Can We Buy Time?

Evaluation of the Government's Directed Grant to Remediation in Sweden

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Sammanfattning

Den främsta samhällsnyttan av att använda allmänna medel för att sanera förorenade områden är att påskynda processen så att skador på hälsa och miljö kan undvikas. Statligt stöd till sanering ges huvudsakligen via Naturvårdsverkets sakanslag till sanering av förorenade områden. I den här rapporten analyserar Konjunkturinstitutet (KI) om sakanslaget påverkar tiden ett förorenat område befinner sig i saneringsprocessen, samtidigt som vi kontrollerar för andra faktorer som kan påverka tidsåtgången.

Våra resultat visar att staten kan öka hastigheten i saneringsarbetet genom att öka sakanslaget, men att de ökningar som krävs för att miljömålet ”Giftfri miljö” ska uppnås är avsevärda. Vår bedömning är att den sortens ökningar kan vara svåra att motivera politiskt, eftersom andra analyser visar att den genomsnittliga kostnaden för att spara ett liv genom sanering av arsenikförorenad mark redan idag uppgår till 7 200 miljoner kronor.

BAKGRUND

Regeringen har beslutat att sexton miljömål med tillhörande delmål ska vara vägledande för Sveriges utveckling i riktning mot ett hållbart samhälle. Målet ”Giftfri miljö” har två delmål som rör sanering av förorenade områden. Enligt dessa delmål ska samtliga förorenade områden som innebär akuta risker vid direktexponering vara utredda, och vid behov åtgärdade, till 2010. Dessutom ska åtgärder ha genomförts vid en så stor andel av de prioriterade områdena att miljöproblemet i sin helhet är löst senast år 2050. I dag finns drygt 80 000 förorenade områden i Sverige. Hittills har saneringen av förorenade områden kostat drygt tre miljarder kronor. Att sanera de mest förorenade områdena beräknas kosta ytterligare 60 miljarder kronor.

ANALYS

I delmålen betonas vikten av att saneringar genomförs snabbt. För att kunna snabba på saneringsarbetet är det därför viktigt att förstå vilka faktorer som påverkar tidsåtgången i saneringsprocessen. På grund av att antalet förorenade områden med helt slutförda saneringar fortfarande är litet i Sverige, fokuserar vi på tidsåtgången i fyra olika ”steg” av saneringsprocessen.

Första steget definieras som tiden mellan den generella riskklassificeringen enligt bransch (så kallad branschklassning) och inledningen av den mer noggranna riskklassificeringen kallad MIFO. Andra steget definieras som tiden mellan MIFO klassificeringens start och dess slut. Tredje steget definieras som tiden mellan MIFO klassificeringens slut och påbörjad operativ sanering. Fjärde steget definieras som tiden mellan påbörjad och avslutad sanering.

Vi skattar effekterna av sakanslaget på tiden i respektive steg med hjälp av en så kallad durationsmodell. Analysen beaktar också andra faktorer som i tidigare forskning visats kunna påverka hastigheten i saneringsarbetet. Till exempel föroreningarnas mängd och spridningspotential, det förorenade områdets känslighets- och skyddsvärde, kommunens skattebas per capita samt andelen röster på miljöpartiet i det senaste valet till kommunfullmäktige.

RESULTAT

Våra resultat visar att sakanslaget ökar sannolikheten att lämna de första och tredje stegen i saneringsprocessen. Det innebär att ju mer sakanslag som ges i dessa steg, desto större är chansen att ett område går vidare i saneringsprocessen. Våra analyser visar emellertid att det tredje steget (från MIFO riskklassificeringens slut till saneringsstart) utgör en stor flaskhals och att det, även om sakanslaget kan öka saneringshastigheten, krävs mycket stora ökningar i förhållande till den tid som kan vinnas.

Våra resultat visar också att höga föroreningsnivåer ökar chansen för att ett område ska riskklassificeras snabbt enligt MIFO. Höga föroreningsnivåer minskar däremot sannolikheten att operativ sanering inleds. En rimlig tolkning av de här resultaten är att områden med höga föroreningsnivåer är lätta att riskklassificera, men att de kräver noggrann och tidskrävande planering innan saneringsarbetet kan inledas.

Vidare finner vi att områden förorenade av polycykliska aromatiska kolväten (PAH) har högre sannolikhet för att snabbt gå från MIFO klassificering till saneringsstart. PAH-förorenade områden framstår därför som relativt snabba att riskklassificera och planera. PAH används bland annat vid träimpregnering, och eftersom vår analys även visar att områden där det förekommit träimpregnering har större chans att påbörja MIFO klassificering, är vår tolkning att impregneringsanläggningar generellt sett har haft en hög prioritet i saneringsarbetet.

Medan andelen röster på miljöpartiet i valet till kommunfullmäktige överhuvudtaget inte påverkar tiden i respektive steg, ökar en högre skattebas per capita i kommunen sannolikheten för att MIFO klassificeringen ska påbörjas. Däremot minskar sannolikheten för att den operativa saneringen ska inledas.

Sammanfattningsvis innebär våra resultat att en ökning av sakanslaget har statistiskt signifikant positiv effekt på hastigheten i två av saneringsarbetets fyra stadier. Den ekonomiska signifikansen av effekterna är emellertid försumbar. Att nå miljömålet ”Giftfri Miljö” i enlighet med delmålen framstår därför som mycket svårt.

Preface

The interim targets of the Swedish environmental quality objective “A non-toxic environment” emphasize that remediation of contaminated sites should progress at a high speed. Since remediation is an expensive venture, it is valuable to gain knowledge about where in the remediation process government funding affects the pace of progress the most. In this paper we analyze how government funding, in the form of a directed grant, affects the pace of progress in four different states of the remediation process. The estimation is performed in a simultaneous sequential duration model in which a site has to exit a state to be eligible for inclusion in the following state. We control for a number of variables that may also affect the pace of the remediation process, such as the municipal tax base and the site’s level of contaminants. Although there is heterogeneity between the sites that contribute to making remediation a slow process, our analyses show that the directed grant positively affects the probability of leaving the first and third states. We identify the third state (i.e., the time between the end of a thorough risk classification and the inception of on-site remediation) as the remediation process’ bottleneck. Even if the directed grant can speed up the process in this state, the effect is minuscule compared to the amount of directed grants needed to do so.

Contents

1. Introduction

Swedish environmental policy is based on 16 environmental quality objectives (Gov. Bill 2000/01:130 and Gov. Bill 2004/05:150).[1] Among these, the 'non-toxic environment' is viewed as one of the most challenging objectives. Several interim targets have been promulgated to operationalize the objective and, in this paper, we focus on the interim target for remediation[2] of contaminated sites, i.e., landfills and areas of soil, groundwater or sediment contaminated by anthropogenic activities.[3] Altogether, there are about 80,000 contaminated sites in Sweden that are hazardous to varying degrees (Swedish EPA, 2008a). Prior to 2006, the interim remediation target stated that all contaminated sites should be identified, that clean-up should have begun at 100 sites, and that 50 of the sites with highest priority should be remediated by 2005. This target was not reached. Two new targets have therefore been set for 2010. The first stipulates that all contaminated sites that pose *acute risks* of exposure or sites that threaten important water sources or other valuable natural environments should be remediated by 2010. The second target requires that from 2005 to 2010, actions should be taken at a sufficiently large proportion of the prioritized sites, to ensure that the contamination problem can be solved at the general level by 2050 at the latest (Gov. Bill 2004/05:150). Thus, both the old and the new versions of the interim targets emphasize that the remediation process progress at a high speed. Since remediation is an expensive venture, it is valuable to gain knowledge about *where* in the process government funding affects the pace of progress the most.

The Swedish government's funding for remediation presently comes in the form of a directed grant (*sakanslag*). The directed grant, administrated by the Swedish Environmental Protection Agency (EPA), subsidizes remediation of contaminated sites that were contaminated prior to modern environmental legislation (in 1969) or for which no liable party can be found. In 1999, when the directed grant was introduced, it amounted to SEK 40 million. The directed grant has increased rapidly over the years to around SEK 500 million in 2007 (Swedish EPA, 2008a).

In this paper we analyze how the directed grant affects the pace of progress of Swedish remediation projects. Since there are very few sites with completed remediation in Sweden, we analyze the pace of progress in four different states of the remediation process. By using unique data on the length of time a contaminated site stays in a specific state, we estimate the effect of funding on the duration. Our focus is motivated by the facts that the previous interim targets were never reached, that the new targets are considered to be very difficult to reach on time (Environmental Objectives Portal, 2008), and that remediation is highly resource demanding. Focusing on the speed by which sites are pushed through the remediation process is therefore of policy interest and has several analytical advantages (as noted by Sigman, 2001). First, speed is a tan-

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[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; A Good Built Environment and A Rich Diversity of Plant and Animal Life.

[2] *Remediation* refers to measures that permanently eliminate or reduce the present or future effect of contamination in soil, groundwater or sediments on health and the environment. Remediation involves identification, registration, and risk classification of potentially contaminated sites, as well as on- or off-site cleanup.

[3] Common contaminated sites are wood preservation, saw mills, mines, pulp and paper industries, glass works, iron and steel mills, metalworks, electroplating etc. (Swedish EPA, 2008b).

gible measure of the Swedish EPA's remediation productivity. Second, speed is a measure that is difficult to manipulate, meaning that actual remediation productivity is hard to disguise. Third, since the EPA has considerable discretion in choosing which sites to remediate, one cannot blame slow pace on the choice of sites (although it can be blamed on a site's technical complexity).

The analysis that comes closest to ours is Sigman (2001), who studied the pace of progress at Superfund sites in the USA. She found that contaminated sites were not prioritized according to their hazardousness, but instead according to private interests associated with, e.g., liable parties and local communities. For instance, sites without a liable party had a 29 percent faster remediation progress compared to sites with a liable party. In addition, sites located in communities with higher voter participation received remediation faster, and sites located in wealthier communities were more quickly listed on the national priority list.

In brief, our results show that the directed grant affects the pace of progress in two of the four different states, implying that funding can speed up the remediation process and, thereby, reduce the risks from contaminated sites. However, speeding up the pace is expensive and even large amounts of additional funding have very small effects on the time spent in these states. The question is if such large increases can be motivated politically given that research elsewhere (Forslund et al., 2009) shows that the cost per life saved associated with remediating arsenic-contaminated sites already is extremely high (on average SEK 7,200 million per life saved).

The paper is organized as follows. The next section describes the environmental problem of contaminated sites in Sweden and the two main forms of government funding for their remediation. Section 3 specifies the model, and Section 4 describes the data. The estimation and the results are presented in Sections 5 and 6, respectively. Our findings are discussed in Section 7, which concludes the paper.

2. Contaminated sites and funding for remediation

Assessing risk

Even though contaminated sites have been a problem for a long time in Sweden, comprehensive inventories did not start until 1990 when the Swedish EPA was assigned the task of developing a strategy for remediation at the national level. From 1992 to 1994, a nationwide inventory of industries was carried out to identify the sites in greatest need of remediation (Swedish EPA, 1995). Depending on their historical and on-going industrial activities, the sites were classified by category of risk ranging from "very high risk" (risk class 1) to "low risk" (risk class 4).[4] This industry inventory was based on available information and did not involve eco-toxicological field investigations. Examples of industries in risk class 1 were pulp and paper, wood preservation, mining, metal workings, and the chemical industries.

To supplement the industry inventory, a more detailed and uniform method for risk assessment, the "MIFO" (i.e., the Method for Inventory of Contaminated Sites) was introduced in 1996.[5] The MIFO involves two different types of investigations. The first (phase 1) contains a collection of data through inspections and interviews, and the second (phase 2) contains a collection of data through field investigations and eco-toxicological samplings (Swedish EPA, 2002a).

The risk class resulting from the MIFO risk classification is based on an overall evaluation of the hazardousness and migration potential of the site-specific contaminants, the contamination level, and the site's environmental sensitivity and protection value (Swedish EPA, 2007a). The sensitivity value is assessed regardless of the number of humans exposed, which means that two sites with equal land use and the same amount of a specific contaminant have equal sensitivity values, even if one is situated in a sparsely populated area and the other in a densely populated area. The protection value is assessed for the species and/or ecosystem exposed to the contaminants at the site and, thus, acknowledges its flora and fauna. As with the industry inventory, MIFO phases 1 and 2 conclude with an overall evaluation of the site's risk on a 1-4 scale, where risk class 1 refers to a "very high risk" to human health and the environment (see Appendix 1 for a more detailed description of the MIFO).

Contaminated sites in Sweden

There are approximately 80,000 contaminated sites in Sweden (Swedish EPA, 2008a). Around 50,000 of these have been risk-assessed according to industrial activity and 15,000 according to the MIFO (Swedish EPA 2008a). Table 1 shows that over 4,200

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[4] The inventory involved about 60 industries which ultimately were given a general "industry classification" (i.e., a risk class according to the type of industrial activity) based on factors such as production processes, raw materials used, products and waste treatment, health and environmental effects of branch specific contaminants, and amounts of contaminants involved (Swedish EPA, 2002a).

[5] The MIFO method was introduced in 1995, and the first MIFO manual was published in 1999 (Swedish EPA, 1999). The MIFO data is stored in a national database referred to as the "MIFO database."

sites are in need of full government funding for remediation. The sites that require no or partial funding will be remediated either voluntarily or by a legally liable party.[6] By the end of 2007, 80 sites financed by government funding had the status "on-going" or "complete" (Swedish EPA, 2008a).

There are approximately 1,400 sites in MIFO risk class 1, i.e., with the highest priority. This far, remediation has cost the government more than SEK 3 000 million.[7], [8] Given that an average remediation costs SEK 30 to 40 million (Swedish EPA, 2008a), an additional SEK 15,000 to 20,000 million is needed to remediate all risk class 1 sites without a liable party (i.e. the sites that are entirely dependent on government funding for remediation). With the present level of annual funding, the Environmental Objectives Council (Swedish EPA, 2008c) estimates that the targets will be reached on time (i.e., by 2050). Still, an annual directed grant of SEK 500 million will only finance remediation of 10-20 sites per year, implying that it will take 35-70 years to remediate just all risk class 1 sites in need of complete or partial funding.[9] Thus, given the present level of funding, we doubt that the target will be reached on time since there are many risk class 2 sites that are in need of complete funding and since remediation has not been completed at 10-20 sites per year so far. These figures are based on simple arithmetic. To evaluate how reasonable these progressions are, we use site-specific data on the pace of progress of the Swedish remediations performed to date.

Table 1 Estimated numbers of sites in MIFO risk classes 1 to 4 and number of sites in need of government funding for remediation.

MIFO risk class	Estimated number of sites	Sites in need of government funding for remediation		
		Entirely	Partially	Not at all
1	1,389	479	437	422
2	14,520	3,785	4,360	6,403
3	25,926	0	0	0
4	38,149	0	0	0
Total	79,984	4,264	4,797	6,825

Source: Swedish EPA (2008a).

Funding for remediation

Historically, the bulk of the public funding for remediation in Sweden has taken two forms: the "LIP" – *Lokala investeringsprogram* – and the directed grants – *sakanslag*.[10]

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[6] The enactment of the Swedish environmental legislation (Gov. Bill 1969:387) in 1969 was a policy landmark; thereafter it became possible to have remediation financed by parties found legally liable. In 1999 the legislation from 1969 was superseded by the Swedish Environmental Code (Gov. Bill 1998:808).

[7] On average, 1 Euro=SEK 9.28 and 1 USD=SEK 7.48 in 2005. Prices are nominal unless otherwise stated.

[8] Until now, measures for remediation have predominantly been financed by government funding. Voluntary cleanups have been conducted by, e.g., an association of oil companies, SPIMFAB.

[9] Assuming that the cost for the sites in need of partial funding is 50 percent of the cost for the sites in need of complete funding.

[10] From the introduction of the directed grant in 1999 to 2004, SEK 1,300 million was allocated in that form (Forslund, 2005). Additional governmental funding for remediation can be raised from the Swedish Armed Forces, the Geological Survey of Sweden and Banverket (Swedish EPA, 2005; Gov. Communication 2003/04:141). Whereas the directed grant and the LIP address all types of contaminated sites, the Swedish Armed Forces, for instance, only finance remediation at sites contaminated by their own activities, e.g., shooting ranges.

The LIP, launched by the Swedish government in 1998, was an investment subsidy program with dual objectives: to speed up Sweden's transformation into an ecologically sustainable society and to reduce unemployment. The LIP projects were categorized into eleven different project groups, of which remediation was one. [11]

To facilitate remediation at sites that were either contaminated prior to modern environmental legislation (i.e., in 1969) or without a legally liable party, the government introduced the directed grant in 1999. The grant can, at most, cover 90 percent of the remediation cost at the prioritized sites, implying that additional public (or private) funding has to be found. The use of the directed grant is regulated in Ordinance 2004:10 and the Swedish EPA's budget document. The directed grants are administrated in a collaboration between the Swedish EPA, the country administrative boards and the municipalities. In this collaboration, the Swedish EPA is responsible for the national coordination and planning, priority-setting and allocation of funds. The county councils are responsible for performing regional inventories, for setting up regional remediation agendas listing the county's ten most prioritized sites, and for handling the directed grants allocated by the Swedish EPA. The municipalities are responsible for carrying out the actual remediations and for applying for directed grants from the county councils.

In this paper we are interested in analyzing how the directed grant affects the length of time sites spend in remediation. We focus on the directed grants since their magnitudes make them imperative to analyze per se and because the LIP subsidies have been analyzed elsewhere (Forslund et al., 2008).

Table 2 shows the directed grants to the Swedish EPA and the LIP subsidies from the introduction of the LIP in 1998 to 2007. The directed grants are the grants stated in the government's budget document to the Swedish EPA (*sakanslag 34:4*). Due to grants being withdrawn (e.g., for state financial reasons in 2003) or transferred from the previous year to the current or from the current year to the next, the actual outcomes of the directed grants are different (lower) than the figures in Table 2.[12] Nevertheless, it is evident that the directed grant has neither been evenly spread nor steadily increasing over the years. The annual variability in the directed grant has, among other things, made the county councils regard the directed grant as short term and non-reliable (Betänkande 2004/05: MJU1). The LIP subsidies in Table 2 are equal to the subsidies granted by the Swedish EPA from 1998 to 2002.

Table 2 The directed grant (government allocation to the EPA) and the LIP (subsidies granted) in SEK million per year and current prices.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Directed grant	0	40	65	152	419	461	319	541	517	499
LIP	264	93	10	30	0.07	0	0	0	0	0

Sources: Swedish EPA (2000; 2001; 2002b; 2003; 2004; 2005; 2006; 2007b; 2008d) and the LIP database at the Swedish EPA.

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[11] Total LIP subsidies were allocated as follows: 11 percent to waste projects, 4 percent to building projects, 6 percent to remediation, 9 percent to energy efficiency and energy saving, 26 percent to renewable-energy projects, 12 percent to multi-dimensional projects, 1 percent to industrial projects, 6 percent to nature conservation, 5 percent to administration and public education, 10 percent to traffic projects, and 10 percent to water and sewerage projects (Swedish EPA and IEH, 2004).

[12] Table 5 in Section 4 gives the actual annual payouts to the county councils from the Swedish EPA.

3. Model specification

We are interested in analyzing the following four states of the remediation process:

1. Time from the completion of the industry inventory to the beginning of the MIFO risk classification.
2. Time from the beginning to the completion of MIFO risk classification.
3. Time from the completion of MIFO risk classification to the beginning of the actual on-site remediation.
4. Time from the beginning to the completion of the actual on-site remediation.

These states are defined by the entry and exit dates given in a database containing information about the objects that have been risk classified according to the MIFO (the MIFO database). With the exception of state 4, they are not ends in themselves. Nevertheless, they are milestones in the remediation process that are both meaningful and simple to define and, consequently, convenient to use in empirical analyses.

In this section, we present a model of the Swedish EPA's possibilities to speed up the remediation of a contaminated site. We use a model where we assume that the Swedish EPA seeks to minimize the total environmental and health costs by minimizing the time spent in each of the above states, subject to a budget constraint and a function that converts grants into speed. This setup gives us the duration of the remediation as a function of the site's hazardousness and grants.

When estimating the environmental and health costs avoided through remediation of a contaminated site, three factors should ideally be considered: the site's hazardousness (h); the size of the exposed populations at the site (e) (e.g., humans, animals and plants, ecosystems etc.); and the length of time in the remediation process (t). We assume the size of the exposed population to be constant across the j states of the remediation process, i.e., $e_{sj} = e_s$. Consequently, the environmental and health costs avoided as a result of remediation are $c_{sj} = c_{sj}(h_{sj}, e_s, t_j)$.

Furthermore, other variables can affect the length of time a site spends in a specific state. For instance, as shown by Sigman (2001) and Hamilton and Viscusi (1999), political pressures and municipal wealth may affect the time in remediation. We control for such variables by including a number of site-specific variables that may vary across the states (m_{sj}), e.g., the share of votes for the environmental party (Miljöpartiet) to the local government in the most recent election, the municipal tax base per capita, as well as a measure of the municipality's previous environmental efforts.

The site's "technical complexity" may also affect the rate of progress. Hence, depending on the amounts and the location of the contaminants present, remediation may be more or less cumbersome. We denote the government's funding for site s (i.e., the directed grant) r_s, and the site's technical complexity g_s. Let $a_j = a_j(r_s, g_s)$ be the function that transforms financial resources into speed. The first derivative of the transformation function with respect to r_s is assumed to be positive ($(\partial a_s / \partial r_s) > 0$), while the first derivative with respect to g_s is assumed to be negative, thus ($(\partial a_s / \partial g_s) < 0$).

Formalized, the Swedish EPA wants to minimize the cost from not remediating a site, controlling for other variables that may affect the pace of progress. That is,

$$\min_{t_{sj}} \sum_s \sum_j c_{sj}(h_{sj}, e_s, t_{sj}; m_{sj}) \,, \tag{1}$$

$$\text{s.t. } t_{sj} \geq a_j\left(r_s, g_s\right) \tag{2}$$

$$\sum_{s=1}^{S} r_{st} \leq B_t$$

$$r_{st} \geq 0 \,,$$

where *S* is the total number of sites and *B* the total funding available.[13] Equation (2) gives the *minimum* time a site needs to complete a state given the resources devoted to the site and the site's technical complexity. Hence, the time in a remediation state can be described as a reduced form function of a number of variables:

$$t_{sj} = t_{sj}\left(r_s, g_s, c_{sj}(h_{sj}, e_s); m_{sj}\right). \tag{3}$$

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[13] $B_t = \sum_{s=1}^{S} r_{st}$.

4. Data

When analyzing how funding can be converted into speed, we focus on the contaminated sites that pose the highest risks to human health and the environment, i.e., the risk class 1 sites. We use data on the contaminated sites extracted from the MIFO database at the Swedish EPA in April 2005 (2005-04-19).[14] At that time, there were altogether 7,895 observations in the MIFO database, from which we extracted 441 risk class 1 observations. In addition, information on another 28 sites with completed remediations at the time of the MIFO extraction was collected from the Swedish EPA, the county councils, and/or the specific remediation project personnel.[15]

Because the time spent in each of the states is sometimes censored, we do not have the time until completion of the state for all observations. The censoring is exogenous due to end of study, i.e. at the date of the data extraction some spells were uncompleted.[16] To take the problem of censoring into account we specify a hazard regression model that allows us to estimate the parameters in Equation (3) by maximum likelihood.[17]

The number of non-censored observations completing each of the four states is given in Table 3. In the data there are some observations that, for unknown reasons, first disappear and then re-appear at a later state. We exclude these observations from the analysis. Thus, in order to be included in the analysis, the observations need to have a sequence of strictly positive durations.

Table 3 Total number of observations, successful (i.e., non-censored) spells, and the success rate (percent success at censoring) in states 1-4.

	Observations (#)	Successful (#)	Percent success at censoring
State 1	451	440	98
State 2	440	300	68
State 3	300	9	3
State 4	9	2	22

From Table 3 it is evident that states 2-4 have lower success rates at censoring than state 1. The observations have a notably low success rate, especially in state 3. Only two observations complete all states of the remediation process.

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[14] Ideally, we would like to define acute risk sites as sites classified as risk class 1 sites in the second phase of the MIFO risk classification. However, due to the limited number of observations with a phase 2 classification, we need to define acute risk sites as sites classified as risk class 1 in the first phase of the MIFO classification.

[15] These sites were, for different reasons, not found in the excerpt from the MIFO database. Some sites were remediated prior to the establishment of the MIFO database and others were less risky (i.e. had risk class 2 to 4) in the MIFO database at the time of our extraction.

[16] Exogenous censoring simplifies the analysis. Had censoring been endogenous, e.g., drop-outs, it would have made the analysis more complicated.

[17] The hazard is a function of time *t* (measured from the inception of a spell either to the completion or to the censoring of the spell), providing the probability (in discrete time) that a spell will be completed at duration *t* *conditional* on it lasting until *t* (c.f. Kiefer, 1988).

Table 4 Average time in months in states 1-4 for the non-censored spells, standard deviations (Std dev), maximum (max), minimum (min), and number of observations (n).

	Average time in state (months)	Std dev (months)	Min / Max (months)	n
State 1	66	27	9/120	440
State 2	27	21	1/101	300
State 3	19	12	1/36	9
State 4	19	21	5/34	2

In the estimation, time is measured at monthly intervals and the duration is, therefore, treated discretely. Table 4 shows that the average time in each state declines across the states and that at least one site in each of the first and second state is extremely slow (120 and 101 months, respectively). On the other hand, some sites are very fast (1 month). In total, there were 23 sites with one month durations in either state 2 or 3. A possible explanation to this is that the entries of the relevant dates were made at approximately the same time and do, therefore, not reflect the underlying entries and exits correctly.

To empirically estimate Equation (3), we need to have measures of the site's amount of funding for remediation (*r*); the site's hazardousness (*h*) in each state *j*; the exposed populations at each site (*e*); the site's technical complexity (*g*); and the municipal variables (*m*) of interest at each site and state. It is important to note that not all these covariates remain constant across the states, meaning that we are dealing with time varying covariates. In the data description below, a sub-index *t* will indicate whether a covariate is time varying (see Appendix 2 for variable definitions).

Site-specific directed grant, r_s

Unfortunately, neither the Swedish EPA nor the county councils keep records of the actual amounts of the directed grants paid to the different sites before a site has ongoing remediation. Hence, there is no site-specific information on the amount of directed grants paid to the sites, except when a site is in state 4. We therefore have to use a cruder measure of the government's funding for a site, and choose the total annual *payouts* (B_t) from the county councils to remediation activities as a proxy. Before 1999, the payouts originated from other Swedish EPA grants than the directed grant. Since these other grants are included in the analysis, our results can not solely be attributed to the directed grant. However, because the other grants, especially for the years 1996-1998, were small, it is reasonable to believe that the observed effects mainly originate from the directed grants.

Furthermore, since the differences in the annual payouts among the counties may be motivated by their different numbers of contaminated sites, we use a variable (*R1*) to control for the county's number of risk class 1 sites at the time of censoring.

The annual payouts to the different county councils can be found in Table 5. Table 5 does not include the amounts of LIP subsidies. To control for the presence of a LIP subsidy in the estimation, we employ a dummy variable equal to 1 for the three consecutive years a site received an LIP subsidy (LIP_t).

Table 5 makes evident that the average annual directed grant varies substantially among counties. There is no significant correlation between the average directed grant and the number of risk class 1 sites in a county (correlation coefficient: -0.01). Note that the directed grants for the years 1999-2005 in Table 5 do not sum up to the directed grants in Table 2. The figures in Table 5 are smaller than those in Table 2, indicating that the Swedish EPA does not have full discretion to use the directed grants given in the annual budget document.

Table 5 Total payouts per year to the county councils, average payouts 1995-2005 (AP) in SEK million per year and the number of risk class 1 sites (R1) per county.

County	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	AP	R1
Blekinge	0.00	0.00	0.67	0.00	0.40	0.50	0.22	3.70	3.70	1.20	1.20	1.05	22
Dalarna	9.00	0.29	0.24	0.00	9.29	1.00	1.50	3.70	2.20	8.43	8.55	4.02	24
Gotland	0.00	0.00	0.00	0.00	0.40	0.80	0.00	1.70	1.85	3.98	2.90	1.06	6
Gävleborg	1.00	0.45	0.23	0.00	0.40	1.00	1.59	1.20	2.29	3.70	12.60	2.22	10
Halland	0.00	0.05	0.20	0.00	0.00	0.40	0.00	3.70	3.20	3.55	3.84	1.36	15
Jämtland	0.00	0.35	0.53	0.00	0.30	0.80	0.60	1.20	1.20	2.00	2.10	0.83	3
Jönköping	2.30	1.43	0.34	0.00	2.90	11.10	9.40	21.40	30.09	17.20	56.14	13.84	65
Kalmar	5.95	3.37	0.15	0.00	2.40	60.30	11.19	27.75	86.90	17.10	53.36	24.41	96
Kronoberg	9.09	1.72	0.63	0.00	0.40	1.00	2.18	4.50	8.45	1.20	70.65	9.07	23
Norrbotten	7.73	1.10	0.25	0.00	0.30	5.50	1.40	26.20	26.20	1.70	1.90	6.57	45
Skåne	22.80	0.43	0.52	0.00	0.90	2.45	1.75	4.40	2.20	18.13	3.80	5.22	66
Stockholm	8.35	1.10	0.35	0.00	0.40	1.00	0.70	2.65	12.70	16.20	4.10	4.32	139
Södermanland	0.00	0.27	0.57	0.00	12.10	11.50	1.80	75.73	31.66	27.78	18.87	16.39	24
Uppsala	1.40	1.98	0.43	0.00	0.40	1.00	1.30	3.80	1.85	1.50	3.00	1.51	60
Värmland	1.50	2.75	0.10	0.00	0.40	4.50	5.10	16.80	9.45	7.05	1.40	4.46	176
Västerbotten	12.93	0.00	0.90	0.00	0.40	1.00	1.00	2.70	4.70	2.20	76.70	9.32	17
Västernorrland	3.58	3.52	0.09	0.00	0.87	6.50	2.00	100.6	105.6	5.30	39.06	24.28	38
Västmanland	3.70	0.80	0.35	0.00	0.40	0.80	0.80	2.48	2.53	3.04	9.35	2.20	163
Västra Götaland	2.28	1.02	1.87	0.00	3.95	6.00	8.56	56.61	6.43	48.34	4.26	12.66	149
Örebro	0.00	2.19	0.64	0.00	0.00	1.00	1.90	2.45	2.28	2.73	4.05	1.57	210
Östergötland	0.25	0.30	0.86	0.00	0.40	1.70	10.50	26.75	10.03	8.34	15.26	6.76	86
Total	92	23	10	0.00	37	120	63	390	355	201	393		

Source: Färnkvist (2007) and personal communication with the different county councils.

Hazardousness and exposed populations, h_{sj} and e_s

To control for a site's risk, we include its hazardousness, h_{sj}, and the populations exposed, e_s, in the analysis. Depending on the site's "primary" contaminant, defined as its most hazardous and/or most frequently occurring contaminant, either the risk to human health or the risk to the environment dimensions the remediation efforts (Swedish EPA, 2008e).

Five assessment criteria are used to define the health and environmental risks of a contaminated site: the *hazardousness* of the present contaminants, their *levels*, the contaminants' *migration potential*, and the site's *sensitivity* (which involves the risk of human exposure) and *protective value* (which involves the presence of valuable natural features).

Because all observations in our data are of (MIFO) risk class 1, all observations contain contaminants of high hazardousness. There is, therefore, no point in controlling for the contaminants' hazardousness, i.e., risk class, per se. The other criteria are assessed separately, pathway-by-pathway, on four-level scales (such as soil, groundwater, surface water, and sediment) (see Appendix 1). Considering the relatively limited number of observations in our data set, it is not possible to use all this information. Instead, we boil down the extensive pathway-by-pathway information into four dummy variables each equal to one if the site is characterized by high sensitivity (*High sensitivity*), a high protection value (*High protection value*), high levels of contaminants (*High levels*), and a high migration potential (*High migration*). This information is, however, only available in states 2-4 of the remediation process, i.e., after the MIFO assessment has been performed. Consequently, a site's environmental and health risk consists of a vector of variables, $\boldsymbol{h}_{s2\text{-}4} = (\textit{High sensitivity}_{s2\text{-}4}, \textit{High protection value}_{s2\text{-}4}, \textit{High levels}_{s2\text{-}4}, \textit{High migration}_{s2\text{-}4})$.

Because of the difficulties identifying and estimating a site's exposed populations (both human and environmental), we use an estimate of the *human* population at risk measured as the inhabitants per square kilometer (km^2) in the municipality (Statistics Sweden, 2007) where the site is situated for e_{st}. The disadvantage of focusing only on humans is that we neglect exposed non-human, environmental populations. Since the environmental populations can be assumed to be negatively correlated with the human population densities, our proxy for e_{st} is likely to underestimate the populations at risk at the most sparsely populated sites. Still, the variable *High protection value* should at least give a crude measure of a site's environmental populations at risk.

Technical complexity of a site, g_s

Contaminated sites differ in terms of technical complexity, g_s. The type and spread of contaminants vary from one site to another. In the first spell of the estimation, little information was available regarding the sites' risks. We, therefore, use the information available at that time, i.e., dummy variables for the six most common industrial activities (sawmill, wood preservation, electroplating, engineering, mine, and other) to control for a site's technical complexity. Since more than one industrial activity may have occurred at a specific site, the dummy variables for industrial activity are not mutually exclusive. However, most observations (n=393) have only one industrial activity, although one observation has four different industrial activities. Thus, in the first state, the technical complexity consists of a vector of variables, $\boldsymbol{g}_{s1} = (\textit{brsag}_{s1}, \textit{brimpr}_{s1}, \textit{brytb}_{s1}, \textit{brverks}_{s1}, \textit{brgruv}_{s1}, \textit{brovr}_{s1})$.

In the second, third, and fourth states, eco-toxicological and other information that constitutes the basis for the MIFO assessment is employed. However, since there were a multitude of different substances in the database (ranging from well-known, such as arsenic, to more indeterminate, such as glue or yellow goo), we summarize the substances present in cruder measures, i.e., dummy variables indicating the presence of ten different types of contaminants, to control for a site's technical complexity. Thus, in the second to fourth spells, the technical complexity consists of a vector of dummy variables, $\boldsymbol{g}_{s2\text{-}4} = (\textit{contmet}_{s2\text{-}4}, \textit{contoorg}_{s2\text{-}4}, \textit{contfeno}_{s2\text{-}4}, \textit{contklor}_{s2\text{-}4}, \textit{contovrk}_{s2\text{-}4}, \textit{contoaro}_{s2\text{-}4}, \textit{contpah}_{s2\text{-}4}, \textit{contovro}_{s2\text{-}4}, \textit{contsyrb}_{s2\text{-}4}, \textit{contpetr}_{s2\text{-}4}, \textit{contovr}_{s2\text{-}4})$.

Municipal influence, m_s

Municipalities may affect the pace of progress of remediation by, e.g., putting pressure on public officials. In Dahlberg and Johansson (2002), as well as in Forslund et al. (2008), municipalities with many "swing" voters (i.e., voters who lack a strong affiliation with a particular party) more readily received LIP subsidies – both for remediation and for other measures. To control for political influences, the municipalities' shares of votes for the environmental party ($green_{st}$) to the municipal council in 1994, 1998, and 2002 were included in the analysis.

To control for the municipalities' previous environmental efforts, a variable measuring a municipality's average environmental ranking 1993-2001 is also included. The environmental ranking variable ($ecorank_{sj}$) is based on a questionnaire to all Swedish municipalities in an annual survey by the magazine "Miljö-Eko" (Miljö-Eko 1997; 1998; 2000; 2001; and 2003).[18] The higher the *ecorank*, the better the municipality's performance with regard to the environment. The rationale for wanting to control for the municipalities' previous environmental efforts is that municipalities that previously have performed a lot of environmental work may already communicate well with the county councils and the Swedish EPA and may, therefore, be handled more expeditiously in the remediation process.

Furthermore, research in the USA has found that remediation in prosperous areas is more ambitious than remediation in less prosperous areas (Hamilton and Viscusi, 1999). To control for a municipality's prosperity, we use its tax base per capita ($taxbase_{jt}$). Thus, the municipal influence consists of a vector of variables, $\mathbf{m}_{sj} = (green_{sj}, ecorank_{sj}, taxbase_{sj})$.

Descriptive statistics

Table 6 shows descriptive statistics for both the time varying and the non-time varying covariates. Interesting to note is that the directed grants are significantly smaller in states 3 and 4 than in states 1 and 2. Also note that no project received LIP funding in states 3 and 4.

The municipal tax base also varies significantly across the states. Observations in states 3 and 4 have significantly smaller tax bases than observations in states 1 and 2. The tax base in state 4 is also significantly smaller than the tax base in state 3, implying that the municipalities where remediation was completed were less prosperous than the municipalities with remediation in progress. Thus, contrary to the findings in the USA (Hamilton and Viscusi, 1999), our data shows that contaminated sites in less prosperous municipalities were remediated faster than sites in more prosperous municipalities.

Furthermore, there are significantly more risk class 1 sites in states 1-3 than in state 4.

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[18] Miljö-Eko is a politically independent magazine established in 1993. The use of a lagged (t-1) ER variable is reasonable but mainly for practical purposes: Miljö-Eko's environmental rankings ceased in 2001. It is noteworthy that the environmental ranking variable is endogenous in 1998, the reason being that the 1998 survey included the question whether the municipality had applied or intended to apply for LIP subsidies. If the answer was affirmative, the environmental ranking was higher. Since the maximum attainable score varied over the years, we employ standardized rankings.

Table 6 State-wise descriptive statistics for time-varying and non time-varying covariates. Means and standard deviations(in parentheses) for the non-censored spells.

Variable / State	t_1 (n=440)	t_2 (n=300)	t_3 (n=9)	t_4 (n=2)
Time-varying covariates				
B	8,989,151 (18,126,344)	8,197,571 (17,666,675)	2,202,219 (5,217,423)	4,306,667 (4,203,154)
LIP	0.004 (0.067)	0.005 (0.073)	0.000 (0.000)	0.000 (0.000)
Taxbase	106,149 (14,583)	106,074 (14,227)	93,055 (9,834)	82,153 (12,870)
Green	4.246 (1.900)	4.212 (1.835)	4.650 (2.444)	4.256 (2.360)
Invkm2	264 (683)	296 (737)	219 (691)	434 (1,261)
Non time-varying covariates				
R1	108 (52)	108 (53)	108 (54)	71 (43)
High sensitivity	0.336 (0.473)	0.303 (0.460)	0.291 (0.455)	0.111 (0.333)
High protection	0.289 (0.454)	0.263 (0.441)	0.240 (0.428)	0.333 (0.500)
High level	0.587 (0.493)	0.622 (0.486)	0.729 (0.445)	0.667 (0.500)
High migration	0.582 (0.494)	0.568 (0.496)	0.592 (0.492)	0.333 (0.500)

Note: See Appendix 2 for variable definitions.

In the estimation we also employ dummy variables to control for the second to fourth states' inception years (YSiL, YSiM) (the inception of the first state is equal for all sites). Thus, the parameters of the time dummies capture time-varying impacts like different price-levels and other year-dependent differences.

5. Estimation

We estimate the hazard to leave a state, using the covariates described above, taking into account any potential unobserved heterogeneity between the sites. To allow for non-monotonous[19] hazards, we specify the hazard in each state to be of the log-logistic form, hence

$$\lambda_{js}(t_j) = \frac{\exp(\gamma_j + u_s + \mathbf{x}_{js}(t)'\boldsymbol{\beta}_j)\alpha t_j^{(\alpha-1)}}{1+\exp(\gamma_j + u_s + \mathbf{x}_{js}(t)'\boldsymbol{\beta}_j) t_j^{\alpha}} .$$

Here t_j is the duration in each of the states, α is a parameter that governs the time profile of the hazard,[20] γ_j is the base level of the hazard in state j, and $\boldsymbol{x}_{js}(t)$ consists of both the time-varying and non time-varying covariates for site s in state j ($\boldsymbol{x}_{js}(t)=(B_t, e_{st}, h_s, \boldsymbol{m}_{st}, \boldsymbol{g}_s)$). u_s is time invariant unobserved heterogeneity (site specific unobserved variables) that affect the hazard in the same way in all states.

Note that the marginal effect of the kth variable in the $\boldsymbol{x}$ vector varies with time since

$$\frac{\partial \lambda_{js}(t_j)}{\partial x_{kjs}(t_j)} = \beta_{kj} \times \frac{\alpha t_j^{\alpha-1} \exp(-(\gamma_j + u_s + \mathbf{x}_{js}(t_j)'\boldsymbol{\beta}_j))}{(\exp(-(\gamma_j + u_s + \mathbf{x}_{js}(t_j)'\boldsymbol{\beta}_j)) + t_j^{\alpha})^2} .$$

Hence, if $\alpha > 0$, the sign of the marginal effect is the same as the sign of the estimated parameter.

We model the unobserved heterogeneity non-parametrically and estimate the mass-points[21] together with the other parameters of interest by using maximum likelihood (c.f. Heckman and Singer, 1984, and Meyer, 1990).[22] Let $f(t_j;\gamma_j,\mu_m,\mathbf{x}_{js}(t)'\boldsymbol{\beta}_s)$ and $F(t_j;\gamma_j,\mu_m,\mathbf{x}_{js}(t)'\boldsymbol{\beta}_s)$ be the density and the distribution functions of the duration. Here $\boldsymbol{\beta} = (\boldsymbol{\beta}'_1, \boldsymbol{\beta}'_2, \boldsymbol{\beta}'_3, \boldsymbol{\beta}'_4)$ and $\boldsymbol{\gamma} = (\gamma_1, \gamma_2, \gamma_3, \gamma_4)$, whereas μ is the parameter characterizing the unobserved heterogeneity. Then we maximize the log-likelihood:

$$\log L(\boldsymbol{\beta},\boldsymbol{\gamma},\boldsymbol{\mu}) = \sum_{s=1}^{S}\sum_{m=1}^{M}\left\{ y_{js} \times \ln f(t_j;\gamma_j,\mu_m,\mathbf{x}_{js}(t)'\boldsymbol{\beta}_s) + (1-y_{js}) \times F(t_j;\gamma_j,\mu_m,\mathbf{x}_{js}(t)'\boldsymbol{\beta}_s) \right\}\pi_m$$

where $y_{js} = 1$ if the spell is not censored and zero otherwise. π_m is the probability for the mth mass-point. Here $\sum_{m=1}^{M}\pi_m = 1$ (and $M \neq \infty$). The intercept μ_1 is normalized to zero. Thus, the population belonging to the first subgroup (first mass-point) $m = 1$

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[19] The advantage with this specification is, hence, that the hazard is, e.g., allowed to first increase and thereafter to decrease.

[20] If $\alpha>0$, the hazard first increases and then decreases with the duration. If $0<\alpha\leq 1$, the hazard decreases with the duration (Kiefer, 1988).

[21] A Bernoulli distribution, for example, has two mass-points, one at zero and one at one.

[22] The length of stay in a state or the probability of leaving a state may be affected by the time already spent in that state. Intuition might suggest that the longer a particular remediation state persists, the more likely it is that it will end soon (positive duration dependence). Nevertheless, it seems equally plausible that the longer a spell has lasted, the more difficult the state is and, thus, the less likely it is to be completed soon (negative duration dependence).

have the basic level γ_j for each state, and hence μ_m, $m > 1$ measures the shift in the baseline hazard.

The model is estimated sequentially. We start by setting $M = 1$ and then increase the number of mass-points until the log-likelihood no longer improves.

6. Results

The log-likelihood improves significantly by adding a mass-point.[23] However, when we add another mass-point, no further increase can be gained. Hence the number of mass-points is determined to be two. The full set of parameter estimates can be found in Appendix 3. Considering the heterogeneity parameters, μ_2 is estimated to be negative and statistically significant, implying that 84 percent of the observations belong to the subgroup with longer durations, and hence 16 percent of the observations belong to the subgroup with shorter durations.[24] Thus, the majority of observations are slow and, therefore, a slow pace is the rule rather than the exception.

From the results (see Appendix 3) we can see that the duration parameter, α, is positive and significant. Consequently, the signs of the marginal effects are the same as the signs of the estimated parameters. Furthermore, we can see that the annual payouts from the county councils (*B*) contribute statistically significantly to increasing the probability of leaving state 1 (from the industry inventory to the beginning of the MIFO risk classification).

In state 2 (from the beginning to the end of the MIFO risk classification), the annual payouts have no significant effect on duration. On the other hand, if the site receives a LIP subsidy, the duration in the second state is shortened (two observations).

In state 3 (from the end of the MIFO classification to the start of the on-site remediation), the annual payouts have a positive and statistically significant effect, implying that higher payouts increase the probability of leaving the state.

In state 4 (from the beginning to the end of the on-site remediation), there are only nine (censored and non-censored) observations. We therefore restrict all parameters except the one for the annual payouts to be equal to the parameters in state 3. Contrary to intuition, we find that the annual payouts significantly decrease the probability of leaving state 4. This result is paradoxical and most likely due to the small number of observations. When separately estimating the fourth state on *all* observations with completed remediation, i.e., also including the 28 observations that had not completed the previous states, the annual payouts has a non-significant effect on the probability of leaving the state (results not included).

In order to evaluate the economic significance of the counties' annual payouts (*B*) on duration in state 3, we perform a policy simulation where we increase the annual payouts from the county council and estimate the average (counterfactual) hazard under this new regime. The reason for focusing on this state is that it appears to be a bottleneck in the remediation process and, therefore, of policy interest (i.e., in order to evaluate the time that funding can buy). By comparing the hazard with the estimated average hazard under the old regime, we can obtain an effect in percent, or months, from the increase of the annual payouts. By doubling the annual payouts, we find that the hazard of leaving state 3 increases by an average 0.73 percent, implying a decrease

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[23] A likelihood ratio test with one degree of freedom is used to perform inference.

[24] Estimating the model with three sub-groups (mass-points) did not significantly improve the results.

in duration by about two weeks over the period studied (87 months). This must be considered to be a very small effect.[25]

Other effects

When it comes to the *hazardousness* of a site, high levels of contaminants increase the probability of leaving state 2, implying that sites with high levels of contaminants are prioritized in the MIFO risk classification procedure. In state 3, high sensitivity values and high amounts of contaminants slow down the process, which could indicate that sites with these characteristics are difficult to remediate and involve careful remediation planning.

When assessing a site's sensitivity, the Swedish EPA pays regard to the site's hazardousness at the individual level, but not to the actual number of individuals exposed. Our results, however, show that sites located in municipalities with high population densities have a decreased probability of leaving states 1 and 2, but an increased probability of leaving state 3.

The variables measuring the *technical complexity* of the site indicate that sites with (historical or ongoing) wood impregnation activities have an increased probability of leaving state 1. Furthermore, the probability of leaving states 2 and 3 is higher for sites contaminated with polycyclic aromatic hydrocarbons (PAH). Because PAH is used, e.g., in wood impregnation, sites with wood impregnation appear to be favored in the remediation process.

The variables measuring *municipal influence* show that neither the share of votes for the environmental party nor Miljö-Eko's environmental ranking of the municipality affects the speed of progress in any of the states. Thus, political lobby groups, measured as the voters for the environmental party, and previous environmental efforts do not appear to affect the pace of progress in remediation projects. Sites located in municipalities with a higher tax base per capita have an increased probability of leaving state 1, but a decreased probability of leaving state 3. Thus, the evidence on environmental injustice is inconclusive.

Furthermore, the results show that the probability of leaving state 1 increases with the number of risk class 1 sites in the county, while the probability of leaving states 2 and 3 decreases. A possible explanation is that the commencement of the MIFO risk classification is quicker in counties with many risk class 1 sites due to a higher awareness of the problem. States 2 and 3 are, however, more complicated and, therefore, most likely more resource demanding. These states are, therefore, also more time-consuming. In a county with many risk class 1 sites, sites may spend more time in states 2 and 3 just because the county council has difficulties making prioritizations.

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[25] If we perform the same policy experiment in state 1, i.e. a doubling of the directed grant, we find that the hazard of leaving state 1 increases by an average 2.21 percent, implying a decrease in the duration by about nine weeks over the evaluation peridod studied (124 months). Thus, the effect is larger in state 1 than in state 3, although it is still very small.

7. Discussion

This paper analyzes how government funding in the form of the directed grant affects the pace of progress of Swedish remediation projects. Because the number of sites with completed remediation is still sparse, we analyze the pace of progress in four different states of the remediation process: from the end of the industry inventory to the start of the MIFO risk classification (state 1); from the beginning to the end of the MIFO risk classification (state 2); from the end of the MIFO risk classification to the start of the actual remediation (state 3); and from the beginning to the end of the actual on-site remediation (state 4). The estimation is performed in a simultaneous sequential duration model in which a site has to exit a state to be eligible for inclusion in the following. To explain the time spent in each state we use the annual payouts of the directed grants from the county councils to the remediation projects within their jurisdictions. Furthermore, we use a number of control variables that have previously been shown to affect the pace of remediation projects, such as municipal tax base, share of all votes cast for the environmental party in the most recent municipal council election, contaminant level and migration potential, as well as a site's sensitivity and protection values. Thus, the number of observations varies across the states and the covariates are both time-varying and non time-varying.

Although there is heterogeneity between the sites (e.g., in the tax base per capita) that contribute to making the remediation a slow process, these variables are not easily manipulate for political purposes. On the other hand, a variable that can both speed up the process *and* be affected by the government is financing through the directed grant. Our analyses show that the directed grant positively affects the probability of leaving states 1 and 3, whereas it has no effect on the probability of leaving state 2. Furthermore, our analysis identifies state 3 as a gigantic bottleneck. Although our results show that the directed grant can speed up the process in this state, the effect is small compared to the amount of funding needed. The question is if large increases in the directed grant can be motivated politically, given that research elsewhere (Forslund et al., 2009) shows that the cost per life saved associated with remediating arsenic-contaminated sites already is extremely high (on average SEK 7,200 million per life saved).

Sigman (2001) suggests that in order to avoid detrimental effects caused by an extended remediation process, it can be beneficial to fund remediation through broad-based taxes. In this paper, we find that government funding can speed up the pace in some states of the remediation process. However, in order for the Swedish government to reach the interim environmental targets of the environmental quality objective "A non-toxic environment," the government needs to increase its funding substantially. To have any chance to reach the environmental target on time, focus and funding must be directed primarily to state 3, which constitutes a gigantic bottleneck in the remediation process. Yet, our findings altogether suggest that the environmental quality objectives are far too visionary and, therefore, of little practical relevance.

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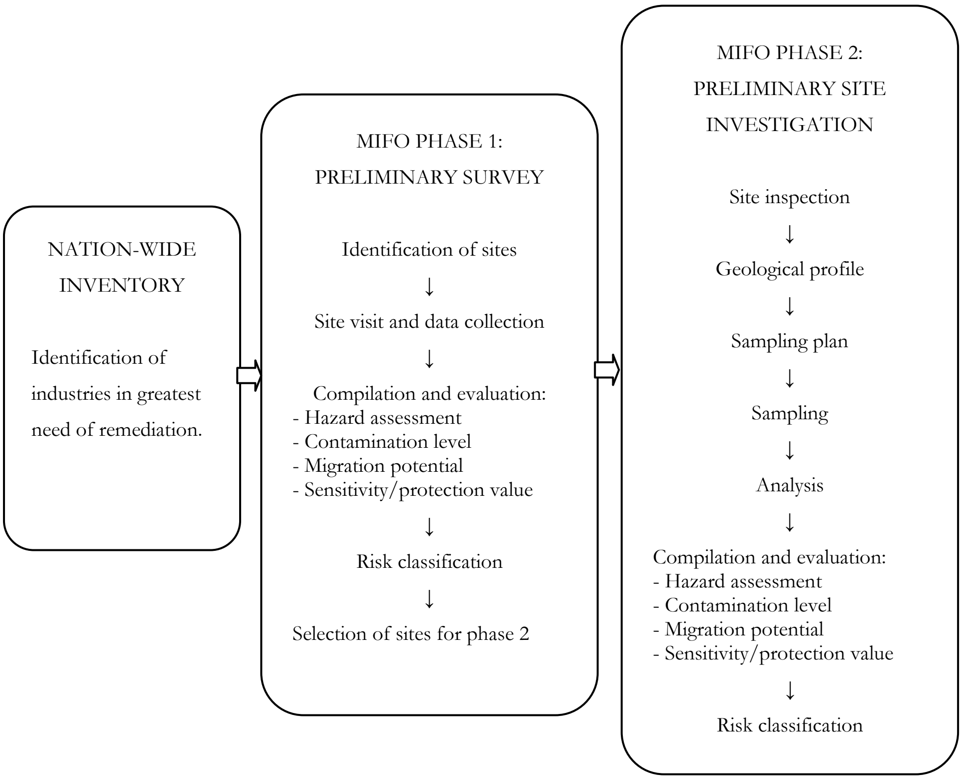
Appendix 1 Risk assessment and classification



Source: Swedish EPA (2002a)

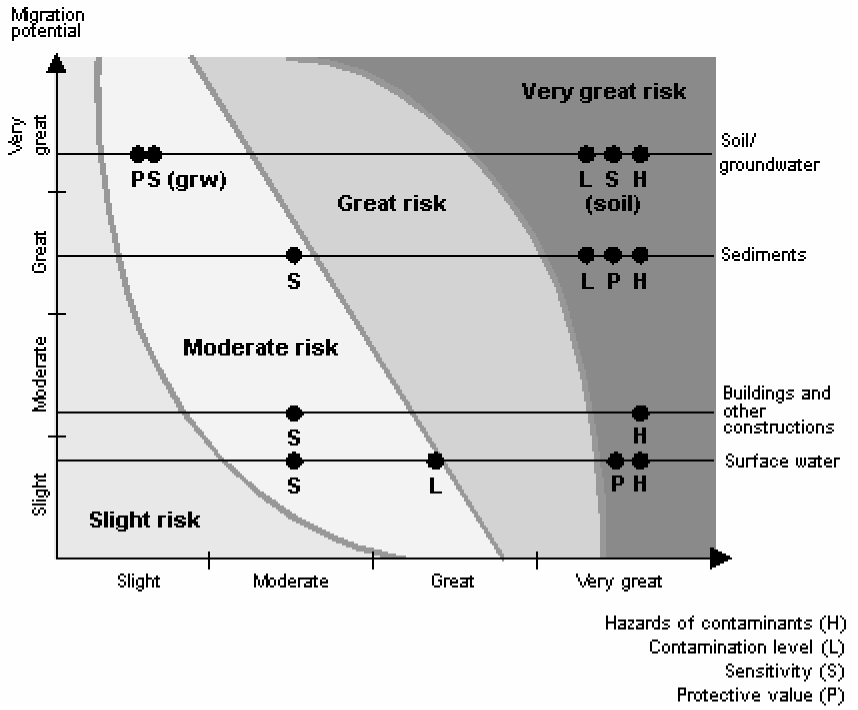
Hazard assessment: Contaminants are classified according to four categories ranging from slightly hazardous (e.g., calcium and magnesium) to extremely hazardous (e.g., arsenic and mercury). Sites with multiple contaminants are generally classified as a greater hazard than sites with single-type contaminants.

Contamination level: Risk assessment related to *i)* the severity of the effects potentially caused by the contaminant concentrations observed, *ii)* the number of contaminants *iii)* the presence and effect of point sources, and *iv)* the total volume of contaminated material. Generally, sites with large volumes of multiple contaminants in high concentrations are found to have high contamination levels. Contamination levels at "hot-spots" ultimately depend on the number of contaminants at these sites.

Migration potential: Risk assessment associated with the estimated or calculated potential for migration. Given high contaminant concentrations, rapid migration generally implies greater risk than slower migration. The combination of soil types and slopes affects the migration potential.

Sensitivity/protection value, or the level of risk related to the sensitivity of exposed humans and to the value of protecting the exposed environment. The two aspects are risk-assessed separately. Sensitivity is assessed at the individual level, i.e., regardless of the number of humans exposed. The protection value is assessed for the species and/or ecosystem exposed to contaminants at a site.

As shown by the schematic diagram below, the *hazard assessment (H)*, *contamination level (L)*, *sensitivity value (S), protection value (P),* and *potential for migration* are ultimately weighted together in a comprehensive assessment. The final risk class (i.e., 1 to 4) is determined in a plotting scheme shown by the graph below. The location of the dots on the horizontal lines is determined by the risk assessment presented above. If all the dots on every line fall within the range for the same class, the site is assigned that particular risk class. In cases where the dots are distributed among two or more risk classes, the class best describing the site condition is to be selected. Then, factors such as the assessors' impressions, the size of a site, and the number of different contaminants involved are decisive. Larger amounts of contaminants generally pose greater health and environmental risks than more limited amounts.



Source: Swedish EPA (2007a)

Based on the comprehensive assessment, the site is assigned one of the following risk classes:

Risk Class 1 – *Very high* health and environmental risk.
Risk Class 2 – *High* health and environmental risk.
Risk Class 3– *Moderate* health and environmental risk.
Risk Class 4 – *Slight* health and environmental risk.

Appendix 2 Variable definitions

Table A2.1 Model variables

Variable	Model notation	Definition
t1	*T*	Duration in months between the end of the inventory by industry (1994-12-31) and the beginning of the MIFO risk assessment.
t2	*T*	Duration in months between the beginning of the MIFO risk assessment and the end of the MIFO risk assessment.
t3	*T*	Duration in months between the end of the MIFO risk assessment and the beginning of site remediation.
t4	*T*	Duration in months between the beginning of the site remediation and the end of the site remediation.
BRSAG	*G*	A dummy variable equal to one if a sawmill is, or used to be, on the site.
BRIMPR	*G*	A dummy variable equal to one if a wood preservation mill is, or used to be, on the site.
BRYTB	*G*	A dummy variable equal to one if an electroplating mill is, or used to be, on the site.
BRVERKS	*G*	A dummy variable equal to one if a manufacturing mill is, or used to be, on the site.
BRGRUV	*G*	A dummy variable equal to one if a mine is, or used to be, on the site.
BROVR	*G*	A dummy variable equal to one if other known mills are, or used to be, on the site.
BRINFOMISSING	*G*	A dummy variable equal to one if there is no information whatsoever about the previous industrial activities on the site.
CONTMET	*G*	A dummy variable equal to one if metals (e.g., arsenic, cadmium and mercury) are found on the site.
CONTOORG	*G*	A dummy variable equal to one if inorganic substances (e.g., cyanid) are found on the site.
CONTFENO	*G*	A dummy variable equal to one if phenols and/or chloropenols (e.g., cresol) are found on the site.
CONTKLOR	*G*	A dummy variable equal to one if chlorobenzenes (e.g., mono-, di-, tri-, tetra- and hexachlorobenzenes) are found on the site.
CONTOVRK	*G*	A dummy variable equal to one if other chlorinated substances (e.g., PCB) are found on the site.
CONTOARO	*G*	A dummy variable equal to one if aromatics and/or aliphates (e.g., benzene, toluene and ethylbenzene) are found on the site.
CONTPAH	*G*	A dummy variable equal to one if polycyclic aromatic hydrocarbons (PAH) are found on the site.
CONTOVRO	*G*	A dummy variable equal to one if other organic substances are found on the site.
CONTSYRB	*G*	A dummy variable equal to one if acids and/or bases are found on the site.
CONTPETR	*G*	A dummy variable equal to one if mineral oils (e.g., petroleum) are found on the site.
CONTOVR	*G*	A dummy variable equal to one if other hazardous substances are found on the site.
CONTINFOMISSING	*G*	A dummy variable equal to one if there is no information about the substances on the site.
R1	*M*	The number of risk class 1 sites per county in 2005.
TAXBASE	*M*	The municipal tax base per capita in SEK, 1990-2005.
GREEN	*M*	The share of all votes cast for the environmental party (Miljöpartiet) in the local government elections in 1994, 1998, and 2002.
ECORANK	*M*	Miljö-Eko's environmental ranking of the municipality, 1997-2001.
INVKM2	*E*	Municipal population per km2, 1995-2005.
B	*R*	Payouts in SEK for remediation, distributed to the county councils from the Swedish EPA, 1995-2005.

HIGH SENSITIVITY	*h*	A dummy variable equal to one if the human sensitivity to the contaminants at the site is considered to be very high.
HIGH PROTECTION	*h*	A dummy variable equal to one if the protection value at the site is considered to be very high.
HIGH LEVEL	*h*	A dummy variable equal to one if the volume of contaminants in the soil/water/sediment is considered to be very high.
HIGH MIGRATION	*h*	A dummy variable equal to one if the migration potential of the site's contminants is considered to be very high.
YSiL		Dummy variable equal to one if spell i (i=2, 3, 4) started before 1999.
YSiM		Dummy variable equal to one if spell i (i=2, 3, 4) started between 1999 and 2002.
YSiS		Dummy variable equal to one if spell i (i=2, 3, 4) started after 2002.
LIP		Dummy variable equal to one if the site received an LIP subsidy.

Appendix 3 Results

Table A3.1 Results from the sequential estimation

Parameters	Estimates	Std.err.	Est./s.e.	Prob.
State 1 (t_1)				
ALFA	1.9321	0.0362	53.376	0.0000
γ1	-17.4022	0.9736	-17.875	0.0000
BRSAG	0.2914	0.2678	1.088	0.1383
BRIMPR	0.5233	0.2724	1.921	0.0274
BRYTB	0.5654	0.3788	1.493	0.0678
BRVERKS	0.3790	0.3534	1.072	0.1418
BRGRUV	0.4526	0.3664	1.235	0.1084
BROVR	0.3147	0.2490	1.264	0.1031
R1	0.0066	0.0018	3.755	0.0001
INVKM2	-0.3109	0.0822	-3.782	0.0001
TAXBASE	1.0966	0.1795	6.108	0.0000
GREEN	0.0267	0.0893	0.298	0.3827
ECORANK	-0.0096	0.0196	-0.489	0.3125
LIP	-1.4766	0.6296	-2.345	0.0095
B	1.3987	0.4402	3.178	0.0007
State 2 (t_2)				
γ2	-2.7819	0.9676	-2.875	0.0020
CONTMET	-0.4569	0.2408	-1.898	0.0289
CONTOORG	0.5081	0.3136	1.620	0.0526
CONTFENO	0.3490	0.2255	1.547	0.0609
CONTKLOR	0.3428	0.5520	0.621	0.2673
CONTOVRK	0.1307	0.2203	0.593	0.2765
CONTOARO	0.3798	0.2638	1.440	0.0750
CONTPAH	0.7366	0.2813	2.618	0.0044
CONTOVRO	-0.2662	0.4468	-0.596	0.2757
CONTSYRB	-0.9439	0.3941	-2.395	0.0083
CONTPETR	0.1193	0.2423	0.492	0.3112
CONTOVR	-0.3500	0.2075	-1.687	0.0458
HIGH SENSITIV.	0.3267	0.2177	1.501	0.0667
HIGH PROTECT.	0.0316	0.2192	0.144	0.4427
HIGH LEVEL	0.6083	0.2183	2.787	0.0027
HIGH MIGRAT.	0.0223	0.0690	0.324	0.3731
R1	-0.0120	0.0019	-6.319	0.0000
YS2L	-7.8051	0.4594	-16.990	0.0000
YS2M	-3.5651	0.3424	-10.413	0.0000
INVKM2	-0.4647	0.1181	-3.934	0.0000
TAXBASE	0.2847	0.2057	1.384	0.0832
GREEN	0.1090	0.0745	1.463	0.0717
ECORANK	-0.1895	0.1095	-1.731	0.0418
LIP	4.8984	1.1256	4.352	0.0000
B	-0.2719	0.2150	-1.265	0.1029
State 3 (t_3)				
γ3	10.4283	3.2292	3.229	0.0006
CONTMET	-0.1862	1.0315	-0.181	0.4284
CONTOORG	4.4539	2.0590	2.163	0.0153
CONTFENO	-1.5364	1.5432	-0.996	0.1597
CONTKLOR	-10.1939	2.1618	-4.716	0.0000
CONTOVRK	-2.8090	1.7151	-1.638	0.0507

CONTOARO	-2.5628	1.3683	-1.873	0.0305
CONTPAH	3.6006	1.6065	2.241	0.0125
CONTOVRO	-4.2695	0.9317	-4.582	0.0000
CONTSYRB	-15.7083	3.6333	-4.323	0.0000
CONTPETR	-14.3936	3.1594	-4.556	0.0000
CONTOVR	-2.3534	1.8297	-1.286	0.0992
HIGH SENSITIV.	-6.9755	2.1189	-3.292	0.0005
HIGH PROTECT.	0.0295	0.4830	0.061	0.4756
HIGH LEVEL	-5.1934	1.0285	-5.049	0.0000
HIGH MIGRAT.	0.8607	1.2005	0.717	0.2367
R1	-0.0841	0.0174	-4.833	0.0000
YS3L	11.7990	3.0563	3.861	0.0001
YS3M	13.9283	3.8320	3.635	0.0001
INVKM2	3.5041	0.5924	5.915	0.0000
TAXBASE	-5.0960	1.3088	-3.894	0.0000
GREEN	-0.5950	0.5756	-1.034	0.1506
ECORANK	0.4247	0.7711	0.551	0.2909
LIP	0.0057	0.0149	0.380	0.3519
B	2.5127	1.0193	2.465	0.0068
State 4 (t_4)				
γ4	15.3480	3.3367	4.600	0.0000
B	-14.0522	6.0438	-2.325	0.0100
Heterogeneity				
μ2	-6.3549	0.2600	-24.440	0.0000
Π2	0.84	0.0528	15.898	0.0000
n		450		
Loglikelihood		-397,296.12		

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