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Behavioral Heterogeneity in the US Sulfur Dioxide Emissions Allowance Trading Program[1]

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Summary: In this paper, we study empirically whether uncertainty has an influence on trades in the US SO_2 market. We especially investigate the role of uncertainty on banking behavior. To do this, we introduce a tractable, structural model of trading permits under uncertainty. The model establishes a relation between banking behavior and risk preferences, especially prudence in the Kimball (1990) sense. We then test this model using data on allowances, for utilities submitted to the Acid Rain Program, carried over from one year to the next. Evidence is found of imprudence, namely utilities bank permits, in order to favor higher profits. Another finding is that larger utilities do not adopt a significantly different behavior compared to smaller ones.

Keywords and phrases: Emissions Trading, Permits Banking, Acid Rain Program, Uncertainty, Risk Aversion, Prudence.

JEL Classification Numbers: D81, G11, Q28.

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1 Introduction

The literature on emissions trading began with the work of [19], who introduced main characteristics and critiques concerning these markets, as tools to control pollution. The first theoretical discussions were revived by large-scale projects and implementations of such programs. Among these programs, can be mentioned American experiences (Acid Rain Program, OTC NOx Budget Program, RECLAIM Program, ...), the European emissions trading scheme which started in January 2005, and the future global greenhouse gas market (Kyoto Protocol, 1997).

At present, it is widely recognized that, under the hypothesis of perfect market[2], a system of emission permits is a flexible instrument to attain an environmental objective at the least aggregate cost. Particularly, these cost savings come from averaging and trading[3] (intrafirm and interfirm flexibility) and from banking[4] (intertemporal flexibility). Unfortunately, perfect market assumptions rarely hold in practice. Indeed, emission permits markets can suffer from several impediments such as uncertainties, transaction costs[5], market power[6] and cheating behaviors[7].

In this paper, we focus our attention on uncertainty. Large scale experiences have shown that well designed markets minimise transaction costs, cheating behaviors, and the risk of the exercise of market power, but do not succeed in reducing the various sorts of uncertainty that firms may face in such markets: permit price uncertainty, demand uncertainty which means production and emissions uncertainty, abatement costs uncertainty and regulatory uncertainty among others. A number of researches have already analyzed the role of uncertainty in emission permits markets. The first conclusions come from experimental economics. In different experimental settings [10], and [25] show that uncertainty faced by regulated firms regarding their total emissions creates price instability, which is higher when banking is not allowed. Moreover, price peaks are higher in high rate emission periods. In a theoretical and numerical paper about marketable permits, [42] analyzes the effects of trade approval and transaction cost uncertainties on market performance and aggregate control costs. Although uncertainty and transaction costs suppress exchanges that

[2] To be more precise, the SO_2 market is not even a single market. In addition to bilateral transactions, permits can be purchased in the EPA auction (see among others [11], [14] and [20]).

[3] For theoretical proofs, see for example [43], [51] and [18].

[4] For theoretical proofs, see for example [51], [17], [44], and [36].

[5] See [49], [42] and [13].

[6] See [27], [41], [22] and [37].

[7] [39], [34], [45] and [40].

otherwise would have been mutually beneficial, it is shown that a marketable permit system is still cost-effective compared to a command-and-control approach.

In a model of perfectly competitive markets, [29] examine the impact of stochastic pollution on production decisions. They show that the existence of uncertainty as to the magnitude of pollution tends to reduce production activities – an effect *à la* Sandmo – compared to the situation of non-stochastic pollution with the same mean rate of emissions[8]. [5] also assume risk aversion to analyze the effects of permit price uncertainty on firms' abatement investments and trading behaviors. Experimental results suggest that abatement efforts of risk-averse permits sellers (buyers) are lower (higher) under uncertainty than under certainty. Consequently, at equilibrium, the number of allowances traded are lower under uncertainty than in a perfect market setting. Very recently, [4] met a quite similar result by using the concept of risk aversion to qualify trading attitude: "... when firms are sufficiently risk averse trade will be limited; in particular, infinitely risk-averse firms would not trade at all."(p. 696).

Note that the financial aspect of emissions trading is especially ignored throughout literature. The majority of papers mentioned here are in a static framework and do not take into account any temporal effect of price discovery. This weakness may be explained by the environmental economics approach, which does not deal with intertemporal pricing and subsequent portfolio management.

The aim of this paper is to fill a gap in the literature of emissions trading under uncertainty by providing an analytical and empirical evaluation of the banking behavior of the utilities under uncertainty using the concept of prudence developed by [35]. Our methodology is similar to the one used in a consumption framework where authors aim to indicate if motivation for precautionary saving is increased in response to uncertainty concerning future income. Our proxies for uncertainty utilities are faced with are: (i) the share of coal-based generation for the utility and (ii) if the utility is located in a deregulated or regulated state. Econometric results provide evidence that utilities bank in response to uncertainty, particularly when their power is mainly coal-generated. However, we do not find a stronger motivation for banking in states where restructuring is active.

The next section continues with a presentation of the SO_2 allowance market and reviews previous

[8]The authors argue that firms' behavior should be represented through a risk averse utility function because of the natural aversion of managers for dismissal (p. 221).

economic studies of permit banking issue that are relevant to this paper. Section 3 provides a simple model of trading under uncertainty. The model gives necessary and sufficient conditions for banking given risk preferences of the firm. Section 4 and 5 describe data and econometric specification respectively. Empirical estimations are discussed at the end of section 5. Concluding remarks follow in section 6.

2 Sulfur dioxide market, uncertainty and banking

The Acid Rain Program, which began in the year 1995, is the first large-scale and long-term environmental program using marketable permits to tackle air pollution. This program required utilities to reduce their emissions of sulfur dioxide by 10 million tons below 1980 levels by the year 2010. The program is divided into two phases. Phase I began in 1995 and affected 263 units at 110 mostly coal-burning electric utility plants located in 21 eastern and midwestern states. An additional 182 units joined Phase I of the program as substitution or compensating units, bringing the total of Phase I affected units to 445. Phase II began in the year 2000, tightening the annual emission limits imposed on these large, higher emitting plants. Phase II also set restrictions on smaller, cleaner plants fired by coal, oil, and gas, encompassing over 2000 units in all. The program affects existing utility units serving generators with an output capacity of greater than 25 megawatts and all new utility units. Actually, every major fossil fuel-burning power production facility in the United States is now affected under Title IV.

Each year, the EPA (Environmental Protection Agency) distributes allowances based on a uniform national emission rate multiplied by the utility's previous use of coal. At the end of the compliance period, a utility must hold allowances at least equal to its yearly emissions. For that, firms are free to trade permits and can also bank allowances held in excess for future use, or sell in subsequent compliance periods. Otherwise, significant penalties are applied to firms which do not comply with this rule. A brief summary of the Acid Rain Program design is depicted in Table 1.

Many studies have already analyzed the functioning of the US Sulfur Dioxide Allowances Market, especially Phase I[9]. From these studies, it appears that firms may face an unexpected evolution of the emissions permit market. For example, the first years of the program are characterized

[9]See [28], [8], [6], [24], [47], [23] and [50] among others.

Table 1

The design of the Acid Rain Program

Aim of the program	Prevention of acid rains (SO2 emissions regulation)
Start and end	1995-2030
Unit value of a permit	1 ton of SO_2
Spatial coverage	United States
Sectoral coverage	Electricity generating units (essentially coal-burning plants)
Compliance	At the firm's level
Opt-in program	yes
Number of phases	2 (1995-1999 and 2000-2030)
Compliance period	Annual
Borrowing of permits	No
Banking of permits	Yes
Initial Allocation	Free annual allocation and 3% by auction
New entrants access	Purchase of allowances on the market
Organizational design	Over-The-Counter more often via a broker
Tracking system	ATS (Allowance Tracking System)
Penalty	2000$/ton and permits deduction for next year (ratio 1:1)
Access to trading	Free for every legal entity or natural person

by low price levels compared to forecasts. More precisely, in the beginning of the year 1996, the price of allowances fell under 70$ whereas early price estimates were in a range of 300$ to 1000$[10] (see [28]). Several reasons can explain the low price levels observed. Firstly, the discounting of future costs led firms to high investments in scrubbers and banking allowances for future use. Secondly, the unanticipated widespread availability of low sulfur coal due to the deregulation of railroads[11] decreased marginal costs. Thirdly, competition with low sulfur coal raised innovation in scrubbers' technologies. Fourthly, forecasts could not exactly predict the general equilibrium effects caused by the emissions permits, for example on electricity demand. Fifthly, bonus allowances subsidies for scrubbing and also substitution and compensation units ("Opt-in Program") delayed future costs. And finally, the two phases of the program segregated sellers and buyers of permits.

Generally speaking, these unanticipated evolutions of the allowance market show that emissions permit markets are extremely risky. In other words allowance prices are very volatile. The figures

[10] Resource Data International: 309$, American Electric Power: 392$, Sierra Club: 446$, EPRI: 688$, Ohio Coal Office: 785$, United Mine Workers: 981$.

[11] Staggers Rail Act (1980). See [24].

1 and 2 show that, as the SO_2 market has matured and as prices have escalated during the past year, the long-term volatility has increased significantly. In practice, permit price uncertainty appears for regulated firms as one of the main problems in making compliance decisions. For example, a great number of factors can suggest that permits prices may rise. Among these factors are: the possibility that electricity demand or fossil fuel prices increase, a possible growth of permit demand because of the presence of new pollution sources, or a potential drastic reduction of emissions in the future phase of the program... So, like oil, gas, coal, or electricity, emission permits are commodities with market values that require a proactive portfolio management by regulated firms even if they are allocated free of charge. In the Acid Rain Program, the value of the emission permits portfolio of an electricity producer often exceeds 500 millions dollars with market price volatility about 40% or 60%. Thus, when electricity producers keep all or a part of their allowances in portfolio, they take a speculative position relying on their expectations of permits prices and electricity demand.

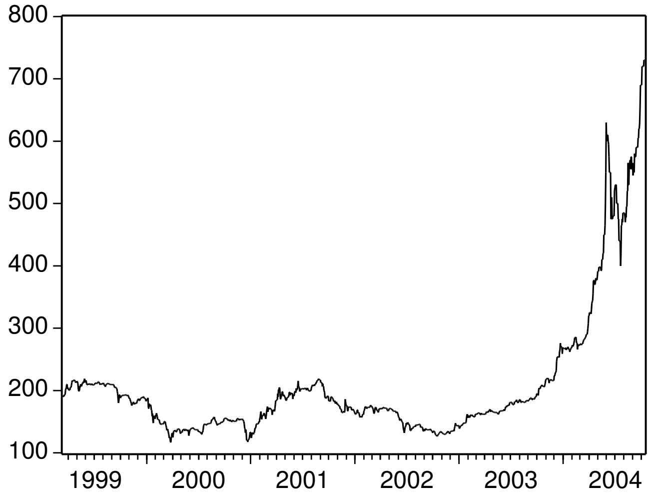

Figure 1

Market-clearing prices in the SO_2 market (1999-2004)

In this sense, pollution permits may be seen as commodities or rather as forward contracts on commodities, which can be traded freely. The difference with standard inputs is that permits are not immediately needed to produce. Emissions markets are designed in such a way that today it is possible to produce without a permit because production periods do not match with the end of the compliance period. That is why we do consider emissions permits as forwards and not as

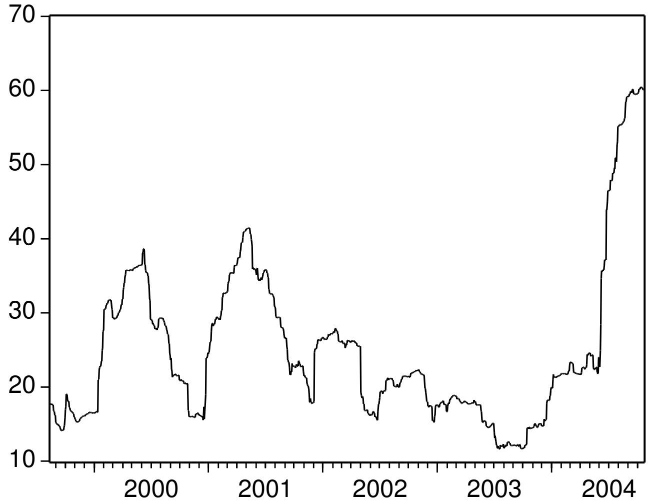

Figure 2

Price volatility in the SO_2 market (1999-2004)

spot commodities[12].

Thus after the initial allocation of permits, regulated firms must choose whether they keep their allowances in portfolio or if they sell them and buy them back later. At constant prices, if a firm sells some permits and buys them back later at a lower price, it realizes a gain due to a good expectation[13]. However, if this firm sells some permits and buys them back later at a higher price, then it supports a loss due to a bad expectation. Consequently, a firm which is long in permits may hesitate to sell permits when there is little chance to have a need for these permits at later dates.

This suggests that firms may have different banking strategies depending on their risk exposure and risk perception. Theoretically, it has been well recognized since [44] that in perfect foresight permit trading, banking and borrowing lead to an efficient allocation of permits that collectively minimizes cost. In practice, the borrowing of permits is not allowed because of environmental reasons and to avoid that firms lobby to reduce the cap at the end of the program. When permits trading and banking are allowed, the rate of change in the price of emissions follows a simple Hotelling's rule ([44]; [17]). In fact, when the permit stocks are positive and the non-

[12]To understand the difference between spot and forward, let us remember that a permit is always designed for a given compliance period.

[13]Given that transaction costs are not too high and interest rate is higher than inflation.

negativity constraint on permits is not binding, the allowance price rises at the rate of interest. Using optimal control theory, [36] find these results again and show that firms have incentives to bank permits when marginal abatement costs are rising, marginal production costs are falling, emission standards are increasing, or output prices are rising. The only study which considers the emission permit market under uncertainty is [46]. In her model, risk-neutral firms minimize their expected discounted costs. In this setting, the rate of change in the price of emissions does not necessarily follow a simple Hotelling's rule. Notably, when firms anticipate that there is a possibility of a permit stock-out, the expected change in marginal abatement costs could be negative. These permit stock-out expectations could partially explain normal backwardation, that is when prices for permits for this period exceed those for future periods[14].

3 A model of emissions trading under uncertainty

This section describes a simple underlying model to perform econometric estimations. Consider a competitive firm which sells a single output. The quantity $\tilde{q}$ is not known prior to emissions trading decision. In addition, the firm faces two other sources of uncertainty, namely: the selling price per unit $\tilde{p}$ and the price of permits $\tilde{c}$ (the support for $\tilde{c}$ is $[\underline{c}, \overline{c}]$). The wealth π_0 is an initial wealth, which incorporates the initial endowment of emissions allowances at date $t = 0$. We take a different road from [4] by assuming that initial endowment has no effect on optimal trading decision because of the opportunity cost of selling permits at the market clearing-price[15]. We assume that $\tilde{q}$ and $\tilde{c}$ are positively correlated through a simple linear relation:

$$\tilde{q} = \mu + \delta \tilde{c} + \tilde{\varepsilon} \tag{1}$$

$\tilde{\varepsilon}$ is a zero-mean random variable independent of $\tilde{c}$ and δ is a positive scalar. The expected quantity is then: $\mu + \delta E(\tilde{c})$. The justification for a positive relation between output quantity and permits price is intuitive (see [15]). The profit of the firm with a constant marginal cost r and an amount h of permits held is given by

[14][3] provide empirical evidence of backwardation. Note that for more convenience, we shall suppose in our model unbiasedness (i.e. neither backwardation nor contango). However, our results remain valid even in a normal backwardation case.

[15]Note that in [4], initial allocation of permits, investment decisions and compliance are simultaneous.

$$\tilde{\pi} = \pi_0 + \tilde{q}(\tilde{p} - \tilde{c} - r) - h(c_f - \tilde{c}) \quad (2)$$

We assume that the firm can trade only at $t = 0$. No trade is possible between $t = 0$ and $t = 1$. At $t = 1$, all uncertainties are resolved. It can be observed that in opposition to previous studies, we do not take into account any abatement costs. Indeed, abatement costs have an impact on the optimal allowances trading strategy of the firm, through the now well-known property that – in absence of banking – marginal abatement cost should equals permits price (see [43]). However, at the end of 2001, permits prices are decreasing (see 1). We can then consider that new investment decisions in abatement technologies cannot be taken at this period[16].

The optimal amount of permits to hold maximizes the expected-utility profit of the firm, which is assumed to possess a standard von Neumann-Morgenstern utility function ($u' > 0$ and $u'' < 0$ indicating risk aversion). The program is then

$$\max_h [Eu(\tilde{\pi})] \quad (3)$$

Because the second-order condition is satisfied given concavity of utility function, the following first-order condition is a necessary and sufficient condition for a unique maximum

$$E[u'(\tilde{\pi})(\tilde{c} - c_f)] = 0 \quad (4)$$

For any two random variables, $\tilde{x}$ and $\tilde{y}$, $E(\tilde{x}\tilde{y}) = E(\tilde{x})E(\tilde{y}) + cov[E[\tilde{x} \mid y], \tilde{y}]$. Condition 4 can then be rewritten

$$[c_f - E(\tilde{c})]E[u'(\tilde{\pi})] = cov[E[u'(\tilde{\pi}) \mid c], \tilde{c}] \quad (5)$$

If SO_2 allowances market is unbiased (or $c_f - E(\tilde{c}) = 0$) as shown empirically by [1] then optimality requires $cov[E[u'(\tilde{\pi}) \mid c], \tilde{c}] = 0$. The following proposition establishes our central result

[16] Of course, ignoring firms' abatement policies is not standard in emissions trading theory. Nevertheless, it does not weaken our empirical results because of the particular considered period.

Proposition 1 *Consider the emissions allowances market as unbiased, then a risk-averse and prudent firm will optimally hold a volume of allowances below the corresponding level for its expected output.*

Proof 1 *The proof is by contradiction. Differentiating* $E[u'(\tilde{\pi}) \mid c]$ *with respect to c yields*

$$\begin{aligned}\frac{\partial E[u'(\tilde{\pi}) \mid c]}{\partial c} &= E[(\delta\tilde{p} - \mu - \delta r - \tilde{\varepsilon} - 2\delta\tilde{c} + h)[u''(\tilde{\pi}) \mid c]] \\ &= [h - E(\tilde{q}) - \delta[E(\tilde{c}) + r - E(\tilde{p})]]E[u''(\tilde{\pi}) \mid c] - cov[\tilde{q}, [u''(\tilde{\pi}) \mid c]]\end{aligned}$$

If $cov[E[u'(\tilde{\pi}) \mid c], \tilde{c}] = 0$ *then* $\frac{\partial E[u'(\tilde{\pi})|c]}{\partial c}$ *cannot be uniformly negative or positive on the support* $[\underline{c}, \overline{c}]$.

First consider the firm as prudent ($u''' > 0$)*. Then* $cov[\tilde{q}, [u''(\tilde{\pi}) \mid c]] > 0$ *because the profit* $\tilde{\pi}$ *is an increasing function with respect to the quantity* $\tilde{q}$*. It follows that* $h - E(\tilde{q}) < 0$ *to obtain* $\frac{\partial E[u'(\tilde{\pi})|c]}{\partial c}$ *not uniformly negative.*

The case corresponding to $u''' < 0$ *is symmetric.* ■

The result appears counterintuitive at first sight. If the firm is prudent (in the [35] sense[17]), it should optimally hold a volume of emissions allowances below the volume corresponding to the expected output[18]. Inversely, an imprudent firm should hold a higher one compared to the expected output. This ambiguous result comes from the difference between prudence *à la* Kimball and prudence in the everyday language[19]. Initially prudence emerges in a consumption setting to explain precautionary saving for an agent facing a future income risk. The aim of the prudent agent is to smooth consumption over time. A parallel can be drawn in a production framework. In order to smooth profits, the prudent firm has an incentive to shift part of the profit from higher realizations to lower ones.

To be more precise, because of the positive relation between quantity (electricity demand) and permit price, two cases must be considered. The first case is positive. If demand is high, profits

[17]See [26] for a presentation of the concept of prudence.

[18]Note that if firms' preferences are assumed to be quadratic, then the separation property [30] applies and the optimal number of permits to hold is the one corresponding to the expected output level.

[19]This difference is pointed out in [21]. The authors consider the case of self-protection to illustrate the counterintuitive meaning of prudence in the [35] sense.

will be increased by holding allowances because the firm will not have to purchase additional allowances at a higher price. But inversely, in the second case, if demand is low, the firm will lose both on output sales and on allowance sales. This is due to the fact that the firm will have to sell excess permits at a lower price, which is itself induced by a low demand. So by holding a lower volume of allowances, the utility faces no risk in losing both on output and on allowances. Nevertheless, in the positive case, the profit will be lower. The model aims to test whether such behavior exists in the SO_2 market. Concretely, are utilities prudent or imprudent?

4 The data

To obtain aggregated data at the utilities level[20], three different information sources are needed: the EPA ATS (Environmental Protection Agency Allowance Tracking System) database, the eGRID 2002 database and the Annual Electric Power Industry database (EIA, Energy Information Administration).

The EPA is responsible for recording the transfer of allowances that are used for compliance and confirms that utilities hold at least as many allowances as tons of SO_2 emitted. The corresponding computer program is the Allowance Tracking System (ATS), which is the official record of allowance holdings and transfers[21]. These data are included in the Acid Rain Program Annual Progress Report (appendix A) published on the EPA Internet website. For each generating unit[22], the allowances allocated for the year, the allowances held in accounts at the end of the year, the allowances deducted at the end of the year and the allowances carried over to the next periods are provided[23]. We then aggregate data at the plant level.

Then, the Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive database of environmental attributes of electric power systems, prepared by the EPA Office of

[20] To capture heterogeneity fully, the [2]'s model examines decisions at the generating unit level. In opposition, [3]'s analysis is at the state level and [16] consider the holding level. For our study, the utilities level is the more relevant. The decisions concerning banking or trading cannot reasonably be made at the generating unit level. Similarly, the holding level may be considered as too synthetic.

[21] Unfortunately, the ATS does not provide any price information.

[22] Each plant is divided in several generating units or boilers.

[23] Of course, the number of allowances carried over to the next year can be calculated by subtracting the allowances deducted at the end of the year from the allowances held in accounts at the end of the year.

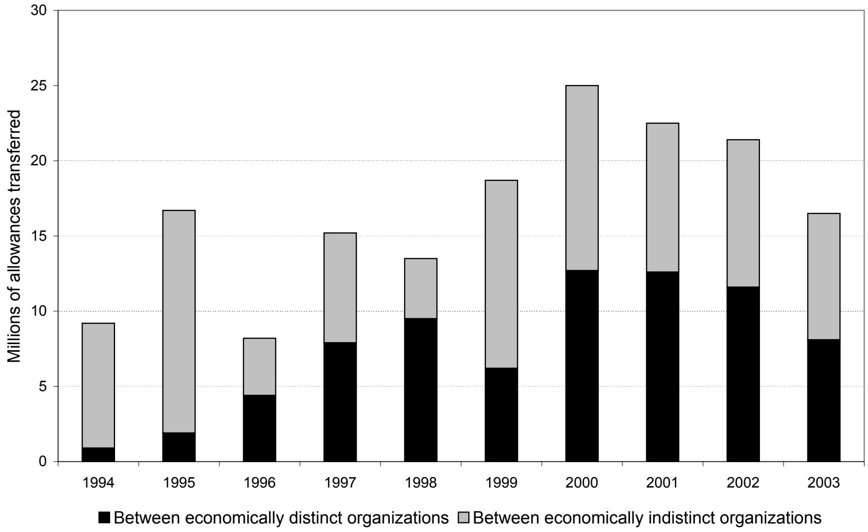

Figure 3

SO_2 allowances transferred under the Acid Rain Program

Source: US EPA 2004

Atmospheric Programs and E.H. Pechan & Associates Inc.'s. eGRID is based on available plant-specific data for all U.S. electricity generating plants. eGRID 2002 includes non-utility power plants as well as utility-owned plants with data for years 1996-2000. From 1998 on, plant level data are available for both utility and non-utility plants. For our analysis, because data are not available for the year 2001, we consider the previous year[24]. We make eGRID data coincide with EPA ATS data for each plant considered. We obtain a vector of characteristics including: the plant generator capacity (MW), the plant annual net generation (MWh), the plant annual SO_2 emissions (tons), the plant annual SO_2 output emission rate (lbs/MWh), the annual net generation (MWh) by fuels, and other more specific features. This vector is now related with allowances data.

Finally, the Annual Electric Power Industry database (Form EIA-861 database) contains aggregate operational data at the utilities level. These characteristics include quantitative variables as retail revenue, resale revenue, delivery revenue or other revenues, as well as a fundamental qualitative variable for our study, namely ownership type.

[24] In fact, data have been updated in 2003.

By aggregating data at the utilities level, we obtain characteristics for about 67.86% of the total sample – in allowances volume – described in the EPA ATS database[25]. For other plants, it is not possible to determine the owner name in the eGRID database satisfactorily. This may be due to mergers and acquisitions, or some errors and lacks in the database.

5 Estimation and empirical findings

Our formulation is similar to formulations in consumption and saving studies, where prudence and precautionary saving are estimated[26]. The aim of these papers is to investigate whether future income risk has a significative impact on saving behavior – namely, precautionary saving – following theoretical formulation by [35]. Our aim is identical, but in a production framework, in that we want to measure the impact of future uncertainty faced by utilities on the banking behavior. Because trading is influenced by many variables, we cannot estimate a coefficient for prudence. We restrict our attention to test for the "precautionary motive" for banking.

We now need to precise how will be measured both banking and uncertainty for empirical test.

5.1 Banking behavior

For each utility, we calculate a ratio measuring the intensity of banking. Let ρ_i be the number of allowances allocated for 2001, τ_i be the number of allowances carried over to 2002 and η_i be the number of allowances deducted in 2001. The ratio is given by

$$ratio_i = \frac{(\rho_i + \tau_i) - g\eta_i}{\eta_i}$$

with g the expected growth rate for total electricity sales in the US. Following the *Annual Energy Review 2003* from DOE/EIA, the expected growth rate was about 4.75% in 2001 for 2002.

One may argue that utilities have different initial position at the beginning of 2001, because of previous banking and endowments. Because a market exists for SO_2, this is not a problem. Utilities may purchase or sell at the market-clearing price the number of permits corresponding

[25]The 137 remaining utilities are presented in the appendix, page 17.

[26]See [48], [33] or [38] among others. For a detailed survey, see [7].

to their risk preferences[27]. Furthermore, banking may be motivated by an absolute obligation to supply, even if allowances prices are very high. A such supply constraint is not present in our model because of the relatively low share of permit price in total production cost. Namely, less than 3 % of the total cost can be attributed to emissions permits [16].

5.2 Uncertainty

The difficulty here is to find a satisfying measure of risk[28]. As stated by [38], 'One needs to identify some observable and exogenous sources of risk that vary significantly across population'.

We consider two sources of risk in this paper. First, we distinguish between states where restructuring is active, and states where it is not. Naturally, some utilities generate power for different states, which may not belong to the same type. In this case, we retain the main state where power is generated. This characteristic is specified through dummy variables D_{jk} with $k = 1, 2$.

The second source of risk considered here comes from the intuition that generators with a higher share of coal-based power are more exposed under Title IV. These generators have a lower ability to diversify their input if permits prices tends to increase. A utility producing exclusively with coal is fully exposed. The variable *coal* representing the share of coal-based generation is calculated for each utility. This last variable is corrected with a factor of emissions rate *pollut*.

5.3 Estimation

Because of the relatively low number of utilities considered, we only retain three characteristics for each utility. *source* is the total volume of power before any sale[29]. *revenue* gives the total revenue of the utilities. D_{jk} with $j = 1, 2, 3$ specifies the type of owner, namely cooperative, private or public.

Following [33], we perform the following semi-log regression

[27]Naturally subject to their liquidity constraint.

[28]Contrary to the saving theory, the so-called self-selection bias, a critique addressed to [48], is not present in our model. Indeed, because deregulation is a posterior fact, utilities do not select states where restructuring is or is not active following their risk preferences.

[29]The variable *source* is the sum of power generated and power sold for resale.

Table 2

Estimation.

Variables	Means	Estimates	Student stat.
coal/pollut	0.147	0.661	2.165**
log(*source*)	6.950	-0,141	−1.767*
revenue	1324061	8.40E-08	1.43
cooperative in deregulated market		2.320	1.848**
private in deregulated market		2.364	1.880**
public in deregulated market		2.935	2.499**
cooperative in regulated market		2.762	2.215**
private in regulated market		2.279	1.795**
public in regulated market		2.724	2.356**
Adjusted R^2		0.195	
Nb. of observations	137	137	

** : significant at 0.05 level

* : significant at 0.10 level

$$ratio_i = \frac{coal_i}{pollut_i} + log(source_i) + revenue_i + \sum_{j=1}^{3}\sum_{k=1}^{2} D_{i,jk} \tag{6}$$

The results are Table 2 on page 15, which gives estimates with Student statistics.

Except for *revenue*, estimates are significant. We obtain six different categories considering each owner type in both regulation and deregulation cases.

5.4 Findings

The evidence indicates a small but significant effect of uncertainty on banking behavior[30]. The dummies coefficients are not significantly different in states where restructuring is active and in states where it is not for private and public owners, but they are different for cooperative owners. However, considering only restructuring dummies, we observe different behaviors in regulated and not regulated states. Utilities hold less permits in deregulated states, perhaps providing support for prudence in the [35] sense. However, the significantly positive coefficient on *coal/pollut* suggest imprudence, because the more exposed is the utility, the more it banks. This coefficient being more large in absolute value, compared to the difference between coefficients

[30]The adjusted R^2 of 0,195 is low, but its level is not surprising for cross-section estimation.

in restructured states and non-restructured states, we may argue in favor of imprudence. So it appears that utilities would favor higher profits despite a resulting more risky probability distribution.

Concerning characteristics, because the coefficient on *revenue* is not significant, and because the one on $log(source)$ is slightly positive, there seems not to be any scale-effect. Surprisingly, large or small utilities have not a significantly different approach for banking.

6 Conclusion

At this time, the banking behavior of risk averse firms has never been taken into account neither theoretically, nor empirically. This first study fills this gap in the literature concerning emissions trading by providing a portfolio management approach to emissions permits. In this way, we draw attention to the financial aspect instead of the classical investment aspect, which is in practice generally limited to short-term analysis[31].

From the viewpoint of economic policy, our results mean that regulators should consider the question of reducing permit price uncertainties by judicious choices as regards allowances market design. Especially, we believe that the regulator may be able to improve the performance of the permits market by trading pro-actively in the allowances market and by allowing permit borrowing in a soft way. More precisely, the regulator can affect the liquidity and reduce market price volatility by withholding and selling allowances to ensure that the market will have an opportunity to function smoothly. This idea that possible welfare gains exist from governmental intervention is unfortunately not implemented in practice although this policy recommendation is not new [19], [4]. With regards to permit borrowing, theoretically it is well known that emissions trading is efficient over periods only if allowance banking and borrowing are permitted [44]. However the permitted use of allowances from a future period for compliance during the current period[32], creates a fairly evident risk for the environment because a firm that uses borrowed allowances in a given period may cease operation before the borrowed allowances are repaid through lower emissions. Moreover, one can imagine that firms voluntarily make no abatement efforts, borrow permits and lobby at the end of the program for a less drastic cap. For these

[31] For instance, a scrubber needs two or three years to be built.

[32] With the implicit commitment that repayment will be made in the form of equivalent reductions in a future period.

two reasons, unlimited borrowing of permits is not allowed in practice. However, the European Emissions Trading Scheme (CO_2) which started in 2005 allows a soft way of permits borrowing that should be generalized in other markets. This rule gives firms permission to use the $t+1$ initial allocation to comply with the commitment period t. In this way, uncertainty is reduced and risk averse firms should have a lower reluctance to sell permits compared to the case where only banking is allowed.

The 137 utilities concerned with the present study are:

Alabama Electric Coop Inc, Alabama Power Co, City of Ames, Appalachian Power Co, Arizona Electric Pwr Coop Inc, Arizona Public Service Co, Arkansas Electric Coop Corp, Associated Electric Coop Inc, Atlantic City Electric Co, City of Austin, Black Hills Power & Light, Carolina Power & Light Co, City of Cedar Falls, Central Electric Power Coop, Central Illinois Light Co, Central Iowa Power Coop, Cincinnati Gas & Electric Co, CLECO Power LLC, City of Colorado Springs, City of Columbia, Columbus Southern Power Co, Consolidated Edison Co-NY Inc, Consumers Energy Co, Corn Belt Power Coop, Dairyland Power Coop, Dayton Power & Light Co, Deseret Generation & Tran Coop, Detroit Edison Co, Dominion Virginia Power, City of Dover, Duke Power Co, East Kentucky Power Coop Inc, Electric Energy Inc, Entergy Arkansas Inc, Entergy Gulf States Inc, Entergy Louisiana Inc, Entergy Mississippi Inc, Entergy New Orleans Inc, Florida Power & Light Co, Florida Power Corp, City of Fremont, Gainesville Regional Utilities, Georgia Power Co, City of Grand Island, Grand River Dam Authority, Great River Energy, Gulf Power Co, City of Hastings, Henderson City Utility Comm, Holland City of, Holyoke Water Power Co, Hoosier Energy R E C Inc, The Illuminating Co, City of Independence, Indiana Michigan Power Co, Indiana-Kentucky Electric Corp, Indianapolis Power & Light Co, Jacksonville Electric Auth, City of Jamestown, City of Kansas City, Kansas City Power & Light Co, Kentucky Power Co, Kentucky Utilities Co, KeySpan Generation LLC, City of Lake Worth, City of Lakeland City of, Lansing, City of Los Angeles, Louisville Gas & Electric Co, Lower Colorado River Authority, Madison Gas & Electric Co, Manitowoc Public Utilities, City of Marquette, MDU Resources Group, Inc, Michigan South Central Pwr Agy, MidAmerican Energy Co, Minnesota Power Inc, Minnkota Power Coop Inc, Mississippi Power Co, Monongahela Power Co, City of Muscatine, Nebraska Public Power District, Nevada Power Co, Northern Indiana Pub Serv Co, Northern States Power Co, Ohio Power Co, Ohio Valley Electric Corp, Oklahoma Gas & Electric Co, Omaha Public Power District, Orlando Utilities Comm, Otter Tail Power Co, City of Owensboro, Pacific Gas & Electric Co, City of Pella, Pennsylvania Power Co, Platte River Power Authority, Portland General Electric Co, Power Authority of State of NY, PSI Energy Inc, Public Service Co of Colorado, Public Service Co of NH, Public Service Co of Oklahoma, City of Richmond, Rochester Gas & Electric Corp, Rochester Public Utilities, Salt River Proj Ag I & P Dist, San Antonio Public Service Bd, San Miguel Electric Coop Inc, Savannah Electric & Power Co, Seminole Electric Coop Inc, Sempra Energy Resources, Sierra Pacific Power Co, City of Sikeston, South Carolina Electric & Gas Co, South Carolina Genertg Co Inc, South Carolina Pub Serv Auth, South Mississippi El Pwr Assn, Southern California Edison Co, Southern Illinois Power Coop, Southwestern Electric Power Co, Southwestern Public Service Co, City of Springfield, Sunflower Electric Power Corp, City of Tallahassee, Tampa Electric Co, City of Taunton, Tennessee Valley Authority, Texas Municipal Power Agency, Toledo Edison Co, Tri-State G & T Assn Inc, Tucson Electric Power Co, Vectren Energy Delivery, WE Energies, Westar Energy, Western Farmers Elec Coop Inc, Wisconsin Public Service Corp, Wyandotte Municipal Serv Comm.

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