Indirect and Avoided Environmental Consequences in Project Evaluation

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Abstract: The paper focuses on indirect environmental consequences, namely the environmental consequences of the production of project inputs. In addition, we introduce the term avoided environmental consequences, i.e. the environmental consequences associated with diversion of production factors from alternative use. The former are always relevant, while the avoided consequences are only relevant in cases involving fully-employed production factors that would otherwise be used in production. The inclusion of indirect and avoided environmental consequences may considerably affect the outcome of traditional project evaluation. In this article it is suggested how the indirect and avoided environmental consequences may be described using the input-output system in combination with environmental coefficients.

1. INTRODUCTION

There is a long tradition for practical project evaluation to be based on the assumptions and results of theoretical welfare economics, welfare being assumed to be a function of the utility the individuals derive from of consumption of marketable goods and environmental quality, see e.g. Pearce and Nash [9] and Johansson [4]. Changes in environmental quality are an integral part of the welfare economic foundation of project evaluation, and should be taken fully into account.

In traditional empirical project evaluation, economists usually omit to take into account the indirect environmental consequences of the project under evaluation. Moreover, avoided environmental consequences - a term introduced in this article - are never considered in such analyses. Indirect environmental consequences can be defined as environmental consequences not directly connected with the project production process, i.e.

- environmental consequences of producing the project inputs,
- environmental consequences of the use and disposal of the products of the project,
- environmental consequences of multiplier effects in cases of keynesian unemployment.

Avoided environmental consequences can be defined as

- the environmental consequences resulting from the diversion of resources from alternative uses in cases of full employment.

The first two types of consequences are normally very thoroughly described in life cycle analysis, but rarely in traditional empirical economic project evaluation. As description of multiplier effects is not an integral part of traditional project evaluation, the environmental consequences connected with these effects are not described. Similarly, avoided environmental consequences connected with the opportunity costs of projects are never taken into account.

In this paper we concentrate on the environmental consequences of producing inputs to the project and on the avoided environmental consequences that result from resources being diverted from alternative use. The former are relevant in the case of both unemployed and fully-employed production factors, while the latter are only relevant in the case of fully-employed production factors that would otherwise have been used in other production processes.

Our presentation of the topic is divided into five parts:

- A description of practical project evaluation as normally performed in cases involving unemployed and fully-employed production factors.
- The assessment of indirect and avoided environmental consequences in cases involving unemployed and fully-employed production factors.
- Use of the input-output system in the assessment of indirect and avoided environmental consequences.
- A case study
- Concluding remarks.

2. INDIRECT AND AVOIDED CONSEQUENCES IN PRACTICAL PROJECT EVALUATION

In practical project evaluation it is always important to answer the question: Does the project represent an additional activity in the economy, or does it just substitute for an existing activity? If the production factors to be used are fully employed, the project, and the production of inputs for it, will always substitute for other activities. The "lost" results of the activities substituted for are termed the opportunity costs of the project. If, on the other hand, the production factors are in excess supply, other activities will not necessarily be affected.

The indirect and avoided *economic* consequences of the projects use of inputs are taken into account when valuing the projects direct economic effects. However, the indirect *environmental* consequences are rarely taken into account and the avoided *environmental* consequences are never considered. Thus, traditional project evaluation practice is subject to serious inconsistency.

In cases where production factors are in excess supply, projects will give rise to additional production activity and consequently to additional environmental consequences attributable to both the direct effects of this activity and the indirect effects associated with producing the project inputs.

When production factors are diverted from alternative employment, the direct environmental consequences and those of producing project inputs will be the same as when production factors are in excess supply. In addition, however, the environmental consequences will be reduced in those sectors from where the production factors are diverted. Such avoided environmental consequences need to be taken into account in the same way as the indirect economic consequences of the project.

The inclusion of indirect and avoided environmental consequences may considerably affect the outcome of traditional project evaluation. Thus a project whose direct consequence is environmental improvement may in fact cause deterioration if the benefits are outweighed by the negative consequences of producing the project inputs. If the production factors are fully-employed, the avoided environmental effects also need to be taken into account and the total effect may still be an environmental improvement. This can be determined by comparing the sum of direct environmental consequences and those of producing the project inputs with the average environmental consequences of economic activity in the economy.

Since omitting indirect and avoided environmental consequences could lead to economically and environmentally incorrect decisions being made, there is a serious need to incorporate systematic description of these environmental consequences into traditional project evaluation practice.

3. ASSESSMENT OF INDIRECT AND AVOIDED ENVIRONMENTAL CONSEQUENCES

In cases involving unemployed production factors, indirect environmental consequences may be assessed using life cycle analysis. This involves describing the production process and the environmental consequences associated with each input to the project, i.e. raw materials and intermediate products, and then following the consequences of the production process backwards as far as production of the primary inputs.

This kind of analysis requires considerable technical skill, and is very resource demanding as each step in the production of all inputs has to be described in detail. Moreover, it is often possible to produce inputs such as energy in different ways, thereby rendering the environmental consequences highly dependent on assumptions as to the production process used. An easier method for assessing indirect environmental consequences is to use the input-output system that is part of the national accounts system. This method assumes the use of average production technology, as described in Section 3.

Assessment of avoided environmental consequences, which is relevant in cases involving fully-employed production factors, is even more difficult. The avoided consequences are associated with resources being diverted from other production processes and it is not usually being known from where the resources are diverted.

In principle, the problem could be overcome by using a general equilibrium model. Such models address total adjustment of the economy to the project and hence which sectors the resources are diverted from. The general equilibrium models most often suffer the disadvantage of a relatively high aggregation level with regard to production sectors, however, and hence are less suitable in connection with project evaluation. A more appropriate means of estimating the avoided environmental consequences is to use input-output models as these are generally more disaggregated. This can be done either

- on the basis of the amount of labour directly and indirectly employed within the project, or
- on the basis of the total project costs.

The first possibility takes directly into account the diversion of labour from other production sectors, the assumption being made that total supply of labour and hence total employment is unchanged and that the diversion of labour from other sectors occurs relative to their use of labour. In this case the avoided environmental consequences for each sector depend on the amount of labour diverted from the sector, the production per unit of labour and the environmental load per unit of production.

Alternatively, it may be argued that production value equivalent to the cost of the project is lost, the assumption being made that the price of each input is equivalent to its marginal value productivity. The total loss of production value is allocated to the various economic sectors relative to their contribution to the production value of the economy as a whole. The avoided environmental consequences can be estimated for each sector as the product of lost production value and environmental load per unit of production.

The first method respects the assumption of unchanged labour supply and total employment, but not the assumption that the calculated opportunity costs are equivalent to the value of lost production. The opposite is the case with the second method, however. If the value of lost production in the second method is adjusted such that it is in accordance with the assumption of constant total employment, then both methods will give the same result.

As labour is usually the most scarce production factor, it seems most correct to respect the assumption of constant total employment. The following analysis is therefore based on the first method, i.e. the estimation of indirect and avoided environmental consequences is based on the amount of labour directly and indirectly employed within the project.

4. USE OF THE INPUT-OUTPUT SYSTEM

From time to time, input-output model systems have been applied in estimating indirect *economic* consequences (see e.g. Bell et al.[1], Kuyvenhoven [5], Londero [6], Mullins [7], or Scott,et.al. [10]), However, the idea of estimating the indirect and avoided *environmental* consequences in project evaluation by input-output models is new. These consequences can only be estimated if the national account system include information on the environmental consequences of production within the various economic sectors.

The traditional economic input-output model provides information on the demand by each production sectors for inputs from other sectors. These relationships are defined by input-output coefficients expressing the value of input from each supplying sector per output value of the purchasing sector.

The economic input-output model system can be extended to encompass emissions from each sector - see e.g. United Nations [12]. This is done by estimating a number of emission coefficients for each sector indicating the amount of various substances emitted per output value. Because fixed input-output coefficients are assumed, it is also possible to calculate the emission coefficients as emissions per labour unit.

The sectorial emission coefficients only relate to emissions resulting directly from the production process. However, the production process also places an input demand on other sectors, thereby raising their production and emissions. The sum of these direct and indirect emissions can be calculated by the Leontief-inverse matrix indicating for each sector the emission coefficients for the total direct and indirect environmental consequences.

With regard to Denmark, energy-related emission coefficients have been estimated for the period 1972 - 92 for CO_2, SO_2 and NO_X (Fenhann & Kilde [3]). In addition to these of

Table 1 Emissions and resource use encompassed by the Danish input-output system

Emissions to air: CO_2, SO_2, NO_X, VOC

Waste water: COD, BOD, Nitrogen, Phosphorous, Oil*, Phenolic Compounds*, AOX*, Heavy Metals

Resources (production sectors): Energy, PVC, Organic Solvents, Lead*, CFC

Solid waste*: Process Waste, Packaging Waste (paper, metal & glass, plastic), Organic Solvents, Organic Chemicals, Non-organic Chemicals

* Data relating to these compounds and resources do not cover all 117 sectors.

Source: Wier (1994)

ficial statistics, environmental coefficients have been estimated for numerous other compounds and natural resources (Wier [13]). The compounds encompassed by this "unofficial" economic-environmental model system are shown in Table 1. The coefficients cover 117 different production sectors.

The input-output system does not describe the specific production process of every single type of input, but it is possible to determine the sector of origin of the project inputs and then use the sector-specific environmental coefficients to calculate the average environmental effects of the production of these inputs. However, the description of indirect environmental consequences will be less exact than with life cycle analysis. On the other hand, the input-output-based analysis is considerably less resource-demanding, and is a more complete and consistent analysis than most life cycle analysis. Moreover, it is the most practical way to assess the extent of avoided environmental consequences in cases involving fully-employed resources.

The principles for calculating indirect and avoided environmental consequences can be summarized as follows. In a situation with unemployed production factors the indirect environmental consequences, e.g. the emissions of compound j, EI_j, are equivalent to the environmental consequences of the production of the project inputs, i.e.

$$EI_j = \sum_{i=1}^{n} e_{ij} \cdot x_i$$

where e_{ij} is the emission coefficient of compound *j* per production value in production sector *i*, x_i is the project´s direct and indirect use of inputs from sector *i*. As not all sectors supply inputs to the project, x_i for some sectors may be zero.

In a situation with fully-employed resources, the avoided environmental consequences have also to be added. Thus, the total indirect and avoided environmental consequences, e.g. the emissions of compound *j*, EIA_j, are expressed as follows:

$$EIA_j = \sum_{i=1}^{n} e_{ij} \cdot x_i - \sum_{i=1}^{n} (L + \sum_{i=1}^{n} l_i \cdot x_i) \cdot a_i \cdot \frac{e_{ij}}{ld_i}$$

where L is the labour use in the project, l_i is the direct and indirect use of labour per production value in sector i, a_i is the percent of total employment that is employed in sector i, and ld_i is the direct use of labour per production value in sector i.

It can be seen that the avoided environmental consequences are calculated on the basis of total amount of labour directly and indirectly diverted from other employment due to the project, i.e.

$$L + \sum_{i=1}^{n} l_i \cdot x_i$$

together with the part of total labour diverted from each sector i, a_i, the lost production value in each sector per unit of labour $1/ld_i$, and the emissions of compound j per production value in production sector i, e_{ij}.

5. CASE STUDY - INCREASED PRODUCTION OF RECYCLED CORRUGATED CARDBOARD

In the following section, the method described above is illustrated by means of a practical example. The example concerns the economic and environmental consequences of increasing Danish production of recycled corrugated cardboard. This has been described in detail earlier (Danish Environmental Protection Agency [2]).

The direct annual consequences for production, resource consumption and atmospheric emissions of increasing the production of recycled corrugated cardboard by 38,000 tonnes per year are summarized in Table 2.

Table 2 Direct economic and environmental consequences of increasing the annual production of recycled corrugated cardboard

	Production recycled cardboard	Collection for recycling	Combustion of cardboard	Collection for combustion	District heating natural gas	coal

Recycled cardboard	38,000 tonnes					
District heating			- 456,000 GJ		228,000 GJ	228,000 GJ
Investment	DKK 200 million (lifetime 15 yr)	DKK 2.6 million (lifetime 15 yr)	DKK - 9.9 million (lifetime 15 yr)	DKK - 1.7 million (lifetime 15 yr)	DKK 0.4 million (lifetime 25 yr)	DKK 1.1 million
Labour	54 men	27 men	- 20 men	- 18 men		
Electricity	17,100 MWh		- 3,700 MWh			
Steam	171,000 GJ					
Natural gas					5,844,000 m^3	
Coal						3,800 tonnes
Glue, etc.	1,925 tonnes					
Water	60,800 m^3					
Misc. Operation	DKK 11.0 million	DKK 17.5 million	DKK - 3.2 million	DKK - 4.5 million	DKK 0.8 million	DKK 0.8 million
CO_2					25,500 tonnes	
SO_2			- 110 tonnes		66 tonnes	
NO_x			- 163 tonnes		68 tonnes	

Source: The authors

As is apparent from the table, production of corrugated cardboard based on recycled materials requires investments in both collection facilities and production equipment, as well as corresponding consumption of labour and resources during the collection and production phases. Waste cardboard has hitherto been collected for combustion at district heating plants. The investments, consumption of resources and emissions of SO_2 and NO_x associated with this will therefore be avoided. On the other hand, the heat produced by district heating plants will be lost, and has to be replaced by district heating from natural gas-powered district heating plants and coal-powered combined heat and power stations. This will result in the investment expenses, resource consumption and emissions of CO_2, SO_2 and NO_x shown in the table.

The net result of the increased production of recycled corrugated cardboard is therefore increased investments, increased labour consumption, increased energy consumption and increased consumption of a number of other resources. The overall direct environmental effects include increased CO_2 emissions and decreased SO_2 and NO_x emissions. This raises the following questions:

- Can the value of the increased production of recycled corrugated cardboard offset the value of the increased resource consumption?
- What are the environmental effects of the production of the raw materials needed to sustain the increased production of corrugated cardboard?
- Can the avoided environmental effects of diverting labour from other employment offset some of the negative consequences of the increase in production of corrugated cardboard and raw materials?

The first question can be answered by undertaking a welfare economic analysis in accordance with the principles stipulated in Møller [8]. Based on a number of assumptions as to the market prices of the products and resources, the import share of the investment expenses, the social time preference rate and the social opportunity costs of capital, as well as the correction factors for indirect taxes and subsidies used in the calculations (Danish Environmental Protection Agency, [2]), the annual socioeconomic surplus is calculated to be approx. DKK 38 million.

This sum is in no way an expression of the enterprise economic profitability of the increase in production of recycled corrugated cardboard, but rather indicates that the increase in production is advantageous from the point of view of society. As its environmental effects other than increased CO_2 emissions are also favourable, a traditional welfare economic project evaluation would normally lead to recommendation of the project.

This type of evaluation does not take into account the indirect and avoided environmental effects, however, which include:

- Environmental effects associated with the production of the raw materials needed to sustain the increase in the production of recycled corrugated cardboard
- Avoided environmental effects associated with the diversion of labour from other employment.

As described in Section 3, the first of these effects can be calculated on the basis of the input-output accounts system's description of the environmental impact of the individual production sectors and their direct and indirect effects on other sectors. The avoided environmental effects can be considerable in a situation with full employment. As also described in Section 3, these too can be calculated on the basis of the input-output accounts system's description of the environmental impact of the sectors from which the labour is diverted.

These calculation methods are used below to determine the indirect and avoided environmental effects of the increase in the production of recycled corrugated cardboard. The results are summarized in Table 3.

The previously mentioned direct environmental effects are shown in the column A. The indirect environmental effects resulting from the increased production of raw materials (electricity, district heating, water and glues) for the project are considerable, as shown in column B. With regard to energy and energy-related emissions (SO_2, NO_x and CO_2), the indirect effects are far greater than the project's direct effects. This is due to the fact that production of the raw materials "electricity" and "district heating" are particularly energy-demanding. Thus if it is assumed that the project's raw material consumption could be covered through increased pro-

Table 3 Direct economic and environmental effects of increased production of recycled corrugated cardboard

	Direct effects (A)	Indirect effects			Total
		Effects due to raw materials production (B)	Avoided effects		(E) = (A)+(B)-(D)
			Due to direct use of labour (C)	Due to direct and indirect use of labour (D)	
Resources					
Energy (TJ)	219	981	31	64	1,136
Lead (kg)		450	510	1,060	-610
PVC (kg)		4,180	1,630	3,370	810
Organic solvents (kg)		4,900	5,540	11,500	-6,600

CFC (kg)		50	100	200	-150
Emissions to air					
SO_2 (tonnes)	-44	445	7	16	385
NO_x (tonnes)	-95	166	6	14	57
CO_2 (tonnes)	25,500	83,200	1,700	3,500	105,200
VOC (kg)		330	550	1,150	-820
Waste water emissions					
Nitrogen (kg)		190	7,940	16,490	-16,300
Phosphorus (kg)		10	160	330	-320
COD (kg)		890	2,680	5,570	-4,680
BOD (kg)		1,700	4,120	8,570	-6,870
Heavy metals (g)		90	300	620	-530
AOX (g)		90	160	320	-230
Oil (g)		1,610	990	2,050	-440
Phenolic compounds (g)		2,290	3,400	7,060	-4,770
Solid waste					
Process waste (kg)		150	200	420	-270
Organ. Chemicals (tonnes)		1,600	1,020	2,120	-520
Non-organ. chem. (tonnes)		170	240	490	-320
Packaging waste					
Paper (kg)		230	330	680	-450
Metal (kg)		70	110	230	-160
Plastic (kg)		30	50	100	-70

Source: The authors

duction and resource consumption – including an increase in total employment – it would still be advantageous from the point of view of the economy, but would have a number of negative environmental consequences.

However, in evaluating the economic surplus, the assumption is made when fixing the labour costs that the labour is diverted from other use. This gives rise to the avoided environmental effects shown in columns C and D. The direct avoided effects – column C – are a consequence of the employment of 43 men in the project, while the direct and indirect avoided effects – column D – reflect the direct and indirect involvement of 91 men in the project and associated production of raw materials.

As is apparent from Table 3, the avoided environmental effects are in by far the majority of cases considerably greater than those associated with production of the raw materials. Thus in most cases, production of the raw materials is less polluting than society's activities in general. Thus in a situation with full employment, the project is both advantageous for the economy and has largely positive environmental consequences (column E).

The energy consumption and energy-related emissions are an important exception, however, the production of the raw materials needed to sustain the increase in production being extremely energy-intensive because the raw materials include electricity and district heating. In this respect, the production of raw materials for the project is therefore far more polluting than society's activities in general.

The raw materials-related effects are also either greater than or of same order of magnitude as the avoided effects with respect to consumption of PVC, lead and organic solvents. In the case of PVC, this is due to the fact that both electricity, district heating and the water supply require large deliveries from the building and construction sector, which accounts for over half of Danish industry's total PVC consumption. The relatively high indirect consumption of lead for raw materials production is partly attributable to the raw materials' demands on the building and construction sector, and partly to their demands on cable, accumulator and engine factories. The relatively high consumption of organic solvents is mainly due to production of the raw material glue, which both directly and indirectly requires large production activity in organic solvent-intensive enterprises such as glue, dye, lacquer and thinner manufacturers.

The overall conclusion is thus that the indirect and avoided effects estimated with the aid of the input-output accounts system provide knowledge on important environmental consequences. The latter are considerable in magnitude and in a situation of full employment, mainly count in the project's favour, and should therefore be of significance for its evaluation.

6. CONCLUDING REMARKS

Traditional empirical project evaluation normally only takes into account the direct environmental consequences of the project. The method for incorporating indirect and avoided environmental consequences suggested in the paper will improve project evaluation in the following ways:

- In cases involving unemployed production factors, traditional evaluation practice underestimates the environmental consequences, it being necessary to also take into account the consequences of producing the project inputs. While a combination of life cycle analysis and economic analysis is probably the most accurate solution to this problem, the suggested input-output approach is a much easier and more consistent approach.
- In cases involving fully-employed production factors, traditional evaluation practice overestimates the environmental consequences. Although, the direct environmental consequences and those of producing the project inputs are the same as in cases involving unemployed resources, one has also to subtract the avoided environmental consequenses associated with the diversion of resources from other activities. Failure to do so could lead to erroneous decisions being made since the avoided consequences might counteract or even outweigh the project input related consequences, thereby rendering the overall environmental consequences of an apparently negative project positive. The proposed input-output approach represents a practical way of assessing these avoided environmental consequences.

Inclusion of avoided environmental consequences on the benefit side in project evaluation may therefore change the conclusion on prioritization of two projects. As an example, consider two projects for which the direct environmental consequences are equal: Project

1 has smaller economic costs than project 2 and according to traditional evaluation practice would therefore be preferred to project 2. However, if the avoided environmental consequences are included on the benefit side the more costly project may prove to be the environmentally most beneficial of the two as it diverts more resources from other activities such that the avoided environmental consequences are greater than in the less costly project.

Incorporation of the assessment of indirect and avoided environmental consequences represents a considerable improvement in project evaluation as a basis for resource allocation. The suggestion of using input-output-based emission and resource use coefficients should facilitate this improvement.

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List of Symbols

e_{ij} is the emission coefficient of compound *j* per production value in production sector *i*

x_i is the project´s direct and indirect use of inputs from sector *i*

L is the labour use in the project

l_i is the direct and indirect use of labour per production value in sector *i*

a_i is the percent of total employment that is employed in sector *i*

ld_i is the direct use of labour per production value in sector *i*

EI_j is the environmental consequences of the production of the project inputs, , e.g. the emissions of compound *j*

EIA_j is the total indirect and avoided environmental consequences, e.g. the emissions of compound *j*