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Abstract

We evaluate the allocation rationality and ex ante cost efficiency of a major Swedish investment subsidy program, the "Local Investment Program" (LIP). The LIP, effective between 1998-2002, had dual purposes: to step up the pace at which Sweden transforms into an ecologically sustainable society and to reduce unemployment. During the program period, more than 6.2 billion Swedish kronor (approximately € 670 million) were granted to different municipal projects. By using data on the projects' subsidies and anticipated environmental and employment effects, we find that these effects to a high degree explain the magnitude of the subsidy granted. We find that the marginal LIP subsidy for carbon dioxide (CO_2) reductions does not vary significantly over the projects, implying that the LIP was cost efficient for such reductions. Furthermore, for a majority of the projects, the marginal subsidy for CO_2 reductions was lower than the, at the time, prevailing CO_2 tax. Assuming successful project fulfillment, we conclude that the LIP was a low cost, cost efficient environmental policy for reducing CO_2 emissions provided that the projects generate spillover effects large enough to justify the subsidy.

Key words: Environmental Policy, Evaluation, Greenhouse Gas, Spillover Effect, Subsidy

JEL Classifications: Q56, Q58

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1 Introduction

The Swedish parliament has enacted fifteen environmental quality objectives to guide Sweden towards a sustainable society.[1] These objectives function as benchmarks in the progress towards the parliament's goal to solve all major environmental problems within one generation. Although the environmental quality objectives are stated in general terms, every objective has clearly defined interim targets and timetables (Gov. Bill 2000/01:130). For the environmental quality objective, "Reduced Climate Impact", the interim target is to reduce the emissions of carbon dioxide (CO_2) by four percent between $2008 - 2012$ relative the level of emissions in 1990 (Gov. Bill 2001/02:55).[2] The progress towards these interim targets should be observed and evaluated on a regular basis. According to the government bill 2000/01:130 (Gov. Bill 2000/01:130), the Swedish environmental quality objectives should be achieved through cost efficient economic and market instruments as well as through regulations and voluntary agreements.

In 1997 the Swedish government initiated an investment subsidy program called *Lokala investeringsprogram* (Local Investment Program), LIP. The LIP had dual purposes: to step up the pace at which Sweden transforms into an ecologically sustainable society and to reduce unemployment.[3] During the program period, $1998 - 2002$, more than 6.2 billion Swedish kronor (SEK) were granted to over $1,800$ different municipal projects.[4] If all LIP projects are carried out according to plan, the emissions of CO_2 will be reduced by $2,085$ thousand tonnes, equivalent to 23 percent of the reduction needed to reach the interim target from the 2010 forecasted level of emissions.[5] Thus, if successful, the LIP will considerably facilitate attainment of Sweden's interim target for CO_2 reductions.

From economic theory there are few reasons for subsidizing polluters. On

[1] The environmental quality objectives are: Reduced Climate Impact; Clean Air; Natural Acidification Only; A Non-Toxic Environment; A Protective Ozone Layer; A Safe Radiation Environment; Zero Eutrophication; Flourishing Lakes and Streams; Good-Quality Groundwater; A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos; Thriving Wetlands; Sustainable Forests; A Varied Agricultural Landscape; A Magnificent Mountain Landscape and A Good Built Environment.

[2] According to the EU burden sharing agreement, Sweden is, however, allowed to *increase* its emissions by four percent.

[3] According to the Swedish Environmental Protection Agency's (EPA) webpage about the LIP (www.naturvardsverket.se), increased employment was subordinated ecological sustainability.

[4] Prices are current unless otherwise stated. € 1 was on average equal to SEK 9.16 in 2002 (www.riksbank.se).

[5] The forcasted emissions of CO_2 in 2010 are 62,794 thousand tonnes and the "four percent less" interim target is 53,823 thousand tonnes (Östblom, 2003).

the contrary, the economic prescription for negative external effects like pollution is often a corrective tax (c.f. Baumol and Oates, 1988). Nonetheless, "spillover" effects from investments in new technology may motivate subsidies to R&D.[6] In fact, since some of the LIP subsidies were granted to R&D investments in new technology, the rationale for the LIP should primarily be seeked in the investments' spillover effects rather than in the program's environmental and employment effects. Presently, too short a time has elapsed since the introduction of the LIP to be able to gauge the magnitude of the spillover effects. Nonetheless, smaller spillover effects are of course needed to justify a subsidy program that is cost efficient.

This paper seeks to, at the general level, *empirically* gain increased knowledge about the allocation rationality and ex ante cost efficiency of the LIP. We try to answer three related questions: *i)* was the allocation of the LIP subsidies "rational", following some implicit rule[7]; *ii)* was the allocation of the LIP subsidies cost efficient with respect to CO_2 emissions[8]; *iii)* was the LIP *relative* cost efficient compared to other economic policy instrument, e.g. the CO_2 tax.

Using the quantified information that was available to the decision makers at the time of decision making, we model the relationship between the LIP subsidy and the project's anticipated environmental and employment effects. Our main focus is on projects aimed at reducing CO_2 emissions. This "CO_2 subsample", constituting approximately a third of all LIP projects ($n_{CO_2} = 602$), received a disproportionate (almost 50 percent) amount of the LIP subsidies. In addition to the subsample's sizable magnitude, the expected achievements of the CO_2 subsample are particularly interesting to evaluate considering the Swedish government's 2003 launching of a successor to the LIP, *Klimatinvesteringsprogram* (KLIMP),[9] aimed only at reducing greenhouse gases.

Based on the government's guidelines for LIP applications (Regeringskansliet, 2000a), we formulate a general subsidy function where the magnitude of the subsidy depends on the projects' ex ante anticipated environmental and employment effects. Having no a priori knowledge about the subsidy function's

[6] A spillover effect is positive external effect - a market failure forcing a wedge between the social and private returns to R&D.

[7] Communication with a Swedish official involved in the allocation process, gave the impression that the allocation was a stepwise procedure involving several administrators. We formally test if the allocation mechanism was ad hoc or following some implicit rule.

[8] According to the LIP ordinance (SFS 1998:23), cost efficiency was not a formal requirement.

[9] The climate investment program (author's translation). In the KLIMP, project cost efficiency is required (4§ SFS 2003:262).

properties, we perform sequential Taylor order expansions of the function with respect to the most frequently nonzero anticipated project effects, i.e. CO_2, NO_x, SO_2 and L. When estimating the first and a second order Taylor expansions of the subsidy function using data on the projects' subsidies and anticipated effects, we find that the projects' anticipated effects to a high degree explain the size of the LIP subsidy granted (both model specifications). We see this as evidence of a rational allocation process. The second order Taylor expansion of the subsidy function shows that the marginal LIP subsidy for CO_2 reductions have little variation over projects, implying that the LIP was cost efficient for CO_2 reductions. Furthermore, the marginal subsidy for CO_2 reductions was, for a majority of the projects, lower than the prevailing CO_2 tax. Thus - postulating successful project fulfillment - the LIP achieves the anticipated CO_2 reductions efficiently and at low cost, proviso the existence of positive spillover effects.[10]

The rest of the paper is organized as follows. Section two describes the LIP and the data used. Section three discusses under what circumstances polluters could be subsidized and the cost efficiency of environmental policies. Section four presents the model used and, in Section five, the estimation results are given. Finally, in a concluding section, we discuss the key findings.

2 The Local Investment Program

The central idea behind the LIP was to use local, municipal, knowledge about environmental problems and opportunities for sustainable development. Eligible to apply was all Swedish municipalities or alliances thereof. Every municipal application could contain many different, three year projects provided that the projects were based on local conditions and needs. Companies, individuals and organizations could gain access to the subsidies if a municipality included their project in its application. According to the LIP guidelines (Regeringskansliet, 2000a), every project's anticipated environmental and long and short term employment effects should be quantified in the application.

Between 1998 and 2001, the LIP subsidies were allocated by the government after preparation in the Ministry of the Environment. In 2002, the allocation was transferred to the Swedish Environmental Protection Agency (EPA). Whereas the latter administration and allocation model is traditional for distribution of government subsidies in Sweden, the former is unusual in at least three ways. First, applications for governmental subsidies are usually

[10] This may be a bold proviso. According to Berglund and Hanberger (2003), the requirement for new technology was not present in the $2000-2002$ allocations.

processed by the "relevant" public authority, not by the government itself. Although many LIP projects are sector crossing, the most relevant public authority would have been the Swedish EPA. Second, investments eligible for subsidies are usually clearly defined and specified. In the LIP, municipalities had to compete for subsidies with projects of very different character. Third, subsidies are normally allocated on a "first come, first served" basis. During 1998 and 1999 there was an annual deadline for the LIP applications. Altogether, these differences gave the government large degrees of freedom in the allocation of subsidies, especially during $1998 - 2001$. Because of the unusual administration model and the sizable magnitude of the LIP subsidy, we are interested in examining the allocation mechanism that governed the decision making.

Although the government allocation model that prevailed between $1998 - 2001$, has been criticized, especially for its 1998 allocation (Kågeson and Lidmark, 1998; Riksrevisionsverket, 1999; Riksdagens Revisorer, 1999; Dahlberg and Johansson, 2000), none has, as far as we know, previously examined the relationship between the subsidies granted and the projects' anticipated environmental and employment effects. That no such evaluation has been performed is surprising, particularly since the guidelines for LIP applications state that "*(T)he projects will, above all, be evaluated on basis of the municipalities' assessment of the projects' results and effects regarding sustainable development and increased employment in relation to the subsidy applied for*" (Regeringskansliet, 2000a, p. 3).[11]

According to the LIP ordinance (SFS 1998:23), the LIP subsidy could constitute a maximum of 30 percent of the total investment costs. For the LIP projects, the ex ante average share of subsidies to investments is, nonetheless, 35 percent (ranging between $0.7 - 100$ percent). Table 1 gives the number of projects and subsidies granted during the program period. Overall, more than 1,800 projects in 128 different municipalities were granted subsidies exceeding SEK 6.2 billion. Evident is that the total amount of subsidies was largest in 1998 while the total subsidies in 2001 and 2002 were significantly smaller.

The LIP subsidies were used both for municipal investments in equipment and capital, as well as for information and education. Many of the projects involved measures to promote efficient use of energy, electricity and water, and of measures to recover, recycle and compost waste. Altogether, the projects were categorized in twelve different project groups.[12]

[11] Author's translation.

[12] The twelve project groups were: nature conservation and biological diversity; water and sewage; remedial measures; waste; traffic; energy efficiency measures; conversion to renewable energy sources; building measures; multi-dimensional projects; industrial projects;

Table 1: Number of projects, total subsidy and average subsidy with standard error (SE), all projects.

Year	Projects	Total subsidy (SEK)	Average subsidy (SEK/project)	SE
1998	456	2,320,457,100	5,088,722	976,822
1999	413	1,432,778,900	3,469,198	566,357
2000	507	1,487,356,470	2,933,642	343,196
2001	315	733,038,250	2,327,106	238,592
2002	123	236,348,500	1,921,533	298,184
Total	1,814	6,209,979,200	3,423,362	297,857

Information about the projects' anticipated environmental and employment effects can be found in the "LIP database", maintained first by the Ministry of the Environment and then by the EPA.

2.1 Data

The data used in this paper is derived from the Swedish EPA's LIP database. The LIP database contains information about all projects granted LIP subsidies during the program period. From a municipal perspective, the data could be viewed as an unbalanced panel since every municipality in the database received subsidies for a minimum of one and a maximum of five program years.[13] However, from the project perspective adopted here, the data is no panel since every project only shows up once.

The LIP database contains information about the subsidies granted and the total investments as well as information about the projects' anticipated environmental effects, as assessed by the municipalities' in their LIP applications (see Appendix A for all the variables).[14]

Focussing on the subset of LIP projects aimed at CO_2 reductions, Table 2 shows a similar pattern to Table 1, where total as well as average subsidies

support measures; other projects (Regeringskansliet, 2000b).

[13]One municipality received subsidies four times (years), five municipalities received subsidies three times and 34 municipalities received subsidies two times.

[14]In the LIP database there is also a variable labelled "Environmental Text" whose contents we disregard in the analysis. This variable could potentially contain anticipated environmental effects not stated elsewhere. The problem with including this variable is that it is very difficult to judge whether the contents are mere explanations of anticipated environmental effects stated elsewhere or nonstated anticipated environmental effects. We choose to exclude the contents of this variable in the analysis at the risk of omitting important, but most likely minor, anticipated environmental effects.

Table 2: Number of projects, total and average subsidies with standard errors (SE) for the CO_2 sample.

Year	Projects	Total subsidy (SEK)	Average subsidy (SEK/project)	SE
1998	141	976,143,000	6,923,000	2,850,185
1999	130	826,418,400	6,357,065	1,644,701
2000	159	750,925,570	4,722,802	899,644
2001	114	399,141,650	3,501,243	487,568
2002	58	116,923,000	2,015,914	371,845
Total	602	3,069,551,620	5,098,923	799,242

decrease every year throughout the program period.

From Table 3 it is evident that the CO_2 projects can be found in all different project groups, although the greatest number of projects can be found in the "energy conversion" and the "traffic" groups. The purpose of many projects in the "energy conversion" group is to extend biofuel-based local and district heating networks and to replace, or upgrade, inferior heating systems. In the "traffic" group, many of the projects have purposes related to improvements in public transport and expansion of pedestrian walkways and cycle tracks. This project group also includes investments in systems for using biogas as a vehicle fuel and purchases of vehicles that run on fuel from renewable sources.

Unconditionally, i.e. without consideration to the projects' other effects, the average project subsidy for a kilo's reduction of CO_2 per year is SEK 389 (SE 121.2). The largest average project subsidy is SEK $60,000$ per kilo and annum while the lowest is SEK 0.02 per kilo and annum. The median subsidy is SEK 2.79 per kilo CO_2 and annum.[15] Judging by the these numbers, there is a great variability in the subsidy for CO_2 reductions over the LIP projects. To examine the cost efficiency of the LIP subsidy it is, however, imperative to condition the subsidy granted on *all* anticipated effects.

In the manifold cases where nothing is stated for an anticipated effect, we assume this effect to be zero (descriptive statistics including the number of zero observations per variable are given in Appendix B). This assumption seems justified considering that the municipalities rather would have had incentives to *overstate* than to understate the project's anticipated beneficial

[15] For SO_2 reductions, the average subsidy is SEK $81,838$ per kilo (median: SEK $3,443$) and the span from the smallest to the largest subsidy is SEK $7.30 - 8,373,750$. For NO_x reductions, the average subsidy cost is SEK $63,844$ per kilo (median: SEK $2,477$) and the span between minimum and maximum subsidies is SEK $0.60 - 5,582,500$ per kilo.

Table 3: Number of projects, total and average subsidies and anticipated annual CO_2 reductions per project group for the CO_2 sample.

Project group	Projects	Total subsidy (SEK)	Average subsidy (SEK/project)	$\Delta\ CO_2$ (tonnes/year)
Waste (G1)	41	250,390,600	6,107,088	97,464
Building (G2)	4	11,022,000	2,755,500	323
Remedial (G3)	1	2,235,000	2,235,000	872
Energy efficiency (G4)	91	316,787,120	3,481,177	480,473
Energy conversion (G5)	300	1,441,597,500	4,805,325	1,334,343
Multi-dimensional (G6)	23	496,057,000	21,567,696	19,849
Industrial (G7)	3	3,315,000	1,105,000	958
Nature conserv. (G8)	1	106,000	106,000	49
Support (G9)	5	3,085,000	617,000	18,691
Traffic (G10)	113	504,899,400	4,468,136	131,362
Water & sewage (G11)	18	39,260,000	2,181,111	589
Other (G12)	2	797,000	398,500	3
Total	602	3,069,551,620	5,098,923	2,084,977

environmental and employment effects. Only if there are other, nonzero, nonstated anticipated environmental effects known to the decision maker and incorporated into the decision making will this assumption bias our results. Understating or neglecting anticipated environmental effects is more likely to occur with anticipated detrimental environmental effects - a fact also noted by Riksrevisionsverket (1999). Another potential empirical problem with including all other environmental and employment effects is that some effects may be significantly correlated due to double counting. For instance, when both the direct effect of a project (e.g. energy savings) and its consequences (e.g. reduced emissions of CO_2 and sulphur dioxide, SO_2) are taken into account, the latter values are related to the former. The empirical analysis will reveal whether this constitutes a problem or not.

Most likely, the LIP database does not give the whole truth about the LIP projects' anticipated environmental effects. On the other hand, the information in the LIP database was, together with the full applications (which, of course, included more descriptive information, blueprints et cetera), all information that was available to the decision makers at the time of decision making.

Table 4: Emissions of CO_2, NO_x and SO_2, 1990-2001 (1,000 tonnes) (MI 18 SM 0201 and Summary Reports for National Greenhouse Gas Inventories, submissions 2002 and 2003).

	CO_2	NO_x	SO_2
1990	56,056	349	111
1991	56,735	340	102
1992	54,958	328	89
1993	54,879	320	80
1994	59,233	334	81
1995	58,574	309	69
1996	62,056	309	74
1997	57,056	291	66
1998	58,142	277	63
1999	56,458	267	54
2000	55,855	247	58
2001	55,269	251	60

2.2 Swedish Emissions

Our analysis will, as previously stated, be concentrated on the anticipated CO_2 reductions of the LIP. Nonetheless, we will also pay due respect to the LIP applications' two other most frequently stated nonzero environmental effects, i.e. reductions of nitrogen oxides (NO_x) and SO_2, as well as to the effects on employment.

Table 4 gives Swedish emissions of CO_2, NO_x and SO_2 between 1990 and 2001. Whereas the emissions of NO_x and SO_2 have been decreasing over time, there is no trend distinguishable in the emissions of CO_2. An interim target of the environmental quality objective "Natural Acidification Only", is to cut SO_2 emissions to air to 60,000 tonnes in 2010. This interim target was achieved in 1999. An interim target for the environmental quality objectives "Natural Acidification Only" and "Zero Eutrophication" is to cut NO_x emissions to air to 148,000 tonnes in 2010. If successfully carried out according to plan, the LIP projects will reduce NO_x emissions by 20 thousand tonnes, amounting to almost 20 percent of the reduction needed to attain the interim NO_x target from the 2001 level of emissions.

3 Why Subsidize Polluters?

From economic theory, there are few reasons for subsidizing polluters. On the contrary, the economic prescription for negative external effects like pollution is in most cases a corrective tax (c.f. Baumol and Oates, 1988). Although it may seem objectionable, both on economic and moral grounds (the "polluters pay principle" is abandoned), we can think of at least one reason for governments to subsidize large scale investment programs like the LIP, - "spillover" effects.

Some of the LIP subsidies were granted to R&D investments in new technology. Such investments have the potential of spillover effects, i.e. indirect or unexpected benefits to others (e.g. firms in the industry) through, for instance, knowledge diffusion or development of technological skills. According to Klette et al. (2000), spillover effects are the main justification for governmental subsidies to commercial R&D and, in the case of the LIP, the social benefits from spillover effects could justify the program. Presently, it is however difficult to gauge the magnitude of the actual spillover effects from the LIP since many of the projects still are being implemented. Clearly, estimating the spillover effects is an important issue for future research. Here we simply assume that the spillover effects are large enough to motivate the government subsidies.

Government subsidies may also be necessary when it is difficult, for legal or other reasons, to make the liable party pay for environmental damages made. Measures to reduce the environmental and health risks from hazardous waste sites contaminated prior to modern environmental legislation and measures to recreate wetlands are two examples where governmental subsidies may be indispensable (Kågeson and Lidmark, 1998). Altogether, approximately nine percent of the LIP subsidies (SEK 548 million) were granted to remedial measures and measures to recreate wetlands.

3.1 Cost Efficiency of Environmental Policies

A natural selection criteria in the choice of policy instrument is the instrument's cost efficiency. The condition for a cost efficient environmental policy is that the environmental goal is achieved at the *minimum* cost to society.[16]

In general, assuming smooth, continuous and nondecreasing total abatement cost functions, the marginal abatement cost should be equal for all emitters for cost efficiency to prevail. If the marginal cost for abatement is

[16] Alternatively, if there are budget restrictions, that the *maximum* environmental benefit is achieved at a given cost.

smaller for emitter m than for emitter n, society would benefit if emitter m abated more and n less. With a tax on emissions, emitters will abate until the marginal cost of abatement is equal to the tax. At higher marginal abatement costs, the emitters will emit and pay the tax. In this way, the marginal cost for abatement will be equal for all emitters.

Transferring this marginal cost (tax) argument to the LIP subsidy, the marginal LIP subsidy per kilo reduced CO_2 should not differ significantly over the projects in order for the LIP to be cost efficient. Hence, the marginal CO_2 subsidy (MS_{CO_2}) - equivalent to the marginal government cost or the government "shadow price" for CO_2 reductions - should be equal in projects m and n for a cost efficient allocation of the LIP subsidies. To illustrate the argument, we assume that the LIP subsidy granted project m, Y_m, is determined by the project's anticipated amount of CO_2 reductions ($CO_{2,m}$) and a vector of other project specific variables, $\mathbf{x}_m$ (e.g. other anticipated environmental and employment effects). Thus, we assume $Y_m = h(CO_{2,m}, \mathbf{x}_m)$. Without parameterizing the subsidy function, we state the general condition for a cost efficient reduction of CO_2 emissions as:

$$\begin{aligned} \left[\frac{\delta Y_m}{\delta CO_{2,m}}|\mathbf{x}_m\right] &= \left[\frac{\delta Y_n}{\delta CO_{2,n}}|\mathbf{x}_n\right] \;;\forall n \neq m \\ MS_{m,CO_2|\mathbf{x}_m} &= MS_{n,CO_2|\mathbf{x}_n} \;;\forall n \neq m. \end{aligned}$$

If the marginal subsidy (the shadow price) for reducing emissions of CO_2 is larger in project n than in project m, society would benefit if subsidies were transferred from project n to m, so that a larger reduction would take place at a smaller subsidy.

Variation in the marginal LIP subsidy for CO_2 reductions could result if the LIP allocation process varied over projects and/or years. With a long-term environmental policy, we see little need for the LIP allocation model to change during the program period and, if marginal subsidies varies over projects, the condition for cost efficiency is not fulfilled. Thus, notwithstanding the cause of variation, the mere existence of significant variation points to cost inefficiency of the LIP subsidies.

4 Model

According to Riksdagens Revisorer (1999, p. 18) "*(T)he subsidies in the local investment program are effect oriented which means that the results, in the forms of positive environmental and employment effects, constitute ground criteria for approval*".[17] Furthermore, a recent EPA publication states that

[17] Author's translation.

"*The most important criterion when judging the LIP applications has been the anticipated environmental effects of the investment program's projects*" (Naturvårdsverket and IEH, 2003, p. 7).[18] Given these statements, it seems reasonable to assume that the size of the LIP subsidy was dependent on some implicit weighing of the project's anticipated environmental and employment effects. Consequently, we formulate a model for the subsidy as a function of the projects' ex ante anticipated environmental (**EE**) and employment (L) effects,

$$Y_{ijt} = g(\mathbf{EE}_{ijt}, L_{ijt}) \; i \in [1, 1814] \; j \in [1, 163]^{19} \text{ and } t \in [1998, 2002] \qquad (1)$$

where Y_{ijt} is equal to the subsidy (in SEK) in project i in municipality j at time t, $\mathbf{EE}_{ijt}$ is a 27×1 column vector of the project's environmental effects, i.e. $ME1 - ME24$, CO_2, NO_x and SO_2 (see Appendix A for variable definitions).

In order to evaluate the CO_2 cost efficiency of the LIP we need to examine the *variation* in the marginal CO_2 subsidy over projects. Thus, we need a flexible model where we allow the marginal subsidy to vary over projects. Having no a priori expectation about the functional form of the subsidy function, we perform sequential Taylor order expansions with respect to the CO_2, NO_x, SO_2 and L variables. Since the Taylor expansions are nested, each successive expansion can be tested against the previous in a conventional F-test (Greene, 1993, ch. 6).

The first order Taylor expansion is linear in the environmental and employment effects,

$$Y_{ijt} = \alpha + \mathbf{EE}'_{ijt}\boldsymbol{\beta} + L_{ijt}\gamma + \varepsilon_{ijt}, \qquad (2)$$

where α, γ and $\boldsymbol{\beta}$ are, respectively, the intercept, a scalar parameter and a 27×1 column vector to be estimated. The derivative of the subsidy function with respect to CO_2 gives the marginal subsidy of reducing CO_2 emissions ($MS_{CO_2} = \beta_{CO_2}$).

Higher order Taylor expansions of the subsidy function contain higher order variables and interactions between the variables. Formally,

$$Y_{ijt} = \alpha + \mathbf{EE}'_{ijt}\boldsymbol{\beta} + L_{ijt}\gamma + \mathbf{v}'\boldsymbol{\delta} + \varepsilon_{ijt}, \qquad (3)$$

where $\mathbf{v}$ is a $s \times 1$ column vector of interaction and higher order variables and $\boldsymbol{\delta}$ is a $s \times 1$ column vector of parameters to be estimated.

[18] Author's translation.

[19] Altogether, 160 of Sweden's 290 municipalities received LIP subsidies at least once during the program period. Furthermore, one sewage treatment works (Käppalaförbundet), one municipal alliance (Dalslands kommunalförbund) and one housing exhibition (Bo01) received subsidies.

Given a second order Taylor expansion, the marginal subsidy may vary over projects, i.e.

$$MS_{CO_2ijt} = \beta_{CO_2} + \delta_1 NO_{xijt} + \delta_2 SO_{2ijt} + \delta_3 L_{ijt} + 2\delta_7 CO_{2ijt}.$$

Thus, we get a *distribution* of the marginal subsidy for CO_2 reductions. The marginal subsidies for NO_x (MS_{NO_x}), SO_2(MS_{SO_2}) and L (MS_L) can be similarly derived as the first order derivatives of Equation (3). When evaluating the relative efficiency of the LIP, we will compare these marginal subsidies with the prevailing taxes and fees on CO_2, SO_2 and NO_x.

5 Results

Here we present the results from the ordinary least squares (OLS) estimation of the first and second order Taylor expanded model specifications. The dependent variable in both models is the consumer price index deflated LIP subsidy (2002 prices).

5.1 First Order Taylor Expansion

The first three columns of Table C in Appendix C give the results from estimation of the first order Taylor expansion of the subsidy function (Equation (2)). Interaction variables between L and an indicator variable for year as well as indicator variables for project group are included. The reason for including the labour/year interactions is that personal communication with an official at the Swedish EPA gave the impression that the anticipated employment effect was of greatest importance in the 1998 allocation, but of less importance the following years. Through including indicator variables for project group we are able to control for cost differences between project groups. Furthermore, because some projects lacked CO_2, NO_x, SO_2 and/or L effects, we include indicator variables (α_{CO_2}, α_{NO_x}, α_{SO_2}, α_L) equal to one if a project have zero such effect(s). These additional "alpha" parameters are needed so that estimation of the relevant CO_2, NO_x, SO_2 and L parameter only is based on projects with strictly positive such effects.[20]

From Table C, we see that the CO_2 parameter is significant at the five percent level with a parameter estimate of SEK 0.06 per kilo. The NO_x and SO_2 parameters are significant with parameter estimates of SEK 0.46 per kilo and SEK 23 per kilo, respectively. The employment effect is also significant,

[20] This is necessary if we want to interpret the first derivative of the general subsidy function (notwithstanding the order of Taylor expansion) with respect to an environmental effect as a marginal subsidy.

with a subsidy granted approximately equal to SEK $255,982$ per annual employment opportunity in 1998. Interesting to note is that the subsidy granted to employment was significantly larger in 1998 than in $1999-2001$, i.e. in accordance with the observation made by the Swedish EPA official. As a comparison, the cost of an annual employment created in another Swedish government subsidy program with dual purposes preceding the LIP was between SEK $250,000$ and SEK $384,000$ (Ds 1998:13). Even though the real employment effect of the LIP is difficult to evaluate, the cost for employment within the LIP is at least no greater than in a comparable program (equally difficult to evaluate).[21]

In addition to the aforementioned CO_2, NO_x and the SO_2 effects, six of the other anticipated environmental effects are significant at the five percent level in the first order Taylor expansion ($ME2$, $ME4$, $ME6$, $ME11$, $ME15$, $ME22$). Since these environmental effects are given in absolute values, all parameter estimates should be positive because more of an anticipated environmental effect should always be preferred. Five of the six significant variables are positive whereas one variable, energy savings ($ME4$), is negative, implying that for every MWh energy saved by a project, the project receives SEK 9.22 less in subsidies. This is a little disturbing since there is no obvious reason why an environmental effect should be punished. A possible explanation is that this negative effect is due to the earlier mentioned possible of double counting of environmental effects.

Altogether, the first order Taylor expansion of the subsidy function has a high degree of explanatory power with an R-square adjusted equal to 0.84. Thus, the LIP allocation process appear to be rational, following an implicit weighing rule.

5.2 Second Order Taylor Expansion

The results from estimation of the second order Taylor expansion are given in the last three columns of Table C. In an F-test between the first and second order expansions, the null of the first order expansion is rejected.[22] Higher order Taylor expansions were also tested for. Whereas expansions to the third order could not be rejected in an F-test, expansion to the fourth order was rejected. In the third order expansion, 20 more variables are added, which

[21] Note that an empirical complication is that project employment is indistinguishable from permanent employment since there is only one employment variable in the LIP database. Altogether, the anticipated employment effect of the LIP consists of more than $19,600$ employment opportunities (permanent and/or project).

[22] F-statistic (9,1756) $=$ 20.69. The constraint on the square of CO_2 was dropped due to high collinearity with the CO_2 variable.

increase the collinearity between the variables as well as the complexity and variance of the marginal subsidies. Since there are no significant differences between the mean marginal subsidies resulting from the second and third order Taylor expansions - the confidence intervals for the means just get wider due to the increased variance - we choose to report the results from the parsimonious second order Taylor expanded model.

From Table C, we see that the CO_2 parameter is still significant at the five percent level with a parameter estimate of SEK 0.18 per kilo. The NO_x and SO_2 parameters are insignificant whereas the employment effect still is significant and equal to SEK $207,903$ per annual employment in 1998. The interaction variables between year and L now have insignificant parameters, meaning that there no longer exist differences between the subsidies granted for L in different years. The results of the other anticipated environmental effects ($ME1 - ME24$) are similar to the results from the first order Taylor expansion. One exception is the insignificance of the previously significant negative $ME4$ parameter. Furthermore, the expansion terms include significant interaction effects between CO_2 and NO_x (positive) and between CO_2 and L (negative). That is, if a project have both CO_2 and NO_x effects it is rewarded, while a project with both CO_2 and L effects is punished. These parameters are, however, small and, in most cases, not of economic significance. The parameter of the square of NO_x is negative and significant which means that the subsidies granted for NO_x reductions increase at a decreasing rate. The R-square adjusted for the second order Taylor expansion is still very high, 0.86.

5.2.1 Marginal Subsidy and Cost Efficiency

Turning to the marginal subsidy for CO_2 reductions derived from the second order Taylor expansion, Tables 5 and 6 show the small variability of the marginal subsidy for CO_2 reductions. For instance, Table 6 shows that the 95th percentile MS_{CO_2} is approximately equal to the industry tax (in 2002 prices) during the program period, which means that MS_{CO_2} in 95 percent of the LIP projects is equal to or lower than the industry CO_2 tax. Furthermore, in almost 99 percent of the projects, MS_{CO_2} is lower than the period's lowest household CO_2 tax (2002 prices). Thus, for almost all the LIP projects, the marginal subsidy for CO_2 is lower than the prevailing CO_2 tax.

Similarly, the MS_{SO_2} is, in about 85 percent of the projects, lower than the SO_2 tax (2002 prices) and, in 97 percent of the projects, the MS_{NO_x} is lower than the NO_x fee (2002 prices).[23]

[23] The SO_2 tax has been equal to SEK 30 since its introduction in 1991. In 2002 prices the SO_2 tax is: SEK 32 (1998-1999); SEK 31 (2000-2001); SEK 30 (2002). The NO_x fee

Table 5: Household and industry CO_2 taxes in SEK per kilo CO_2, 1998-2002. Consumer price index deflated 2002 prices within parentheses.

	Household tax (SEK/kilo)	Industry tax (SEK/kilo)
1998	0.37 (0.39)	0.18 (0.20)
1999	0.37 (0.39)	0.18 (0.20)
2000	0.37 (0.39)	0.18 (0.19)
2001	0.54 (0.55)	0.19 (0.19)
2002	0.63 (0.63)	0.19 (0.19)

Table 6: Marginal subsidies (MS) in 2002 prices from the second order Taylor expansion; means, standard errors (SE) and percentiles.

	Mean	SE	Percentiles (%)					
MS_k			1	50	90	95	99	N
CO_2	0.22	0.04	0.02	0.17	0.18	0.19	0.40	602
NO_x	7.17	5.23	-206.05	18.85	23.88	28.27	80.13	328
SO_2	16.82	16.76	-37.12	-22.54	39.87	82.24	1,133	208
L	164,472	8,509	83,502	198,664	231,873	232,098	233,703	1,748

Note: SE is not corrected for the variation caused by estimation of the parameters in MS_k.

The box and whiskers plots in Figure 1 shows the great difference in variability of the unconditional, average CO_2 subsidy and the conditional MS_{CO_2} from the second order Taylor expanded model. Thus, when all other environmental and employment effects are taken into account, the variability is considerably smaller (Figure 1 however excludes outside values).

5.3 Model Extensions and Sensitivity Analysis

Based on the first order Taylor expansion, various model extensions were tested for. Altogether four model extensions were made in a sequential fashion. First, interaction variables between geographic location (county council dummies) and some of the anticipated environmental effects were included to examine whether regional differences in severity of environmental problems motivated differentiated LIP subsidies. Because acidification and eutrophication are more severe in southern Sweden, larger subsidies to sulphur, nitrogen

has been equal to SEK 40 since its introduction in 1992. In 2002 prices the NO_x fee is: SEK 42 (1998-2000); SEK 41 (2001); SEK 40 (2002).

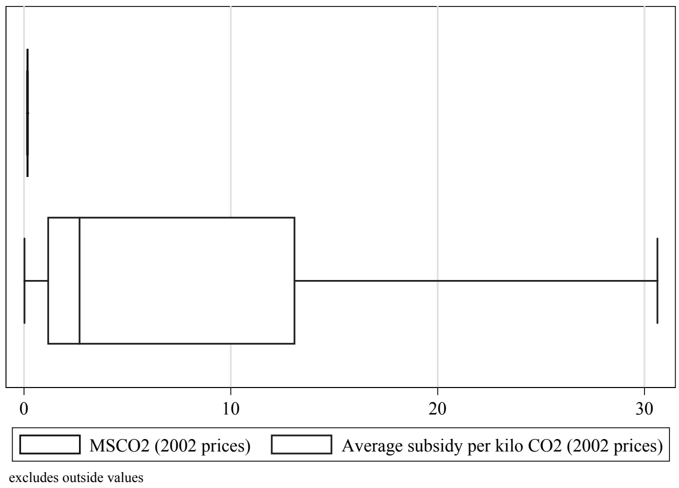

Figure 1: Dispersion of the conditional MS_{CO_2} (top box) and the unconditional average subsidy per kilo CO_2 (bottom box) in 2002 prices.

and phosphorus reductions to LIP projects in southern Sweden could be motivated. By using interaction variables between the 21 counties of Sweden and the NO_x, SO_2, phosphorus and nitrogen variables[24], we find some significant regional interaction effects. The results are, however, too patchy and inconsistent to prove the existence of regional mitigation strategies in the allocation of the LIP subsidies.

Second, we employed indicator variables for municipal category according to the Swedish Association of Local Authorities' classification.[25] The 1998 allocation of the LIP subsidies had proved to be unequal with respect to municipal category, where big and larger cities had received relatively more subsidies than sparsely populated and rural municipalities (Riksdagens Revisorer, 1999). For the complete LIP allocation we find no such results, i.e. when all environmental and employments effects are accounted for, there is no difference in subsidies granted to municipalities of different categories.

[24] Since there are a number of phosphorus and nitrogen variables in the LIP database, we merged ME18, ME21 and ME17 into a "phosphorus emissions variable" and ME16, ME19, ME20 into a "nitrogen emissions variable". Then we employed interactions between these merged variables and county council dummies in the regression analysis.

[25] This classification contains nine different categories based mainly on the municipalities' population, geographical location and employment characteristics. The nine different categories are: big cities; suburbs; larger cities; middle sized cities; industry municipalities; rural municipalities; sparsely populated municipalities; other larger municipalities; other smaller municipalities.

Third, "political" variables were included to control for the political composition of the municipal council.[26] Two variables previously shown by Dahlberg and Johansson (1999) to affect the extensive margin of the allocation decision - the shares of socialist and environmental party votes in the last government election - were employed and their effect on the intensive margin of the LIP allocation was examined. No support whatsoever was, however, found for these variables being of any significance in the intensive margin LIP allocation decision. Thus, we find no evidence of "vote purchasing behaviour" (Dahlberg and Johansson, 1999) on the intensive margin of the LIP allocation. It must, however, be stressed that we differ from Dahlberg and Johansson's analysis in both sample size and scope of analysis.

Another variable used to control for the level of municipal politico-environmental work, was the municipality's environmental ranking. This environmental ranking is based on a questionnaire to all Swedish municipalities performed annually by the magazine "Miljö Eko" (Miljö Eko 1997:5; 1998:5; 2000:1; 2001:1 and http://www.miljo-eko.nu/kommunrank2001.htm).[27] We have no a priori hypothesis about the sign of the environmental ranking variable. On one hand we believe that high environmental ranking could result in high LIP subsidies because of a high municipal environmental awareness. On the other hand, a low environmental ranking could result in higher subsidies because of the larger need for environmental investments. However, the parameter turned out insignificant, implying that the municipality's previous environmental efforts - large or small - did not affect the size of the LIP subsidy.

Fourth, because one of the dual aims of the LIP was to reduce unemployment, we also included the municipality's unemployment rate as a control variable.[28] The hypothesis we tested was whether the municipal "demand"

[26] Since the 1998 deadline for LIP applications was in February the same year, we use the result from the 1994 election for the 1998 allocation. For the 1999-2002 allocations we use the result from the September 1998 election.

[27] We used the environmental ranking in the previous year. The reason for using one year lagged environmental rankings was mainly practical: Miljö Ekos environmental ranking ceased in 2001. Noteworthy is that the environmental ranking variable is endogenous in 1998. This is because the 1998 questionnaire included a question about whether the municipality had applied for, or intended to apply for, the LIP subsidies. If the municipality had applied or intended to apply the environmental ranking was higher. It is also worth noting annual differences in the questionnaire and that the maximum attainable score varied over the years. We use standardised (by the relevant year's maximum points) rankings consisting of an index between 0-100.

[28] The municipality's unemployment rate consists of the number of persons in unemployment and labour market programs relative the corresponding municipal population group (figures from the Swedish National Labour Market Administration, www.amv.se).

for employment affected the size of the LIP subsidy, i.e. whether municipalities with high unemployment got more subsidies. A little surprisingly, the unemployment parameter turned out negative and significant, meaning that municipalities with high unemployment received significantly less subsidies than municipalities with lower unemployment. Possibly municipalities with high unemployment applied less frequently and/or for smaller subsidies due to them already receiving substantial government support for unemployment reductions.

Since none of these model extensions increase the models' explanatory power dramatically or quantitatively alter the results of the variables of primary interest (CO_2, NO_x, SO_2 and L) in the first order expansion, we choose to omit these results.[29]

In a sensitivity analysis performed by first excluding the 1998 projects and then the 2002 projects from the second order Taylor expansion, we find that exclusion of the 1998 projects affects the mean and median marginal subsidies more than exclusion of the 2002 projects. The differences in the mean marginal subsidies for CO_2, NO_x and SO_2 are, however, not statistically significant. The mean marginal subsidy to employment is, on the other hand, significantly higher in 1999-2002 than when the observations for 1998 are included. This result, which contradicts the findings from the first order Taylor expanded model, is solely due to two projects' extreme reductions of NO_x in 1999 and 2000. If these outlier observations are removed, there is no significant difference in the mean MS_L over the years.

6 Conclusions

We evaluate the allocation rationality and ex ante cost efficiency of a major Swedish investment subsidy program, the LIP. The LIP, effective between $1998-2002$, had dual purposes: to step up the pace at which Sweden transforms into an ecologically sustainable society and to reduce unemployment. During the program period, more than 6.2 billion Swedish kronor (approximately € 650 million) were granted to different municipal projects, first by the government itself and then by the Swedish EPA.

Based on the government's guidelines for LIP applications (Regeringskansliet, 2000a), we formulate a subsidy function where the magnitude of the subsidy depends on the projects' anticipated environmental and employment effects. We find that the projects' anticipated effects to a high degree explain the size of the LIP subsidy granted. Thus, the allocation of LIP subsidies appear to have been rational, following an implicit weighing rule.

[29]The results are available from the author upon request.

The marginal subsidy for CO_2 reductions is lower than, or equal to, the $1998-2002$ household CO_2 tax in almost 99 percent of the projects (2002 prices). The marginal CO_2 subsidy was also smaller than or equal to the $1998-2002$ industry CO_2 tax in 95 percent of the projects. Even though cost efficiency was not an official requirement in the LIP, evaluation of the ex ante cost efficiency reveals that the LIP subsidy shows little variation over projects and, thus, appears to be CO_2 cost efficient. Assuming project fulfillment and that the prevailing CO_2 tax is equal to the social value of the benefits obtained from CO_2 reductions, our general conclusion is that the LIP achieves CO_2 emission reductions cost efficiently at low cost - provided that the projects generate spillover effects large enough to motivate the subsidy in the first place.

Similarly, if the value of the social benefits received from NO_x reductions is equal to the NO_x fee, emissions of NO_x are also reduced at low cost in the LIP. However, even if the marginal LIP subsidy for SO_2 reductions is lower than the SO_2 tax in 85 percent of the projects, we see no cause for the government to subsidize SO_2 reductions. The reason is that the interim target of the environmental quality objective "Natural Acidification Only" already is fulfilled. Since there are many other costly interim targets for the environmental quality objectives, government funding should be directed towards unfulfilled targets. Subsidizing already fulfilled targets is never an efficient environmental policy.

Whereas this *ex ante* analysis can provide information about the mechanism governing the decision making and about the forecasted cost efficiency of the LIP projects, *ex post* analysis, based on the LIP projects' achieved environment and employment effects, can provide information about the real outcomes. Ex post cost efficiency of the LIP projects is an issue that will be addressed in future research. Last but not least, to justify a subsidy program as sizable as the LIP, it is of utmost importance to gauge the magnitude of the program's spillover effects.

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Appendix A: Variable Definitions

Table A: Variable and parameter definitions.

Variable/Parameter	Definition
Y	The LIP subsidy in SEK (2002 prices).
α_{CO_2}	Variable equal to one if the project had no anticipated CO_2 effects.
α_{NO_x}	Variable equal to one if the project had no anticipated NO_x effects.
α_{SO_2}	Variable equal to one if the project had no anticipated SO_2 effects.
α_L	Variable equal to one if the project had no anticipated L effects.
CO_2	The reduction in CO_2 emissions (kilos/year).
NO_x	The reduction in NO_x emissions (kilos/year).
SO_2	The reduction in SO_2 emissions (kilos/year).
ME1	The reduction in emissions of volatile organic compounds (kilos/year).
ME2	Energy savings; electricity (MWh/year).
ME3	Energy savings; oil (MWh/year).
ME4	Energy savings (MWh/year).
ME5	Energy savings; other (MWh/year).
ME6	Energy conversion; oil to renewable energy (MWh/year).
ME7	Energy conversion; electricity to renewable energy (MWh/year).
ME8	Other energy conversion (MWh/year).
ME9	Return of phosphorus to cultivation soil (kilos/year).
ME10	Reduced amounts of waste; other (tonnes/year).
ME11	Reduced amounts of waste; sludge (solids in tonnes/year).
ME12	Reduced amounts of waste (tonnes/year).
ME13	Reduced amounts of waste; household waste (tonnes/year).
ME14	Reduced vehicle kilometers.
ME15	Reduced person kilometers.
ME16	Reduced water emissions; nitrogen to the Baltic Sea (kilos/year).
ME17	Reduced water emissions; phosphorus to the Baltic Sea (kilos/year).
ME18	Reduced water emissions; phosphorus to other (kilos/year).
ME19	Reduced water emissions; nitrogen to other (kilos/year).
ME20	Reduced emissions to water; nitrogen (kilos/year).
ME21	Reduced emissions to water; phosphorus (kilos/year).
ME22	Reduced use of CFC (kilos).
ME23	Soil measures to promote biological diversity (hectares).
ME24	Reduced use of natural gravel (tonnes/year).
L	Direct employment as a consequence of the investment (annual full-time employment opportunities).
DL98	Interaction variable; L and a year indicator variable for 1998.
DL99	Interaction variable; L and a year indicator variable for 1999.
DL00	Interaction variable; L and a year indicator variable for 2000.
DL01	Interaction variable; L and a year indicator variable for 2001.

Table A continues...

Table A continued...	
Variable/Parameter	Definition
DL02	Interaction variable; L and a year indicator variable for 2002.
G1	Indicator variable for projects in the group "Waste".
G2	Indicator variable for projects in the group "Building measures".
G3	Indicator variable for projects in the group "Remedial measures".
G4	Indicator variable for projects in group "Energy efficiency measures".
G5	Indicator variable for projects in group "Conversion to renewable energy sources".
G6	Indicator variable for projects in group "Multi-dimensional projects".
G7	Indicator variable for projects in group "Industrial projects".
G8	Indicator variable for projects in group "Nature conservation and biological diversity".
G9	Indicator variable for projects in group "Support measures".
G10	Indicator variable for projects in group "Traffic".
G11	Indicator variable for projects in group "Water and sewage".
G12	Indicator variable for projects in group "Other projects".
CO_2NO_x	Interaction variable between CO_2 and NO_x.
CO_2SO_2	Interaction variable between CO_2 and SO_2.
CO_2L	Interaction variable between CO_2 and L.
NO_xSO_2	Interaction variable between NO_x and SO_2.
NO_xL	Interaction variable between NO_x and L.
SO_2L	Interaction variable between SO_2 and L.
CO_2^2	The square of CO_2.
NO_x^2	The square of NO_x.
SO_2^2	The square of SO_2.
L^2	The square of L.

Appendix B: Descriptive Statistics

Table B: Means, standard errors (SE), medians, number of zeros and observations (N) for the anticipated environmental and employment effects.

Variable	Mean	SE	Median	Zeros	N
CO_2	1,149,381	231,610	0	1212	1814
NO_x	11,168	7,191	0	1486	1814
SO_2	1,171	383	0	1606	1814
ME1	28	21	0	1812	1814
ME2	99	26	0	1693	1814
ME3	123	45	0	1777	1814
ME4	503	377	0	1726	1814
ME5	555	207	0	1687	1814
ME6	646	320	0	1732	1814
ME7	337	192	0	1720	1814
ME8	520	287	0	1766	1814
ME9	239	112	0	1786	1814
ME10	90	38	0	1787	1814
ME11	73	51	0	1801	1814
ME12	2,496	2,400	0	1773	1814
ME13	31	21	0	1797	1814
ME14	47,760	30,168	0	1741	1814
ME15	385	333	0	1809	1814
ME16	67	30	0	1804	1814
ME17	6	3	0	1802	1814
ME18	6	2	0	1798	1814
ME19	69	25	0	1794	1814
ME20	1,651	450	0	1639	1814
ME21	95	40	0	1657	1814
ME22	3	3	0	1812	1814
ME23	3	3	0	1747	1814
ME24	40	29	0	1810	1814
L	11	1	3	66	1814

Appendix C: Results

Table C: Parameter estimates and standard errors (SE) from OLS estimations of the first and second order Taylor expanded models. Dependent variable: Y_{ijt}

	First order expansion			Second order expansion		
Variable/Parameter	Estimate	SE	t	Estimate	SE	t
α	2,672,494	605,385	4.41	2,067,392	597,842	3.46
α_{CO_2}	176,906	413,526	0.43	24,752	401,937	0.06
α_{NO_x}	-529,696	449,967	-1.18	266,248	397,469	0.67
α_{SO_2}	-818,088	435,645	-1.88	-851,603	383,938	-2.22
α_L	-423,198	234,469	-1.80	-324,929	267,624	-1.21
CO_2	0.06	0.02	2.92	0.18	0.08	2.24
NO_x	0.46	0.09	5.10	22.70	22.77	1.00
SO_2	23.29	10.87	2.14	-37.56	45.89	-0.82
L	255,982	13,008	19.68	207,903	41,205	5.05
ME1	59.20	35.29	1.68	69.10	28.96	2.39
ME2	778.89	307.97	2.53	712.07	315.56	2.26
ME3	104.37	76.92	1.36	43.08	80.96	0.53
ME4	-9.22	3.30	-2.79	-3.49	12.85	-0.27
ME5	28.95	15.99	1.81	19.36	13.69	1.41
ME6	243.70	22.95	10.62	-15.06	45.33	-0.33
ME7	-5.61	82.69	-0.07	-113.67	277.84	-0.41
ME8	-7.90	48.19	-0.16	-4.62	42.22	-0.11
ME9	7.20	28.12	0.26	8.96	29.65	0.30
ME10	997.81	615.81	1.62	983.64	661.49	1.49
ME11	501.65	89.13	5.63	797.86	325.45	2.45
ME12	2.52	1.31	1.93	2.00	1.06	1.88
ME13	-128.58	67.40	-1.91	-156.53	81.34	-1.92
ME14	0.02	0.44	0.04	-0.01	0.39	-0.02
ME15	3.72	0.75	4.97	3.47	0.86	4.03
ME16	-37.92	84.90	-0.45	59.31	77.64	0.76
ME17	1,258	1,284	0.98	162.92	259.80	0.63
ME18	-4,907	3,378	-1.45	-3,262	2,803	-1.16
ME19	-105.12	118.37	-0.89	-77.57	97.83	-0.79
ME20	10.41	7.54	1.38	10.93	7.78	1.41
ME21	-6.00	57.70	-0.10	-1.40	60.18	-0.02
ME22	1,145	214.60	5.34	1,452	567.89	2.56
ME23	426.49	1,814	0.24	-667.34	1,923	-0.35
ME24	-1,239	743.45	-1.67	-1,215	798.04	-1.52
G2	-1,975,792	1,985,423	-1.00	-1,592,870	1,876,799	-0.85
G3	9,116,573	3,294,731	2.77	9,781,399	3,424,042	2.86
G4	-827,714	487,071	-1.70	-751,513	465,634	-1.61

Table C continues...

Table C continued...						
	First order expansion			Second order expansion		
Variable/Parameter	Estimate	SE	t	Estimate	SE	t
G5	-1,121,743	564,072	-1.99	-1,045,240	560,069	-1.87
G6	-3,566,496	886,516	-4.02	-2,759,993	875,080	-3.15
G7	-1,768,647	539,496	-3.28	1,377,330	504,470	-2.73
G8	-760,259	477,129	-1.59	-899,831	481,012	-1.87
G9	-1,156,895	400,059	-2.89	-1,215,962	395,595	-3.07
G10	-212,278	575,382	-0.37	-125,280	570,101	-0.22
G11	-97,616	432,310	-0.23	-186,887	431,854	-0.43
G12	-1,114,847	474,699	-2.35	-1,141,907	486,589	-2.35
DL99	-79,264	37,747	-2.10	-9,479	62,844	-0.15
DL00	-139,902	46,269	-3.02	-104,438	58,553	-1.78
DL01	-191,865	28,004	-6.85	23,874	48,039	0.50
DL02	-130,096	91,468	-1.42	-70,041	99,063	-0.71
CO_2NO_x				1.86e-06	6.25e-07	2.97
CO_2SO_x				9.15e-07	1.41e-06	0.65
CO_2L				-1.35e-03	2.24e-04	-5.99
NO_xSO_2				1.66e-04	5.09e-04	0.33
NO_xL				-1.12	2.73	-0.41
SO_2L				2.11	2.42	0.87
CO_2^2				-6.10e-11	3.20e-10	-0.19
NO_x^2				-3.40e-06	1.09e-06	-3.12
SO_2^2				6.67e-05	8.16e-05	0.82
L^2				40.12	30.15	1.33
N	1,814			1,814		
Adj R^2	0.84			0.86		

Note: Standard errors (SE) are estimated using the robust White estimator (Greene, 1993, ch. 14).

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