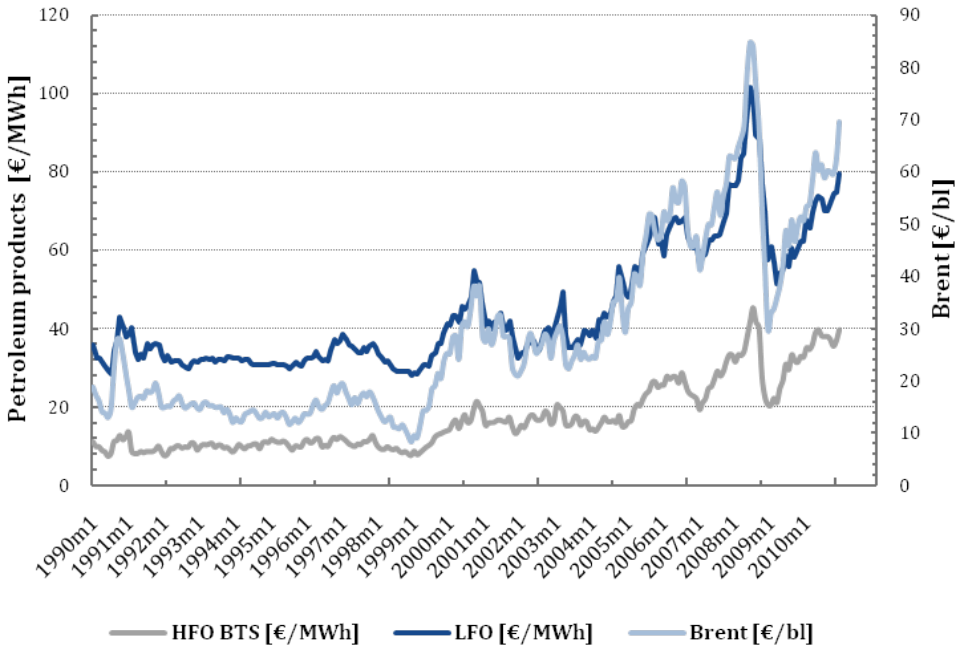


Figure 2: Evolution of the prices of oil and oil derivatives products included in the indexation formula.

In Figure 1, we have schematically represented the fact that the formula is a tool to estimate the evolution of the utility's natural gas supply cost. Yet, it does not constitute the entire regulatory mechanism in itself. Setting the new tariff requires to go through a decision process in which different actors interact and have various roles and responsibilities.

The regulatory decision process currently in force has been set by the decree dated of 18 December 2009. According to this decree, the choice of the formula for each natural gas retailer should be taken in a decree by the Economy and Energy minister(s), after consultation of the CRE.

Tariffs are evolving to take into consideration the evolution of the retailer natural gas supply cost according to the supply formula published in the decree, as well as the evolution of the other costs such as transport, storage, distribution and commercial costs.

During the period between two consecutive decrees setting retail tariffs, the suppliers can propose an adjustment of the tariffs according to the application of the formula to reflect changes in natural gas supply cost or to reflect other modifications initiated by the supplier (for instance, a change in its supply contracts). These modifications are directly applicable, but they should be first approved by the CRE, which should check that the demand complies with the formula of the decree in effect, and they should be notified to the Minister(s) in charge of the Economy and of Energy.

In France, the regulatory framework has been quite unstable. Over the decade preceding the last decree to date (18 December 2009), the decision process has been undecided with unclear rules of tariff adjustment. During some periods, detailed rules of tariff adjustment have even been totally absent. The detailed evolution of the modalities of the decision process is presented in appendix.

In particular, we can stress that, as opposed to what may be claimed, there has not been any binding frequency set by the regulation for tariff adjustment, except for approximately a year between two decrees in 2005[22] and 2006[23]. Figure 3 reports the tariff modifications history. Beyond the absence of a regulatory binding tariff adjustment frequency, the tariff updates have not either been made, by usage, at a constant frequency, even in 2005-2006 when the decree in effect was clearly stating that tariffs adjustments were to be made quarterly.

The decision process has also been highly exposed to the discretionary power of the government, by which the latter:

- has cancelled tariffs updates initially authorized (cf. Figure 3)
- has sometimes performed under-adjustment against the advice of the independent energy regulator[24]
- or has opposed and frozen tariffs adjustments, as shown recently[25], even after the introduction of clearer modalities for the decision process.

This regulatory framework, using a tariff-setting formula but within a decision process which has been quite unstable and prone to renegotiation, has satisfied neither the regulated utility GDF Suez, nor the consumer, the former arguing that it was not covering its costs, and the later arguing that GDF Suez was benefiting from tariffs set too high, and was therefore given windfall profits.

On the one hand, although there could have been to some extent an inter-temporal compensation (GDF Suez is penalized when tariffs are frozen while its supply cost increases, but is benefiting when tariffs are frozen while its supply cost decreases), GDF Suez has

[22]Decree of 16/06/2005 - " Arrêté du 16 juin 2005 relatif aux prix de vente du gaz combustible vendu à partir des réseaux publics de distribution " - http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000812886&dateTexte=

[23]Decree of 28/04/2006 - " Arrêté du 28 avril 2006 modifiant l'arrêté du 16 juin 2005 relatif aux prix de vente du gaz combustible vendu à partir des réseaux publics de distribution " - http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000266962&dateTexte=

[24]CRE (2006). Avis relatif au projet d'arrêté modifiant l'arrêté du 16 juin 2005 relatif aux prix de vente du gaz combustible vendu à partir des réseaux publics de distribution; CRE (2007). Avis de la Commission de régulation de l'énergie du 27 décembre 2007 sur l'évolution des tarifs de vente de gaz en distribution publique de Gaz de France au 1er janvier 2008; CRE (2008). Avis du 17 avril 2008 sur le projet d'arrêté relatif aux tarifs réglementés de vente de gaz naturel en distribution publique de Gaz de France

[25]Following a 5.2% increase in tariffs on 1st April 2011, the French government has decided to freeze any price increase for at least a year, while prices were supposed to be increased by around 7% in July 2011. See http://www.cre.fr/fr/content/download/10684/178036/file/110405CP-Decisions_concernant_les_prix_de_l_energie.pdfandhttp://www.lesechos.fr/entreprises-secteurs/energie-environnement/actu/0201281264033.htm

claimed that tariff adjustments have been insufficient, leading to substantial negative financial consequences. Table 3 reports figures given by GDF Suez's annual financial reports for the losses and gains resulting from the claimed mismatch between the regulated tariff and the natural gas supply costs of the utility. For instance, over the period 2004-2008, the cumulated negative impact of this mismatch would have reached 1.6 billion euro according to GDF Suez.

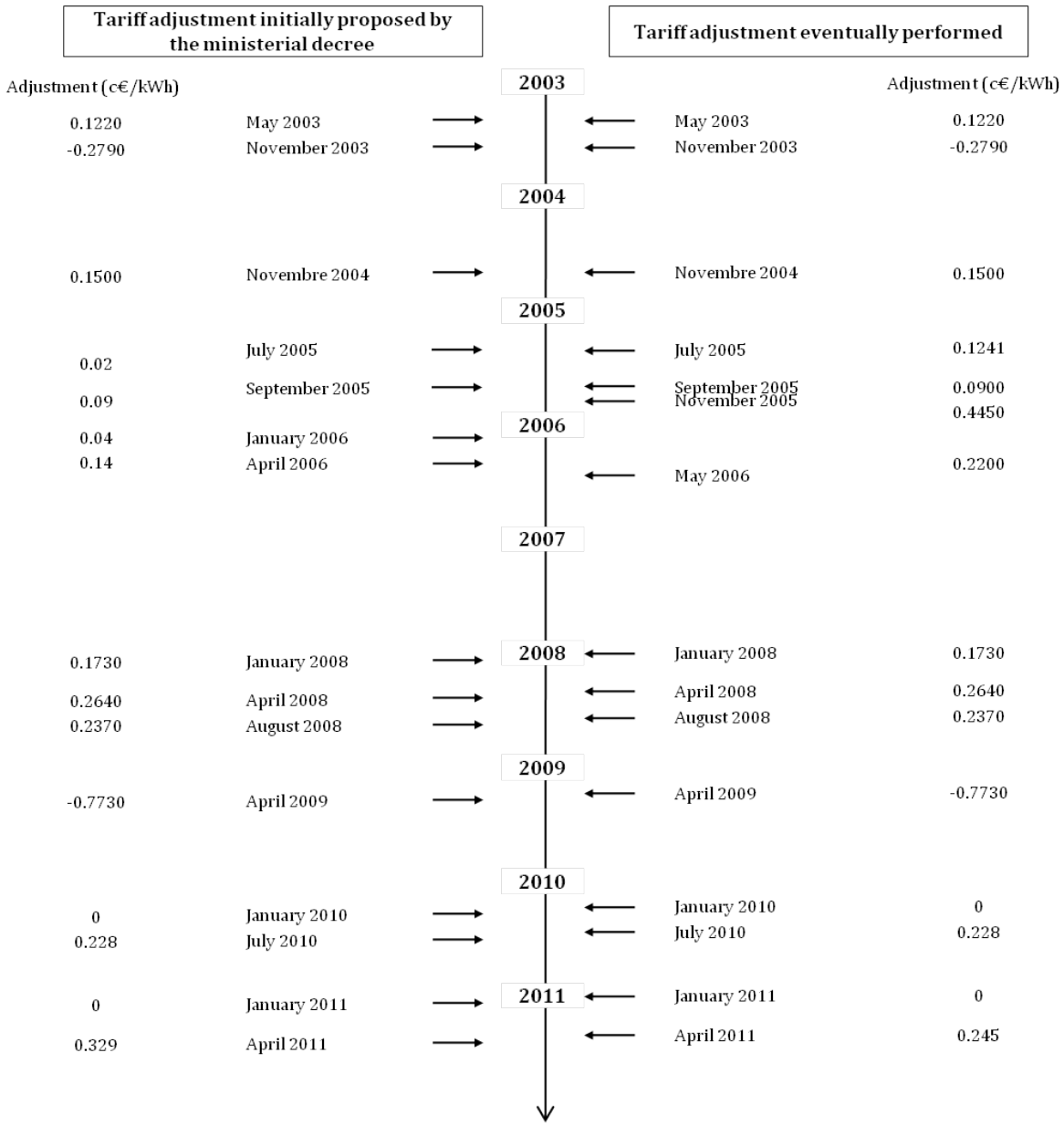


Figure 3: Natural gas retail tariffs evolution history *(Source: CRE)*

Year	Figure given by GDF SUEZ
2004	-130 M€
2005	-370 M€
2006	-511 M€
2007	+84 M€
2008	-679 M€
Total	-1606 M€

Source: GDF Suez

Table 3: Losses and gains as a result of mismatch between the evolution of the regulated tariffs and the evolution of the natural gas supply costs of the utility

On the other hand, consumers associations have almost systematically contested tariff increases[26]. Recently, they have claimed the formula was not reflecting the true supply cost of GDF Suez because the latter would be sourcing more natural gas from the spot market than implied by the coefficients of the formula, and because the natural gas spot price was - and still is at the moment - lower than long-term contract prices, while it used to be higher. They have made such claims although the formula has (always) been validated by the CRE[27].

To sum up, in France, the regulatory environment in which the regulation of natural gas retail prices has been performed has seemingly been undecided and quite unstable, with intense debates between parties having conflicting interests, and leaving scope for interference of the political agenda in the economic regulation.

In this paper, we are interested in assessing the possible regulatory designs and in discussing the challenges associated with their implementation. We focus in particular on the indexation formula used in France to adjust retail tariff following oil and oil derivatives prices variations. We show that while tariff regulation using an *ex-ante* formula seems theoretically the most appropriate solution, there are several practical issues that can undermine the economic properties of this regulatory tool.

The paper is organized as follows. In section 2, we discuss the main functions the regulation should ideally fulfil and the different regulatory instruments at the disposal of the regulator. After discussing their respective advantages and shortcomings, we explain why an *ex-ante* indexation formula seems in theory the most appropriate regulatory tool to deal with retail gas tariff. Section 3 discusses several practical and implementation issues

[26]See for instance: UFC - Que Choisir (2011), "Hausse des prix du gaz: après la trêve, un nouveau coup de massue injustifié!" - Press release - 22 February 2011

[27]See: CRE (2008) "Délibération de la CRE du 17 décembre 2008 portant avis sur la sur la nouvelle formule servant de base au calcul de l'évolution des tarifs réglementes de vente de gaz naturel de GDF Suez";
CRE (2010) "Délibération de la CRE du 31 aout 2010 portant communication sur l'audit de la formule servant de base au calcul de l'évolution des tarifs réglementes de vente de gaz naturel de GDF Suez";
CRE (2010) "Délibération de la CRE du 2 décembre portant avis sur le projet d'arrêté relative aux tarifs réglementes de vente de gaz naturel en distribution publique de GDF Suez"

of an *ex-ante* indexation formula using a numerical example. After having presented our model, the price formula, and our methodology, we present the results of the simulation of the estimation and use of the price formula in different scenarios; and interpret and discuss the imperfections and their origins. Finally, section 4 concludes with some policy recommendations for the regulation of natural gas retail prices in France.

2 Is an (*ex-ante*) indexation formula the best regulatory tool for the retail gas tariff?

2.1 What function should the regulatory mechanism fulfil?

The tariff setting mechanism set by the regulatory authority should fulfil four main functions. First, the regulatory mechanism and the resulting price should allow the regulated company to recover its costs and should therefore ensure its financial viability. Second, regulated prices should not be far from the equilibrium prices prevailing in a competitive market, in order to send good signals to the demand side, and should incentivize the customers to have an optimal demand level for natural gas. Third, the regulatory mechanism should incentivize the natural gas supply company to make efficiency gains, and therefore to reduce its costs, while the benefits of these gains should be passed on to the consumers via a reduction in tariff. Fourth, regulated prices should allocate risks between economic agents (the regulated company and its consumers notably) taking into account revealed preferences.

Enabling the regulated company to recover its costs would not be a difficult task if they were mainly fixed and predictable (e.g., capital and operating expenditures associated with the financing and maintenance of its assets). Instead, the challenge is rather to enable the recovery of the cost of the commodity. Indeed, this part of the cost, whether commodity purchase is done on the spot market or through long-term contracts indexed on oil and oil derivatives prices, can vary significantly; and it represents a non-negligible fraction of the total cost of the company.

The ideal objective of the regulator is, via the regulatory mechanism, to restore efficiency and ensure the maximization of the social welfare as would prevail in a perfectly competitive market. A first best solution is out of reach. But the regulatory mechanism should send economic agents (on the supply and the demand side) the good signals and the right incentives to respectively supply and consume amounts of natural gas which are close to the socially optimal ones. In particular, the regulated price should not lead consumers to consume too much or too little natural gas.

Another necessary condition to restore optimality is that the natural gas company should make all the efficiency gains possible. Not only should the regulatory mechanism enable the regulated company to fully recover its costs, but it should also incentivize it to reduce them. Optimality on the supply side means the company should supply the right quantity, at the lowest possible cost. To lower its costs, the regulated company could for instance (try to) renegotiate its contracts with the gas producers; optimize - if contractually possible - the real-time management of its demand from each producer/supplier of

its portfolio; perform arbitrages on the spot market; or develop and use storage facilities or other infrastructure.

When designing and implementing a regulatory mechanism which should fulfil these functions, the regulator faces two incentives problems resulting from a situation of information asymmetry, by which the insider - the regulated company - has better information than the regulator about its costs and its required efforts to be efficient. Two incentives problems are generally associated to the information asymmetry between the regulator and the regulated company. First the regulator does not know the capabilities of the gas company. In particular, it cannot know *ex-ante* the effort required to improve productivity and reduce cost. The regulator must rely on information revealed by the management of the firm, but the latter has no incentive to reveal costs and required efforts truthfully. This problem is an adverse selection problem. Moreover, there can be a moral hazard problem. The regulation changes the profits the firm can achieve, and therefore, regulating a firm will alter the way the latter is operated. The regulator cannot know *ex-post* whether the firm had a cost-minimizing behavior and has made all the required and/or possible efforts to reduce its costs.

A first best regulatory instrument which would meet all the objectives we have described does not exist. Choices have to be made, and the design of the instrument will likely require to make some trade-offs, for instance between the provision of incentives for cost reduction and the concern for setting cost-reflecting prices. Moreover, conflicts between regulatory objectives are common (e.g., allocation of risk and cost recovery) and therefore some flexibility in the regulatory options is necessary. Indeed flexibility could be used to fine-tune the regulatory option in order to weight different goals, depending on the regulator's priorities.

2.2 Two extreme regulatory options

The economics literature has proposed several regulatory instruments which could be applied for the regulation of retail natural gas tariff. Among them, we can distinguish two standard options: i) a cost-plus - also known as cost-of-service - regulation, and ii) a fixed-tariff set *ex-ante*. These two approaches are diametrically opposed and favour some objectives over others and an ideal mechanism will probably be an intermediary mechanism. Defining tariffs via a formula reflecting the underlying supply cost of the retailer, set *ex-ante* and not modified *ex-post* in the short-run, seems to be a good intermediate solution.

2.2.1 Cost-plus adjusted to costs

The 'cost-plus adjusted to cost' regulation is based on the idea of remunerating the company on the basis of its costs. This implies to compensate *ex-post* all costs incurred by the natural gas retailer. To do so, the retail tariff is set and adjusted to exactly cover the costs reported by the retailer.

- Cost recovery. This regulatory mechanism enables cost-recovery as long as the audit of the costs incurred is accurate and complete. With this option, there is no problem of adverse selection since the regulated company cannot extract information rent. Its costs are observed *ex-post* and compensated.
- Incentive to the regulated company to reduce their costs. Although this mechanism does not give any undue rent to the company, it does not either give it a good incentive to improve its effectiveness and reduce its costs. The moral hazard problem is maximal. The regulator uses the information on firms' costs to update output price *ex-post* but it cannot observe the efforts of management and the appropriateness of investments (or contracts in our case). Therefore the firms' managers do not have *ex-ante* any incentive to cut costs, since they know in advance that every potential cost reduction only benefits consumers[28].
- Signals to consumers. A cost-plus regulation may however give appropriate incentives to consumers. Although natural gas prices may not reflect the costs of the retailer achieved in an efficient situation, and considering these inefficiencies, natural gas prices do reflect the actual costs incurred by the retailer. For a given cost of supply, there is therefore an equilibrium price reflecting the demand-supply equilibrium and leading economic agents to act efficiently in this context.
- Risk allocation. Given accurate signals to consumers implies that all the (price) risk presented in upstream market will be directly and completely transferred to final consumers.

2.2.2 Fixed tariff (price cap)

Another possible regulatory approach is for the regulator to impose a fixed tariff. This tariff, set *ex-ante*, defines the revenue of the company before knowing the actual costs that the gas company will incur. In this scheme, there should ideally not be any *ex-post* adjustment in the short-run[29].

[28] See: Laffont, J-J. and J. Tirole (1993): A Theory of Incentives in Procurement and Regulation, MIT Press.)// Armstrong, M., Cowan, S. and J. Vickers (1994): Regulatory Reform: Economic Analysis and British Experience, MIT Press.// The company strategically exploits the information asymmetry by relaxing its cost-cutting and management efforts - which are costly.

[29] On the supply side, these tariffs are biasing competition, and do not allow for alternative energy sources to compete. Also, if the price of gas is set too low there is a distortion of competition between the various suppliers because potential new entrants cannot align their tariffs on the regulated tariff, which is too low, and therefore cannot enter.

- Cost recovery. The regulator has a limited ability to determine *ex-ante* the costs of the company. Even *ex-post*, this ability can be limited. If the regulator asks *ex-ante* the firm for an estimate over its future costs, again, an adverse selection arises, by which the firm will have an incentive to distort its costs reports. The fixed price is likely to be either too low or too high compared to the actual underlying cost. A fixed-tariff without *ex-post* adjustment may not enable cost-recovery if it is set too low. On the contrary, if the price is set too high, it will give the company an undue regulatory rent[30].
- Incentives to the regulated company to reduce their costs. Fixed tariff mechanism will give good incentives to gas companies to reduce their costs. Indeed, any decrease in cost will be a net profit for the company since it will not be passed on to consumers.
- Signals to consumers. Setting a fixed-tariff, which does not dynamically adjust to the supply and demand conditions as well as to the underlying supply cost of the retailer does not give appropriate signals to economic agents. If for instance there is a positive shock in the cost of purchase by the retailer, the retail price does not adjust and does not give the signal to consumers of this higher wholesale price. Consumers will not adjust their consumption. The absence of demand response to an increase in the underlying cost of purchase of natural gas will lead to a socially sub-optimal level of consumption. Pushing the analysis further, on the demand side, consumers are not incentivized to adjust their choice of energy source and their level of consumption to natural gas market prices.
- Risk allocation. With this mechanism, the whole (price) risk present in the upstream market is supported by the regulated company.

2.3 Regulating retail tariff through an indexation formula: the bridge between two extreme regulatory tools

Columns [1] and [2] of Table 4 summarize the economic properties of the two 'extreme' regulatory instruments presented above. From this table, it can be seen that none of these two instruments would meet all the regulatory objectives. For instance, a cost-plus regulation could allow cost recovery and could send appropriate price signals to consumers but does not give the good incentives to the regulated company to improve efficiency and reduce its costs. On the contrary, a fixed-tariff without any *ex-post* adjustment, although it may incentivize cost reduction, does not necessarily allow for cost recovery and does not send the good price signals to economic agents.

[30] Additionally, if there are several companies with different costs structures and levels, the problem is even worse. With a unique fixed-tariff, some companies will not recover their costs, while others will be offered an unjustified rent. And if the regulator set prices such as to ensure that even the company which has the highest supply costs recovers them, it will increase even more the rents of the other companies.

	Regulatory instrument		
	[1]	[2]	[3]
Objective	Cost plus	(ex-ante) Fixed tariff	Ex-ante indexation formula
Adequate cost recovery and no rent	++	−	++
Incentive to reduce cost	−	++	++
Signal to consumers	+	+	Depends on formula parameters and tariff adjustment frequency
|Risk allocation	Consumers	Regulated company	Depends on formula parameters

Table 4: Economic properties of the regulatory instruments

An intermediary solution could be to set *ex-ante*, not directly the tariff, but a formula which in turn determines the tariff. This formula would be a function of the underlying determinants of the supply costs incurred by the company, so that any variation in the underlying supply cost of the company is mirrored by a variation in the retail natural gas tariff.

Compared to a tariff set *ex-ante*, a formula introduces flexibility and allows for variability in the tariff. Consequently, the regulated company is theoretically able to recover its costs with this mechanism. Moreover, if the tariff is following more or less closely the supply cost of the regulated company, this regulatory framework should provide relatively good signals to consumers.

Finally, it is important that the *ex-ante* formula does not undergo *ex-post* review in the (very) short-run. Indeed, doing so would remove the incentives of the regulated company to reduce its cost and/or increase its efficiency as it would not retain any benefit from it[31]. Without short run *ex-post* review in the short-run, this regulatory framework apparently solves the agency problems.

[31] We are not arguing that the regulator should define once and for all the price of gas and that the regulator should take an infinite commitment. What we are saying is that when the review period for the formula has been defined (be it one, two or five years), the regulator should commit not to deviate from the formula during the period between the reviews.

3 Regulating retail tariff through an indexation formula: practical and implementation issues

Although theoretically attractive, this regulatory option nevertheless faces several challenges. It is a priori not easy to find a good formula. Setting *ex-ante* a tariff formula supposed to mirror the future evolution of tariff determinants is equivalent to performing a forecasting exercise, with the corresponding forecasting errors[32]. If the formula is totally at odd with the real supply cost of natural gas, it will not send good signals to customers and may not allow the gas company to recover its costs.

The regulatory mechanism should also allocate appropriately the risks born by the gas company and the risks passed on to the consumers. One of the reasons for which retail tariffs regulation is kept can be to preserve an 'acceptable' tariff level for domestic consumers. But a consequence of the regulation, as long as tariffs are not adjusted every period/instantaneously, is also to smooth tariffs compared to the underlying cost evolution. And the extent of this tariff smoothing determines the allocation of price variability risks between the utility and the consumers. The shortest the tariff adjustment period, the more price variability risks consumers are required to bear. Taking into consideration these price variability risks implies to make a trade-off between the allocation of these risks and the concern for setting cost-reflective tariffs.

Beyond the errors of the formula and trade-offs between conflicting objectives, there can be political barriers or problems of commitment to the proper implementation of the regulation, that is to say the initially planned adjustment of tariffs. When underling costs are rising, there will be a strong incentive for domestic consumers to lobby their representatives to set themselves against any tariff adjustment which will be negatively affecting consumers. On the contrary, when underlying costs are decreasing, the gas utility will try to block decisions to review tariffs and pass on the gains to final consumers. These political pressures may lead the regulator, who initially estimated the formula for specific implementation rules and procedures, to renegotiate and change these rules *ex-post*. This could eliminate any benefit from the regulatory scheme. To ensure the success of this regulatory scheme - as for any regulatory regime - the rules of the games should be clearly defined and the institutional framework should be stable.

In the remaining of the paper we unfold through a particular example some of the challenges and imperfections arising when setting such a regulatory mechanism. We consider a single gas utility supplying gas to the entire French domestic market and purchasing natural gas from a given portfolio of long-term contracts for which the price is indexed

[32]Strictly speaking two types of errors exist in a forecasting exercise: estimation errors and forecasting errors.

on petroleum products prices (through an ad-hoc formula). In this setting, we estimate a tariff-setting formula, assess its performances and discuss its imperfections and the sources of these imperfections. The main objective of this numerical illustration is to show that there is no magic tariff-setting formula which would fulfil the required functions assigned to an adequate regulatory mechanism.

We show that even in a very simple hypothetical example with one retailer and a couple of long-term contracts indexed on petroleum products via a formula which has the same form as the estimated tariff-setting formula, there are several implementation issues and imperfections.

3.1 Characterizing the natural gas retail company and the long-term contracts portfolio

We define a perfectly controlled system made of a single regulated company, which purchases natural gas from a portfolio of suppliers through long term contracts which are perfectly known, and which supplies a given demand. We can observe everything in this simple system. The regulated natural gas retail company sources natural gas from a portfolio of 3 producers[33]. We have defined a reference portfolio characterized by specific contractual arrangements between the producer and the retail company[34]. These arrangements include the functional form of the price indexation on the various petroleum products' prices, the period and dates of the tariff reviews[35]. We have taken an identical functional form for the 3 contracts, namely a linear combination of the following variables[36]: the exchange rate USD/€, the price of light fuel oil (domestic fuel oil), the price of heavy fuel oil price, and the price of the barrel of brent. The differences between the contracts are the values of the parameters of the indexation formula as well as, potentially, the tariff review periods and dates, and specific clauses. More details on the data considered and used are given in appendix.

Since there is a single retailer in our illustration, it is entitled to cover the entire domestic demand in France[37]. The total demand of the single retailer is therefore given by the French domestic consumption. This demand is variable and characterized by sea-

[33]For simplicity, we are not including the wholesale spot market in the portfolios in this version of the paper, which means that the utility is not performing any arbitrage on the spot market. In a future version, we will see that adding arbitrage on the wholesale market does not affect our findings and conclusions.

[34]Simulations are also done for other portfolios and results are presented in appendix.

[35]Actual long term contract include other specific clauses such as whether the quantities bought are fixed or variable, whether the contract includes 'take or pay' or destination clauses, etc.

[36]The regulator doesn't know the precise indexation formulas of the contracts of the retailer since it is confidential. So the precise formulas of the contracts are not important or needed for the exercise we perform or for the regulator. Voluntarily we do not detail them here (since the exercise is a blind exercise by definition), but for more details and for reproduction purposes, the reader can refer to appendix. We give details of the 3 portfolios used in our analysis in appendix.

[37]This does well reflect the French market situation in which GDF-Suez is still supplying almost 93% of all domestic customers.

sonality. Figure 4 represents residential consumption in France for the years 1990 to 2011.

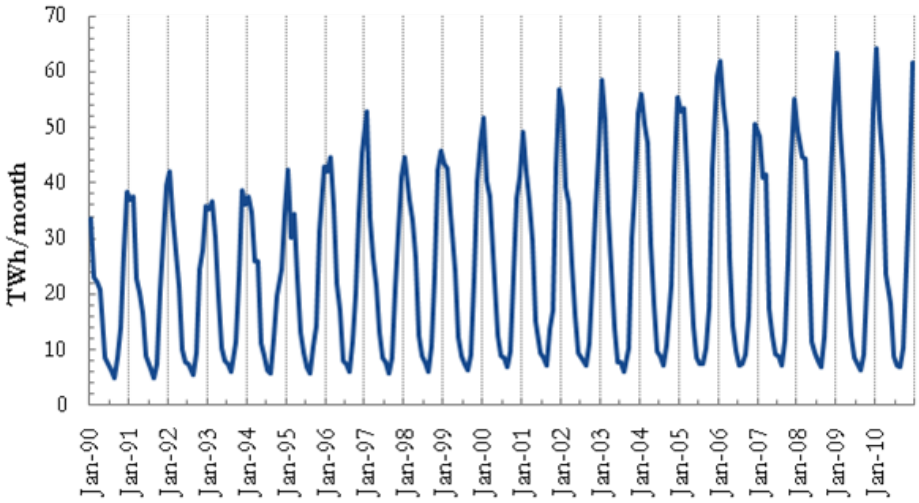


Figure 4: Total consumption at household's level (domestic customers and small businesses) *(Source: Ministry of Energy)*

The repartition of this demand among the gas producers depends on the contractual arrangements. The average supply cost of the retailer is varying not only because prices of petroleum products vary but also because the quantities sourced from each supplier are evolving. The quantities sourced from each contract and their respective price give us the average supply cost function, which the tariff set by the formula is supposed to mirror.

Figure 5 reports the evolution of the average supply cost per unit of gas volume for the reference portfolio of contracts over the period [1990-2010] in order to supply all domestic customers[38].

[38] Again, details on the indexation of each contract for the reference portfolio as well as on the repartition of the total demand between the contracts is given in appendix.

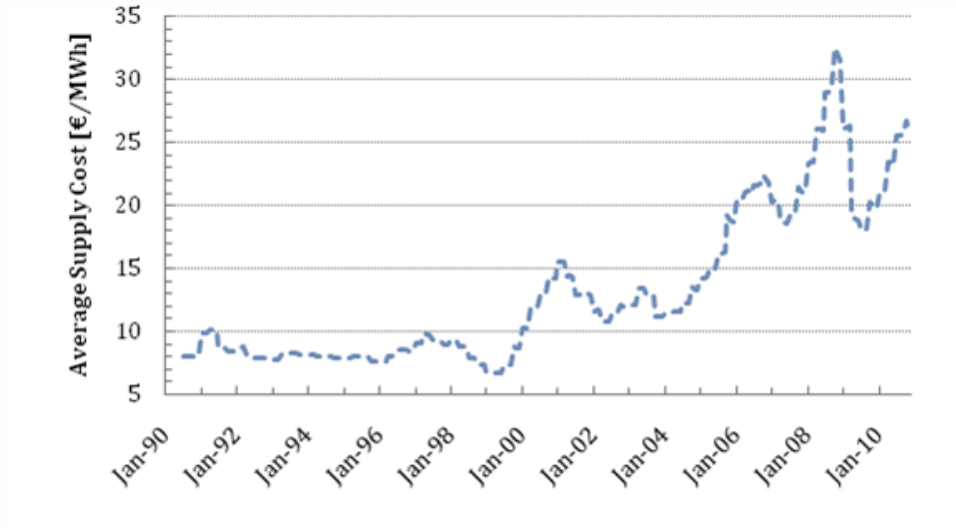


Figure 5: Evolution of average supply cost for reference portfolio

3.2 Defining the structure and estimating the parameters of the tariff-setting formula

We simulate here the work and the choices of the regulator who estimates a tariff-setting formula. The regulator, as in a real context, faces an information asymmetry problem as he cannot observe directly the underlying supply cost of the regulated company. He could only observe this cost by performing an audit of this company, which is a costly process. On the other hand, although the regulator does not have information on the contractual clauses of the underlying long term contracts, it can observe the evolution of the prices of the determinants of these contracts (petroleum products notably).

Defining the structure

The underlying cost of the utility varies in response to variations in the price of petroleum products. The aim of the regulator is to set a formula which will reflect these variations and which will be applied to adjust tariffs at a given time frequency. This frequency of tariff adjustment is in fine linked to the risk allocation between the utility and the consumer, and it should reflect the preference of the regulator. The tariff-setting formula could take several functional forms and include various variables. The best choice depends on the characteristics of the underlying supply contracts - notably the functional form of their indexation and the variables included - which might or might not be known by the regulator. Since our objective is not to find the best formula but rather to find the main sources of imperfections, we focus on a specific example of formula which has the same structure as the one used by the CRE in France - with the exception that initially we omit the wholesale natural gas spot price.

Note that the regulator cannot observe the details of long term contracts. If all contract information were available to the regulator, he would be able to compute exactly the supply cost and would not need a formula. This would however correspond to a cost plus regulation, mechanism which does not provide incentives for the regulated company to reduce costs.

The tariff-setting formula structure is described below. The retail tariff is not adjusted according to the formula at each period, but every T months (i.e. at date t such that t=1+n*T n=0,1,2 . . .). At date t, corresponding to a date of tariff adjustment, the tariff is updated according to the following equation:

$$\begin{aligned} p(t) = \alpha_0 + \alpha_1.p(t-T) + \alpha_{EX}.[I_{EX}(t-1) - I_{EX}(t-T)] \\ +\alpha_{LF}.[I_{LF}(t-1) - I_{LF}(t-T)] \\ +\alpha_{HF}.[I_{HF}(t-1) - I_{HF}(t-T)] \\ +\alpha_{B}.[I_{B}(t-1) - I_{B}(t-T)] \end{aligned} \tag{2}$$

where p(t) is the retail tariff of natural gas at date t. EX refers to the USD/€ exchange rate, and LF, HF and B refer respectively to the tariff of domestic fuel oil, of heavy fuel oil and of brent dated[39]. For each petroleum product (respectively exchange rate) the index I(t) at date t corresponds to the average of the monthly price (respectively exchange rate) calculated over the 6-month period preceding t with a 1-month delay, i.e. calculated over the period [t-6, t-1][40]. For any other time t' which is not a date of tariff adjustment, the natural gas retail tariff is unchanged and remains equal to the tariff at the preceding period ($p(t') = p(t'-1)$).

Estimating the formula

Once the regulator has defined the structure of the formula he intends to use to set the retail tariff, he needs to estimate the parameters ($\alpha_{EX}, \alpha_{LF}, \alpha_{HF}, \alpha_B$). It can do so using a given estimation period during which he can observe both the evolution of the supply cost of the company (the dependent variable which he wants to forecast in the future) and the explanatory variables included in the formula, i.e. the determinants of this cost. The regulator can unveil the underlying cost of the regulated company during this period

[39] LF refers to the price of domestic light fuel oil (Gasoil O.1% in Sulfure) FOB in Rotterdam; HF refers to the price of heavy fuel oil (BTS) (Fuel Oil 1% in Sulfure) (€/ton); and B refers to the price of Brent Dated (€/barrel).

[40] For instance,

$$I_{LF}(t) = 1/6. \sum_{i=t-6}^{t-1} LF(i) \tag{3}$$

If $\alpha_0 = 0$, $\alpha_1 = 1$ and if the tariff adjustment period T is equal to 3 months, this would mean that the tariff increase/decrease for the months of July, August and September would correspond to the linear combination of the increases/decreases of the petroleum products prices and of the exchange rate over the preceding period December-May.

by performing an audit for instance. Subsequently, once set, the formula will be used by the regulator to set the retail tariff, without any *ex-post* modification.
We simulate the estimation of the formula by the regulator with varying choices (for instance, with respect to the tariff adjustment period T chosen for the implementation period).

The tariff adjustment mechanisms presented in the previous section as a set of two equations can be summarized as a single equation, with the retail tariff at any period t given by:

$$\begin{aligned} p(t) = p(A(t)) + \alpha_{EX}.[I_{EX}(A(t)+T-1) - I_{EX}(A(t))] \\ +\alpha_{LF}.[I_{LF}(A(t)+T-1) - I_{LF}(A(t))] \\ +\alpha_{HF}.[I_{HF}(A(t)+T-1) - I_{HF}(A(t))] \\ +\alpha_{B}.[I_{B}(A(t)+T-1) - I_{B}(A(t))] \end{aligned} \tag{4}$$

With:

$$A(t) = (\lfloor t/T \rfloor - 1).T + 1 \tag{5}$$

where $\lfloor . \rfloor$represents the floor function which maps a real number to the largest previous integer. In other words, $\lfloor x \rfloor$ is the integer part of x i.e. is the largest integer not greater than x. Given this floor function, the tariff is indeed only modified with a periodicity of T months. The right hand side of the tariff-setting equation is observable, so it can be estimated by Ordinary Least Squares. We determine the values for the set of parameters $(\alpha_{EX}, \alpha_{LF}, \alpha_{HF}, \alpha_B)$ so as to minimize the estimation error, i.e. the sum of the differences between the level set by the tariff setting formula and the true underlying supply cost over the entire period of estimation. Schematically, if we consider the two curves represented on Figure 6, one being the supply cost and the other being the tariff set by the formula; the coefficients of the formula are estimated so as to minimize the shaded area between the two curves.

We adopt the same approach as the regulator would in a real case, by dividing our data set into two samples: [1990-2000] and [2001-2010]. We estimate the parameters of the formula using the first data sample, period for which we assume that the regulator can observe the underlying costs of the company. Then, we use the estimated formula to set the retail tariff over the period [2001-2010], period for which we assume the regulator cannot observe the underlying cost of the utility. Put differently, what we do is to forecast the series of average cost values over the period [2001-2010] using a formula estimated over the period [1990-2000].

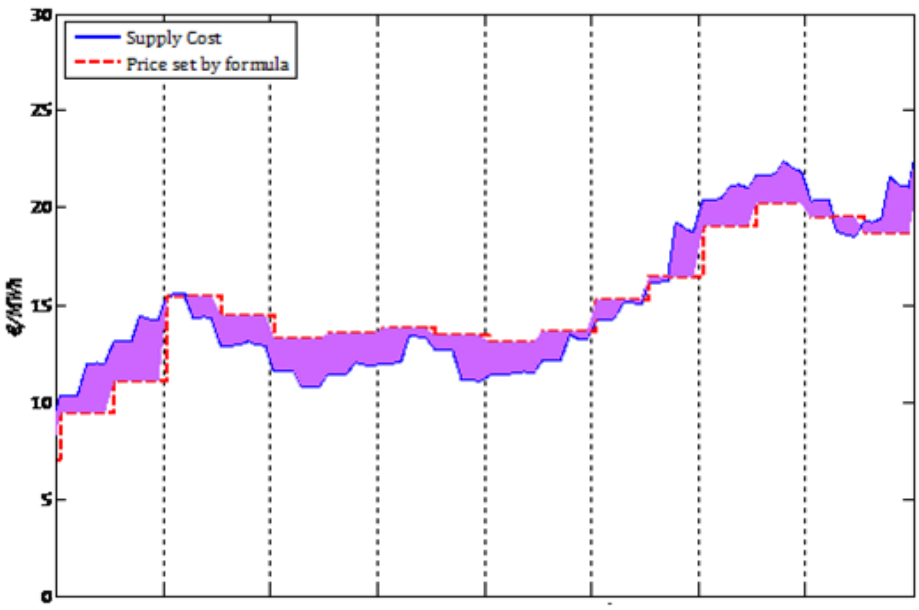


Figure 6: Principle of the coefficients estimation

3.3 Results and discussion

The regulator has to make several choices when defining, estimating and applying the tariff-setting formula. We assess the performance of the formula, and therefore of the regulatory mechanism designed and used according to various criteria related to the functions that an optimal regulatory mechanism should fulfil. We define quantitative performance indicators to assess 3 of the 4 main functions of the regulatory mechanism: the fact that it should ensure cost recovery, should give good signals to consumers (i.e. be cost-reflective) and should properly allocate risks between the regulated company and the consumers. The evaluation of the performance of the formula should therefore be done along these 3 objectives.

- Cost recovery/rent (Bias). The tariff set by the formula is biased if the error with respect to the underlying (average) cost is more important in one direction than in the other, i.e. the method tends to under-estimate or to over-estimate the unobserved cost. The bias is an indicator of the extent to which the utility benefits from an undue regulatory rent or on the contrary cannot recover its costs. To measure the bias of the formula, we compute the following indicators: i) the Mean Percentage Forecast Error (MPFE) and ii) a measure of the total rent earned by the utility over the period[41].
- Signals to the consumers (accuracy). The accuracy of the formula refers to the distance between the tariff set by the formula and the actual underlying cost, ignoring

[41] To compute the total rent, we consider the tariff per MWh and multiply it by the total volume of consumption covered by the company which is here the total French domestic consumption. The rent given is considering no discounting.

the actual sign of that error. This is an indicator of the ability of the formula to give good price signals to the consumers on the short term. To measure the accuracy of the formula, we compute the following indexes: i) the Mean Absolute Percentage Error (MAPE[42]) and ii) the Root Mean Squared Error (RMSE).

- Risk allocation (frequency of adjustment). The regulator is interested in the allocation of cost variations risks between the utility and the consumers, which is reflected through the frequency of tariff adjustments. If the tariff is adjusted too frequently, changes in the underlying supply cost are mainly born by consumers (be they positive or negative variations). And on the contrary, if the frequency of adjustment of tariffs is low, cost variations risks are mainly born by the utility. To proxy this risk allocation, we compute the following indicator: the frequency of tariffs adjustment (=1/period of adjustment).

The expressions of the performance indicators we compute are given in appendix.

In section 2.1., we had set a fourth function that the regulatory mechanism should fulfil, namely to incentivize the natural gas supply company to make efficiency gains and to reduce its costs. We discuss this property only qualitatively since in our simplified model the regulator sets the formula *ex-ante* and the regulated company is always incentivized to reduce cost. Indeed, the formula reflects costs which prevailed during the estimation period ([1990-2000] in our example). Therefore, as long as a new formula is no re-estimated by the regulator at some point during the implementation period ([2000-2010] in our example), any efficiency gain and decrease in cost performed by the company will be a net profit as it will not be passed on to consumers. We will see in section 3.3.2, that this is no more the case if the formula is renegotiated too frequently (or simply if the regulatory commitment not to renegotiate it is not credible); or if the formula is not applied as initially planned (or simply if the regulatory commitment not to delay or change the tariff adjustment period is not credible). Therefore, we consider two different scenarios. First, we consider that the only problem of the regulator is to estimate and to define the tariff-adjustment formula (cf. section 3.3.1). In this situation the implementation and commitment of the application of the formula is perfect and the tariff adjustments are realized exactly as provided by the formula. This first scenario allows to understand the impossibility to get a perfect formula, fulfilling simultaneously all the function of the regulation, even in a situation of perfect implementation. In a second scenario (section 3.3.2), we consider the impact of an imperfect implementation of the formula by looking at the errors when the tariff adjustment period actually implemented is different from the one used when defining and estimating the formula. This second scenario shows a

[42]The advantage of using percentage error and not absolute values is that instead of comparing forecasting error with the actual price, we look at the percentage accuracy, therefore the metrics are pure numbers and thus do not depend on the scale we use to measure the price.

second source of errors, coming from the lack of commitment of the regulator to apply the formula following preset rules.

3.3.1 Impossibility to get a perfect formula, fulfilling simultaneously all the functions of the regulation

Starting from the average supply cost of the retailer, we estimate formula coefficients using different tariff adjustment periods: 3 months (same period as for portfolio contracts prices adjustment), 6 months and 9 months. The series obtained for the reference portfolio are graphed and displayed in Figure 7 (7a to 7c).

Figure 7a shows the comparison between tariff formula and actual (unobservable) average supply cost for the case when the formula is determined to be applied every 3 months. As the indexation formula corresponds exactly to the characteristics of the contract portfolio, the forecasting error is very small, and tariffs and costs curves are matching almost perfectly. This very good fit is due to the combination of four simultaneous and particular conditions: i) The three contracts have the same indexation formula, and the latter has the same form as the tariff-setting formula; ii) The three contracts are reviewed at the same dates; iii) The tariff adjustment period and dates are the same as the review period and dates of the contracts; iv) And finally, the percentage of total natural gas sourced from each producer remains constant over time. When these four conditions are met, the tariff-setting formula is simply a set linear combination of the indexation formulas of the contracts. This explains why it is easy to estimate the formula and to forecast the cost without any error in this very specific case.

But the latter conditions are unlikely to be met in reality even in a simple framework. This is why the results for the other configurations (7b and 7c) are more relevant to draw conclusions. As soon as we depart from the specific conditions underlined above, which is likely to be the case given that contracts are potentially negotiated with various suppliers, there could be large errors in the estimation. One typical departure from a perfect fitting of the structures of tariff formula and of the contract portfolio is the restriction on the frequency of tariff adjustment. Indeed the regulator could find more appropriate to determine a formula adjusting tariffs less frequently than supply contract portfolio (again, to smooth prices).

In this case, one of the conditions mentioned before is not anymore met (and forecasting errors and bias will appear[43]).

This is the configuration we look at in 7b and 7c, with tariff adjustments being performed

[43]Other conditions are in reality not met either. See in appendix for the results derived with two other portfolios of contracts for which these conditions are not met.

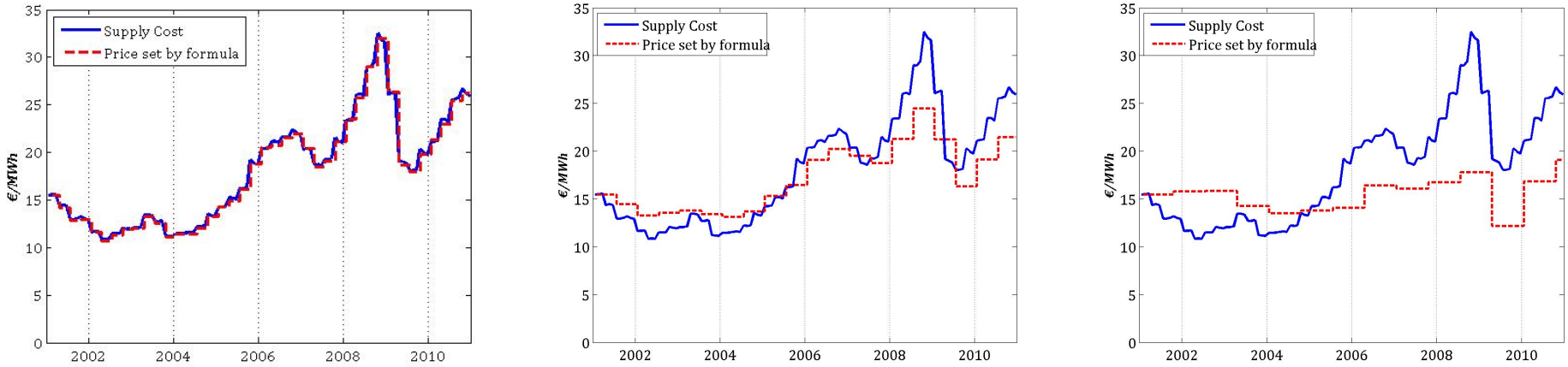
respectively every 6 and 9 months.

As the tariff adjustment period increases (i.e. the frequency of adjustment decreases), the smoothing of tariffs is improved, and therefore less tariff volatility risk is transferred to consumers.
Table 5 reports the values computed for the performance indicators in each configuration. Details about how to read these indicators are provided in appendix.

We see in Table 5 that when the tariff adjustment period increases (i.e. the flexibility of the formula decreases), the absolute values of the performance indicators (MAPE, RMSE and Rent) increase. This evolution suggests that the longer the tariff adjustment period (for a given long-term contracts portfolio price adjustment), the larger the inaccuracy and the bias of the formula, which means less cost-reflective tariffs allowing cost recovery. The larger inaccuracy can also be seen graphically in Figures 7b and 7c.

We clearly uncover here the trade-off to be made between cost-reflective tariffs allowing cost recovery, and a relatively low tariff adjustment frequency allowing a better risk allocation[44].
The formula defined by the regulator, even if built while knowing perfectly the cost of supply, is not perfectly reflecting the cost of supply. This could either lead to the inability of the company to recover its costs, or to an unjustified rent.

[44]These conclusions are also valid when the various contracts of the portfolio are all reviewed with a period of 3 months, but the review is performed at different dates for each contract of the portfolio. This can be observed from the series displayed for portfolio 2 in appendix.



(a) Te=3/Tf=3

(b) Te=6/Tf=6

(c) Te=9/Tf=9

Figure 7: Portfolio 1

Portfolio		1	1	1
Estimation period		[1990-2000]	[1990-2000]	[1990-2000]
Price adjustment period chosen for estimation (Te)		3	6	9
Price adjustment period actually implemented (Tf)		3	6	9
Performance indicators over the period [2001-2010]				
MAPE	%	1.0	11.6	28.8
RMSE	€/MWh	0.2	2.6	5.5
MPE	%	-0.7	-2.4	-16.1
Rent	m€	-144.8	-3085.1	-8770.8
Average Monthly Rent	m€	-1.2	-25.7	-73.1

Table 5: Performance indicators

It is important to note that the errors (inaccuracy and bias) observed for the second period (2000-2010) can have two main sources. First, the error could reflect estimation errors, or the fact that the formula cannot account for the variation of the series we try to proxy, either because it does not use enough explanatory variables or because the functional form is too rigid and is unable to follow the fluctuations of the series we want to model. The second possible explanation for this error would be that the series we try to forecast takes very different values in the forecasting period and in the estimation period, or that the estimation period is too short.

Given the supply cost patterns for the whole period shown in Figure 5, one could argue that the second process plays an important role given that values are quite different in the second period compared to the first period. This is not the case. Indeed, we perform the same (forecasting) exercise with an estimation of the formula done on the full sample ([1990-2010]) instead of on the subsample [1990-2001].

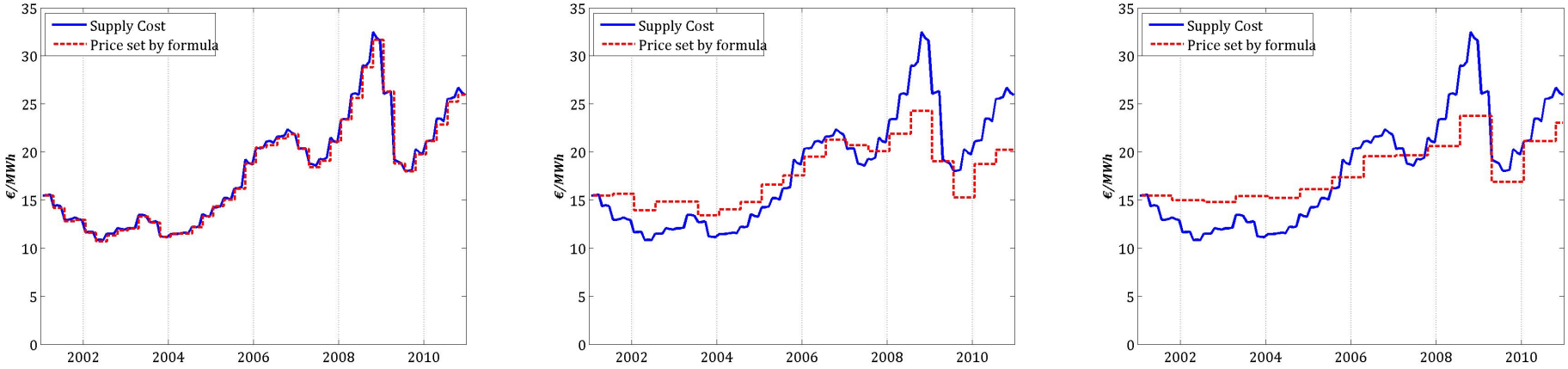
The series obtained over the forecasting period [2001-2010] (tariff set by the formula and actual supply cost) are displayed in Figures 8a to 8c, and the computed values for the performance indicators are given in Table 6.

When the period of the tariff adjustment is 3 months (similar to the contracts portfolio prices adjustment period), the results remained unchanged, and we still get a perfect matching for this perfect situation with idealistic assumptions.

When the tariff adjustment period is 6 and 9 months (Figures 8b and 8c), the inaccuracy and bias of the tariff set by the formula compared to the actual supply cost is still significant.

Therefore, even when taking the full sample to estimate the formula, i.e. even if we knew perfectly the future natural gas supply cost of the utility, we would still be enable to define a formula which does not depart significantly from the cost function.

Consequently, the main source of error seems to be the lack of flexibility of the formula. Moreover, this reinforces the idea that there is an inherent trade-off to be made between objectives of tariff setting (e.g., cost-reflective tariff vs. cost variability risk-allocation). In the real world, this would be even worse since the portfolio of contracts of the supplier can be very heterogeneous, and therefore, inaccuracy and bias of the tariff set by the formula compared to the actual underlying supply cost would be even greater.



(a) Te=3/Tf=3

(b) Te=6/Tf=6

(c) Te=9/Tf=9

Figure 8: Portfolio 1 - 'Perfect Foresight'

Portfolio		1	1	1
Estimation period		[1990-2010]	[1990-2010]	[1990-2010]
Price adjustment period chosen for estimation (Te)		3	6	9
Price adjustment period actually implemented (Tf)		3	6	9
Performance indicators over the period [2001-2010]				
MAPE	%	0.8	14.3	14.4
RMSE	€/MWh	0.2	3.1	3.0
MPE	%	-0.7	-0.2	1.7
Rent	m€	-240.2	-1762.1	-323.6
Average Monthly Rent	m€	-2.0	-14.7	-2.7

Table 6: 'Perfect Foresight' - Performance indicators

3.3.2 The impact of the lack of regulatory commitment on the performance of the formula

In the previous section, we have assumed that the regulator was estimating and setting the formula *ex-ante*, and that once it had done so, for a given adjustment period (3, 6 or 9 months), it would comply with its commitment and actually implement tariff adjustments at the same frequency and timing.
The formula reflects costs which prevailed during the estimation period ([1990-2000] in our example). Therefore, as long as a new formula is no re-estimated by the regulator at some point during the implementation period ([2000-2010] in our example), any efficiency gain and decrease in cost performed by the company will be a net profit as it will not be passed on to consumers.

This means that whatever the structure and parameters of the formula, and whatever the *ex-ante* tariff adjustment period, the regulated company is always incentivized to reduce cost.
In this section, we will see that this is no more the case if the formula is renegotiated too frequently (or simply if the regulatory commitment not to renegotiate it is not credible); or if the formula is not applied as initially planned (or simply if the regulatory commitment not to delay or change the tariff adjustment period is not credible).

This can be the case when the authorities (government or regulator) fail to adjust the tariff of natural gas at the dates and at the time intervals that were considered when estimating the formula. Indeed, the estimated coefficients for the formula depend on the modalities of tariff adjustments considered *ex-ante*. Therefore, whether or not the new tariff is indeed reflective of the evolution of the underlying natural gas supply cost is likely to be highly influenced by the fact that the tariff adjustment is actually performed with the modalities and according to the process which has been considered *ex-ante* when estimating the tariff setting formula.

Quantifying the impacts of the lack of regulatory commitment and their channels is all the more relevant in France since the regulatory framework has been unclear, unstable and subject to the discretionary power of the government.

We show the impact of this lack of regulatory commitment on the performance of the formula in 3 cases:

- Case 1: The adjustment period actually used during the implementation period remains the good one, but a time lag in the implementation is introduced.
- Case 2: The adjustment period actually used is different from the one used for the estimation of the formula.

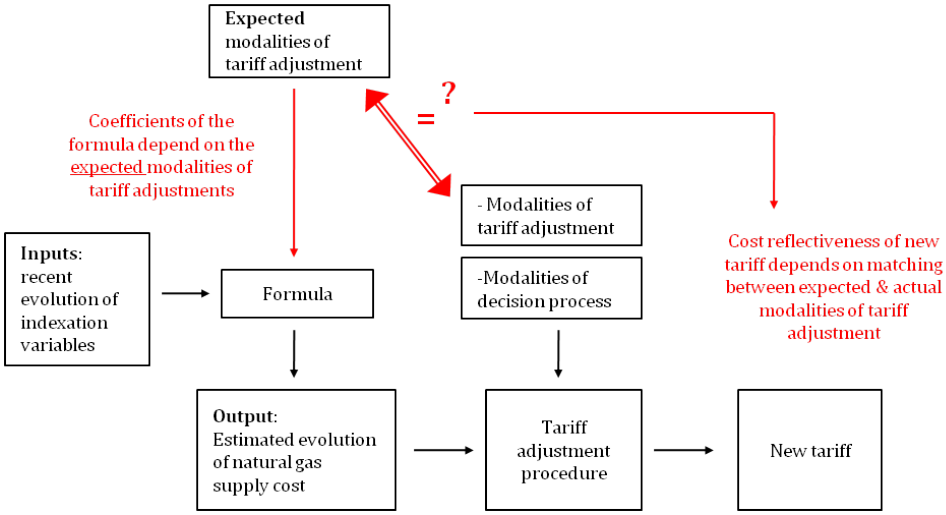


Figure 9: Impact of the lack of regulatory commitment

- Case 3: This case combines the features of the 2 previous cases, meaning that the adjustment period is modified, and a lag is introduced in the implementation. This would be for instance the case if the tariff adjustment is performed at only one given date (for instance in August) every year.

Case 1

The parameters of the indexation formula are estimated for a certain expected adjustment period. Although the actual period for tariff adjustment is the same, the adjustment is made with a lag.

Figures 10a to 10d report the series obtained over the forecasting period [2001-2010] (tariff set by the formula and actual supply cost of the utility), for a value of the time lag respectively equal to 0, 1, 3 and 4 months. Table 7 reports the computed values of the performance indicators.

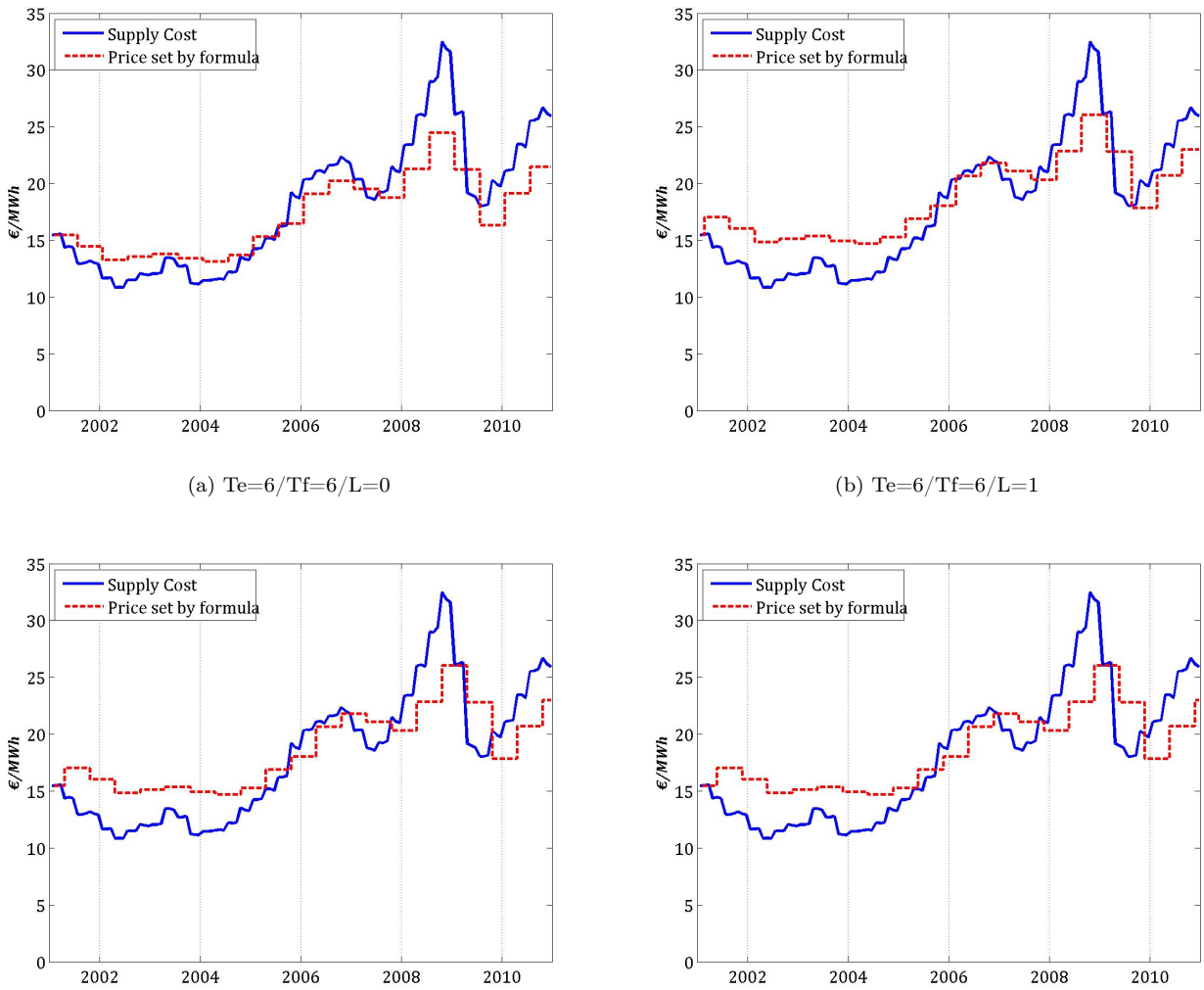
The MAPE and the RMSE are increasing as the lag in the tariff adjustment is increasing. This means that the larger the lag, the less accurate the tariff set by the formula.

Without any time lag in the tariff adjustment, the MPE and the rent are negative. This means that the regulated utility is losing money, as the tariff is not set high enough, on average, for the latter to recover its supply cost.

When there is a lag, the MPE and the rent are positive, meaning that the tariff is set at a level higher, on average, than the utility's supply cost, and the latter benefits from a regulatory rent. But the larger the lag is, the lower the MPE and the rent. This comes from the fact that although the forecast is less accurate in the later case (higher MAPE),

there is a better intertemporal compensation, i.e. excess profit at the beginning of the period (2001-2006) is compensated by losses over the second half of the period (2006-2011).
Yet, it remains that with a lag in the tariff adjustment compared to the timing initially considered for the estimation of the formula, inaccuracy and bias increase.

Therefore, a clear review period must be set and there should be no time lags in tariff reviews.



(a) Te=6/Tf=6/L=0

(b) Te=6/Tf=6/L=1

(c) Te=6/Tf=6/L=3

(d) Te=6/Tf=6/L=4

Figure 10: 'Lack of regulatory commitment' - Portfolio 1 - Tariff adjustment performed with a lag (L)'

Portfolio		1	1	1	1
Estimation period		[1990-2000]	[1990-2000]	[1990-2000]	[1990-2000]
Price adjustment period chosen for estimation (Te)		6	6	6	6
Price adjustment period actually implemented (Tf)		6	6	6	6
Lag in the implementation (L)		0	1	3	4
Performance indicators over the period [2001-2010]					
MAPE	%	11.6	13.3	14.5	15.2
RMSE	€/MWh	2.6	2.8	3.0	3.3
MPE	%	-2.4	5.8	5.0	4.5
Rent	m€	-3085.1	1842.8	1209.1	985.7
Average Monthly Rent	m€	-25.7	15.4	10.1	8.2

Table 7: Performance indicators

Case 2

The parameters of the indexation formula are estimated for a certain expected adjustment period. In this case, the actual adjustment period used *ex-post* is different (yet, it is constant over time, and the initial tariff adjustment takes place at the same date as in the initial scenario).

Figures 11a to 11c report the series obtained over the forecasting period [2001-2010] (tariff set by the formula and actual supply cost of the utility). Table 8 reports the computed values of the performance indicators.

The MAPE and the RMSE are increasing as the adjustment period is increasing. This means that the larger the adjustment period, the less accurate the tariff set by the formula.

The MPE and the rent are negative - i.e. the regulated utility incurs losses - and are increasing in absolute value when the tariff adjustment period increases from 3 months (12a) to 6 months (12b), meaning that the bias increases.

For a tariff adjustment period of 9 months however, the MPE and the rent are positive, meaning that the regulated utility would be benefiting from a large regulatory rent.

To sum up, if after the formula has been estimated for a given tariff review period, the actual tariff review period implemented is longer, the tariff set by the formula is less accurate, i.e. does not reflect the true underlying supply cost as well as in the reference case, and this tariff could lead either to a larger loss for the regulated utility or large windfall profits depending on the circumstances.
The conclusions from this hypothetical case can be used to inform the issues arising from the current regulatory setting in France. The present formula must have been calculated by GDF Suez considering that it will be applied with a given and fixed periodicity. This periodicity influences the estimated coefficients of the formula. The results from our simulation in case 2 show that with a different periodicity of application, the tariff set can be substantially different from the underlying supply cost of the retailer. It is therefore crucial, in order to ensure the best efficiency of the formula that the regulatory authorities commit to apply the formula at the given period which has been agreed when the retailer estimated it.

This point is all the more important to stress for France, where no clear and stable regulatory framework has been established. If a formula, estimated for a specific tariff adjustment frequency, is not strictly applied with the same frequency, then stakeholders must expect large deviations of the tariff from the supply cost.

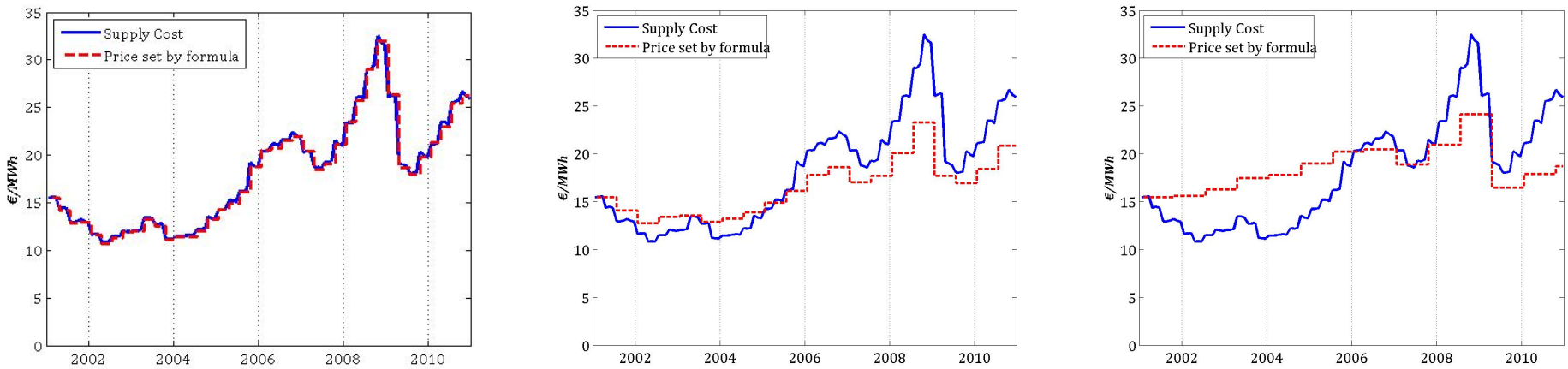
So far, we have considered a static setting, in which the regulatory framework is defined *ex-ante* and then applied throughout the entire period. In a dynamic setting, outcomes of the regulation may trigger attempts by some stakeholder to push for a regulatory renegotiation. In that case the problems we have underlined so far worsen because of the presence of a vicious circle. If the formula is not applied on time and at the right frequency, it may lead to inaccuracy of the tariff, which in turn may lead either the utility or the consumers - depending on the sign of the deviation - to claim that the formula is not adapted and that further tariff adjustment should be blocked. But then, if tariffs adjustment is delayed or blocked, it could increase even more the mismatch between the supply cost and the tariff.

Case 3

In this case, the work of the regulator is simulated while combining the two imperfections in the adjustment presented in cases 1 and 2, i.e. we consider a change in the adjustment period, and we implement the adjustment with a lag. This is for instance the case if the adjustment is performed every august only, case we consider here.

Figures 12a and 12b report the series obtained over the forecasting period [2001-2010] (tariff set by the formula and actual supply cost of the utility). Table 9 reports the computed values of the performance indicators.

Inaccuracy and bias are not necessarily greater than in cases 1 and 2. Yet, conclusions are similar to the ones for the previous case, namely, if the *ex-ante* scheduled tariff adjustment period is not respected, there can be significant inaccuracies, resulting in large rents or windfall profits for the regulated utility, or as in the example given here, large losses for the regulated utility.

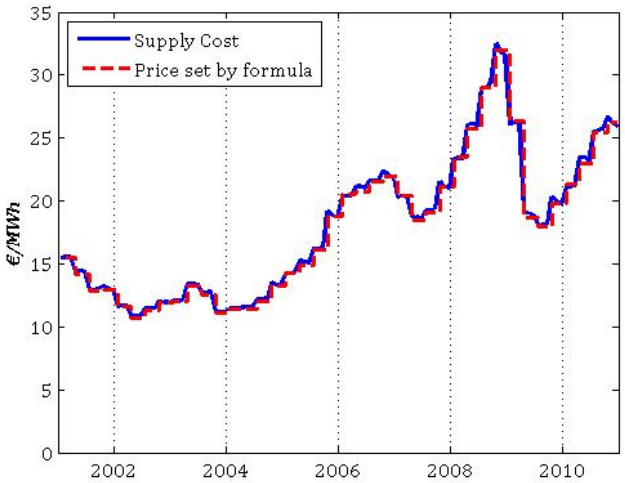


(a) Te=3/Tf=3 (b) Te=3/Tf=6 (c) Te=3/Tf=9

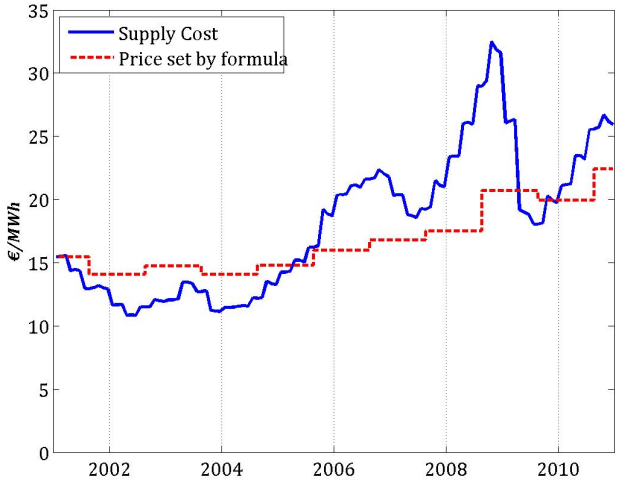
Figure 11: 'Lack of regulatory commitment' - Portfolio 1 - Tariff adjustment performed with a wrong periodicity

Portfolio		1	1	1
Estimation period		[1990-2000]	[1990-2000]	[1990-2000]
Price adjustment period chosen for estimation (Te)		3	3	3
Price adjustment period actually implemented (Tf)		3	6	9
Lag in the implementation (L)		0	0	0
Performance indicators over the period [2001-2010]				
MAPE	%	1.0	14.2	19.3
RMSE	€/MWh	0.2	3.3	4.2
MPE	%	-0.7	-7.0	4.1
Rent	m€	-144.8	-5782.8	1884.7
Average Monthly Rent	m€	-1.2	-48.2	15.7

Table 8: Performance indicators



(a) Te=3/Tf=3/L=0



(b) Te=3/Adjustment in August only

Figure 12: 'Lack of regulatory commitment' - Portfolio 1 - Tariff adjustment only performed in August every year

Portfolio		1	1
Estimation period		[1990-2000]	[1990-2000]
Price adjustment period chosen for estimation (Te)		3	3
Price adjustment period actually implemented (Tf)		3	in August
Performance indicators over the period [2001-2010]			
MAPE	%	1.0	18.3
RMSE	€/MWh	0.2	4.0
MPE	%	-0.7	-5.9
Rent	m€	-144.8	-4732.2
Average Monthly Rent	m€	-1.2	-39.4

Table 9: Performance indicators

4 Conclusion and policy recommendations for the regulation of retail natural gas prices in France

The regulation of retail natural gas prices in France has been subject to intense debate. This debate has focused mainly on the question of whether the tariff-setting formula was appropriately reflecting the natural gas supply cost of the retail company. As discussed in this paper, using an *ex-ante* formula to set the tariff is theoretically a good regulatory option which fulfils the functions expected from the regulation. Yet, through a simulation of the work of the regulator, we have shown that there are significant imperfections and inaccuracies.

Some imperfections are inherent to the structure of the formula and therefore cannot be prevented whatever the decision process. The lack of flexibility of the formula - which is supposed to aggregate all supply contracts of the utility which have different indexation coefficients and adjustment periods - indeed leads to imprecision and potential biases. However, some inaccuracies and biases arising from the use of the formula to set tariffs are linked to the regulatory process and mechanism, and more precisely, to the improper implementation of rules set at the beginning of the regulatory period. Inherent inaccuracies and biases are worsened when price adjustment is either not performed with the initially set periodicity or is delayed.

Stakeholders must be aware of the inherent inaccuracies. If they are not, they could be tempted to try to renegotiate the formula or the regulatory process as soon as there is a small deviation (positive or negative) between the tariff and the supply cost of the utility. While updating the formula when supply contracts are modified could make sense, changing or blocking the adjustment schedule without changing the formula will most likely worsen any inaccuracy or bias.

Moreover, stakeholders, especially the government and the regulator, must acknowledge the fundamental necessity to stick to initial rules, even if imperfect, in order to reach a second best regulation and limit further imperfections. If they do not stick to rules set *ex-ante*, this could lead to further inaccuracies, which in turn would trigger attempts of renegotiation, which if they successfully delay or change the periodicity of the tariff adjustment, would worsen the situation.

The inability to create a stable regulatory environment, without political interference is probably at the core of the problem in France. While the whole debate has focused on getting the presupposed accurate formula, we argue that the main problem is the lack of commitment to the rules.

Therefore, we recommend transferring all price-setting power to the independent energy

regulator, and *de facto* to remove the discretionary power of the government on this matter. This is actually no more than what is required by European Commission directives. Then, the regulator should set stable rules (periodicity, decision process, ...) of tariff adjustment using a tariff-adjustment formula and should stick to these rules throughout a pre-determined regulatory period. Only once this has been completed, should the regulator estimate the tariff setting formula, which would eventually be re-evaluated at the end of the regulatory period.

Unless such measures are taken, the same issues and debates will arise again and again over the coming years.

A Evolution of the regulatory framework

Modalités de la procédure décisionnelle

	Texte	Evolution apportée	Règles en vigueur
1990	**Décret du 20/11/1990**		**- Pas de règles détaillées d'établissement des tarifs** -Tarifs fixés par arrêté ministériel après avis de la CRE **- Fréquence de révision n'est pas déterminée réglementairement** - Dans les faits: évolution des tarifs à peu près 2 fois pas an -2003: **Projet** d'arrêté visant à fixer **fréquence de révision biannuelle**
2001			
2002			
2003			
2004			
2005	**Arrêté du 16/06/2005**	Modifie procédure décisionnelle	-Opérateurs déposent propositions de tarifs auprès des Ministères (Energie et Economie) - Ministres saisissent la CRE pour avis et peuvent demander des modifications aux opérateurs le cas échéant -Evolution trimestrielle des tarifs
2006			
2007	**Arrêté du 28/04/2006**		- Opérateurs déposent propositions de tarifs auprès des Ministères (Energie et Economie) - Ministres saisissent la CRE pour avis et peuvent demander des modifications aux opérateurs le cas échéant - Plus de fréquence de révision réglementaire
2008	**31/12/2007**	**Fin d'application de l'arrêté du 16/06/2005**	**- Absence totale de règles détaillées d'établissement des tarifs** -Tarifs fixés par arrêté ministériel après avis de la CRE selon décret du 20/11/1990 - Fréquence de révision n'est pas déterminée réglementairement
2009			
2010	**Décret du 18/12/2009**	Etablit nouvelle procédure décisionnelle	- Pour chaque opérateur: tarifs fixé par arrêté ministériel, après avis de la CRE, et sur possible proposition de l'opérateur - Tarifs réexaminés et si nécessaire modifiés au moins une fois par an - Sauf disposition contraire dans ce décret annuel, fournisseur autorisé à modifier ses tarifs, jusqu'à l'intervention d'un nouvel arrêté tarifaire, sous réserve d'approbation par la CRE, pour répercuter les variations de ses coûts d'approvisionnement
2011			

Figure 13

Formule

	Texte	Formule en vigueur	Publique?	Audits
2001 2002 2003		-Formule d'évolution tarifaire du contrat Etat-groupe (2001-2003) - Formule indexée sur : - FOL - Exch rate €/USD - Fréquence de révision n'est pas déterminée réglementairement - Dans les faits: évolution des tarifs à peu près 2 fois pas an -2003: Projet d'arrêté visant à fixer modalité pour	Non	
2004 2005 2006		- Formule indexée sur : - 'Produits pétroliers' - Exch rate €/USD - Formule « 6-1-3 » selon Arrêté du 16/06/2005		
2007 2008	2006	- Formule indexée sur : - FOL / FOD - Exch rate €/USD - Formule « 6-1- ? » selon Arrêté du 28/04/2006	Non	
2009 2010	Publication CRE: Juillet 2008 Décret du 18/12/2009	- Formule indexée sur : - FOL / FOD / Brent - Exch rate €/USD	Oui	
2011	Arrêté du 9/12/2010	- Formule indexée sur : - FOL / FOD / Brent - Exch rate €-USD - TTF	Oui	

Figure 14

B Contracts

For each long-term contract of our portfolios, we have used the following indexation formula:

$$\begin{aligned} p(t) = \alpha_0 + \alpha_1.p(t-T) + \alpha_{EX}.[I_{EX}(t-1) - I_{EX}(t-T)] \\ +\alpha_{LF}.[I_{LF}(t-1) - I_{LF}(t-T)] \\ +\alpha_{HF}.[I_{HF}(t-1) - I_{HF}(t-T)] \\ +\alpha_{B}.[I_{B}(t-1) - I_{B}(t-T)] \end{aligned} \tag{6}$$

Where p(t) is the retail tariff of natural gas at date t. EX refers to the USD/€ exchange rate, and LF, HF and B refer respectively to the price of domestic fuel oil, of heavy fuel oil and of brent dated[45]. For each petroleum product (respectively exchange rate) the indice I(t) at date t corresponds to the average of the monthly price (respectively exchange rate) calculated over the 6-month period preceding t with a 1-month delay, i.e. calculated over the period [t-6, t-1][46]. This formula is only applied at each review period (T) which can be different for the different contracts of the portfolio. Therefore, for each contract, the tariff is given by the following formula:

$$\begin{aligned} p(t) = p(A(t)) + \alpha_{EX}.[I_{EX}(A(t)+T-1) - I_{EX}(A(t))] \\ +\alpha_{LF}.[I_{LF}(A(t)+T-1) - I_{LF}(A(t))] \\ +\alpha_{HF}.[I_{HF}(A(t)+T-1) - I_{HF}(A(t))] \\ +\alpha_{B}.[I_{B}(A(t)+T-1) - I_{B}(A(t))] \end{aligned} \tag{8}$$

With:

$$A(t) = (\lfloor t/T \rfloor - 1).T + 1 \tag{9}$$

where $\lfloor . \rfloor$represents the floor function which maps a real number to the largest previous integer[47]. Below, we give for each portfolio, the coefficients of the indexation formula and the prevailing review period for each contract. For each contract, the coefficients of the indexation formula in the 3 portfolios are the same. However, in each portfolio, each contract has different tariff review periods. We summarize these differences in Figures 15 to 16.

[45] LF refers to the price of domestic light fuel oil (Gasoil O.1% in Sulfure) FOB in Rotterdam; HF refers to the price of heavy fuel oil (BTS) (Fuel Oil 1% in Sulfure) (€/ton); and B refers to the price of Brent Dated (€/barrel).

[46] For instance,

$$I_{LF}(t) = 1/6. \sum_{i=t-6}^{t-1} LF(i) \tag{7}$$

.

[47] In other words, $\lfloor x \rfloor$ is the integer part of x i.e. is the largest integer not greater than x. Given this floor function, the tariff is indeed only modified with a periodicity of T months.

Portfolio 1: Contractual Agreement details / Indexation formulas

$p(t)=\alpha\_0+\alpha\_1.p(t-T)+\alpha\_EX.[I\_EX(t-1)-I\_EX(t-T)]+\alpha\_LF.[I\_LF(t-1)-I\_LF(t-T)]+\alpha\_HF.[I\_HF(t-1)-I\_HF(t-T)]+\alpha\_B.[I\_B(t-1)-I\_B(t-T)]$

	Contract 1	Contract 2	Contract 3
α0	0	0	0
α1	1	1	1
αEX	1.3107	1.33	1.3
αLF	0.1988	0.25	0.2
αHF	0.2652	0.27	0.25
αB	0.06206	0.07	0.05
Price Adjustment Period (months)	3	3	3
Adjustment Lag with respect to contract 1	0	0	0

Figure 15

Portfolio 2: Contractual Agreement details / Indexation formulas

$p(t)=\alpha\_0+\alpha\_1.p(t-T)+\alpha\_EX.[I\_EX(t-1)-I\_EX(t-T)]+\alpha\_LF.[I\_LF(t-1)-I\_LF(t-T)]+\alpha\_HF.[I\_HF(t-1)-I\_HF(t-T)]+\alpha\_B.[I\_B(t-1)-I\_B(t-T)]$

	Contract 1	Contract 2	Contract 3
α0	0	0	0
α1	1	1	1
αEX	1.3107	1.33	1.3
αLF	0.1988	0.25	0.2
αHF	0.2652	0.27	0.25
αB	0.06206	0.07	0.05
Price Adjustment Period (months)	3	3	3
Adjustment Lag with respect to contract 1	0	1	2

Figure 16

Portfolio 3: Contractual Agreement details / Indexation formulas

$p(t)=\alpha\_0+\alpha\_1.p(t-T)+\alpha\_EX.[I\_EX(t-1)-I\_EX(t-T)]+\alpha\_LF.[I\_LF(t-1)-I\_LF(t-T)]+\alpha\_HF.[I\_HF(t-1)-I\_HF(t-T)]+\alpha\_B.[I\_B(t-1)-I\_B(t-T)]$

	Contract 1	Contract 2	Contract 3
α0	0	0	0
α1	1	1	1
αEX	1.3107	1.33	1.3
αLF	0.1988	0.25	0.2
αHF	0.2652	0.27	0.25
αB	0.06206	0.07	0.05
Price Adjustment Period (months)	3	6	9
Adjustment Lag with respect to contract 1	NA	NA	NA

Figure 17

The repartition of the total demand between the 3 LT contracts is considered to be the same in the 3 portfolios and is summarized below: With D(t) the total demand (in

GWh/month), at any time t, the quantity sourced from each contract is given by:
Contract 1: Q1(t)=min(8000,D(t))
Contract 2: Q2(t)=min(7000, (D(t)-Q1(t))/2)
Contract 3: Q3(t)=D(t)-Q1(t)-Q2(t)

C Performance indicators

Noting p(t) the tariff set by the formula at date t, c(t) the actual underlying supply cost of the utility, and V(t) the total volume of natural gas sold at period t; the performance indicators we compute are given by the following expressions:

$$MAPE = 1/T_1 \sum_{t=1}^{T_1} |p(t) - c(t)|/p(t) \tag{10}$$

$$MPE = 1/T_1 \sum_{t=1}^{T_1} (p(t) - c(t))/p(t) \tag{11}$$

$$RMSE = [1/T_1 \sum_{t=1}^{T_1} (p(t) - c(t))^2]^{1/2} \tag{12}$$

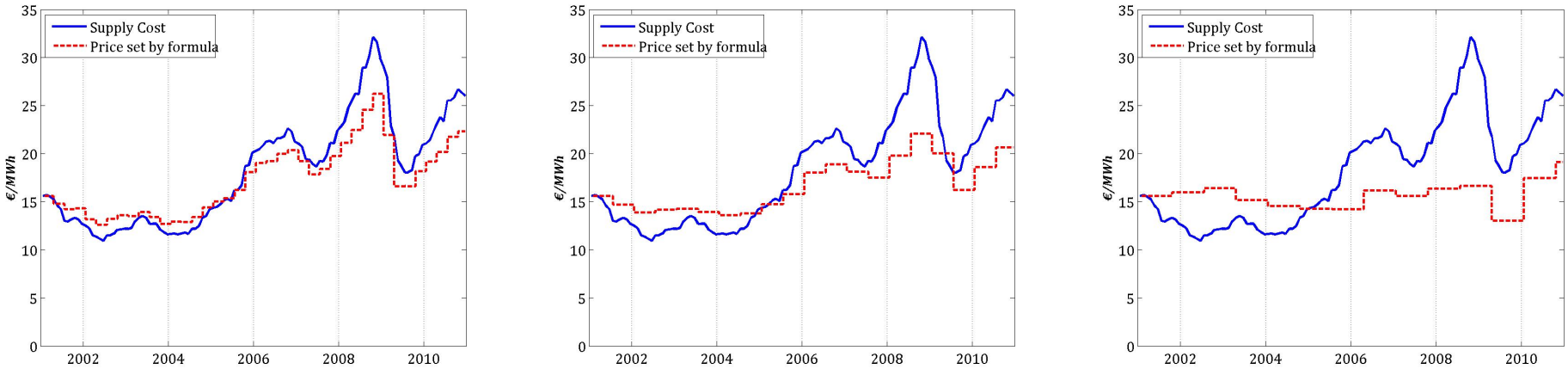
$$Rent_{TOT} = \sum_{t=1}^{T_1} [p(t) - c(t)].V(t) \tag{13}$$

For the example given below, the 'MAPE' and 'Rent' performance indicators read as follows: - MAPE: On average, over the forecast period, the tariff set is set with an error of 1% - Rent: Without discounting, over the whole period, the utility is losing 144.8 m€ given that the tariff set is (on average) below the actual cost incurred by the company. If the figure was positive, this would mean that the tariff set would be (on average) higher than the cost incurred by the utility and that the company would be benefiting from a rent of 144.8 m€ over the period considered.

Performance indicators over the period [2001-2010]		
MAPE	%	1.0
Rent	m€	-144.8

Table 10: Performance indicators value

D Results for portfolio 2

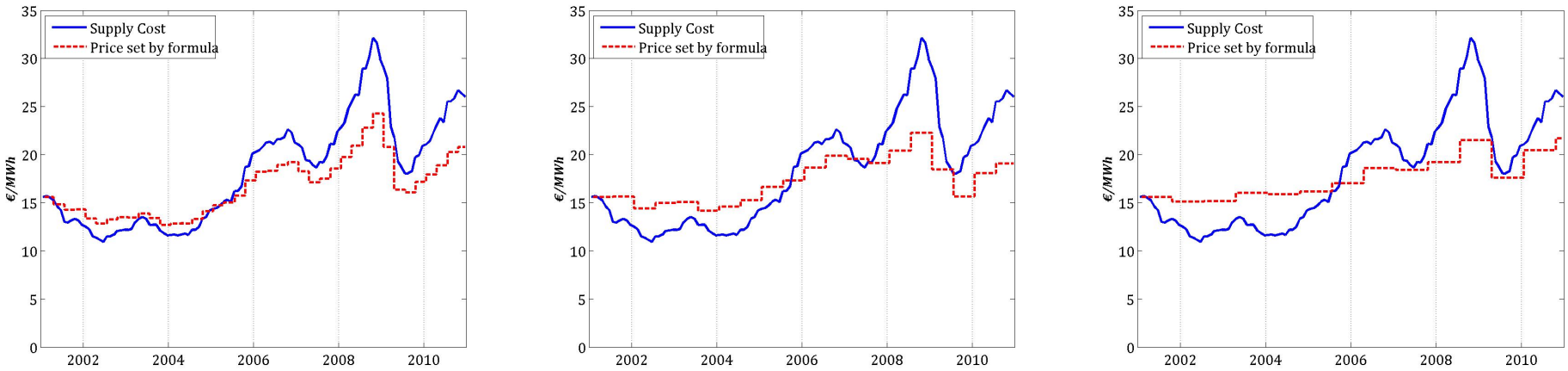


(a) Te=3/Tf=3 (b) Te=6/Tf=6 (c) Te=9/Tf=9

Figure 18: Portfolio 2

Portfolio		2	2	2
Estimation period		[1990-2000]	[1990-2000]	[1990-2000]
Price adjustment period chosen for estimation (Te)		3	6	9
Price adjustment period actually implemented (Tf)		3	6	9
Performance indicators over the period [2001-2010]				
MAPE	%	9.6	15.4	30.3
RMSE	€/MWh	2.3	3.5	5.7
MPE	%	-3.4	-6.2	-16.1
Rent	m€	-3357.7	-5490.5	-9051.3
Average Monthly Rent	m€	-28.0	-45.8	-75.4

Table 11: Performance indicators



(a) Te=3/Tf=3

(b) Te=6/Tf=6

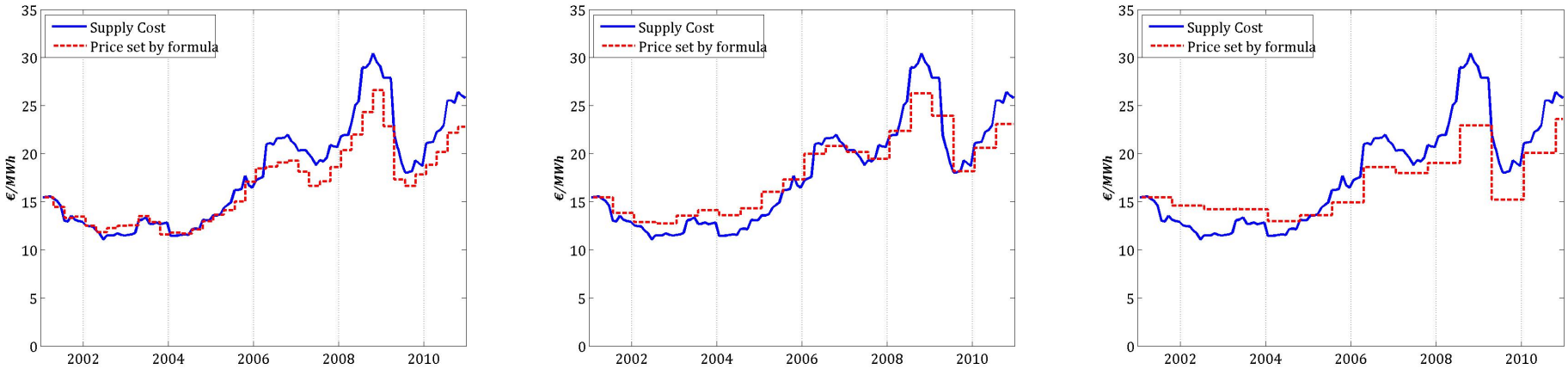
(c) Te=9/Tf=9

Figure 19: Portfolio 2 - 'Perfect Foresight'

Portfolio		2	2	2
Estimation period		[1990-2010]	[1990-2010]	[1990-2010]
Price adjustment period chosen for estimation (Te)		3	6	9
Price adjustment period actually implemented (Tf)		3	6	9
Performance indicators over the period [2001-2010]				
MAPE	%	13.1	17.1	17.3
RMSE	€/MWh	3.1	3.7	3.7
MPE	%	-7.1	-3.2	-1.4
Rent	m€	-5549.2	-3763.4	-2513.6
Average Monthly Rent	m€	-46.2	-31.4	-20.9

Table 12: 'Perfect Foresight' - Performance indicators

E Results for portfolio 3

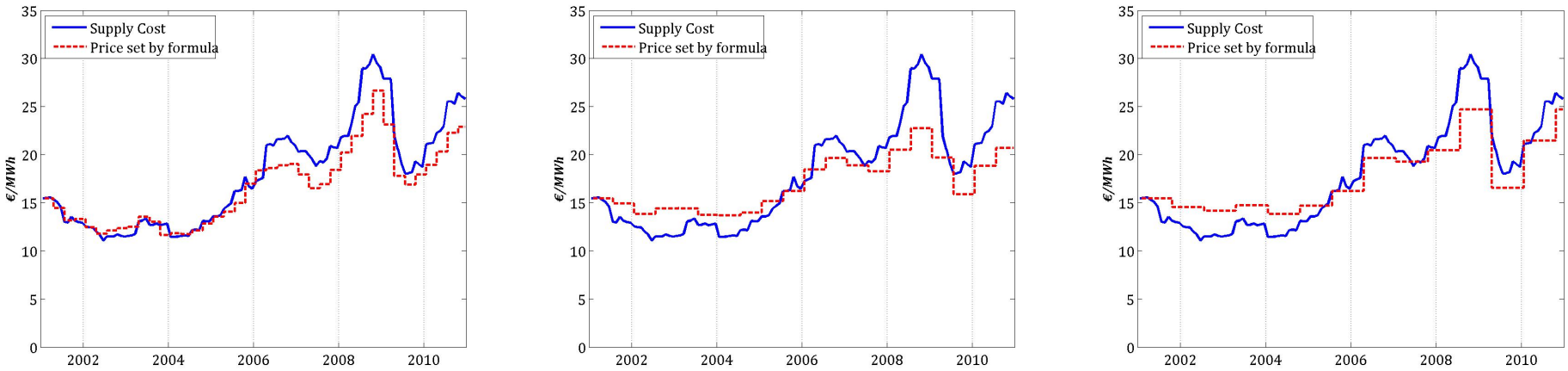


(a) Te=3/Tf=3 (b) Te=6/Tf=6 (c) Te=9/Tf=9

Figure 20: Portfolio 3

Portfolio		3	3	3
Estimation period		[1990-2000]	[1990-2000]	[1990-2000]
Price adjustment period chosen for estimation (Te)		3	6	9
Price adjustment period actually implemented (Tf)		3	6	9
Performance indicators over the period [2001-2010]				
MAPE	%	8.1	7.9	14.2
RMSE	€/MWh	2.0	1.8	2.9
MPE	%	-5.8	2.4	-5.0
Rent	m€	-3536.2	605.6	-3472.5
Average Monthly Rent	m€	-29.5	5.0	-28.9

Table 13: Performance indicators



(a) Te=3/Tf=3 (b) Te=6/Tf=6 (c) Te=9/Tf=9

Figure 21: Portfolio 3 - 'Perfect Foresight'

Portfolio		3	3	3
Estimation period		[1990-2010]	[1990-2010]	[1990-2010]
Price adjustment period chosen for estimation (Te)		3	6	9
Price adjustment period actually implemented (Tf)		3	6	9
Performance indicators over the period [2001-2010]				
MAPE	%	8.0	13.1	10.7
RMSE	€/MWh	2.0	2.9	2.2
MPE	%	-6.0	-2.6	0.6
Rent	m€	-3630.4	-2688.4	-320.1
Average Monthly Rent	m€	-30.3	-22.4	-2.7

Table 14: 'Perfect Foresight' - Performance indicators