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BANKING BEHAVIOR UNDER UNCERTAINTY: EVIDENCE FROM THE US SULFUR DIOXIDE EMISSIONS ALLOWANCE TRADING PROGRAM

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Banking behavior under uncertainty: Evidence from the US Sulfur Dioxide Emissions Allowance Trading Program*

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Abstract

Summary: The aim of this paper is to examine portfolio management of emission allowances in the US Sulfur Dioxide Emissions Allowance Trading Program, to determine whether utilities have a real motive to bank when risk increases. We test a theoretical model linking the motivation of the firm to accumulate permits in order to prepare itself to face a risky situation in the future. Empirical estimation using data for years 2001 to 2004 provides evidence of a relationship between banking behavior and uncertainty the utility is facing with.

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

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1 Introduction

The literature on emissions trading began with the work of Dales (1968), 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[1], 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[2] (intrafirm and interfirm flexibility) and from banking[3] (intertemporal flexibility). Unfortunately, perfect market assumptions rarely hold in practice. Indeed, emission permits markets can suffer from several impediments such as uncertainties, transaction costs[4], market power[5] and cheating behaviors[6].

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 Carlson and Sholtz (1994), and Godby *et al.* (1997) 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, Montero (1997) analyzes the effects of trade approval and transaction cost uncertainties on market performance and aggregate control

[1]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 Cason (1993), Cason and Plott (1996) and Dijkstra and Haan (2001)).

[2]For theoretical proofs, see for example Montgomery (1972), Tietenberg (1985) and Cropper and Oates (1992).

[3]For theoretical proofs, see for example Tietenberg (1985), Cronshaw and Kruse (1996), Rubin (1996), and Kling and Rubin (1997).

[4]See Stavins (1995), Montero (1997) and Cason and Gangadharan (2003).

[5]See Hahn (1984), Misiolek and Elder (1989), van Egteren and Weber (1996) and Liski and Montero (2005).

[6]Malik (1990), Keeler (1991), Sandmo (2002) and Malik (2002).

costs. Although uncertainty and transaction costs suppress exchanges that 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, Hennessy and Roosen (1999) 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[7]. Ben-David *et al.* (2000) 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, Baldursson and von der Fehr (2004) 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 Kimball (1990). 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 economic studies of permit banking issue that are

[7] 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).

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[8]. 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 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

[8] See Hahn and May (1994), Burtraw (1996), Bohi and Burtraw (1997), Ellerman and Montero (1998), Schmalensee *et al.* (1998), Ellerman *et al.* (2000) and Swift (2001) 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

a range of 300$ to 1000$[9] (see Hahn and May (1994)). 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[10] 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 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

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

[10] Staggers Rail Act (1980). See Ellerman and Montero (1998).

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.

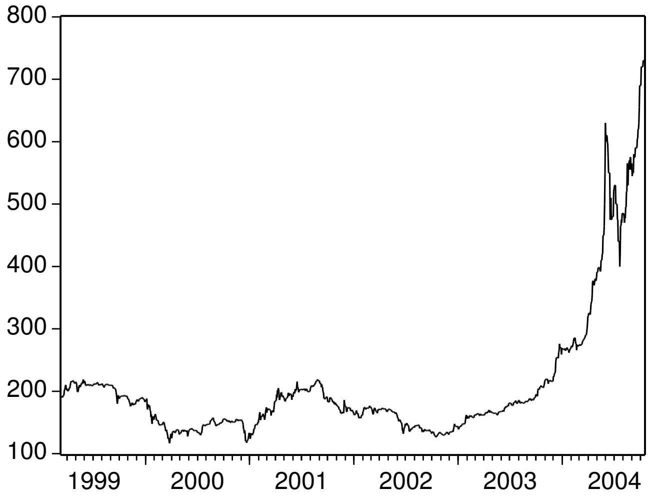

Figure 1
Market-clearing prices in the SO_2 market (1999-2004)

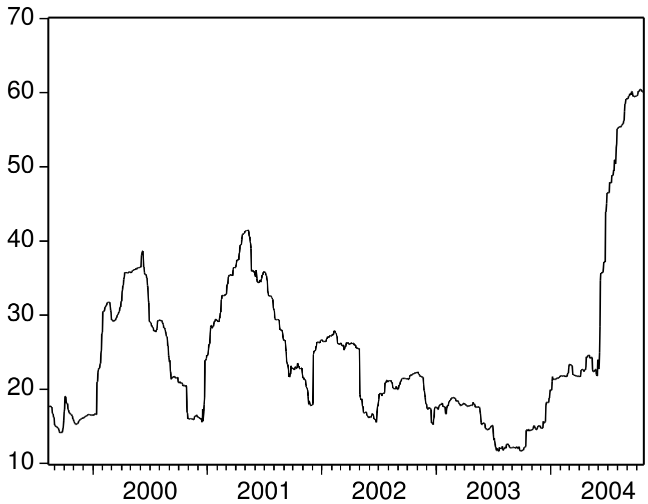

Figure 2
Price volatility in the SO_2 market (1999-2004)

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 spot commodities[11].

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[12]. 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 Rubin (1996) 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 (Rubin (1996); Cronshaw and Kruse (1996)). In fact, when the permit stocks are positive and the non-negativity constraint on permits is not binding, the allowance price rises at the rate of interest. Using optimal control theory, Kling and Rubin (1997) 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 Schennach (2000). 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[13].

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

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

[13] Bailey (1998) 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.

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 Baldursson and von der Fehr (2004) 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[14]. 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 Chicago Climate Exchange, 2004). The profit of the firm with a constant marginal cost r and an amount h of permits held is given by

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

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 Montgomery, 1972). 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[15].

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

[14] Note that in Baldursson and von der Fehr (2004), initial allocation of permits, investment decisions and compliance are simultaneous.

[15] 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.

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

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

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

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

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

If SO_2 allowances market is unbiased (or $c_f - E(\tilde{c}) = 0$) as shown empirically by Albrecht *et al.* (2004) then optimality requires $cov[E[u'(\tilde{\pi}) \mid c], \tilde{c}] = 0$. The following proposition establishes our central result

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 Kimball (1990) sense[16]), it should optimally hold a volume of emis-

[16] See Gollier (2001) for a presentation of the concept of prudence.

sions allowances below the volume corresponding to the expected output[17]. 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[18]. 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 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[19], three different information sources are needed: the EPA ATS (Environmental Protection Agency Allowance Tracking System) database, the eGRID 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

[17]Note that if firms' preferences are assumed to be quadratic, then the separation property from Holthausen (1979) applies and the optimal number of permits to hold is the one corresponding to the expected output level.

[18]This difference is pointed out in Eeckhoudt and Gollier (2005). The authors consider the case of self-protection to illustrate the counterintuitive meaning of prudence in the Kimball (1990) sense.

[19]To capture heterogeneity fully, the Arimura's (2002) model examines decisions at the generating unit level. In opposition, Bailey's (1998) analysis is at the state level and Considine and Larson (2004) 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.

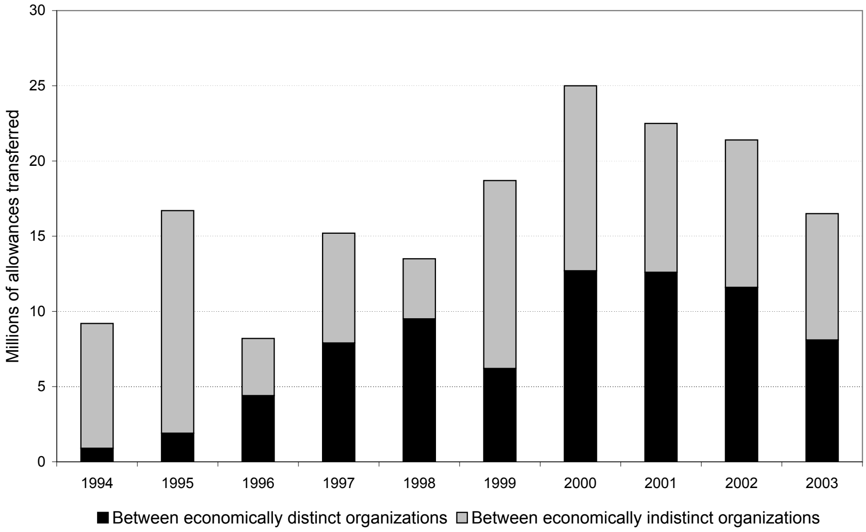

Figure 3
SO_2 allowances transferred under the Acid Rain Program

Source: US EPA 2004

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[20]. These data are included in the Acid Rain Program Annual Progress Report (appendix A) published on the EPA Internet website. For each generating unit[21], 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[22]. We then aggregate data at the plant level.

The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive database of environmental attributes of electric power systems, prepared by the EPA Office of 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 includes non-utility power plants as well as utility-owned plants with data for years 1996-2004. From 1998 on, plant level data are available for both utility and non-utility plants. 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

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

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

[22]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.

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. As we will see, these characteristics cannot be fully incorporated in the estimation.

By aggregating data at the utilities level, we obtain characteristics for about 97.32% of the total sample – in allowances volume – described in the EPA ATS database. 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[23]. 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 Kimball (1990). 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.

Another strand of the economic literature has examined the impact of uncertainty on the level of investment in different industries (see Ghosal and Loungani (1996), Leahy and Whited (1996) and Guiso and Parigi (1999)), on the structure of the industry (see Ghosal, 1996) or the impact of the structure of uncertainty on the level of firm-specific investment (see Henley *et al.*, 2003).

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

[23]See Skinner (1988), Kazarosian (1997) or Lusardi (1998) among others. For a detailed survey, see Browning and Lusardi (1996).

6 Estimation and empirical findings

6.1 Endogenous variable

For each utility, we calculate a ratio measuring the intensity of banking. The expression of this ratio for the firm i is the following:

$$RATIO_{i,t} = \frac{\rho_{i,t}}{\tau_{i,t}}$$

with $\rho_{i,t}$, the number of allowances carried over to year $t+1$ and $\tau_{i,t}$, the number of allowances held in portfolio at the end of the year i.

Of course, one may argue that utilities have different initial position at the beginning of the year, because of previous banking and endowments. Because a market exists for SO_2, this is not a issue in our framework. Indeed, utilities may purchase or sell at the market-clearing price the number of permits corresponding to their risk preferences[24]. 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 following Considine and Larson (2004).

6.2 Measures of uncertainty

The difficulty in this section is to find a satisfying measure of risk[25]. Indeed, as stated by Lusardi (1998), '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.

The second source of risk considered here comes from the model described above, namely the risk concerning the level of demand in the state where the utility sell the major part of its production. To take this risk into account,

[24] Naturally subject to their liquidity constraint.

[25] Contrary to the saving theory, the so-called self-selection bias, a critique addressed to Skinner (1988), 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.

Table 2
Descriptive statistics.

Variable	Mean	Std. dev.	Minimum	Maximum	Skewness	Kurtosis
RATIO	0.310863	0.268958	0.000000	0.995313	0.792816	2.648627
NETGEN (MWh)	15887966	20195976	41898	1.53E+08	2.880171	15.79094
EMI-RATE (lbs/MWh)	9.277366	8.006943	0.014000	62.13800	2.749490	15.28149
COAL-SHARE (%)	73.22738	30.07497	0.000000	100.0000	-1.163408	3.357849

we first estimate an autoregressive specification, as in Leahy and Whited (1996) or in Ghosal and Loungani (1996):

$$D_{s,t} = \alpha_0 + \alpha_1 t + \alpha_2 D_{s,t-1} + \alpha_3 D_{s,t-2} + \epsilon_{s,t} \tag{6}$$

This kind of specification does not allow to improve significantly a simple ten-years moving average. We then use this moving average on the last ten years to estimate the volatility of demand in a given state.

Note that a third source of risk, or rather a factor of exposition to risk may 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 $COALSHARE$ representing the share of coal-based generation is then retained for each utility.

6.3 Estimation

We estimate the following linear equation:

$$RATIO_{i,t} = f(\sigma_{i,t}, X_{i,t}) + e_{i,t} \tag{7}$$

with $\sigma_{i,t}$ the measures of risks the firm is facing with, $X_{i,t}$, the exogenous variables and $e_{i,t}$, the error term. Namely, we use the pooled-OLS method with the following specific equaltion :

$$\begin{aligned} RATIO_i \quad = \quad & \beta_0 + \beta_1 log(NETGEN) + \beta_2 EMIRATE \\ & + \beta_3 COALSHARE + \beta_4 VOLSTATE + \beta_5 VOLSTATE^2 \\ & + \beta_6 MUNICIP + \beta_7 IOU + \beta_8 NONUTILITY \\ & + \beta_9 COOP + \beta_{10} ND \end{aligned} \tag{8}$$

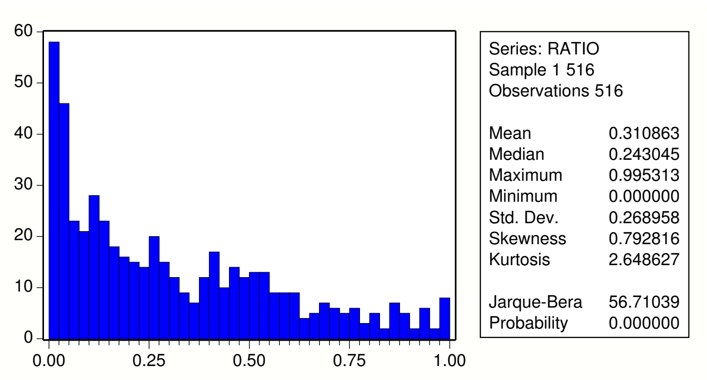

Figure 4
Distribution of variable RATIO.

Table 3
OLS Estimation.

Variable	Coefficient	t Student	H0 proba
$intercept$	1,348795	9,643359	0,0000
$log(NETGEN)$	-0.057154	-7,631455	0,0000
$EMIRATE$	-0,006568	-4,520636	0,0000
$COALSHARE$	-0,002546	-6,327906	0,0000
$VOLSTATE$	0,008531	1,863923	0,0629
$VOLSTATE^2$	-0,000148	-2,063971	0,0395
Ownership type			
Invested Own Utility	0,003289	0,072636	0,9421
Nonutility	-0,055828	-1,115453	0,2652
Cooperative	0,023899	0,461924	0.6443
Municipal	0,084785	0,050704	0,0951
Restructuring risk			
Regulated state	0,091560	3,692388	0,0002
Adjusted R^2	0.274221		
Nb obs.	516		

Due to the non-normal nature of the distribution of the variable $RATIO$, a log-log or semi-log specification may be preferred. We test this assumption but the linear specification always gives better results. Further, the nature of the $RATIO$ term (bounded by 0 and 1) may need a TOBIT model (type I or II in the Amemiya's (1985) typology), but due to the very limited number of utilities banking none permit, the improvement is insignificant. We then estimate a simple OLS regression, whom results are in table 3, which gives estimates with Student statistics.

6.4 Findings

The evidence indicates a small but significant effect of uncertainty on banking behavior[26]. The dummies coefficients are 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 Kimball (1990) sense. The estimated coefficient for the variable $VOLSTATE$ is negative and also significant, but lower in absolute value than the coefficient for the restructuring dummy. So it appears that utilities would favor higher profits despite a resulting more risky probability distribution.

7 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[27].

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 Dales (1968), Baldursson and von der Fehr (2004). 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 Rubin (1996). However the permitted use of allowances from a future period for compliance during the current period[28],

[26] The adjusted R^2 of 0,274 is low, but its level is not surprising for cross-sectional estimation.

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

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

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 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.

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