Load-Based Licensing: Getting the rates right[†]

Tiho Ancev* and Regina Betz**

Abstract

Load-based licensing is a form of pollution taxation that has been recently adopted for various air and water pollutants in New South Walles. As with other taxation based systems for pollution control, the effectiveness of load-based licensing depends on the levels of the set marginal fee rates and the responsiveness of the abatement activities by the polluters to those rates. After four years of the load-based licensing system in NSW, whereby the marginal fee rates gradually increased, data were available to conduct testing as to the effects of the changes in the marginal fee rates on the level and on the changes of NOx emissions by licensed emitters. Analysis was conducted using econometric methods suitable for panel data analysis. Results from the conducted analysis suggests that overall, the marginal fee rates were probably set too low to warrant substantial reduction in NOx emissions. This finding calls for modification of the existing system by increasing the load-based fee rates, perhaps in combination with a system of tax revenue recycling, along the lines of the Swedish NOx system. An alternative that warrants serious consideration is a tradable permit system for NOx as implemented in some parts of the US.

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* Discipline of Agricultural and Resource Economics (A04), University of Sydney, t.ancev@usyd.edu.au

** School of Economics and Centre for Energy and Environmental Markets, University of New South Wales, r.betz@unsw.edu.au

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Introduction

Load-Based licensing is a relatively novel application of Pigouvain pollution fees where a given installation is liable to pay pollution emission fees that are assessed based on the quantity of emissions, the marginal fee rate, the noxiousness of the pollutant, and the location of the installation. This system of load based fees has several advantages over the conventional approaches to regulating emissions, and provides more flexibility for emitters. They are left with the choice to either pay the fee or to invest in abatement technology and reduce the amount of emissions.

In New South Wales, a system of load-based licensing has been in place since 1999. This system was introduced by the *Protection of the Environment Operations (General) Regulation 1998*. Among other pollutants, the scheme covers nitrous oxides (NOx). The system was introduced gradually, and one of the elements that comprises the payable fee formula, the "pollutant fee unit value" was incrementally increased every year from zero in 2000 to $35 in 2003, a level at which it remains at present. This gradual rise in the rate of the pollutant fee, which in essence represents a Pigouvian tax on NOx emissions, allows researchers to observe four different levels of fee rates in four years. It is theoretically expected that as the rate of the fee increases, more abatement should take place and hence emissions should be reduced. Observing the behavior of the regulated industries in relation to their emissions under this system of load based taxation, can in principle provide us with some insight as to their abatement intensity and costs, and the ex-post effectiveness of the set fee rates given those characteristics of abatement.

From the regulatory perspective, the main concern is that if the rates are set too low, the effectiveness of the load-based scheme in reducing emissions would be limited. Emitters, finding it cheaper to pay the fee, would do so rather than abate more. Thus, with fees set too low, the load-based licensing system would not be addressing the problem that it was designed to address in the first place − reducing pollution emissions.

After having the load-based licensing system for NOx in NSW in place for some time, data are now available to conduct testing on whether the marginal fee rates reflected in the load-based fee formula have been set at least approximately effectively, and whether the scheme has in fact resulted in reduced emissions. The aim of the paper is to empirically test the hypothesis that the marginal fee rates implemented under the load-based licensing scheme for NOx in NSW have been effective in reducing NOx emissions. Based on the results obtained from this study, policy recommendations can be put forward and the rates can be reassessed and adjusted.

The economics of load-based licensing has not been extensively studied in the literature. The adoption of the scheme in NSW, has been predated by government department studies with some economics content (EPA NSW, 1999). Taxation of air pollutants, and in particular NOx emissions, which are of main interest in the current paper, has been empirically surveyed in a predominantly European context by Cansier and Krum (1996). Also, the French air pollution system and its effectiveness have been analyzed by Millock and Nauges (2003) in an empirical setup that is similar to the one presented in the current paper. A body of literature that relates emissions to physical output and treats the system of tax revenue recycling has been pioneered by Fisher (2001) and Sterner and Höglund (2000). Abatement costs functions for NO_x from energy production in three industrial sectors have been analyzed in a recent paper by Höglund (2005). The data used in the study were based on the Swedish tax revenue recycling system and showed that a number of relatively inexpensive abatement cost options are available in these industries (e.g. optimization of combustion processes). In addition, substantial published work assessed RECLAIM, the NOx trading system in California (Foster and Hahn 1995; Fromm and Hansjürgens 1996).

The article is structured as follows. In the next section we outline a theoretical discussion that underlies the ensuing empirical analysis of load-based licensing. Following is a section where we describe the data that were used in the empirical study. This is followed by description of the methods used. The results from the empirical study are reported in the penultimate section, together with a discussion. The ultimate section provides a summary and discusses policy implications.

Theory

Since Pigou (1920), economists have contended that an efficient tax on emissions for an individual emitter will equate the tax rate with the cost of reducing the emissions at the margin. The emitter will find it advantageous to abate emissions as long as the abatement activity is less costly than paying a tax at the marginal rate. Once it becomes more expensive to abate, the tax will be paid. Conceptually then, under an emission tax regime, a pollutant emitting firm will maximize profits:

(1) $$\max_{y,e} \Pi = py - c(y,e) - te\,,$$

where p is the exogenous price for the firm's product y, c is a cost function, e is the quantity of emissions and t is the marginal tax rate. From the first order conditions pertaining to the above optimization problem one can derive the familiar expressions that price equals marginal cost of production $p = c_y$, and that the costs of abatement are equal at the margin to the tax rate $-c_e = t$, where subscripts denote partial derivatives.

This basic model should hold true in the case of load-based licensing after care has been taken of the particularities. The key modification is the way the payable load-based fee is calculated. The following formula is used in a load-based licensing scheme:

$$PF = \frac{e\ t\ P_w\ S_w}{10000} \tag{2}$$

where PF denotes the payable pollution fee, e denotes the quantity of emissions of a particular pollutant, t is the fee rate, P_w is a pollutant weighting according to the noxiousness of the pollutant, and S_w is a spatial weighting, which puts heavier weight on the installations that are located in "critical" zones where environmental damages are perceived to be more severe[1]. In the light of the load based licensing formula, the standard representation of equation 1 suggests that under a regime of increasing fee rates (marginal tax rates), it is theoretically expected that more abatement will be undertaken and emissions reduced. If this is not empirically observed, then it will be an indication that the marginal fee rates were perhaps set at a too low level and did not provide sufficient incentive for the emitters to engage in substantial abatement. To conduct an empirical study and to be able to test whether the marginal rates of the load-based fees have been set correctly, one would aim at relating the emissions of pollution to the level of produced output, the components of the load-based fee formula, including the varying tax rates, and potentially some industry or firm specific characteristic.

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[1] This representation of payable fee formula is in a general form. The formula can have another form dependent on the "fee rate threshold". This is discussed in greater detail in the "Data" section of the article.

To conceptualize this, some modifications to the representation of equation 1 are needed. We begin with the firm's profit maximization problem[2]:

(3) $$\max_{\mathbf{x},e} \Pi = py - c(\mathbf{x}, e) - etP_w S_w ,$$

where $y = f(\mathbf{x})$ and $e = g(y)$. y is the physical output, $\mathbf{x}$ is a vector of inputs, and e, t, P_w and S_w are components of the load-based licensing formula as defined above. This relates the emissions to both the level of input use $\mathbf{x}$, as well as to the particular production technology $f(\bullet)$. The first order condition with respect to emissions result in the familiar finding that cost of abatement should equal the tax rate at the margin. The first order condition with respect to the input use is:

(4) $$p\frac{\partial y}{\partial x} - \frac{\partial c}{\partial x} - tP_w S_w \left[\frac{\partial e}{\partial y}\frac{\partial y}{\partial x} \right] = 0 .$$

This can be manipulated by dividing through by $\partial y / \partial x$:

(5) $$p - \frac{\partial c}{\partial x}\frac{\partial x}{\partial y} - tP_w S_w \frac{\partial e}{\partial y} = 0 ,$$

and

(6) $$tP_w S_w \frac{\partial e}{\partial y} = p - \frac{\partial c}{\partial x}\frac{\partial x}{\partial y} .$$

This allows us to express the change in emissions as the level of produced output changes by:

(7) $$\frac{\partial e}{\partial y} = \frac{p - \dfrac{\partial c}{\partial x}\dfrac{\partial x}{\partial y}}{tP_w S_w} .$$

[2] We drop the denominator of 10,000 here for notational simplicity. It may be assumed that the either the emissions or the tax rate are expressed as a ratio to 10,000.

This suggests that in a general form, the emissions of a pollutant can be expressed as a function of the output produced, its price and the cost of production, as well as the marginal tax rate, pollutant weighting and spatial weighting: $\int \frac{\partial e}{\partial y} dy = e = \psi\ (y, p, c, t, P_w, S_w)$. Taking a ratio of emissions to output $e/y = E$, we can restate the above expression as $E = \psi(p, c, t, P_w, S_w)$. Here, we would like to evaluate the following[3]: $\frac{\Delta E}{\Delta S_w}$ and $\frac{\Delta E}{\Delta t}$. We are particularly interested in the last one —the effect of the changes in marginal fee rate on the emission of pollutants. This can be measured by the elasticity of emissions with respect to the fee rate: $\frac{\Delta E}{\Delta t}\frac{t}{E}$.

The theoretical relationship between the quantity of emissions and the fee rate will depend on the possibilities for abatement that are at disposal to the emitting installations. When the abatement has to be achieved by a substantial investment in new end-of-pipe abatement technology it is expected that the emissions will be less responsive to the initial implementation of the load based fees, as a result of a large, lumpy nature of the abatement investment required (McKitrick, 1999) and inertia. On the other hand, if there are technical possibilities to achieve emission reductions without such large investment, by optimizing the combustion process and exploiting abatement options within the system, it is expected that emission abatement achieved in this manner would be fairly responsive to implementation of increasing load fees.[4]

[3] The pollutant weighting was constant during the sample period, with a value of 6. It has recently increased to 9, but the data reflecting this change are not yet available. Therefore the changes in pollutant weighting are not treated further in this analysis, but are of imminent research interest.

[4] NOx emissions abatement options range from energy saving measures or trimming the combustion process up to end-of- pipe technologies such as Flue Gas Desulphurization or Selective Catalytic Reduction. The latter is able to reduce emissions substantially but with substantial costs, www.pollutionengineering.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,6646,107005

In addition to this, it seems that installations in NSW have a choice of implementing either a continuous emission monitoring system (CEMS) or periodic monitoring. While continuous monitoring offers a possibility for verification of abatement achieved through optimising the combustion process, periodic monitoring is not conducive to such verification. This may reduce the incentives for the installations to adopt these relatively low cost abatement options (Sterner, 2003). We were not able to collect data on the type of monitoring across the installations in NSW covered in the data sample, but some anecdotal evidence suggests that the periodic monitoring is predominant.

In relation to the levels of fee rates, it is expected that when they are set at a low level and the end-of-pipe technology is the only available abatement option, the changes in emissions as the fee rates are marginally increased are not going to be substantial. In this case, the cost of paying the fee is likely to be smaller than the cost of the equivalent abatement by any end-of pipe technology which involves substantial investment. However, as the fee rate is increased it is expected that the incentives to reduce emissions on the part of the emitters become greater.

Data

Data were obtained from the Department of Environment and Conservation, NSW. The data set consisted of information on NOx emissions and physical output for seventy-five installations that are licensed to emit NOx in NSW. The observations were for the years 2000, 2001, 2002, and 2003. The corresponding marginal rates for the pollutant fee unit value for NOx were $0, $24, $29 and $35 for these years, respectively.

For each installation in the data set, the payable fee is based on the "assessable load" of the pollutant in kilograms of NOx per year. This load may represent the actual emissions monitored on the basis of standardized protocols, or it may be a value agreed between the government and the emitter based on various criteria (Clause 18, *Protection of the Environment Operations (General) Regulation 1998*). These criteria are not treated in this paper, and the assessable load is taken at “a face value”. This assessable load is multiplied by the pollutant weighting (P_w) for NOx, which was 6 for the period covered in the data set (2000-2003), but has recently increased to 9. The assessable load is further multiplied by the spatial weighting (S_w) based on the critical zone where the installation is located.[5] All of this is then multiplied by the marginal fee rate for the appropriate year (0 for 2000, $24 for 2001, $29 for 2002 and $35 for 2003), and divided by 10,000.

An alternative formulation of the payable load-based fee has been used when the assessable load is above the fee rate threshold (FRT). The FRT is determined based on the FRT factor, which varies according to activity classification so that the FRT factor for NOx would be very different between industries.[6] The threshold is obtained by multiplying this factor with the output quantity for a given installation. If the assessable load is greater than this fee rate threshold, then the operator has to pay double the fee for

[5] For the following areas the critical zone weighting of 7 applies: Ashfield, Auburn, Bankstown, Baulkham Hills, Blacktown, Blue Mountains, Botany, Burwood, Camden, Campbelltown, Canterbury, Concord, Drummoyne, Fairfield, Hawkesbury, Holroyd, Hornsby, Hunters Hill, Hurstville, Kiama, Kogarah, Ku-ring-gai, Lane Cove, Leichhardt, Liverpool, Manly, Marrickville, Mosman, North Sydney, Parramatta, Penrith, Pittwater, Randwick, Rockdale, Ryde, Shellharbour, South Sydney, Strathfield, Sutherland Shire, Sydney, Warringah, Waverley, Willoughby, Wollongong, Woollahra. The critical zone weighting of 2 applies for the following areas: Cessnock, Gosford, Lake Macquarie, Maitland, Muswellbrook, Newcastle, Port Stephens, Singleton, Wollondilly, Wyong. For all other areas in NSW a critical zone weighting of 1 applies.

[6] For example electricity industry has an FRT factor of 2,700 which only applies to installations with a capacity to generate more than 250 GWh per annum. For refineries the FRT factor is 0.5 and applies to refineries with more than 100 t output per year (see Schedule 1 in POEO(General) Reg).

emissions above the threshold. The formula used in the calculations of the payable load-based fee can be represented as:

$$(8) \qquad PF = \begin{cases} etP_w S_w / 10000 \;\; if \;\; e < FRT \\ \\ (2e - FRT)tP_w S_w / 10000 \;\; if \;\; e > FRT \end{cases}$$

Based on these variables, the panel that the data formed was highly unbalanced, with records for some installations only covering one or two years. In response to this, a criterion of at least three time series records per cross-section (i.e. for each installation, records for at least three of the above four years were required for this installation to be included in the data set) was established. Only data on installations that satisfied this criterion were included in the refined data set. Data were further inspected visually and by plotting, which was followed by filtering erroneous records out of the data set. This resulted with data for 65 installations remaining in the sample.

Even after this filtering the panel was still unbalanced with records for 14 installations only covering a period of three years. Moreover, the missing year was not the same for all of these 14 installations, being either the first year in the sample (2000) or the last year in the sample (2003). This amounts to having contiguous observations over time for all cross-sections, albeit of various length and various starting and ending points. The total number of data points in the set was 246.

Spatial weightings for each individual installation were also included in the data set according to the regulatory requirements. The weightings had values of 7, 2 and 1, dependent on the location of the installation (see footnote 3). Forty installations included in the data set were in fact located in the critical zone with weighting of 7, fifteen in critical zone with weighting 2, and ten installations in critical zone with weighting 1.

Individual installations were grouped according to the industries to which they belonged. The sixteen industry groupings in alphabetic order were: Agricultural fertilizers, Biomedical waste incineration, Cement or lime production, Ceramics production, Coke production, Electricity generation, Glass production, Paper production, Paint production, Petroleum refining, Plastics production, Primary aluminum production, Primary iron and steel production, Secondary aluminum production, Secondary iron and steel production, and Other secondary non-ferrous alloys production.

Individual installations were also classified by their size in terms of emission of NOx based on the assessable load. The cutoff point was established at 200,000 kg of NOx emitted per annum. A binary variable was then created, with a value of unity for the installations with emissions greater than this cutoff, and a value of zero for installations with emissions lower than this cutoff. The resulting distribution was approximately one third of installations being classified as large emitters and two thirds as smaller emitters.

An additional binary variable was formed reflecting the formula used to calculate the paid fee according to equation 8. The value of this variable was zero if the emissions were lower than the fee rate threshold and unity otherwise. There were 26 occurrences where this variable had a value of 1, across nine installations.

Pooling the data for all facilities and all industries together gives a broad picture about the dynamics of the physical output and NOx emissions under the increasing fee rates. This is presented in Table 1. The information displayed in the table suggests that over the four years in which the load fees gradually increased from \$0 to \$35, the aggregate emissions of NOx from the installations included in the sample initially increased but than decreased. In the same time, the aggregate physical output from these installations increased by about one third. This suggests that there has been some reduction of NOx emissions per unit of output in NSW over the sample period. Moreover, apparent in Table 1 is the relationship between the physical output and NOx emissions. At the time of the first increase in the rate of load fee from zero to $24, the physical output grew very strongly (almost 44%, and this was the year of the Sydney Olympics) and the NOx emissions consequently followed suit. As the growth in physical output settled down in the following years, the emissions also dropped significantly, going below the initial level. This relationship between the physical output and emissions is visually presented with a plot in Figure 1.

Table 1 also displays the total and average fees paid over the sample period. The average fee paid across all installations was $33 per ton of NOx, $37 per tNOx and $46 per ton of NOx in 2001, 2002 and 2003 respectively, which is considerably lower than comparable figures paid under the RECLAIM program in the US, or under the Swedish NOx tax system.

Both Table 1 and Figure 1 indicate that there has been some abatement of NOx taking place in the installations covered in the sample. As presented in the theory section, the expectations are that this is due to the increasing fee rates. However, this has yet to be proved in an empirical setting. To that end, for each observed data point (i.e. a cross section − time series entry) we have taken the ratio of emissions to physical output, effectively representing the amount of emissions per unit of output, which is consistent with the discussion in the theory section above. This has two effects. Firstly, it eliminates the potential need for weighing individual facilities according to their emissions, since some emit many times more than the others. Secondly, it eliminates the effects that variation in output has on the variation in emissions. In some instances a natural logarithm of this newly created variable was a dependent variable, and in other instances the first difference of the same variable was a dependent variable. In the ensuing econometric analysis they were regressed against a set of explanatory variables, based on the theoretical expectations discussed above.

Method

Given the available data and the aims of the research, an econometric study was conducted in an attempt to isolate the effects of individual variables on the NOx emissions per unit of output. The data were in an unbalanced panel format where for each installation (cross-section) there were observations for either three or four years. Several models were estimated using maximum likelihood estimation in SAS® (Proc Mixed). The semi-log functional form was chosen for the model where the dependent variable was the natural logarithm of the ratio of NOx emissions to output. This functional form corresponds well with the theoretical expectations and has straightforward interpretation.

Since the key relationship of interest was how emissions per unit of output relate to the increasing fee rates, the simplest model – the pooled estimator – was initially used to get a feeling about the strength and the direction of the relationship (Johnston and DiNardo, 2002). This model was of the form:

(9) $$\ln E = \beta_0 + \beta_1 t + \varepsilon \ ,$$

where E represents emissions per unit of output, t is the fee rate, β_0 and β_1 are coefficients to be estimated and ε is a normally distributed random error term.

Even though this model in essence ignores the panel data structure and is therefore inappropriate, it should still capture a strong correlation between the variables if such correlation exists. Surprisingly in this case, the estimate for β_1 was negative, but insignificant, suggesting that the relationship between the fee rate and NOx emissions per unit of output is not strong.

Next, a model was tested that included all the variables specified previously. For this model, an individual intercept was estimated for each industry. In addition to the fee rate variable, it also included the critical zone and the fee rate threshold variables. Interaction terms between these variables and the fee rate were also tested, but were found insignificant. Groupwise heteroscedasticity was suspected for observations for large emitters (emissions greater than 200,000 kg NOx per year) and observations for smaller emitters (emissions less than 200,000 kg NOx per year), so that the variance of the error term may not be constant across smaller and larger emmiters. A test for heteroscedasticity was conducted. This was done by estimating a model and outputting the residuals, which were subsequently regressed on the "*size*" variable (binary variable, being 0 for emissions less than 200,000 and 1 otherwise). The estimated coefficients were significant, suggesting strong presence of groupwise hetereoscedasticity. This covariance structure was taken into account in estimating a model of the following form:

(10) $$\ln E_k = \beta_0 + \sum_{i=1}^{15} \beta_{1i} D_i + \beta_2 t_n + \sum_j \beta_3 CZ_j + \beta_4 FRT + \varepsilon_k ,$$

where the k^{th} observation on the natural logarithm of the emissions per unit of output was a function of an industry specific intercept D_i, the fee rate in a given year t_n, the critical zone weighting CZ_j (with j = 1 or 2, since j =7 was the base level) and the fee rate threshold, $FRT = 0$ (since the $FRT = 1$ was the base level). Due to groupwise heteroscedasticity the covariance structure of the error term was $\sigma^2_{size=0}\mathbf{\Omega}$, where

$$\mathbf{\Omega} = \begin{bmatrix} \mathbf{1}/\boldsymbol{\sigma}^2_{\mathbf{size=0}} & \mathbf{0} \\ \mathbf{0} & \mathbf{1}/\boldsymbol{\sigma}^2_{\mathbf{size=1}} \end{bmatrix}$$

, and "*size*" is the variable pertaining to the emissions above (or below) the determined cutoff of 200,000 kg NOx.

Estimating this model will produce results that can be used to make inferences about the effects of each of the considered variables on the NOx emissions per unit of output. However, we are interested here in explaining the change in NOx emissions (or the lack of it) over the sample period, by looking at the effects that the considered explanatory variables had on those changes. For this purpose, the first difference of the ratio of emissions to output was taken. This was then regressed on the same set of explanatory variables as in the previous model (i.e an industry specific intercept, the fee rate, the critical zone weighting, and the fee rate threshold binary variable. The model had the following form:

$$E_{k,n} - E_{k,n-1} = \beta_0 + \sum_{i=1}^{15} \beta_{1i} D_i + \beta_2 t_n + \sum_j \beta_3 CZ_j + \beta_4 FRT + \varepsilon_{k,n-(n-1)}, \tag{11}$$

where the variables were as defined above and the same covariance structure was used due to presence of groupwise heteroscedasticity. A test for autocorrelation was also conducted but did not indicate presence of autocorrelation.

Results

The results from the pooled estimator (equation 9) indicated poor data fit. Both the intercept and the coefficient on the fee rate were insignificant. The estimate for the coefficient on the fee rate was -0.0011 with a standard error of 0.2. This poor fit was also indicated by the F-statistics for the fee rate (a value of 0.08, with denominator d.f. 244)

The results for the model where natural logarithm of NOx emissions per unit of output was a dependent variable (equation 10) indicate much better data fit. These results are summarized in Table 2. The results suggest that apart from the fee rate, all other variables are significant in explaining the NOx emissions per output for the installations in the sample. This was strongly supported by the F test for joint significance. The results indicate insignificance of the fee rate, which is counter to the theory presented in this paper, and counter to intuition. This leads to an inference that the rates have probably been set too low, and are not a major determinant of the patterns of NOx emissions under the load-based licensing scheme in NSW. Other variables that are part of the formula used to determine the payable fee, such as the spatial weighting (CZ) and the fee rate threshold (FRT) are much more influential in explaining NOx emissions from installations included in the sample. The coefficients on spatial weighting according to critical zones (1, 2 or 7) indicate that installations located in the zone with weighting of 7 had lower emissions as compared to other zones. This result is expected, since the formula for payable fee strongly penalizes emissions that are coming from installations in urban areas, where the perceived damages (predominantly health effects) from NOx emissions are much higher. Also large emitters, such as electricity generation plants tend to be located outside urban areas for other obvious reasons (e.g. availability of coal deposits).

Estimated coefficient for the fee rate threshold suggests that installations that had at least one occurrence of emissions greater than the threshold were in essence emitting more NOx compared to installations that were always below the threshold. As mentioned above, an interaction term between the fee rate and the fee rate threshold was statistically tested but was found insignificant.

Estimates of covariance parameters are significant indicating strong presence of groupwise heterscedasticity based on whether the installation was classified as large (more than 200,000 kg of NOx) or relatively smaller emitter (below that value). The likelhoood ratio test of heteroscedasticity confirms its presence.

The results for the model where the first difference of the emissions per unit of output was a dependent variable (equation 9) are reported in Table 3. Results indicate very poor data fit, suggesting problems caused by autocorrelation. However, in addition to testing for autocorrelation, which did not confirm its presence, an autoregressive covariance structure was also tested, but the covariance parameters were found insignificant. This has led us to work with the model as estimated and with results as presented in Table 3.

Estimated coefficients on the explanatory variable were insignificant at the usual significance levels for all variables. This suggests that the considered variables have not influenced the changes in NOx emissions per unit of output in any recognizable manner. The emissions have changed, and in fact as shown previously in Table 1, they have reduced, but those reductions can not be explained by the variables that are part of the load-based fee formula, including the changes in the marginal fee rates.

In addition, changes in emissions can not be explained by industry specific intercepts. The results in Table 3 show that the industry specific intercept was significant but positive for only one of the considered industries. This is the electricity generation industry, which is by far the greatest emitter of NOx in NSW. This result suggests that the members of this industry tended to increase the emissions per unit of output during the sample period. Closer inspection of the data reveals interesting findings. The average emissions per unit of output for the industry in fact declined from 2341.82 in 2000 to 2049.51 in 2001, to 1914.29 in 2002 to 1764.35 in 2003. However, this pattern of average emissions was driven by substantial reduction of emissions in a single installation which apparently invested in end-of-pipe abatement technology in 2000 and was able to reduce its emissions per unit of output by about 3000 during the sample period. It is worthwhile mentioning that this installation has started with rather high level of emissions per unit of output and the reductions during the sample period has brought down their emissions to be more in line with the industry average. This is indicative of a late adoption of end-of-pipe technology that was earlier adopted by other members of the industry, which might have been due to regulations for new plants.

Conclusion

Load-based licensing is a particular form of Pigouvian taxation of pollution that has been operating in NSW since 1999. The interesting feature of this scheme is that the fee rates have gradually increased in the period 2000-2003, from zero to $35. Based on economic theory, and under the hypothesis that the fee rates have been chosen at least approximately correctly, one would expect a significant reduction of emissions as the fee rates increased. Data on NOx emissions and physical output across range of industries in NSW are now available and were used to empirically test the theoretical expectations. The variability of the fee rates over the period 2000-2003 allows for an empirical study that relates emissions to those rates.

After some data manipulation, the sample included data on sixty five facilities that emit NOx in NSW. The data covered the period 2000-2003 and were in a form of an unbalanced panel. Individual facilities were classified in sixteen industries. Natural logarithm, and the first difference, of the ratio of emissions to output were used as dependent variable in several econometric models. The models were from a broad family of panel data models, ranging from a simplest pool estimator, to the more complex models with heteroscedastic covariance structure.

The results from the empirical study suggest that some reduction of NOx emissions took place during the sample period. However, these reductions can not be clearly attributed to the elements of the formula used to calculate the payable fees under the load-based licensing scheme. This is an indication that fees were set at a too low level. The effect of increasing fees was insignificant in explaining both the level and changes of emissions per unit of output. While other elements of the formula for the payable load-based licensing fee had significant explanatory power for the levels of emissions per unit of output, this was not the case when the change in emissions per unit of output was a dependant variable. An exception was an industry specific intercept for the electricity industry, indicating that this industry, which is the largest emitter of NOx in NSW did not respond significantly to the increasing load-based fee rates. This can be probably explained with inflexible technologies and limited abatement options, but also indicates a lack of economic incentives that the load-based licensing should have provided.

Several conclusions can be drawn from this discussion. While the load-based licensing has probably contributed toward reduction of the overall NOx emissions in

NSW in the sample period, it seems that those reductions are not in line with what would be theoretically expected, provided the fee rates were set “correctly”. This suggests that many facilities are finding it more advantageous to pay the fee than to abate. From a regulatory perspective, if more abatement of NOx is aimed for, it seems inevitable to further increase the fees. This might have been attempted by the recent increase in the pollutant weighting for NOx from 6 to 9, which amounts to a 50% increase in the amount of the payable fee and could therefore be interpreted as a 50% increase in the marginal fee rate. While the results presented here show that the past increases in the fee rates in the period 2000-2003 did not have a great impact on reduction of NOx emissions in NSW, it is of imminent research interest to establish the effects of the most recent increase in the payable load-based fees and whether it has been high enough to trigger substantial NOx reductions.

It is suspected however that further increases might be necessary, since the average fees for NOx paid in NSW are substantially lower than similar fees elsewhere. For instance in Sweden, the average fees for NOx are set at levels almost 200 times higher (around $7,240 per ton of NOx) than what was an average fee paid in NSW during 2000-2003.

These substantially higher fees may be paralleled with a tax revenue recycling system, similar to the one operating in Sweden. To make the high emission fee levels acceptable for the businesses, the tax revenues are returned to the polluting companies relative to their output. Such a tax has been very successful in reducing NOx emissions. Under this tax system, as Höglund (2005) has shown, there was a significant amount of "low hanging fruits", or relatively inexpensive abatement options available to regulated entities. This was in part due to the improved continuous-time monitoring equipment, which provided an incentive for emitters to explore reductions by trimming, optimization of combustion process, and operational adjustments. Greater use of continuous-time monitoring of emissions in NSW could potentially deliver similar results.

Load-based licensing has several desirable characteristics relative to the more standard, concentration based taxation of pollutant emissions. However, there is a considerable challenge to set the level of fee rates right under this scheme. Based on the sample presented in this study, the fees of the load-based licensing scheme in NSW have likely been set too low, and the latest upward revision in the pollutant weighting for NOx from 6 to 9 shows that the regulators came to similar conclusions.

Worthwhile alternatives to consider would be the NOx tax systems in Europe that have already showed some positive results e.g. the Swedish tax revenue recycling system, or the French air pollution taxation system, which is earmarking the tax revenue to finance abatement technologies and research. As shown by the Swedish experience, continuous-time monitoring equipment is necessary to realize the substantial possibilities for abatement, without investing in expensive end-of-pipe technologies. Therefore, one of the first steps seems to be to ensure that such monitoring requirements are incorporated in NSW legislation and rigorously enforced.

In addition, and as an alternative, the problem with NOx emissions in NSW may warrant a serious look at the possibilities for a tradable permit schemes. Such tradable permit schemes have been mainly used for NOx reductions in the US and in principle ensure that the set reduction level will be achieved, provided that the enforcement is effective.

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Table 1. Aggregate emissions of NOx and load-based fee paid under the load-based licensing scheme in NSW (2000-2003)

	Year (Load fee)			
	2000 ($0)	2001 ($24)	2002 ($29)	2003 ($35)
Emissions				
tons of NO_x	159,980	178,901	172,522	151,353
index (2000 =100)	100	111.82	107.83	94.60
Output				
million units	16,400	23,496	21,466	21,165
index (2000 =100)	100	143.27	130.89	129.06
Emissions / Output (t NO_x/million units of output)	9.75	7.61	8.04	7.15
Total NOx load-based fee paid across all installations in a year ($mill)	0	59.2	63.9	70.1
Average load-based fee paid across all installations in a year ($/t NOx)	0	33.07	37.06	46.31

Table 2. Results from estimation of an econometric model of a natural logarithm of NOx emissions per unit of output from installations in NSW (2000-2003)

Explanatory variables	Levels of class variables	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		1.4289	0.8137	224	1.76	0.0805
Rate		-0.00374	0.00472	224	-0.79	0.4285
FRT	0	-1.0159	0.2431	224	-4.18	<.0001
FRT	1	0	.	.	.	.
CZ	1	0.9346	0.3027	224	3.09	0.0023
CZ	2	0.9138	0.2835	224	3.22	0.0015
CZ	7	0	.	.	.	.
IndID	10	-0.4273	0.8229	224	-0.52	0.6041
IndID	12	0.6818	0.7894	224	0.86	0.3886
IndID	13	-2.264	0.7794	224	-2.9	0.004
IndID	14	-1.1822	0.8987	224	-1.32	0.1897
IndID	17	-4.0589	0.8246	224	-4.92	<.0001
IndID	21	-0.7106	0.8129	224	-0.87	0.3829
IndID	27	-3.371	0.9216	224	-3.66	0.0003
IndID	34	6.2847	0.8104	224	7.75	<.0001
IndID	55	0.2843	0.833	224	0.34	0.7332
IndID	56	-2.934	0.8294	224	-3.54	0.0005
IndID	57	-3.361	0.9418	224	-3.57	0.0004
IndID	58	-1.3968	0.9191	224	-1.52	0.13
IndID	60	-2.5527	0.8925	224	-2.86	0.0046
IndID	66	-3.5772	0.9047	224	-3.95	0.0001
IndID	67	-0.3079	0.8466	224	-0.36	0.7165
IndID	68	-2.1878	0.7776	224	-2.81	0.0053
IndID	74	0	.	.	.	.

Covariance parameter estimates

Residual size 0	1.7147
Residual size 1	0.3670

L.R. test for heteroscedasticity 15.47 at 1 d.f.

Table 3. Results from an estimation of an econometric model of the first difference of NOx emissions per unit of output from installations in NSW (2000-2003)

Explanatory variables	Levels of class variables	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		-0.5554	8	168	-0.07	0.9447
Rate		0.02584	0.1687	168	0.15	0.8785
FRT	0	-0.224	3.9174	168	-0.06	0.9545
FRT	1	0	.	.	.	.
CZ	1	-0.02265	3.1113	168	-0.01	0.9942
CZ	2	-0.2004	2.838	168	-0.07	0.9438
CZ	7	0	.	.	.	.
IndID	10	0.08847	7.1893	168	0.01	0.9902
IndID	12	0.01716	134.45	168	0	0.9999
IndID	13	0.03514	5.098	168	0.01	0.9945
IndID	14	0.1008	8.2492	168	0.01	0.9903
IndID	17	0.0215	5.476	168	0	0.9969
IndID	21	0.009317	5.9983	168	0	0.9988
IndID	27	-0.2027	7.1645	168	-0.03	0.9775
IndID	34	17.6988	6.9179	168	2.56	0.0114
IndID	55	-0.1302	190.06	168	0	0.9995
IndID	56	0.09319	5.5571	168	0.02	0.9866
IndID	57	0.07125	7.4081	168	0.01	0.9923
IndID	58	0.3536	6.4313	168	0.05	0.9562
IndID	60	-0.00135	6.3103	168	0	0.9998
IndID	66	0.001583	6.1983	168	0	0.9998
IndID	67	0.05297	134.48	168	0	0.9997
IndID	68	0.008241	5.4667	168	0	0.9988
IndID	74	0	.	.	.	.

Covariance parameter estimates

Residual size 0	71.9674
Residual size 1	110831

L.R. test for heteroscedasticity 623.43 at 1 d.f.

Figure 1. Plot of physical output vs. NOx emissions from installations in NSW (2000-2003)