A new approach to the valuation of production investments with environmental effects

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Abstract *Firms are increasingly aware of environmental degradation and this has led many of them to include "quality, safety and protecting the environment" among their competitive priorities. This also involves large capital investments aimed at reducing the environmental impact of their manufacturing activities. This study suggests a method for estimating the return of manufacturing investments with environmental effects (costs and benefits). It considers the value of the asset being preserved as a consequence of a firm's social responsibility. The practical case studied is Huelva's industrial area.*

Introduction

The social awareness of environmental problems that has its origins in the 1960s has increased over time. One result of this, also influenced by legal pressures and the increasing importance of the issue, is an increase in firms' awareness of the problem associated with the environmental deterioration generated by industrial activities. Where this change of attitude has had most impact is in the production/operations area, since this is where we find the greatest opportunities to reduce environmental impact (Sarkis, 1995; Shen, 1995). The bibliography is full of examples (Hart, 1997; Buchholz, 1998; Sroufe *et al.*, 2000; Theyel, 2000). On the one hand, some see the environment as a threat to industry (Sharma and Vredenburg, 1998; Walley and Whithead, 1994). On the other hand, others consider that a business-environment relationship based on good environmental management is capable of improving both the environment and the competitive level of the business concerned (Shen, 1995; Hart, 1995); they analyze the impact of different aspects of the problem. Since the early 1990s, most studies have fitted into the second group. This occurs both on an operations strategy level (Gupta, 1995; Sarkis, 1995), and in the company in general (Azzone and Bertele, 1994; Maxwell *et al.*, 1997), although in this case it is always related to productive activities.

In spite of this, one aspect to which little attention has been paid refers to the indicators to be used when making decisions with an environmental impact, most of which refer to the production area. This goes further than the decisions relating to the so-called environmental technologies (Klassen, 2000; Shrivastava, 1995), which refer to production equipment, methods, practice,

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product design and distribution systems aimed at limiting or reducing the negative impact on the natural products and services environment (Klassen, 2000). It also includes all strategic decisions which, even if they are not aimed at correcting negative environmental impact, do have an effect on the natural environment. In a general approach for the adoption of strategic decisions on the selection and design of products and processes or capacity planning, for example, Domínguez *et al.* (1995) or Heizer and Render (1996) propose the use of traditional financial analyses (estimating performance by the internal rate of return or the net present value). The same method is also proposed by many authors, occasionally including facility design and location decisions in work on operations management (for example Noori and Radford, 1995; Riggs, 1998; Heizer and Render, 2001). Other authors sometimes include the Payback Period or Decision Trees criteria, when the decisions refer to sequential investments (Riggs, 1998; Heizer and Render, 2001). We must also remember the decisions relating to the implementation of ISO 14000 quality certification, since, as Alberti *et al.* (2000) maintain, it is necessary to identify the costs and benefits derived from environmental quality investments in order to determine their efficacy.

Nevertheless (Noori and Radford, 1995; Chase *et al.*, 1998), the use of traditional financial analysis as a fundamental decision-making criterion, although it is generally accepted, does not contemplate intangible benefits or costs. In fact, whichever method is used to evaluate return, the way in which the monetary flows is established (net cash flow) makes no consideration of the intangible environmental benefits and costs produced in these cases. This is incoherent when the company has included environmental protection among its strategic objectives in the first place.

Therefore, as Henn and Fava (1994) point out, the evaluation of projects that involve these productive decisions should somehow consider their environmental objectives and/or consequences, a somewhat complex issue considering the large number of factors to be taken into account, none of which is usually applicable to the other type of investments that the financial area analyses. The operations area thus has to define new concepts to replace the traditional indicators that the finance area uses to estimate the return on these investments, in order to consider also the project's compliance with environmental objectives (Hart and Ahuja, 1996; Klassen, 2000), and the general objectives of the operations sub-system. As on other occasions, an integrated approach by the different company areas is fundamental here.

This study comes within this scope. The solution to this problem has been the subject of studies published in different journals, both in the field of operations management (for example Klassen, 2000; Alberti *et al.*, 2000; Chinander, 2001; Rajaram and Corbett, 2002; Corbett and Pan, 2002) and business management (for example Nehrt, 1996; Cortazar *et al.*, 1998). We intend to identify an alternative route, an indicator to be added to those that are already used when making decisions related to the aspects of operations management described earlier, providing information on environmental efficacy when there are several of these productive alternatives with or without different environmental objectives and effects, in order to employ the resources available as efficiently as possible, providing that the company has included environmental quality, safety and protection among its strategic objectives.

From this perspective, this article suggests that, when evaluating and comparing different alternatives related to productive aspects that require major investments and involve environmental objectives and/or consequences, in relation to a decision to be made by the operations area, not only should the cash flows that are traditionally used to calculate return on investment (whatever the valuation criterion to be applied) be used, but that the up-dated value of the social cost or benefit derived from the environmental impact generated should also be taken into consideration. This would provide a more realistic view of the project's possible return, not only including the tangible financial costs and benefits, but also the intangible costs and benefits derived from the environmental impact of the different alternatives, besides other advantages that we will identify later.

We start by identifying social costs (or benefits) as the main factor that distinguishes between investments with and without environmental objectives and/or consequences. The following section analyses the method used to evaluate environmental assets. We go on to consider the use of the Contingent Valuation method to value environmental assets, and apply the result to the evaluation of the return of a real investment of this kind. As usual, the last section is a summary of our conclusions.

Income and costs associated to investments with environmental impact

There is a large number of studies on the income and costs derived from productive investments with environmental consequences, although they do not always reach the same conclusions (see for example Shen, 1995; Porter and Van der Linde, 1995; Kolluru, 1994; Aragón Correa, 1998). Nevertheless, besides considering the tangible economic benefits, they all include a social benefit based on the fact that environmental performance helps to improve the social image of a business and increases local confidence.

Nevertheless, the importance of the social image, as a typical benefit included in this point, is not really the only aspect of interest. The degradation of the socio-economic environment of a business is, to a large extent, a direct result of the manufacturing process itself, which generates social or external costs when it is not officially regulated, or there are no other incentives. Back in 1966, Kapp identified them as the net avoidable damage in excess of the aggregate benefits, either of the industry responsible for the specific harm or the entire economy. They include, then, all the direct or indirect losses supported by third parties or society in general. They are therefore third party costs (supported by society in general) that have never been included in the firm's operating accounts.

It is also evident that if productive activities damaging the environment generate social costs consisting of environmental decay, activities or investments that eliminate or reduce this cost, or improve the company's environmental impact, represent a social benefit that can equally be attributed to the firm.

Social benefit valuation method

Once the social benefit associated with the reduction of a project's environmental impact has been acknowledged, and following the arguments included in the introduction, the problem lies in evaluating this benefit. We begin by defining the asset to be valued, which in this case is the atmosphere, or "air quality".

It is evidently not easy, however, to calculate the economic value of an intangible asset such as "air quality", and the first step consists of defining the method to be applied.

Economic valuation of environmental assets

Firms that deposit their waste in the air do not incur an explicit cost, because unlike other productive inputs, there is no specific market on which the asset can be directly acquired. When a business needs a site to install a production facility, it has to pay for it. And the same applies when it comes to financing the disposal or recycling of solid waste. The fact that the cost incurred (when it is the air used as a deposit) is intangible and has no market "price" does not mean that the decision-making process should not take it into consideration.

The economic valuation of non-market goods (including environmental assets) is aimed at obtaining a monetary assessment of the welfare or utility gain (or loss) experienced by a certain group of people from the improvement of (or damage to) a non-financial asset. The techniques and methods used to measure the expected benefits and costs derived from the use of an environmental asset and/or environmental improvement or harm, are what is called environmental evaluation (see for example Azqueta Oyarzun, 1994; Folmer and van Ierland, 1989; Johnson and Johnson, 1990).

Mitchell and Carson (1989), classify environmental evaluation methods according to the origin of the information, and on whether the method is direct or indirect[1]. In the case that concerns us, it is evidently impossible to use direct evaluation methods based on observed data, since there is no market to observe and the asset to be valued has no price. Three of the other methods have been used to evaluate environmental assets.

The Travel Cost method has frequently been used to evaluate natural areas, (Trice and Wood, 1958; Bell and Leeworthy, 1990; Azqueta and Pérez, 1996). This theory and procedure attempt to estimate how the demand for the environmental asset (the number of visitors to a park, for example) changes with the cost of the asset in question.

On the other hand, Sherwin Rosen suggested the hedonic prices method in an article published in 1974 in the *Journal of Political Economy*. The basic idea behind this technique is to allocate an implicit price to each characteristic or attribute of a private asset, the sum of which determines the price of the market asset in question (Bartik, 1988; Bateman, 1993).

Unlike the previous methods, the contingent valuation technique is based on value pollution abatement benefits according to the monetary amount that the beneficiaries would be willing to pay for it, or the costs associated with environmental damage according to the amount of money that the individuals affected would accept as compensation (willingness to pay or willingness to be compensated). The first empirical study did not appear until 1963 (Davis), although it was really Peter Bohm, in the early 1970s, who empirically tested and rejected Samuelson's strategic bias hypothesis published in *The Review of Economics and Statistics* (1954). Like other authors (Cummings *et al.*, 1986; Mitchell and Carson, 1989 etc.), he completed important studies that represented a decisive contribution to increasing the acceptance and reliability of the method. More recently, the debate on the practical validity of the contingent valuation technique as a reasonable way of evaluating social welfare changes associated to from external environmental factors appears to have ended with the favorable reaction of the committee of experts[2] named by the US Department of Trade's National Oceanic and Atmospheric Administration (NOAA, 1993).

Choice of the most suitable method

Having considered all the different methods, for this purpose (air quality valuation), we have decided to use contingent valuation, for the following reasons:

- *Scope of application.* It is more appropriate for the characteristics of the asset being analyzed (air quality), since the Travel Cost and Hedonic Prices methods are only applicable to concrete locations, since people have to be mobile on the market analyzed for the method to be valid and for the market to indicate reliable prices (Bell and Leeworthy, 1990; Azqueta and Pérez, 1996).
- *Adaptability.* It is impossible to establish a link between air quality and the consumption (market) of a private asset, and this is essential for the other methods analyzed to be applied.
- *Time of evaluation.* The Contingent Valuation method allows us to evaluate changes in people's welfare before and after they occur, whereas the indirect methods that we have mentioned can only value assets a posteriori (Azqueta, 1994).
- Validity of the method for the valuation of external environmental factors, as a result of the favorable report issued by the US Department of Trade's NOAA.
- To follow the most generalized trend, since it nearly always provides more conservative estimates than the indirect methods (Riera *et al.*, 1994; Carson *et al.*, 1996; León, 1995; Pérez *et al.*, 1996).

Contingent valuation of social benefits

Having defined the method to be used, we will now apply it to a specific case, in order to further consider the many aspects that the use of this methodology implies.

The case under study

The case to which we are going to apply our proposal concerns the city of Huelva. Together with its surrounding areas, the city has experienced a profound socio-economic change in the last few decades, with a very important negative effect: the increase in environmental pollution. This has given rise to significant atmospheric degradation episodes that placed the population at risk with limit situations in 1978. The situation has improved considerably with the development of the Urgent Action Plan for the Punta del Sebo Industrial Estate, established by the government in 1979, and the Atmospheric Correction Plan created by the Andalusian local government (Junta de Andalucía) in 1994.

Since 1994, the industries involved, aware of the environmental problem, continue to introduce less pollutant technologies in their productive processes. Table I includes a summary of the characteristics of the main potentially polluting firms in Huelva and vicinity. Although there are not many of them, they are all large industries within nine miles of the city.

Design of the study

We now describe the design of the contingent valuation study, which will imply (Riera, 1994):

- *Defining the factor for which we are attempting to assign a monetary value.* In this case, we are attempting to "establish an economic value for pollution abatement benefits for the local population, generated by reducing the atmospheric pollutant emissions from the factories operating in these industrial areas", which is the cost of depositing the excess waste from the production process in the air.
- *Defining the relevant population.* In this study, the relevant population is the population affected by these measures: the inhabitants of locations close[3] to the industrial areas. The target population will be over 18 years of age. The target population, then, consist of 147,854 individuals (112,331 from the city of Huelva itself and 35,523 from the other locations), representing 78.8 per cent of the total.
- *Market simulation elements.* We decided to determine the amount to be paid for clean air (air that receives productive pollutant deposits beneath legal limits). We have preferred an open-format question, considering that this is the best way of reflecting the actual situation, and also because it provides lower valuations than other formats (León, 1995).
- *Choice of the type of interview.* Of all the different possibilities, we prefer the personal interview.

Table I.
Basic characteristics of the main potentially pollutant companies

Companies	Location /year of installation	Production activity	Main emissions	Productive capacity (tons/year)
Atlantic Copper (Freeport-McMoran)	Punta del Sebo (1970)	Minerals and metals	Particles, SO_2, fog acid	191,122
Ertisa (CEPSA)	Nuevo Puerto (1976)	Basic chemistry	SO_2 and NO_x	950,000
Tioxide (Huntsman)	Nuevo Puerto (1976)	Basic chemistry	Particles, SO_2	62,774
Fertiberia Palos (Fertiberia)	Nuevo Puerto (1976)	Fertilizers	Particles, SO_2	1,880
Aragonesas	Nuevo Puerto (1973)	Basic chemistry	Particles, SO_2, CO_2, NO_2	222,927
"La Rábida (CEPSA)" Refinery	Nuevo Puerto (1967)	Petroleum and gas refinery	Particles, SO_2	5,000,000
Ence	Tartessos (1964)	Paper	Particles, SO_2, NO_x, sulfur	302,934
Foret	Punta del Sebo (1967)	Phosphoric acid and tripoliphosphates	Particles, NO_x	355,000

- *Selection of the sample.* We have chosen stratified random sampling, to eliminate sampling bias or at least reduce it to a minimum. We therefore divided the population into two strata: inhabitants of the city of Huelva and inhabitants of other locations close to the factories (since there are considerable differences between the two areas with regards to the size of the population, income level, socio-cultural level, etc.). To distribute the sample size (n) between the two strata, we decided on proportional allocation, distributing the sample in proportion to the strata size (76 per cent for the city and 24 per cent for the other locations), and applying simple random sampling to each. To determine the optimum size to represent each of the populations (112,331 and 35,523), we established a confidence level and a margin of error of 95 and 5 per cent respectively for the city of Huelva and 90 and 10 per cent for the other locations.The sampling size obtained is 400 for Huelva and 100 for the other locations.
- *Questionnaire design.* When designing the questionnaire, we have taken expert advice into consideration (for example García Barbancho, 1994; Pulido San Román, 1992). Before considering the questionnaire completed, we tested several pilot questionnaires on small groups in order to detect possible deficiencies before the survey was conducted. We also referred to the structure of a standard questionnaire used in most contingent valuation applications (see for example Hadker *et al.*, 1997; León, 1995).

The survey

The interviews were made by a group of interviewers in the first quarter of 1999. The quality of the responses from 25 per cent of the interviewees was controlled by a further phone call. Of the 500 interviews, 454 responded satisfactorily, and this was the final sample.

We checked that the sample obtained was random by comparing the frequency of some known variables (sex and age) with the population frequency, applying the χ^2 test to confirm the null hypothesis of the population sample studied ($p > 0.95$).

Before the statistical analysis, we had to decide what treatment to give to the responses that refused to answer the valuation question. A total of 113 people refused to reveal their willingness to pay (24.8 per cent of total responses, which coincides with other contingent valuation applications in the USA, which usually obtain between 20 and 30 per cent of this type of response (Mitchell and Carson, 1989)). They have been considered in our study, but eliminating all the responses for which the proposed change would really have no value[4].

We now make a descriptive analysis of the variable under study (willingness to pay) and some of the socio-demographic variables included in the third part of the questionnaire. We have calculated statistical differences: mean and median values, standard deviation, variance, asymmetry, minimum and maximum, and their frequency distribution (see Appendices 1 and 2). To study the possible relations between the most significant socio-demographic variables and the willingness to pay of the people interviewed, we used contingency analysis and independence testing to identify if variables are independent or in association.

The joint study of the frequency distribution of two or more variables (contingency analysis) was based on two-way $R \times C$ contingency tables include two variables, each of which is on two levels or modalities ($R = m$ and $C = n$).

Once the contingency table is completed with the sampling information, the way in which we test the independence of the two variables (x and y) with R and C levels respectively, will depend on the model considered in relation to the experimental design, or the sampling procedure (Ruiz-Maya *et al.*, 1995). In this case, the marginal totals of both variables (for example, willingness to pay and age) are not fixed, and therefore reflect population parameters. Since testing independence is significant, to test the null hypothesis H_0: "variables x and y are independent", against alternative H_1: "variables x and y are associated", we use the most practical and simple method (when asymptotic distributions are applicable, and irrespective of the model of the variables for which we are analyzing independence (Ruiz-Maya *et al.*, 1995)), which is the likelihood-ratio chi-square, G^2.

To complete the test, further analyses are required to detect the sources of association, such as the residuals analysis suggested by Haberman (1973).

Results

The results of the statistical analysis are shown in Appendices 1 (Huelva) and 2 (other locations). For the sake of brevity, we have only shown the results that are significant for the purpose of this study, relating to willingness to pay.

The city of Huelva

Of the 336 people interviewed who answered the valuation question, 259 (77 per cent) were willing to pay amounts of between \$5.17 and \$1,294. The mean willingness to pay value (including negative valuations) for the total sample is \$51.13 per person and per year (see Appendix 1).

For the contingency analysis and the independence tests, we have grouped the sample's willingness to pay (WTP) on five levels[5]. The results were as follows (see contingency table in Appendix 1):

- With regards to the income variable (see contingency table in Appendix 1) the association is statistically significant. The higher the income level, the greater the willingness to pay (as expected), since the p-value associated to the test statistic ($p = 0.000$) is less than $\alpha = 0.05$.
- Education and age also conditions willingness to pay ($p = 0.000 < 0.05$; $p = 0.011 < 0.05$).
- No significant relation ($p = 0.937 > 0.05$) was found with regards to the sex variable.

Other locations
In the other locations close to the industrial areas, of the 87 people who answered the valuation question, 82 (94.2 per cent) indicated their willingness to pay. The mean willingness to pay value for the total sample is $28.53 per person and per year, and the minimum and maximum values were $0 and $77.55 per person and per year, respectively (see Appendix 2).

On the other hand, the results obtained from the contingency analysis for this group of surveys reveal the same trend as the previous group.

Social benefits estimation
From the 423 final respondents in the sample (see Table II), we obtained a mean willingness to pay of $45.7 per person and per year.

In this way, once the mean willingness to pay per person ($45.7) and the target population (147,854) is known, the associated social benefit to the abatement of air pollutants coming from industrial facilities reaches $6,757,509.42 per year. This benefit is taken into consideration for the valuation of investment on environmental correction according to the rationale presented in previous sections.

Valuation of productive investments

Following a classic approach and without entering into the debate of the problem of setting up financial objectives (see for example Pérez-Carballo and Vela Sastre, 1997; Loring, 1995), the finance area would determine the return by calculating the annual net cash flow as the difference between the incoming (revenue) and outgoing (expense) flows during the period under consideration. It has to be borne in mind that the possibility of choosing between one project or another would be determined by the available funds and not by the flow of income, which might not be cash (Durbán, 1994). Following this approach with investments in environmental technology, the return will be negative, or at least insufficient to justify the expense. Neither will the intangible benefits or costs derived from other productive investments with environmental effects be included, in coherence with the classical financial objectives based on increasing profits, growth, maximizing the firms' value from the point of view of the shareholder, and so on.

However, as we have pointed out from section one onwards, in the 1980s it was very difficult to find a firm that included the environment within its

Table II. Distribution of replies according to locations

	Huelva	Other locations	Total
Number of people interviewed	400	100	500
Number of respondents	354	100	454
Protest-like reply	95	18	113
Unwilling to pay	77	5	82
Protest	18	13	31
Number of the final sample	336	87	423

competitive priorities[6]; however, when asked, 100 per cent of the firms in this study (see Table I) asserted that protecting the environment was one of their three main strategic priorities, which reflects the tremendous changes taking place. If the corporation's strategic objectives are the ones to give shape to the goals of different projects, then having "quality, safety, and protecting the environment" as strategic objectives should be reflected in those projects involving these kinds of objectives and/or consequences; therefore, it would be reflected in the indicators used to make productive decisions.

We therefore suggest that the operations area use incremental return or the payback period[7] as indicators for productive decision making, including, in addition to traditional cash flows, the value of the environmental effects obtained, which we have called "social benefits". This makes our approach closer to the traditional cost-benefit analysis (CBA) (Calero, 1995; Trueba *et al.*, 1995). Traditional dynamic investment evaluation criteria are applied in risk conditions (net present value, internal rate of return, profitability index, and payback period), by including social benefit as a random variable whose value is estimated through the survey (Brealey and Myers, 1998; Keown *et al.*, 1999). This would help to compare projects with environmental objectives and/or impacts or other projects, since all the effects are measured in monetary values, thus showing the efficacy (not only the return) of each productive project in relation to all the objectives involved.

Nonetheless, in order to justify the inclusion of social benefit (SB_i) in the cash flow, the two following conditions have to be fulfilled:

(1) The firm has included protecting the environment among its strategic objectives, and this is reflected in the policies and action plans developed.

(2) The option to be evaluated must have among its objectives reducing the environmental impact of the firm's activity and/or some tangible consequences on the environment.

The CEPSA case

As an example designed to illustrate this proposal, we go on to describe the entire process for one of the most important firms operating in the area under study (see Table I). We refer to the "Complejo Petroquímico La Rábida", one of the production facilities belonging to the CEPSA (Compañía Española de Petróleos S.A.) industrial group, all of which are crude oil refineries. Our evaluation of the productive measures that have an impact on air pollution includes all associated benefits, costs and investments. The information relating to this firm is shown in Table III, which summarizes the environmental costs (including investments) derived from the productive action taken, allocated to the units designed to correct atmospheric emissions[8].

Table III. Environmental costs and benefits (thousand of dollars)

Years	Investment	Social benefit	Costs Fixed	Variable	Depreciation	Total[a]
1993	1,294	5,601.57	1,227.31	675.97	553.16	1,903.28
1994	1,294	5,864.84	799.74	583.02	658.97	1,382.76
1995	14,492.75	6,140.49	1,355.12	767.05	546.6	2,122.17
1996	14,068.52	6,361.55	822.65	1,031.78	859.64	1,854.43
1997	912.46	6,488.78	800.02	1,130.43	859.64	1,930.45
1998	3,276.92	6,605.58	1,003.99	1,037.25	859.64	2,041.24

Note: [a]It does not include the depreciation

Valuation from a classical financial perspective to obtain an indicator reflecting efficacy in the achievement of return objectives

Although the productive measures subject to valuation were applied by the firm in the 1993/1998 period, they will continue to generate costs and income after 1998. Since they are productive investment in material fixed assets, for which the firm has estimated a useful life of 15-20 years, we have considered a 15-year planning horizon.

For a valuation based on the procedure described at the beginning of section 4, after the costs and income for the selected period are identified, allocated and quantified (Table III), their values have to be standardized at a certain date in order to be comparable. This is achieved by applying a discount rate. Following the same criterion used by the firm to analyze the return on productive investments, the discount rate used in our study is the minimum rate of return on investment. It is a rate based on the return on investments without risk, including a risk premium, specifically the annual MIBOR + 2 points.

As far as the costs are concerned, the investments being evaluated will involve values similar to those of last year for the rest of the period, considering an annual increase based on the consumer price index (the same index used to calculate the social benefit), to estimate price variations.

After these considerations, and therefore considering the investment project from a classical financial perspective (A) depending on income (I_i) (excluding the value of the social benefit) and tangible associated costs (C_i), for each of the n periods in the time horizon selected, discounted by a discount rate (k), we apply classical dynamic investment valuation criteria, the results of which are shown in Table IV (third column). The residual value is identified as the net book value of the project's assets at the end of the period under study.

Valuation to obtain an indicator reflecting global efficacy in achieving return and environmental objectives

As we have been saying, since the productive investments valued were fundamentally aimed at environmental correction, the tangible income allocated to them by the company is inappreciable from a classical financial perspective.

We must remember, however, that to justify including the present value of this social benefit when estimating return, we mentioned two conditions at the end of the previous section. With regards to the first, CEPSA included "environmental quality, safety and protection" among its strategic priorities in 1995, and since then it has been either the first or second on the list.

As for the second condition, as we mentioned earlier, all the action included in the valuation had environmental correction goals. Nevertheless, we have attempted to verify that there is really a reduction in the emission of the most important atmospheric pollutants during the period covered by the investments under valuation (1993/1998). We can appreciate the fall in the mean levels of SO_2 (from 2,019 mgr/Nm^3 in 1993 to 1,414 in 1998). For particles,

Table IV. Methods of ranking investments

Method	Classical financial perspective: return indicator Expression	Value	Productive perspective: return and environmental efficacy indicator Expression	Value
Net present value (NPV)	$-A+\sum_{i=1}^{n}\frac{Q_i^*}{(1+k)^i}$	\$30,490,463.85	$-A+\sum_{i=1}^{n}\frac{Q_i^*+SB_i}{(1+k)^i}$	\$4,104,267.4
Internal rate of return (IRR)	IRR|NPV(IRR) = 0	$<k$	IRR|NPV (IRR) = 0	12 per cent $>k$
Profitability index (PI)	NPV/A	PI < 0	NPV/A	PI > 0
Payback period	$n\vert\ A=\sum_{i=1}^{n}\frac{Q_i}{(1+k)^i}$	–	$n\vert\ A=\sum_{i=1}^{n}\frac{Q_i+SB_i}{(1+k)^i}$	14

Note: * After-tax cash flows for period t (I_t-C_t)

the legal limits were never exceeded, so we can consider that compliance with the second condition has been verified. All this considering that the mean annual production volume increased by 10 per cent in the years under study.

To define a value for the different years in the period concerned, we have two alternatives:

(1) *Dichotomic approach (the air is either clean or not).* If emissions of the different pollutants are within legal limits, the air is clean and the benefit is for the total amount. On the other hand, if just one of the values exceeds the legal limits required for the air to be considered clean, the benefit will be zero.

(2) *Establishment of a scale of values.* Based on an initial value for the different pollutant emissions, for which society would pay $0, we allocate $45.7 to the emission level to be reached and calculate the willingness to pay for each year based on the reduction achieved.

We have preferred the first alternative[9].

Considering (assuming there are no unexpected accidents) that the atmospheric pollutant emission levels guaranteed by these productive investments, for the different years, are within legal limits, the air will be considered as clean, and the income associated to this concept will therefore be $6,757,509.42 a year. This is the amount obtained in 1999 and, since it is impossible to conduct the survey every year, the amount for the other years is adjusted by the average rate of inflation (CPI) for the period under study. The resulting social benefit for each year is shown on Table III. For the years after 1999 (2000 to 2007), we have estimated a social benefit equal to the previous year, increased by the average rate of inflation.

The results obtained for each of the valuation criteria applied confirm the absolute and relative return on the investments analyzed, and in our opinion, justifies the firm's investment decision.

Sensitivity of the valuation

The result of this valuation is evidently not exact. It may vary with the figures that define the investment (k, n, Q_i, SB_i, and A), considering that some of them are not absolute values but random variables. As we have seen in the development of the case used as an example, many of the possible variations are not derived from what we are proposing, but from the investment valuation process currently accepted and employed in the finance area.

For example, the method employed to obtain the return on investment also has an impact, irrespective of whether the social benefit is included or not. The first problem is related to the inflation adjustment factor to be employed (k). Although we have followed the firm's criterion when evaluating the investments (applying a risk premium to the discount rate), it is possible to make use of statistical methods that do not include the risk factor in the return calculation, but evaluate it, generally by return variance (see Loring, 1995; Suárez Suárez, 1997; Pérez-Carballo and Vela Sastre, 1997). For example, applying Hillier's statistical model, the mean value of the NPV (E(NPV); calculated considering a risk-free discount rate: the return on short term Spanish Treasury bills) is \$8,555,059.265, and the probability that the investment is profitable (P (CV) $\geq$ 0) is 90 per cent (applying the central limit theorem).

As an alternative to the previous model, the Hertz model using a Monte Carlo simulation (Suárez Suárez, 1997), after a number of simulations that is equal to the optimal real sample size for the years following 1999, results in E (NPV) = \$4,985,377.019 and P (NPV $\geq$ 0) = 80 per cent.

The second problem is related to the structure and value of the net cash flows (Q_i), which depend on estimates of the income and costs associated to the project, often unknown.

We must also remember the other disadvantages of classical valuation criteria, which have still not found an adequate solution in the discussion that started in the 1950s (see for example Lorie and Savage, 1955; Solomon, 1956). These disadvantages have been identified but are still important (see for example Brealey and Myers, 1998; Keown *et al.*, 1999; García Machado, 2001). It is one of these disadvantages (they do not value the project's intangible results) that our proposal intends to mitigate, regarding intangible environmental benefits and costs. However, we have been able to introduce a deviation in this calculation, derived from the determination of the social benefit (SB). Since it is intangible, its value has been estimated, for the want of a more exact method, by contingent valuation. It is evident that its final value will depend on the size of the population.

With regards to the other variable that determines the social benefit, willingness to pay, it will be conditioned by different aspects, mentioned previously, of the market simulation process, the statistical treatment and the impact of the sociodemographic variables (see "Contingent valuation of social benefits" section). The alternative chosen for this calculation (dichotomic choice) is also decisive, since if the other proposal is chosen, the result will change, but not exceed our calculation.

To complete our analysis of the sensitivity of the valuation, Table V summarizes the impact that the other variables have on the NPV and the IRR, by changing some of their estimated values.

Variables	Values	NPV (\$)	IRR
Temporary horizon (n)	10 years	–607,869.04	9
	20 years	8,080,383.02	11
Discount rate[a] (k)	7 per cent	5,412,537.58	12
	10 per cent	3,528,653.21	12
Inflation rate[a]	2.5 per cent	3,735,018.22	11
	4.5 per cent	4,488,268.01	12

Note: [a] From 1999

Table V. Valuation sensitivity

Conclusions

Having accepted the fact that firms can not ignore the environmental problem that they represent, it is clear that they have no alternative but to adapt their strategic behavior, which will affect all fields of management. Here, however, there is still a great deal to be done.

One of the aspects that must be considered is related to decisions on productive investments with environmental objectives and/or consequences. Because of how they calculate the cash flow figures used, the valuation and investment selection methods traditionally used in financial analysis do not contemplate the positive or negative environmental impact of the investment being evaluated. We consider that incremental return (absolute or relative, net present value, internal rate of return or profitability index), or the payback period could be the start of a new way of studying indicators for making decisions capable of correcting the problem, providing that cash flow calculations include the value of the environmental impact, what we have called "social benefit". The reasons are as follows:

- It could be helpful for comparing projects that, besides correcting the environmental impact of the productive activity, are also associated to return or growth targets. This comparison can be with similar projects or with others that have no environmental impact or are exclusively to correct environmental problems. Using incremental return along the lines suggested here, this would to an extent reflect the efficacy in relation to all the objectives concerned by allocating them monetary values.
- This could help to encourage a change of business attitude to environmental problems (still insufficient).
- The company would be acting coherently by including its commitment to the environment among its priorities and strategic objectives.

To estimate this social benefit, and until a more exact method is developed, we believe that contingent valuation could be, at least for now, an acceptable procedure with low application costs, even if there is evident room for improvement. Admitting that the results will vary with the variables, parameters, method and criteria employed, we can not but confirm the convenience of our proposal, for several reasons:

- In the first place, because we did not intend to provide an "exact" valuation of the type of project in question, but to show the effect of considering the social benefit (or cost) derived from the environmental impact involved with the effect of not considering this factor. We believe that this helps to describe a situation that we hope will lead to further research, perfecting the effects of the procedure proposed, or at least open new lines of research, capable of obtaining more exact indicators than ours to measure the efficiency with which strategic operative objectives (including environmental goals) are achieved in relation to making productive decisions.

- An important part of the inexactitude of the calculation derived from our proposal is determined by the procedure used to estimate the incremental return. The only deviations in the calculation derived from our proposal refer to obtaining the value of the social benefit. The others are currently used in investment valuation from a "traditional" perspective.
- We identify a third justification in the need for a change of orientation in the problem in question. The process proposed, although it may not be perfect, could lead the way for firms' awareness of environmental preservation to go one step further than to avoid social or legal problems.

Notes

1. Such as direct valuation methods with observed data, based on competitive market prices that represent the willingness of people who are supposedly aware of the quantity and price of the public asset being valued. Direct valuation methods using hypothetical data obtain information by directly questioning people on their valuation of environmental assets, by hypothetical or constructed markets or referendums. Indirect valuation methods with observed data are based on the study of real behaviour that tends to maximize utility but, since environmental assets do not usually have a market price, their value has to be determined using models that relate them to market goods. Finally, indirect valuation methods with hypothetical data obtain data from answers to hypothetical questions, and not from observations on actual decisions.
2. Presided by Nobel Economy Prize winners Kenneth Arrow, from the University of Stanford and Robert Solow, from MIT. The rest of the group were E. Leamer, P. Portney, R. Randner and H. Schuman.
3. The concept of "close" is relative. In general terms, they could be said to affect the entire planet (like the ozone layer). Here, however, we refer to more direct and harmful effects on people. They may vary with the wind and other weather conditions. Nevertheless, we have used the relevant locations (from a population perspective) included in the Industrial Area Emergency Plan.
4. There are 82 responses with zero value, representing 72.56 per cent of the protest responses and 18.06 per cent of the total.
5. (1) WTP = \$0, (2) \$0 < WTP ≤ \$25.85 per year, (3) \$25.85 < WTP ≤ \$77.55 per year, (4) \$77.55 < WTP ≤ \$129.25 per year and (5) WTP > \$129.25 per year (see contingency table in Appendix I. We only show the WTP Income table, the most significant for this study)
6. Ferdows *et al.* (1986) studies and Miller and Roth (1988), show the evolution of competitive priorities from 1983 to 1988, and environmental related issues is not among the ten first priorities in either of the cases studied. However, later other authors (Domínguez *et al.*, 1995, pp. 36-7) found they are ranked within the ten priorities.
7. The same updated net social benefit value could also be included with the use of other measurements of absolute or relative return, or the use of techniques such as decision trees, multiple criteria analysis, etc.
8. When the cost information provided by the company is grouped together, the costs of the different productive actions taken during the period (some with purely environmental goals and others related to capacity increases, process changes, etc.), without distinguishing between them, the valuation is performed for all the actions taken in the period considered, and not for each of them separately.
9. The reasons for that are inter-related: First, because of the way in which the valuation question was phrased in the interviews: what is the maximum yearly amount that you

would be willing to pay for clean air in the city of Huelva? Second, because of the difficulty involved in establishing the scale values for the second option. Although the willingness to pay for initial emission levels is $0, the problem lies in establishing the values for which society is willing to pay $45.7 per person and year. Third, because it would be impossible to obtain all the information required to proceed with the second alternative. Much of it would also be highly subjective (what mix of pollutant units should be valued at 0, 1, 2, … etc.?) Fourth, the pollution levels that the law defines as acceptable represent the most objective of the data available, and we are not concerned with the reasons behind them. Consequently, the "keep air clean" target evidently implies complying with legal pollutant emission limits. For this and the previous reasons, we have preferred the dichotomic approach.

10. First, they are not valid for a comparison of investment projects with different durations (n) and/or initial costs (in the case of net present value). Second, the internal rate of return is not consistent for mixed projects. Third, the determination of the useful life of the investment project. Fourth, the implicit hypotheses on the reinvestment of the intermediate net cash flows released by the investment project, which are not very realistic. Fifth, they do not value the project's intangible results.

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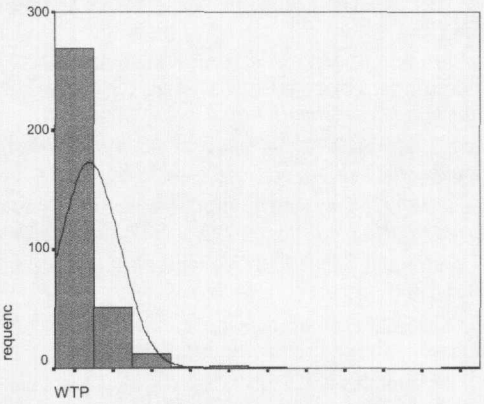
Appendix 1. Descriptive analysis of the variable willingness to pay (WTP)/Huelva

Descriptive Statistics

	Mean	St. Dev.	Mode	Median	Maximum	Minimum
Willingness to pay (dollars)	51.13	5.46	0	25.85	1,294	0

Frequency Distribution of the variable *Willingness to pay*

Willingness to pay (dollars)	Frequency
0 - 46.58	209
51.75 - 150.10	109
155.28 - 253.62	6
258.8 - 357.14	8
362.32 - 460.66	1
465.84 - 564.18	2
+564.18	2
Total	337



Willingness to pay of people for clean air (dollars)

	0	2.58 - 25.85	25.88 - 77.55	77.64 - 129.25	129.25 +	Total
Age						
18- 25	14	25	13	8	-	60
26- 40	24	41	46	10	8	129
41 - 60	30	35	25	5	10	105
60	9	22	8	2	-	41
	77	**123**	**92**	**25**	**18**	**335**
Sex						
Woman	42	66	47	13	8	176
Man	35	57	46	12	10	160
	77	**123**	**93**	**25**	**18**	**336**
Level of studies						
None	9	7	1	-	-	17
Bachelor	48	76	38	14	8	184
University	19	40	49	10	9	127
Other	1	-	5	1	1	8
	77	**123**	**93**	**25**	**18**	**336**
Household Income						
0 - 388.2	10	6	2	-	-	18
393.37 - 776.39	24	44	13	3	-	84
781.57 - 1,035.19	16	34	24	4	1	79
1,040.37 - 1,294	12	13	23	4	5	57
1,299.17 – 1,552.79	10	9	9	4	1	33
1,552.79 +	2	11	22	9	11	55
	74	**117**	**93**	**24**	**18**	**326**

(continued)

Table AI.

Contingency Table WTP*INCOME

			INCOME[1] 1	2	3	4	TOTAL
WTP	1	Count	50	22	1	1	74
		Expected Count	41.2	24.9	5.7	2.3	74
		Residual	8.8	-2.9	-4.7	-1.3	
		Std. Residual	1.4	-0.6	-2	-0.8	
		Adjusted Residual	2.3	-0.8	-2.3	-1	
	2	Count	84	27	3	3	117
		Expected Count	65.1	39.4	8.9	3.6	117
		Residual	18.9	-12.4	-5.9	-0.6	
		Std. Residual	2.3	-2	-2	-0.3	
		Adjusted Residual	4.4	-3	-2.6	-0.4	
	3	Count	39	39	14	1	93
		Expected Count	51.8	31.3	7.1	2.8	93
		Residual	-12.8	7.7	6.9	-1.8	
		Std. Residual	-1.8	1.4	2.6	-1.1	
		Adjusted Residual	-3.1	2	3.2	-1.3	
	4	Count	7	12	2	3	24
		Expected Count	13.4	8.1	1.8	0.7	24
		Residual	-6.4	3.9	0.2	2.3	
		Std. Residual	-1.7	1.4	0.1	2.6	
		Adjusted Residual	-2.7	1.8	0.1	2.8	
	5	Count	2	10	5	2	19
		Expected Count	10.6	6.4	1.5	0.6	19
		Residual	-8.6	3.6	3.5	1.4	
		Std. Residual	-2.6	1.4	2.9	1.9	
		Adjusted Residual	-4.1	1.8	3.2	1.9	
	Total	Count	182	110	25	10	327
		Expected Count	182	110	25	10	

[1](1) \$388.2 - \$1,035.19, (2) \$1,040.37 - \$1,682.19, (3) \$1,687.37 - \$2,329.19, (4) \$2,329.19 +

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	66.148[a]	12	0.000
Likelihood Ratio	64.514	12	0.000
Linear-by-Linear Association	43.504	1	0.000
Number of Valid Cases	327		

[a] 7 cells (35%) have expected count less than 5. The minimum expected count is 0.58.

Table AI.

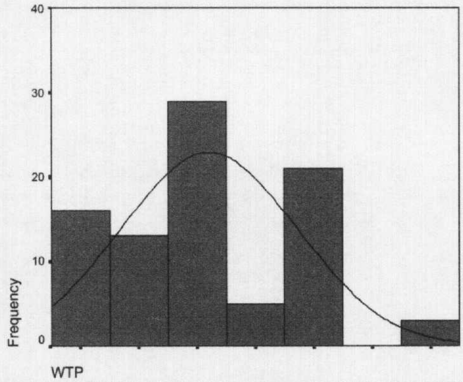
Appendix 2. Descriptive analysis of the variable willingness to pay (WAP)/other locations

Descriptive Statistics

	Mean	St. Dev.	Mode	Median	Maximum	Minimum
Willingness to pay (dollars)	28.53	2.09	0	25.85	77.55	0

Frequency Distribution of the variable *Willingness to pay*

Willingness to pay (dollars)	Frequency
0 – 10.35	17
10.35 - 20.70	12
20.70 - 31.05	29
31.05 - 46.58	6
46.58 - 72.46	20
77.64	3
Total	87



Willingness to pay of people for clean air (dollars)

	0	2.58 - 25.85	25.88 - 77.55	77.64 - 129.25	129.25 +	Total
Age						
18- 25	-	8	-	-	-	8
26- 40	3	16	18	-	-	37
41 - 60	1	11	19	-	-	31
60	1	9	-	.	-	10
	5	**44**	**37**	**-**	**-**	**86**
Sex						
Woman	2	20	12	-	-	34
Man	3	24	26	-	-	53
	5	**44**	**38**	**-**	**-**	**87**
Level of studies						
None	2	11	1	-	-	14
Bachelor	3	33	27	-	-	63
University	-	-	10	-	-	10
Other	-	-	-	-	-	-
	5	**44**	**38**	**-**	**-**	**87**
Household Income						
0 - 388.2	3	9	1	-	-	13
393.37 - 776.39	1	14	2	-	-	17
781.57 - 1,035.19	-	15	16	-	-	31
1,040.37 - 1,294	1	4	6	-	-	11
1,299.17 – 1,552.79	-	2	6	-	-	8
1,552.79 +	-	-	7	-	-	7
	5	**44**	**38**	**-**	**-**	**87**

(*continued*)

Table AII.

Contingency Table WTP*INCOME

			INCOME[1]				
			1	2	3	4	TOTAL
WTP	1	Count	4	1	-	-	5
		Expected Count	3.5	1.5	-	-	5
		Residual	0.5	-0.5	-	-	
		Std. Residual	0.3	-0.4	-	-	
		Adjusted Residual	0.5	-0.5	-	-	
	2	Count	38	6	-	-	44
		Expected Count	30.7	13.3	-	-	44
		Residual	7.3	-7.3	-	-	
		Std. Residual	1.3	-2	-	-	
		Adjusted Residual	3.4	-3.4	-	-	
	3	Count	18	19	-	-	37
		Expected Count	25.8	11.2	-	-	37
		Residual	-7.8	7.8	-	-	
		Std. Residual	-1.5	2.3	-	-	
		Adjusted Residual	-3.7	3.7	-	-	
	4	Count	-	-	-	-	-
		Expected Count	-	-	-	-	-
		Residual	-	-	-	-	
		Std. Residual	-	-	-	-	
		Adjusted Residual	-	-	-	-	
	5	Count	-	-	-	-	-
		Expected Count	-	-	-	-	-
		Residual	-	-	-	-	
		Std. Residual	-	-	-	-	
		Adjusted Residual	-	-	-	-	
	Total	Count	60	26	-	-	86
		Expected Count	60	26	-	-	86

[1](1) $388.2 - $1,035.19, (2) $1,040.37 - $1,682.19, (3) $1,687.37 - $2,329.19, (4) $2,329.19 +

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.818[a]	2	0.001
Likelihood Ratio	14.084	2	0.001
Linear-by-Linear Association	10.793	1	0.001
Number of Valid Cases	86		

[a] 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.51.

Table AII.