DG Regional Policy

Study on the "Identifying and Aggregating Elasticities for Spill-over Effects due to Linkages and Externalities in the Main Sectors of Investment Co-financed by the EU Cohesion Policy"

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Executive summary

In order to support its economic and quantitative analytical capacity, in 2007 DG REGIO acquired the Cohesion System of HERMIN models (CSHM), a set of macroeconomic models designed to assess the impact of Cohesion Policy at national level on eighteen EU Member States (BG, DE, CY, CZ, EL, EE, IE, ES, HU, IT, LT, LV, MT, PL, PT, RO, SK, SI). One of the main aspects to be improved in the CSHM concerns the spill-over elasticities for the main categories of expenditure over sectors of the economy (for example, the spill-over elasticities of human resource expenditure on the sector of manufacturing) calculated on the basis of European data. Spill-over elasticity is defined in this study and in the HERMIN models as percentage changes in productivity and output in the manufacturing and market services sectors due to changes of public expenditure.

Spill-over elasticities used in HERMIN represent the direct effect of investments on the sector unless the economy is highly distorted. In the later case spill-over elasticity is equal to the sum of direct and indirect effects of investments.

The *objective* of this study is to improve the current CSHM by identifying elasticities for the main categories of expenditure. The study will in particular provide elasticities for the main categories of expenditure which:

(a) are differentiated per country;

(b) include elasticities for the main sectors of investment;

(c) allow for environmental impacts of alternative sectors of investment;

(d) and are also expressed in terms of EU Cohesion Policy expenditure and co-financing rates for the main sectors of investment.

Table 1: HERMIN Spill-Over Elasticities

	Manufacturing output	**Manufacturing productivity**	**Market Services output**	**Market Services productivity**
Physical infrastructure	Output/ infrastructure	Total Factor Productivity/ infrastructure	Output/ infrastructure	Total Factor Productivity/ infrastructure
Human resources	Output/human capital	Labour embodied technical change/ human capital	Output/human capital	Labour embodied technical change/ human capital
RTD	Qutput/RTD	Total Factor Productivity /RTD	Output/RTD	Total Factor Productivity /RTD

The result of the present study will allow for having:

- more robust elasticities for each category of expenditure in each country;

- to run simulations aiming at identifying the ECP (sub) optimal policy mix taking also into account environmental impacts;
- to run simulations assessing alternative hypotheses on EU co-financing rates on sector of investment.

The methodological approach, which allows us to link micro and macro levels of analysis within the context of this study, is general equilibrium framework. This framework represents the meso (sectoral and regional) level of analysis. General equilibrium is the only type of methodology, which can provide us with the framework that includes both micro and macro-economic elements in a theoretically consistent way. Hence, it is indispensible to this study given the objectives presented in the terms of reference: to estimate spill-over elasticities based on the micro-level data of investment projects and then

In order to estimate the spill-over elasticities for HERMIN model we have to proceed in several inter-related steps, which are represented in Figure 1. We work on a several level of aggregation, starting with the level of ECP subsector of investment and moving consequently to the sector of investment level and, finally, to the category of expenditure level. The last level of aggregation represents the HERMIN sectoral breakdown.

A starting point of the project is the creation of complete and comprehensive database of CBA studies covering all types of ECP investment sectors. We have assembled a dataset of 362 project files in cohesion countries financed by ECP or the World Bank. We then extracted from this dataset information about average/representative physical and economic impacts of ECP investment via selecting representative projects, by ECP subsector of investment and by country. For this sake, we applied stratified quota sampling dividing total sample fame into homogeneous strata by subsector and country, given available information.

We divided all cohesion countries into groups based on their level of economic developments as expressed by their GDP per capita. The basic rationale behind this country breakdown was a relative shortage and higher efficiency of capital in less-developed countries in comparison to higher-developed countries. We also considered several other indicators, including population density, as affecting the rates of return to capital. Based on these criteria we divided the total sample of cohesion countries into three groups:

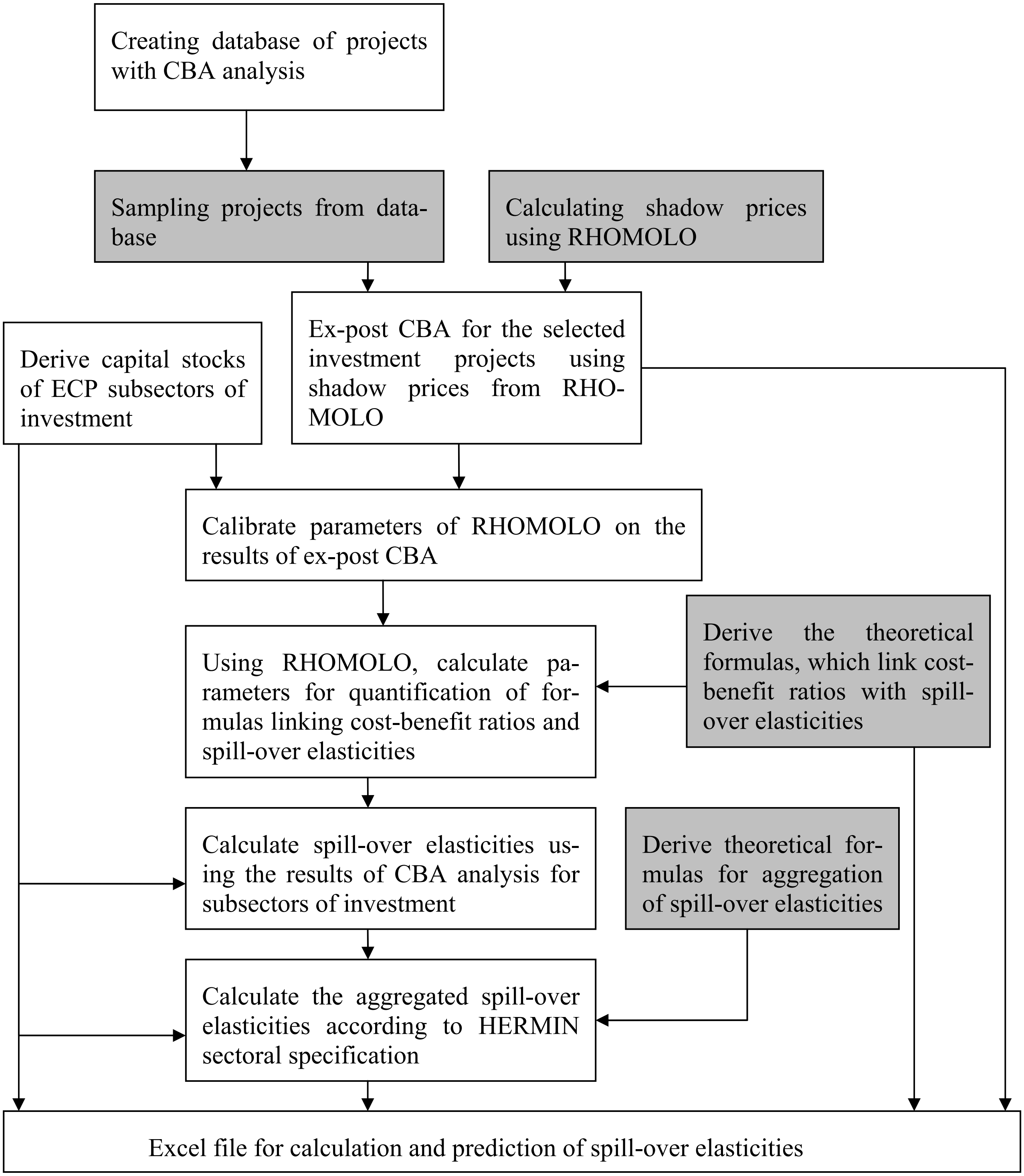
1. Low-income East European countries: Bulgaria, Romania, Latvia, Lithuania, Poland;

2. High-income East European countries: Slovakia, Hungary, Estonia, Czech Republic, Slovenia, East Germany; and

3. Mediterranean countries: Cyprus, Spain, Greece, Ireland, South Italy, Malta, Portugal.

We also took into account the administrative capabilities of member states to implement public projects.

Figure 1: The overall structure of the project



Sector-wise, we selected the following ECP subsectors of investment:

1. Road
2. Rail
3. Port
4. Waste water
5. Solid waste
6. Drinking water
7. Air emissions and environmental protection
8. Energy
9. ICT
10. Social infrastructure
11. Education
12. Labour market institutions
13. RTD (including aid to productive sectors related to RTD)

For each of the 36 selected projects (RTD was treated separately), a full fledged ex post CBA, including demand analysis, was carried out using the shadow prices of labour calculated for different Cohesion Countries using RHOMOLO. Other shadow values, like the value of statistical life, were evaluated with methodologies established in DG REGIO CBA Guide (2008). The end-result of this exercise was a set of physical economic and indicators including ENPV, BCR and ERR for each of the 36 projects, which give micro-based evidence of rates of return.

In order to link indicators reflecting the rates of return on investment (namely ERR and BCR) with spill-over elasticities at the level of ECP subsector of investment, we have developed a set of theoretical formulae. The methodology is based on a theoretical general equilibrium model which captures all the main features of RHOMOLO. We have also developed a second set of theoretical formulae for the aggregation of the detailed spill-over elasticities to the higher aggregation level (category of expenditure, which is used in HERMIN).

Both sets of formulae need information on capital stock of ECP investment sectors (including physical capital, human capital and RTD stock) in each Cohesion Country as well as sectoral outputs and several coefficients reflecting general equilibrium effects (which were obtained from RHOMOLO). While sectoral outputs are available in statistics, the estimates of capital stocks by ECP subsector of investment had to be derived. The calculated capital stocks were also used in our sampling methodology as well as for the aggregation of spill-over elasticities.

Then the required set of spillover elasticities was evaluated in an Excel model, first, at the lowest level of aggregation and then, via aggregation formula also incorporated in the Excel file, at the level of category of expenditure. Thus the obtained elasticity estimates are, on one hand, micro-founded and, on another hand, reflect general equilibrium relationships. In order to ensure robustness of results, a sensitivity analysis has been carried out by varying some assumptions and allowing for errors in underlying variables, most importantly, in capital stock. In addition, a relation of the elasticity values with the scale of investment was investigated via RHOMOLO.

The Excel file with formulae linking rates of return with spill-over elasticities and aggregating elasticity estimates from lower to higher level of aggregation is an important output of the project. It allows for (i) calculation of spill-over elasticities based on the results of CBA analysis and (ii) for the predicting of spill-over elasticities based on information about CBA analysis by type of ECP sector of investment, sectoral composition of ECP, and macro-economic forecast.

The Table below presents the calculated values of spill-over elasticities for all eighteen Cohesion Countries estimated on the basis of the results from ex-post CBA studies. These include the productivity, output and environmental spill-over elasticities. Our average over countries elasticities are similar to those reported in the HERMIN Manual for manufacturing output with respect to physical infrastructure, market services output with respect to RTD and market services productivity with respect to human resources. Our averaged estimates are higher for market services output with respect to physical infrastructure, for market services output with respect to human resources, and for market services productivity with respect to physical infrastructure.

And, finally, our averaged estimates are lower for manufacturing output with respect to human resources, manufacturing output with respect to RTD, manufacturing productivity with respect to physical infrastructure and manufacturing productivity with respect to human resources. This is not surprising in the light of results of econometric studies which have been reviewed in the HERMIN use manual. These studies in general report the values of elasticities of manufacturing as being lower than the ones presently being used in HERMIN.

Our estimates for output and productivity spill-over for market services are higher then for manufacturing which is explained by the mapping between economic NACE sectors and the HERMIN sectors. According to the present mapping all main infrastructure sectors such as transport, telecommunications, water, electricity and gas are a part of the market services sector of the HERMIN model. Hence it is logical to expect that the effect of investment into infrastructure will have higher effects on this particular sector of HERMIN. The effect of infrastructure investments on manufacturing sector is lower.

Average spill-over elasticities of human capital are roughly the same in case of market services and manufacturing. Average spill-over elasticities of RTD are higher on manufacturing output and productivity than on market services. Impact of RTD on productivity and output is lower than the impact of human capital.

Table 2: The values of spill-over elasticities for the HERMIN model calculated on the basis of ex-post CBA studies

Type of ECP investment	HERMIN sector	BG	CY	CZ	DE	EE	ES	GR	HU	IE	IT	LT	LV	MT	PL	PT	RO	SI	SK	Ave
Physical infrastructure	Manufacturing output	0.0444	0.0194	0.1135	0.2171	0.1148	0.1689	-0.0248	0.1135	0.1496	0.3335	0.0483	0.1841	0.0982	0.0661	0.2335	0.0921	0.1447	0.0560	0.19
Physical infrastructure	Market services output	0.1937	0.0939	0.2069	0.3349	0.3049	0.3711	0.5416	0.1678	0.2822	0.3911	0.1176	0.4307	0.3420	0.1582	0.5126	0.1845	0.2883	0.1030	0.32
Human resources	Manufacturing output	0.0094	0.0081	0.0048	0.1546	0.0161	0.0124	0.0098	0.0043	0.0179	0.0568	0.0056	0.0064	0.0072	0.0055	0.0276	0.0057	0.0255	0.0035	0.09
Human resources	Market services output	0.0143	0.0090	0.0051	0.1160	0.0137	0.0137	0.0124	0.0052	0.0262	0.1508	0.0054	0.0118	0.0163	0.0105	0.0220	0.0095	0.0189	0.0030	0.09
RTD	Manufacturing output	0.0069	0.0107	0.0030	0.0414	0.0073	0.0184	0.0205	0.0073	0.0104	0.0334	0.0099	0.0276	0.0299	0.0043	0.0094	0.0029	0.0240	0.0120	0.03
RTD	Market services output	0.0082	0.0123	0.0035	0.0046	0.0136	0.0181	0.0157	0.0023	0.0027	0.0116	0.0047	0.0132	0.0086	0.0046	0.0112	0.0020	0.0052	0.0141	0.00
Physical infrastructure	Manufacturing productivity	0.0038	0.0026	0.0041	0.0060	0.0017	0.0148	0.0373	0.0040	0.0053	0.0059	0.0081	0.0112	0.0076	0.0021	0.0073	0.0047	0.0043	0.0054	0.00
Physical infrastructure	Market services productivity	0.0606	0.0296	0.0723	0.1179	0.1050	0.1050	0.2400	0.0515	0.0955	0.1264	0.0414	0.1202	0.1025	0.0416	0.1301	0.0466	0.0839	0.0423	0.10
Human resources	Manufacturing productivity	0.0057	0.0056	0.0033	0.1132	0.0071	0.0077	0.0053	0.0023	0.0108	0.0206	0.0026	0.0037	0.0051	0.0020	0.0087	0.0029	0.0106	0.0020	0.06
Human resources	Market services productivity	0.0050	0.0059	0.0032	0.0778	0.0098	0.0085	0.0076	0.0027	0.0195	0.0813	0.0026	0.0035	0.0113	0.0026	0.0116	0.0024	0.0103	0.0017	0.05
RTD	Manufacturing productivity	0.0057	0.0107	0.0032	0.0406	0.0053	0.0155	0.0180	0.0070	0.0101	0.0300	0.0089	0.0276	0.0299	0.0022	0.0090	0.0024	0.0216	0.0078	0.02
RTD	Market services productivity	0.0065	0.0123	0.0017	0.0036	0.0112	0.0122	0.0110	0.0019	0.0012	0.0081	0.0027	0.0130	0.0086	0.0022	0.0106	0.0013	0.0029	0.0078	0.00

Table 3: Main outputs of project WPs and links between them

Name of WP	Main tasks	Main outputs	Links with other WPs
WP1: Micro-economic analysis	• Creating project database • Sampling of investment projects • Calculating shadow prices with RHOMOLO • Ex-post CBA analysis	• Project database • Sampling methodology • Shadow prices • Results of ex-post CBA in terms of physical and economic indicators	• Results of ex-post CBA are used for calibration of RHOMOLO parameters in WP2
WP2: From micro-economic to macro-economic analysis	• Further development of RHOMOLO • Calibration of RHOMOLO parameters on results of ex-post CBA • Deriving theoretic formulas which link determinants of ERR (in particular CBR) with spill-over elasticities • Parameterization of formulas with the help of RHOMOLO • Calculation of capital stocks of ECP sectors of investment • Calculation of detailed spill-over elasticities using results of CBA analysis using theoretical formulas	• Version of RHOMOLO which includes relations between investments and energy and emissions intensity and inter-temporal effects of externalities • Version of RHOMOLO where parameters are calibrated on results of ex-post CBA • Detailed spill-over elasticities • Formulas linking determinants of ERR with spill-over elasticities • Capital stocks of ECP sectors of investment	• Detailed spill-over elasticities are used as an input to aggregation formulas in WP3 • Derived formulas linking determinants of ERR and spill-over elasticities are used in order to create Excel file in WP3 • Capital stocks are used for aggregation of spill-over elasticities in WP3
WP3: Macro-economic analysis	• Deriving theoretic formulas for aggregation of spill-over elasticities • Calculation of aggregated spill-over elasticities • Sensitivity analysis of aggregation formulas • Implementation of Excel file for prediction of spill-over elasticities	• Formulas for aggregation of spill-over elasticities • Aggregated spill-over elasticities • Excel file for prediction of spill-over elasticities	

Introduction

In order to support its economic and quantitative analytical capacity, in 2007 DG REGIO acquired the Cohesion System of HERMIN models (CSHM), a set of macroeconomic models designed to assess the impact of Cohesion Policy at national level on eighteen EU Member States (BG, DE, CY, CZ, EL, EE, IE, ES, HU, IT, LT, LV, MT, PL, PT, RO, SK, SI). One of the main aspects to be improved in the CSHM concerns the spill-over elasticities for the main categories of expenditure over sectors of the economy (for example, the spill-over elasticities of human resource expenditure on the sector of manufacturing) calculated on the basis of European data.

Spill-over elasticity is defined in this study and in the HERMIN models as percentage changes in productivity and output in the manufacturing and market services sectors due to changes in public expenditure. Effects of public expenditure can be direct or indirect, external or internal. Internal direct and indirect effects arise when significant distortions exist in the economy.

These effects arise both at the investment and operational stage of a project. When a project is under construction, the disbursed funds lead to an increase in incomes of parties that realize the project. These are the demand-side or Keynesian effects, which are of temporary nature. When the project is completed, it impacts the economy via direct and indirect benefits during the operation stage of the project. These are supply-side effects of a permanent nature. The HERMIN model defines elasticities as permanent effects.

The *objective* of this study is to improve the current CSHM by identifying elasticities for the main categories of expenditure. The study will in particular provide elasticities for the main categories of expenditure which:

(a) are differentiated per country;

(b) include elasticities for the main sectors of investment;

(c) allow for environmental impacts of alternative sectors of investment;

(d) and are also expressed in terms of EU Cohesion Policy expenditure and co-financing rates for the main sectors of investment.

The report is divided into three work packages. Work Package 1 consists of sections dealing with sampling investment projects for microeconomic CBA; calculation of shadow prices used in CBAs via CGE RHOMOLO; and performing CBA on sampled projects.

The work package starts with setting the framework of sampling ECP investments (section 1.1). Firstly, the most important sectors of investment in the current programming period are identified. The first step of the exercise is to identify the main sectors of investment in which spill-over elasticities will be evaluated. In general, EU Cohesion policy can be grouped into four broad categories: investment in physical infrastructure; investment in human capital development; investment in R&D; and aid to productive investments. These broad categories can be further classified into several sub-categories resulting in a three-level categorization. Then we divide the population of all projects into homogeneous strata/cells with similar determinants of rates of return to capital, by sector and by country.

The methodology of calculating shadow prices used in the consequent analysis via RHOMOLO is described in section 1.2. The chapter sets up the general equilibrium framework in which such evaluation is carried out via RHOMOLO. The chapter discusses theoretical underpinnings for the calculation of the shadow price of labour and derives consistent formulae. Section 1.3 describes the methodology of ex-post CBA analysis of individual projects with the use of the derived shadow prices. We have grouped various ECP investment projects into 13 groups and developed ex-post CBA methodology separately for each of these groups.

Work Package 2 consists of four sections. Section 2.1 presents the results of econometric analysis and explains our approach to modelling of inter-temporal effects of environmental externalities. Section 2.2 derives theoretical formula which link the overall measures of project efficiency (benefit-cost ratio and ERR) with spill-over elasticities. Section 2.3 explains the methodology used for the calculation of capital stock by ECP sector of investment. The developed methodology is applicable to physical capital, human capital and knowledge capital (RTD). Section 2.4 presents the methodology and estimates of spill-over elasticities for subsectors of investment at the disaggregated level and for all cohesion countries.

Work Package 3 concerns with the aggregation of elasticities for categories of expenditure and sensitivity analysis of obtained elasticity estimates. Derivation of aggregation formulae is presented in section 3.2. The methodology and outcomes of sensitivity analysis are described in section 3.3.

A stand-alone chapter 4 describes the general structure and contents of the excel file which contains the calculated spill-over elasticities and formulas for their aggregation for the use in HERMIN model. Implementation of the derived aggregation formulas in excel is explained.

1 Work Package 1. Microeconomic Analysis: Identification of Economic Rates of Return per Sector of Investment

The micro economic level dataset necessary for the project will include a sample of Cohesion Policy funded projects and other ex-ante and ex-post cost benefit studies needed to achieve the objectives of this study. The objective of WP1 is not to validate the results of the ex-ante analyses, nor is it to perform an ex-post impact assessment of ECP expenditures in the countries chosen for this study. It is rather to provide a suitable dataset for the identification of ERR, ENPV, CBR and other important indicators per sector, and their determinants in the main sectors of investment of the EU Cohesion Policy. On the basis of these results, a comprehensive analysis will be undertaken to relate the said microeconomic indicators from CBAs to spill-over effects. The extent to which CBAs can capture indirect effects which are actually spill-over outside their sector of investment will constitute a crucial analysis of this study.

Modelling is also used in WP1 in order to provide reliable estimates of shadow prices of labour necessary for micro-level CBA analysis. Shadow prices will be estimated using RHOMOLO Computable General Equilibrium (CGE) model for the Cohesion Countries. Discounting will be also duly examined in relation to regional and national government financing to ECP projects. Estimated shadow prices will be used as an essential input into all micro-level CBA studies performed in WP1. This exercise will complement the identification of microeconomic indicators based on ex-ante or incomplete CBAs, to identify robust ex-post indicators, namely ERRs and ENPVs at project level.

WP 1 has the objective of identifying robust estimates of: micro-economic indicators such as CBRs, NPVs and ERRs along with their own determinants by an integrated use of CBAs and general equilibrium modelling.

1.1 Sampling of investment projects

1.1.1 Identification of main sectors of ECP investments based on DG REGIO data warehouse

The first step of the exercise is to identify the main sectors of investment/ fields of intervention to which spill-over elasticities will be evaluated. In general, EU Cohesion policy can be grouped into four broad categories: (1) investment in physical infrastructure, including TEN-T and infrastructure to reduce the negative impacts of waste and pollution; (2) investment in human capital development; (3) investment in research and innovation (R&D); (4) aid to productive investments. This categorization is consistent with the

HERMIN model. Specifically, in the HERMIN model, R&D enters in the aid to productive sectors (APS). Accordingly, "the remainder of the APS, i.e., the element that is not devoted to R&D is assumed to have only transitory Keynesian impacts, and no long-term spill-over impacts" (Bradley and Untiedt, 2008; p. 54).

These broad categories can be further classified into several sub-categories resulting to a multi-level categorization. In this study, we consider three levels of sectoral aggregation. We refer to the first and second level as the categories of expenditure and sectors of investment, respectively, and the third level being the subsectors of investment. A schematic diagram is provided in Figure 2. For discussion purposes, we also included in this diagram the other direct aid to productive sectors. Under this categorisation scheme, the second level categories of physical infrastructure include (i.a) transport, (i.b) (i.c) environment, (i.d) energy and (i.e) ICT. The third level under the transport includes (i.a.1) highways, (i.a.2) railways, (i.a.3) airports, and (i.a.4) ports.

Based on this categorisation scheme, we aggregated and categorised the investments projects under the current programming period (2007 – 2013). Under this programming period, EU cohesion policy is represented with 86 available expenditure categories or field of intervention (FOI) extracted from Business Objects INFOVIEW (BOREGIO) database.[1] Under the current programming period, Cohesion Policy budget is also intended to support Lisbon-related priorities such as research, innovation and new information technologies, energy efficiency and the development and use of renewable and alternative energies, the promotion of entrepreneurship, increasing the adaptability of the labour force, environmental protection and risk prevention, and Trans-European Transport Networks. In addition, the fields of intervention in the previous programming periods (e.g., 2000-2006) are quite aggregated that they preclude us to identify the main sectors down to the 3rd level of aggregation.[2]

The figures inside the parenthesis (Figure 2) correspond to the percentage share of the category/(sub)sector to total ECP investment computed for the 16 cohesion countries including the East German Lander and South of Italy. It is apparent that, around 60% of the total ECP investment in these regions is allocated to physical infrastructure-related projects. Around 25% of the total ECP investment is allocated to the transport-type of projects where the bulk will go construction of roads and highways. This (road/highway subsector) accounts for around 14% of the total ECP fund in these regions which corresponds to a total of 142 projects with each project amounts to an average of 277 million euro. Of the remaining total ECP funds, around 19 and 11% are allocated to human re-

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1 The current programme runs from 1 January 2007 to 31 December 2013 with a total budget of EUR 336.1 billion, which is approximately one third of EU's budget.

2 For example, under the 2000-2006 programming period, expenditures on transport are not classified into highways, railways, etc. Similarly, expenditures on R&D are not classified by public and private sectors (SMEs, large firms).

sources- and R&D- related projects, respectively. It can be concluded that 50% of the total investment to aid to productive sectors consists of R&D.

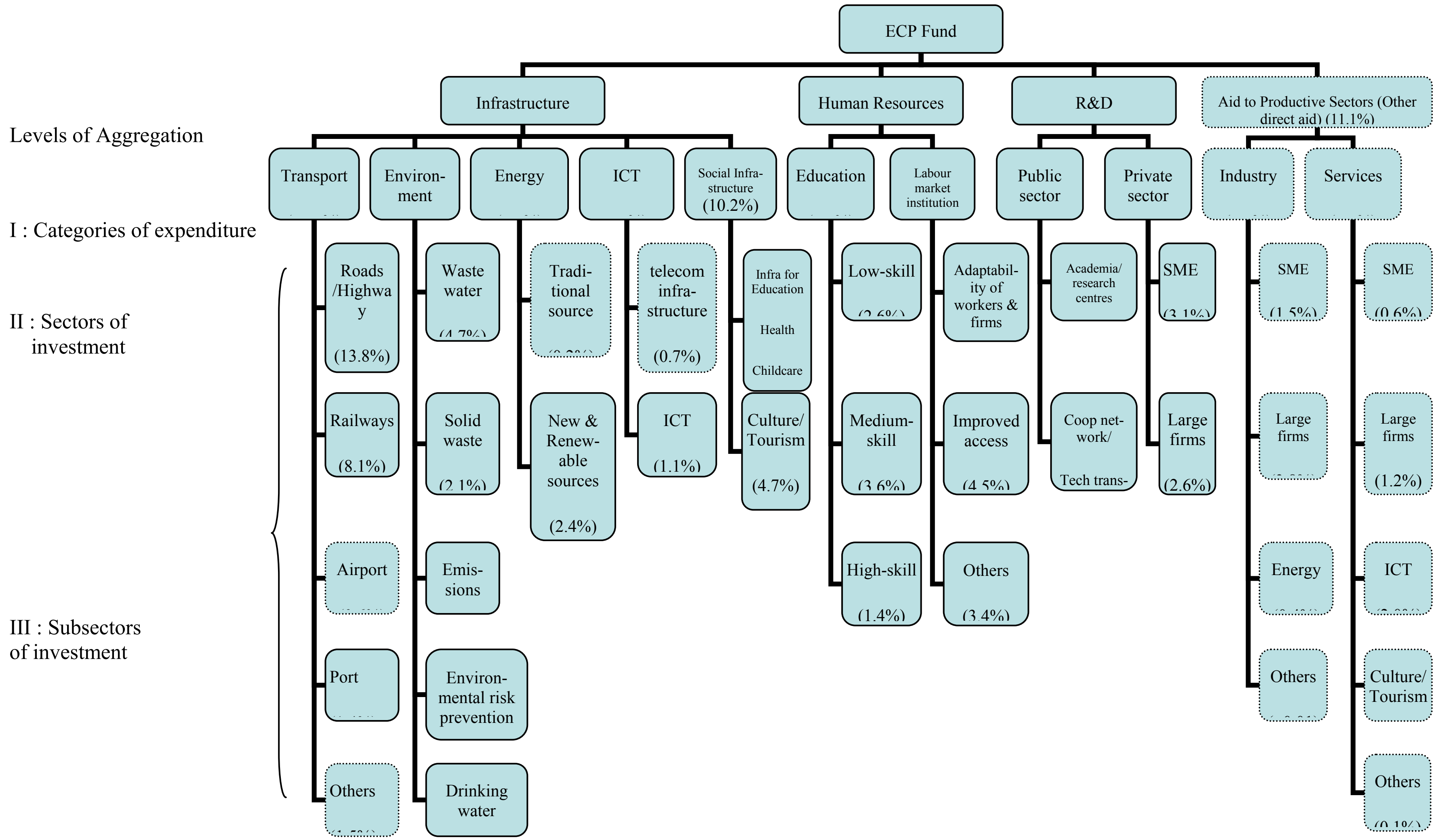
Going back to physical infrastructure, environment-related projects accounts around 16% of the total ECP investments of which around 5% is allocated to (waste) water management treatment. A sizable number of low-budget (41 million euro/project on average) environmental risk prevention projects (235) account another 4% of the total ECP investment. Social infrastructure accounts for another 10.2% of the total ECP investments. ICT and energy account for only 1.8 and 2.6%, respectively. New & renewable energy resources account the bulk of energy infrastructure investment. See the figure below for the main important ECP sectors in terms of budgetary relevance.

We started out with developing project database of ECP investment projects (see Annex 4). We created a database of projects financed by ECP over all Cohesion countries and major sectors of investment. We have a total of 362 such projects in the database, including 208 with ex-ante CBA files and154 with ex-post CBA files.

Projects are selected based on their quality of information and characteristics. Good quality of information means that the correct quantitative indicators that are necessary to calculate NPV, ERR and spill-over elasticities are present, either in ex-ante or preferably in ex-post project documentation. In order to calculate a project's NPV and ERR information on the following aspects is required: the lifetime of the project, the discount rate and individual costs and benefits over the time period (in prices times quantities). Each project that we find is screened for meeting these criteria.

We further select representative sample of projects based on country group and sector selection (see the next sections). Then we choose representative projects based on country and sector grouping for each sector and country group.

Figure 2: Levels of Sectoral Aggregation and Budgetary Relevance.



1.1.2 *Clustering of EU countries according to their economic characteristics*

We have divided all cohesion countries into groups based on their level of economic developments as expressed by their GDP per capita. The basic rationale behind this country breakdown is relative shortage and higher efficiency of capital stocks (physical, human, and R&D stocks) in less-developed countries in comparison to higher-developed countries. Nevertheless, we also compared this country ranking with country rankings based on other indicators that may have a relationship with the efficiency of capital. These indicators included GDP per capita in purchasing power parity, share of agricultural employment. We also considered population density. All above indicators point to similar country rankings, with small exceptions.

We divided the total sample of cohesion countries into three groups:

4. Low-income East European countries: Bulgaria, Romania, Latvia, Lithuania, Poland;

5. High-income East European countries: Slovakia, Hungary, Estonia, Czech Republic, Slovenia, East Germany; and

6. Mediterranean countries: Cyprus, Spain, Greece, Ireland, South Italy, Malta, Portugal.

Another important issue is to take into account the administrative capabilities of member states to implement ECP-funded projects. The World Bank government effectiveness indicator is a good relative indicator of such capacities. In general, it follows the country grouping, since these indicators are highly correlated with the country GDP per capita, as shown in the report for DG REGIO on quality of government[3]. The two exceptions are Greece and Italy, which have rather low rankings and relatively high GDP per capita.

It must be understood however that available CBA files present rather successful projects and the degree of government effectiveness is not likely to be reflected in the project's ERRs and cost/benefit ratios. Indeed, government effectiveness plays a role in the pace and cost of project implementation but a better way to take account of the government effectiveness would be via the inclusion of correction coefficients on ECP investment shocks based on the government effectiveness rankings.

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[3] "Measuring the quality of government and subnational variation". Report for the European Commission DG REGIO. University of Gothenburg, December 2010.

Table 4: Country groupings

	GDP at market prices (euro per inhabitant) 2006	GDP growth rates, 2010-20	WB Governance indicators -- govt effectiveness (country rank)	Agriculture employment (share), 2006	Population density (inhabitants per km²), 2006
Poor East Europe					
Bulgaria	3400	0.058	16	0.42	69.4
Romania	4500	0.058	17	0.51	93.9
Latvia	7000	0.054	12	0.30	36.7
Poland	7100	0.046	14	0.33	122
Lithuania	7100	0.047	11	0.32	54.2
Average		**0.053**			
Rich East Europe					
Slovakia	8300	0.045	9	0.10	110
Hungary	8900	0.035	10	0.19	108.3
Estonia	10000	0.038	5	0.13	30.9
Czech Republic	11100	0.036	6	0.08	132.9
Slovenia	15500	0.026	7	0.19	99.6
Germany (East)		0.017	1	0.15	
Average		**0.033**			
Mediterranean					
Cyprus	19000	0.036	4	0.17	83.5
Greece	18800	0.028	13	0.36	85.2
Ireland	41600	0.035	2	0.17	62.3
Italy	24300	0.019	15	0.41	199.7
Malta	12600	0.037	3	0.07	1281.2
Portugal	15100	0.027	5	0.29	114.9
Spain	24000	0.029	8	0.38	*87.2*
Average		**0.030**			

1.1.3 Identification of representative investment project

The goal of selecting individual projects for analysis is to provide a solid estimate of rates of returns of projects by sector of investment, by country. Hence, the total sample of projects will be divided into strata/cells and typical projects to be analysed will be selected for each cell. The following principles apply:

- By sector of investment: Similar types of projects with similar production function properties (increasing vs. decreasing vs. constant returns impacting upon the ERRs/ENPVs of consequent projects).
- By country: Coverage of Cohesion countries by grouping Cohesion countries with similar characteristics.

These principles are superimposed, so that each cell represents similar project types with same production function properties in the same group of countries. It should be noted however that this approach is not identical for the standard stratified sample approach with random sampling within strata. Random sampling will not provide reliable estimates of ERRs. The reason for this is that our sample of projects is determined by data availability and projects within our sample and the quality of data of projects within each stratum/cell varies to a great degree. As the analysis of our database containing about 300 CBA files of projects financed under ECP shows, the quality of data in the CBA files is highly uneven and a high percentage of project files do not contain information reliable enough for evaluating ERRs. And, indeed, ERRs stated in the project files cannot be taken as they are, without a thorough scrutiny and re-evaluation. Therefore we choose to analyse in-depth a relatively small number of projects with reliable information which will allow us to arrive at solid estimates of ERRs in each stratum/cell. This will provide more reliable estimates than a superficial analysis of a large number of projects with poor data. Based on data availability, we found representative projects for the following ECP subsectors of investment:

- Transport
    - Road
    - Rail
    - Port
- Environment
    - Waste water
    - Solid waste
    - Drinking water

- Emissions and other

- Energy
  - New and renewable sources
- ICT
- Social infrastructure
  - Infrastructure for education, health, childcare, housing
- Human resources
  - Education
  - Labour market institutions
- RTD

As to RTD, we did not find in the database a representative projects but rather resorted to meta-analysis of rates of return to RTD based on practically all studies on the matter in the last half century (see section 1.4). Distinguishing between return to public and private RTD is an extremely uncertain and tricky issue. Literature suggests that public RTD enhances spending on private RTD while not having significant returns on its own. Hence, the estimate of return to RTD is more sound at an aggregate level.

Then we selected typical projects with good data for the ex-post CBA analysis for each sector-country cell. In selecting typical projects, make sure that these projects have relevant values of ERR/ENPV for their respective country group. Here we had to deal with sectors with possible network externalities and we select countries with average network externalities in the country group.

Hulton (1994, 2005) and Fernand (AER, 1999) have demonstrated by using econometric estimation of transport network productivity with externality effects that return to investment in road infrastructure does change as more infrastructure is being added. Fernand demonstrated the change from the high return on road investment in U.S. prior to 1973 (completion of Interstate System) to low return after 1973 (once network is established, opportunity for complementary investments diminish). Hulton showed that effects in developing countries with low density networks (such as India) are much higher than in developed countries with higher density of networks (such as U.S. and Spain). This reasoning leads to likely higher external effects in Cohesion Countries with low density networks than in richer EU countries.

For other sectors with networks relating to, for instance, waste water treatments, we follow this approach as well. In the sectors where we cannot identify networks explicitly, we can base our reasoning on the underlying production functions and expected impacts of extra investment on the whole economy (since the ultimate goal of the study is to assess the spill-over elasticity of investment on the whole economy).

We have to identify in each country group those projects that are done on a moment that the existing capital stock of that particular kind was of an average size. For example, in the case of roads, we have to find a CBA on a road project in a country where the quantity of roads was average for that group of countries. In other words: if that road project was done in a country with a few roads, the benefit would be very high, if the project is done in a country with an already dense road network, diminishing returns and benefits will show up. We want to have a road project that lies in between these two extreme situations. We looked for projects corresponding to the country in the respective country group which has the average ratio of country's GDP to respective country's ECP sector's capital stock. This ratio reflects a relative shortage of capital stock in a particular sector across countries and hence has an indication of marginal return of capital in this sector reflected in ERR.

The database on capital stock by ECP sectors provides the necessary information. The capital stock by ECP sector gives the opportunity to determine how much capital stock a country has. Accordingly, this ratio is also calculated for all countries together in a group; this is considered as average. Then, we look for an individual country with a ratio nearest to that level, and then we look for a project in that country. We are sure then, that in case of roads, we have a project in a country where the capital stock of roads is near the average value of that country group. It is then expected that the benefit from that road project is also representative.

After sampling, we have redone the ex-post CBA in great detail, which includes full demand analysis and ENPV/ERR calculation with shadow prices derived from the CGE RHOMOLO. We also apply to the analysed projects shadow prices for different countries from this particular cell in order to obtain numerous ERRs and ENPVs. In this way we introduce country specificities and obtain multiple estimates of ERRs.

1.2 Calculation of shadow prices

1.2.1 Introducing principle behind the calculations of shadow wage rates

Definition and key elements

Given an objective function and specific constraints, shadow prices are net impact on a social welfare function associated with a marginal variation of a resource.

In a first-best economy[4], marginal rates of substitution and marginal rates of transformation coincide with shadow prices. This means that if one extra unit of a resource is introduced or withdrawn from the economy, it does not matter if it was used for production or consumption. Furthermore, if the allocative mechanism of the economy is given by perfectly competitive markets, shadow prices coincide with market prices.

However, the conditions for a first-best economy are in general not achieved, due to market failures or non-availability of lump-sum transfers. This makes observed market prices a flawed representation of values, which distorts the incentives of both private agents and policy makers. Therefore, shadow prices need to be calculated by adequate models representing the economy at stake.

The concept of shadow prices for the appraisal of public projects gained considerable attention in the early 1970s, after the publication of the Little and Mirrlees, whose application was an important mile-stone in the analysis of public appraisal for less developed countries. The main recommendation of Little and Mirrlees was that the output and/or inputs used by the public sector should be evaluated at world prices or the foreign equivalent price. This method was first proposed by Little and Mirrlees (1968) in a partial equilibrium setting, and then developed further by Ray (1984). A clear derivation of this rule in a general equilibrium setting is made in Dinwiddy and Teal (1996). The statements of Little and Mirrlees should be put in the context of the project aids and establishment of modern industries in the 50s and 60s, with governments actively involved in import-substitution. According to Dinwiddy and Teal (1996), many of these projects were misconceived.

In Dreze J. & Stern N. (1987) a framework is developed to offer researchers and practitioners guidance to structure their thoughts on how market distortions should influence proposals for policy reform. While the model developed is theoretical, it provides a starting point for all types of analysis involving the cost and benefit of public policies in formal setting.

We will follow the approach of Dreze J. & Stern N. (1987) and other authors in defining shadow prices as the social opportunity cost, or the net loss (or gain) associated with one unit less (or more) of a good, service or resource. We define social opportunity costs equal to the change in social welfare, which is evaluated as the sum of utilities ('well-being') of each individual in the society. Utility is defined in a 'strict' sense and is mainly limited to 'consumption based' and individualistic utility.

In this regard, given the objective of this study, it is important to compare net marginal changes in gross domestic product associated with one unit less (or more) of a good, service or resource. In the results of this report, we report these as a means of reinforcing our intuition of shadow prices and checking the validity of our results.

[4] As determined in the formal framework of Arrow and Debreu

Calculation of shadow prices in the presence of market distortions is not a straightforward task as they should allow for market failures and government distortions.

The general equilibrium setting

Economic systems are essentially large interacting systems, using inputs of resources and production factors such as capital and labour to generate added value in the form of goods and services. Goods and services are traded on the domestic and international markets and finally consumed by the agents in the system, which could be households, the government or firms. Payments for the goods are in turn, financed by selling factors of production and resources, owned by households. This means that the flow is circular and that factor incomes, consumption and production should be balanced or 'in equilibrium'. Governments are agents that can influence markets through in particular taxation, regulation, i by public supplies.

In a general equilibrium model, the behaviour of each agent is based on micro-economic theory. This means that consumers and producers will behave rationally, where consumers optimise utility (well-being) and producers maximise profits. The outcome of the system will be determined by the constraints on primary factors and the assumptions on market closure.

Shadow prices are to be derived in a general equilibrium setting, where the theoretical framework is used to gain intuition on the nature of markets and prices, as well as offering a theoretical framework to think about changes in government policies. In some cases, pricing rules or 'rules of thumb' are defined to approximate shadow prices in specific circumstances. The general equilibrium setting offers a unique framework to make such derivations, as it enables an analytical derivation of the welfare effects of marginal changes in the system, including the effects on all markets and all economic agents considered.

Computable general equilibrium: the RHOMOLO model

Computable general equilibrium (CGE) models represent and quantify economic systems by a set of traceable equations, calibrated on a rich dataset of economic interactions. Computable general equilibrium models are based on the general equilibrium theory, but are essentially applied mathematical tools used for policy analysis. The main difference of CGE models with the common theoretical general equilibrium setting is that CGE models that all elements of the model are quantified.

The results in this report were produced by using the RHOMOLO regional CGE model. This model is currently under development by a consortium led by TNO. A version of the model, operational for all eighteen Cohesion Countries was used for calculations. The RHOMOLO model is a large scale general equilibrium model on regional (NUTS-2) level. The full description of RHOMOLO model is provided in Annex 5.

Shadow prices are defined as a change in social welfare, based on adding or withdrawing a unit of some production factor, commodity or service. In this study, changes in social welfare will be analysed by RHOMOLO. The main advantage of using a CGE model like RHOMOLO is that the model has the capacity to calculate welfare effects from changes in policy setting or availability of a factor directly from the model results. This means that RHOMOLO is capable of calculating shadow prices for all factors of production, markets and commodities which are represented in the model.

1.2.2 Modelling of labour market in RHOMOLO

The type of imperfection and their presence on the labour market is important for the correct calculation of shadow prices for labour. In general the following three types of labour markets could be distinguished: (1) competitive labour markets, (2) labour markets with involuntary unemployment and (3) labour markets with involuntary unemployment absorbed in household activities.

The present version of RHOMOLO includes the third type of the labour market and combines modelling of involuntary unemployment with its partial absorption in agriculture and paid household activities. The model differentiates between three different types of labour by level of education. The presence of agricultural sector and sector with paid household activities in the model allows for absorption of some part of involuntary unemployment (especially of low educated labour) in household activities. This will be mostly true for low skilled labour in the rural areas of each country.

In the present version of RHOMOLO unemployment is determined by the wage curve. Wage curve represents one of the "empirical" laws of economics and has been tested in multiple studies all over the world. The theoretical basis of the wage curve is in bargaining and efficiency wage models. It captures the phenomena of the existence of involuntary unemployment in equilibrium.

Wage curve provides a link between the real wage, calculated as (PL_{ed}) divided by a price index (INDEX), and the unemployment rate. According to the wage curve, increase in real wages will reduce unemployment rate since more people will be willing to enter the labour market:

$$\left(\frac{PL_{ed,r}}{INDEX,r}\right) = elasUnemp \cdot \log\left(u_{ed,r}\right) + rest_{ed} \tag{1.1}$$

The parameters $elasUnemp$ and $rest_{ed}$ are determined from econometric analysis. Following the literature $elasUnemp$ in RHOMOLO is set to -0.1 (see Blanchflower and Oswald, 2005).

1.2.3 Calculation of shadow price rates using RHOMOLO

According to Dinwiddy and Teal (1996), a shadow price measures the marginal effect on social welfare of a change in a control variable, where a control variable is any variable which is under the control of the government. It can be for example an endowment of labour, capital, taxes or subsidies.

As has been discussed above, RHOMOLO uses the following measure of welfare change:

$$dW = \sum_h \sum_i \frac{\partial U^h}{\partial C_i^h} dC_i^h = \sum_h \sum_i p_i dC_i^h \qquad (h = 1, 2, ..., H), (i = 1, 2, ..., n) \tag{1.2}$$

We make an assumption that the marginal utility of income does not vary between the household types. Following Dinwiddy and Teal (1996), we also assume that changes in control variables do not have any impact upon the value of the marginal utility of income. The prices used in the calculation of welfare change are market prices, which might include some distortions. The shadow price of a resource (labour, capital or good) is given by the marginal change in welfare due to the marginal variation in a resource, such that the change in welfare is written as:

$$dW = \frac{\partial W}{\partial L_j} dL_j + \frac{\partial W}{\partial K_s} dK_s + \frac{\partial W}{\partial X_s} dX_s \tag{1.3}$$

Where $\partial W / \partial L_j$ is the shadow price of labour of type j and L_j is the endowment of the corresponding type of labour; $\partial W / \partial K_s$ is the shadow price of capital of sector s and K_s is the capital stock of the corresponding sector; $\partial W / \partial X_s$ is the shadow price of good s and X_s is the output of the corresponding good.

To understand how the RHOMOLO model can be used to derive shadow prices of labour, it is necessary to understand how the model is calibrated and what it gives as a simulation output. Any applied CGE model will reproduce the baseline dataset if no changes in control variables are introduced. Given that the data on market prices is quite rare and of insufficient quality one normalises all initial prices of an applied CGE model to one. This means that the model only produces the relative change in the market prices.

RHOMOLO incorporates the representation of aggregated groups of commodities and services. For example agriculture in the model incorporates a range of various non-homogenous products such as grains, vegetable, fruits etc. From detailed statistics we know prices of very detailed commodities but not for the aggregated groups of commodities such as agriculture. In general if we would know the prices of disaggregated commodity groups such as grains, vegetable, fruits etc. in case of agriculture and quantities (tons) in which they are produced we could calculate the prices of aggregated group "agriculture". However, this detailed information is not available from statistics and hence we cannot know the price of the aggregated commodity groups used in RHOMOLO.

Because of the lack of data about prices of the base year of various aggregated groups of commodities and services (explained above), we make an assumption that all prices in RHOMOLO are equal to one in the base year and that the produced and consumed quantities are equal to their monetary values available from statistics (supply and use tables). Let us consider an example of production of agriculture: from statistics we know that the monetary value of the output of agriculture is equal to 120 mil Euros. We assume that the price of the aggregate commodity "agriculture" is equal or normalised to one, hence the output of agriculture in normalised physical units are equal to 120 units in the model. In case of labour endowment, we know the total wage bill of the economy. Let us assume that it is equal to 50 mil Euros. We make an assumption that the price of labour (wages) are normalised to one, hence the normalised quantity of labour is equal to 50 units.

Let us now assume that we have performed a simulation with RHOMOLO. This has resulted in the new price level, reported by an applied CGE model, of 1.05 (remember that it is equal to1 in the baseline). This means that the market price has increased by 5% relative to the baseline. Prices of commodities and services in monetary units are not calculated explicitly in applied CGE models. Applied CGE models only calculate the new set of normalised prices. In order to derive new market prices using the output of an applied CGE model one should multiply the initial market prices by the normalised prices from applied CGE model. In case of our example, one needs to multiply the initial market price P with 1.05 in order to get the new market price, such that $P_{new} = 1,05 \cdot P$.

Normalization of prices in applied CGE model means that the labour endowment and capital endowment will be given in monetary units rather then in hours or number of people employed, that is $LS_{ed,r} = LH_{ed,r} P_{ed,r}$, where $LH_{ed,r}$ is the number of hours worked and $P_{ed,r}$ is hourly wage rate.

Using notation of RHOMOLO the we call the change in social welfare resulting from the marginal change in endowment of labour valued in monetary units (LS) as conversion factor, $CF_{ed,r}$, calculated as (under assumption and all the change in labour endowment is due to the change in hours worked):

$$CF_{ed,r} = \frac{\partial SWF}{\partial LS_{ed,r}} = \frac{\partial SWF}{\partial (LH_{ed,r} P_{ed,r})} = \frac{\partial SWF}{\partial LH_{ed,r}} \frac{1}{P_{ed,r}} = P_{ed,r}^{shadow} \frac{1}{P_{ed,r}} \qquad (1.4)$$

Where $P_{ed,r}^{shadow}$ is the shadow price calculated as the change in welfare due to the change in labour endowment in hours worked, As we have seen from the above example the prices in RHOMOLO are set to one in the baseline normalized to one and do not correspond to the real market prices. We apply the same conversion mechanism as in the example above to calculate the real (non-normalized) shadow prices as (which follows directly from the previous formula):

$$P_{ed,r}^{shadow} = P_{ed,r} \cdot CF_{ed,r} \tag{1.5}$$

Where $P_{ed,r}^{shadow}$ is the shadow price and $P_{ed,r}$ is the initial market price. The above formula for the shadow price follows This means that the values of $CF_{ed,r}$ calculated from RHO-MOLO model as $\partial SWF / \partial LS_{ed,r}$ can be interpreted as **the conversion factors**, where the conversion factor is by definition calculated as the ratio between shadow price and market price.

In correspondence with the above discussion, in all subsequent paragraphs, the RHO-MOLO model results are called conversion factors and not shadow prices. In order to calculate shadow prices we need to multiply the conversion factors calculated with RHO-MOLO with the annual wages in Euros. The results of these calculations are presented in Annex 6. The full description of RHOMOLO model is given in Annex 5.

1.3 Methodology and its application to micro-level CBA analysis by sector of ECP investment

1.3.1 Highways

1.3.1.1 Demand analysis

Demand analysis of road transport is performed at both the national/macro-economic level and project level. Long-term projections of the future growth of population, GDP and GDP per capita, as well as the growth of passengers and of freight transport are provided by (former) DGTREN (*European Energy and Transport Trends to 2030*: *Update 2007*). Average growth rates are available for ten year periods from 1990 to 2030; actual growth levels were obtained from EuroStat. Transport demand is measured by EuroStat in terms of passenger-kilometres and ton-kilometres (millions). The projections by DGTREN provide stable growth paths and consistent demand for transport at the national level. In the absence of estimates, appropriate substitutes are used. For example, growth projections for Slovenia are applied to Eastern Germany, since the rate of economic development and the level of GDP/capita in Eastern Germany are comparable to those of Slovenia. Similarly the pace of economic development in Cyprus, not available from EuroStat or the OECD, is based on figures from Greece.

Size figures for road networks are provided by EuroStat in kilometres. These networks are categorised by road type (ranging from motorways to regional roads). In general, the current use of the road/highway sections in the projects under consideration is determined by the ratio of passenger kilometres and road kilometres. Each kilometre of road in a country 'processes' a certain amount of passenger kilometres or ton-kilometres. If possible, regional data as provided by EuroStat (e.g. Eastern Germany) are used. If these figures are not available, national ratios are taken. In case of the Polish road project national figures are used, as numerous bottlenecks across the country improved. In the case of Cyprus, it is possible to do more precise measurements, because of the fact that the initial road use is given.

The current level of demand is assessed for the starting year of the project, i.e. the year that the first expenditure of a project started. In the Business As Usual (BAU) scenario, growth of demand is determined by national DGTREN projections. A correction by regions is not made, since the road projects comprise the entire, or a large part, of the countries concerned. It is assumed that the projects do not influence the national demand figure; this would change the DGTREN projection. The project, it is assumed, shifts the supply from inefficient roads to more efficient roads which will lower the cost of transport. This shift benefits road users. This benefit is measured and monetised in euro. Therefore, in the Alternative scenario, annual demand during the 30 year-period is determined by the DGTREN scenario.

The shift in demand as a result of the project is determined for several categories: business passengers, other passengers and freight. The demand shift comprises existing users experiencing a benefit and new users who are attracted by the additional infrastructure. The change in road capacity in the projects is based on the increase of average speed (and capacity) and the difference in required time due to complete the alternative new or improved road. It is assumed that if average speed rises by 10%, the use of the improved road also rises by 10 percent. Existing users experience a time advantage of 10 percent. It is assumed that new users, who would take alternative roads with the same cost in time in the BAU scenario, experience the benefit of the faster road after completion of the project. Accordingly, the price is measured in terms of hour per kilometre (i.e. the time required to drive a certain amount of kilometres). As a result of the project, the required time will be lower. With the available project information, this could be assessed quite precisely. Average speed indications are provided in the CBAs.

1.3.1.2 Total investment, operating costs and revenues

Total investment in the three projects has been 312 million euro (Poland), 1.174 million euro (Eastern Germany) and 114 million euro (Cyprus), respectively. Only the real investment cost is given and used in the recalculations. Operating cost and revenues are not available, except for the Eastern German road project. The toll , according to the road CBA Eastern Germany, will yield 3.1 million euro in revenue annually. Operating cost of the roads is not given either. The cost of maintenance is considered to be equal in both the BAU and the Alternative scenarios.

1.3.1.3 Conversion of market to accounting prices

Since no financial analysis was made for any of the road projects, market prices were not applied in the recalculations. Time value is a key indicator in transport CBAs. Completion of the projects aim at a cost reduction measured in time for road users. Road users are attributed time values. The sources for these values are HEATCO and the Guide to CBA of investment projects. These values are used in all calculations. Shadow prices are given in 2002 euros per hour, resulting in an estimate of the total time advantage generated by each of the projects. The consumer surplus is calculated for business passengers, other passengers and freight transport companies, and expressed in the number of hours by using the rule of half. Accordingly, the value of transport time savings of business passengers, other passengers and freight in the future is adjusted for economic growth and rising GDP per capita. In making this adjustment, an equation explaining the value of time by country in 2002 by GDP per capita is used. A rising GDP per capita in the future, following the DGTREN scenario, will result in a higher value of time. The equation of value of time in the future of business passengers is as follows:

Passenger: $\text{Ln VTTS} = 1.798 + 0.474 \ln \text{GDP/Cap}$

Freight: $\text{Ln VTTS} = 1.0654+0.34 \ln \text{GDP/Cap}$

The VTTS of other passengers on the road follows the annual change of business passengers. We assume that these coefficients will be constant in the future.

1.3.1.4 Monetisation of non-market impacts and inclusion of indirect effects

Non-market impacts and inclusion of indirect effects are calculated only if mentioned as explicit goals of the projects. These include safety (decrease of the number of fatalities), toll and environment. Environmental impact is calculated for passengers as well as for freight transport.

Value of Statistical Life (VSL)

The values of statistical lives are given by the Guide to Cost Benefit Analysis of Investment Projects and its source HEATCO. These values are given in factor prices and in Purchasing Power Parities (PPP). Since all future projections are from DGTREN and at real GDP levels, the values at factor cost are used in the recalculations. Future values of VSL are calculated as follows:

$$\text{Ln VSL} = -2.494 + 0.928 \text{ Ln GDP/Cap}$$

The number of fatalities avoided, as provided in the project CBAs, is not used as these numbers appeared overly optimistic. Instead, as the road rehabilitation programme deals with provincial roads being upgraded to highways (as in Poland) or new highways replacing provincial roads, the expected number of fatalities is adjusted using Dutch figures on the distribution of fatalities over highways, provincial roads and urban areas. This is expressed as a ratio of passenger kilometres on the various types of highways. Highways tend to exhibit more fatalities per passenger kilometre than provincial and regional roads.

Since, however, there are far more provincial and regional roads than highways, the majority of fatalities occurs on provincial and regional roads. These numbers are projected on the kilometres of road that are added or upgraded. In the BAU-scenario the provincial numbers are taken, whereas in the Alternative scenario the highway numbers are taken. The difference is multiplied using the VSL results to arrive at the social benefit. The development of the number of fatalities over the years is taken from EuroStat and extrapolated into the future. The number of fatalities generally tends to decrease. It is assumed that this will also happen in the future. In the case of the Polish project, this results in higher safety, but not as such in the Eastern German project. Highways look safer, but in this case a lot of traffic is shifting from a provincial road to highway (the existing users). On highways average speed is higher than on provincial roads. Per unit of passenger kilometre, the fatality rate on highways is higher.

Toll

Truck toll has to be paid on German highways, also on the new highway between Wismar and Magdeburg. The toll is based on a price per kilometre. Since the demand analysis provides the number of passenger kilometres and ton kilometres in the BAU as well as in the Alternative scenario, the amount of kilometres is known for both scenarios. Accordingly, it is assumed that the share of heavy trucks obliged to pay toll is the same on the new highway connecting Wismar and Magdeburg. The composition of the trucks by type of fuel and weight levels above a certain threshold is not known for this highway section. The unweighted average of toll tariffs is taken to multiply the number of ton kilometres. The actual tariff develops parallel with the value of time of freight in the future. The higher that value, the more transport companies are willing to pay for toll. The CBA of this project yields a revenue of 3.1 million euros, held constant for a period of 30 years. Recalculating this value results in a revenue amounting to 3.9 million euro in the starting year and is increasing subsequently due to rising value of time and rising volumes due to economic growth.

Environment

The environmental impact is calculated as an external effect from passenger (car) traffic and freight for several air emission components: NOx, NMVOC, SO2, Nonurban PM25, and CO_2. Monetary values of these components are provided by CE Delft. European values are used, based on emissions per kilometre for cars as well as for trucks.

1.3.1.5 *Calculation of ENPV, ERR and other CBA indicators*

Table 5 :Results of recalculating the three road projects

	ENPV (5%)	ERR	BCR
	Million Euro	%	
PL	49.8	6.2%	1.4
DE (E.)	-456.4	0.9%	0.7
CY	-10.7	4.1%	1.3

The Eastern German road project appears unprofitable. The Benefit/Cost Ratio (BCR) is below 1. The main cause of this result is the negative social benefit due to air emissions, especially CO_2. Also, the relatively high cost and the rather large number of years of construction (6 in total) contribute to the negative result. The Polish case shows positive figures, however emissions were not taken into account. Safety improvements contributed to the positive result. The Polish project consists of removing traffic bottlenecks resulting in increased average car speed. Combined with the growth of the time value in the future, a relatively large amount of valuable time is saved.

1.3.2 Rail

1.3.2.1 *Demand analysis*

Similar to the approach followed concerning road transport, demand analysis of rail transport is performed at two levels: the national and macro-economic level and project level. Long term projections of future growth of population, GDP, GDP per capita, and growth of passengers and freight transport by rail are based on DGTREN (*European Energy and Transport; trends to 2030: Update 2007*). These growth levels are given for ten year periods between 1990 and 2030; actual growth levels were obtained from EuroStat. Demand for transport is given by EuroStat in passenger-kilometre and ton-kilometre (in millions). The projections of DGTREN provide stable growth paths of the future and consistent demand for transport at the national level. The rail network in terms of kilometres is based on EuroStat figures. In general, the current use of the road/highway sections in the projects is determined by the ratio passenger kilometre/ per kilometre of rail.

Sometimes this ratio is given for regions by EuroStat; if not available national ratios are taken.

The Polish project provides detailed information on the improvement of several railway sections to be renewed. Several bottlenecks were removed, allowing for higher speed limits and higher punctuality. For each section, the relative increase in speed could be calculated. The current level of demand is assessed for the starting year of the project, i.e. the year that the first expenditure of a project starts. In the BAU scenario, demand growth is determined by the national DGTREN projections. A correction by region is not made. The projects concern railway sections in large parts of the country (Poland, Ireland), or in less sizeable regions (Slovenia). It is assumed that the projects do not influence the national demand figure; otherwise this would change the DGTREN projections. It is assumed that the projects shift goods and passenger transport from inefficient railway sections to more efficient railway sections. This will lower the cost of transport, benefiting rail users. This benefit is measured and monetised. Therefore, in the alternative scenario, after completing the project, annual demand during the 30-year period is consistent with the DGTREN scenario.

The shift in demand due to the project is determined for several categories: business passengers, other passengers and freight. Existing users have a benefit, while new users will be attracted. The change in capacity of the railway sections in the projects is based on the increase of average speed and the difference in required time due to the alternative new or improved railway sections. It is assumed that if average speed rises by 5%, the use of the improved railway also rises by 5% percent. Existing users will have a time advantage of 5%, and it is assumed that new users will also have the benefit of a faster train connection after completion of the project.

Thanks to the project, travel time decreases. With the information provided by the CBA of the projects, travel time savings could be assessed quite precisely. Time savings are further valorised.

1.3.2.2 Total investment, operating costs and revenues

The total investment cost in the three projects amounts to, respectively:

- 135 million euro in the Polish project,
- 106.8 million euro in the Irish project,
- 18.1 million euro in the Slovenian project.

Operating cost and revenues are not given in the CBA documentation or are only partially given.

1.3.2.3 Conversion of market to accounting prices

Since no financial analysis is made in any of the road projects, market prices have not been applied in the recalculations. Value of time is a key variable in transport CBAs. Fulfilment of the projects aims at a reduction of travel time for users of rail transport. The corresponding values are given by HEATCO. Actually the time value for rail passengers is identical to the HEATCO values for road users. The cost of freight transport per ton/hour on railways is lower than on roads (costs given by HEATCO). Consumer surplus is calculated for business passengers, other passengers and freight transport by applying the rule of half,, expressed as the valorised number of travel hours.

Accordingly, the future values for transport time savings (VTTS) of business passengers, other passengers and freight are used for economic growth and rising GDP per capita. The same approach as for road transport was taken, using an equation explaining the value of time by country in 2002 by GDP/capita (see section 1.3.1.3). A rising GDP per capita in the future, according to the DGTREN scenario, will result in a higher time value in the future.

The VTTS of other passengers on the road follows the annual change of business passengers.

1.3.2.4 Monetisation of non-market impacts and inclusion of indirect effects

Other non-market impacts or indirect effects are not mentioned in the project documents as goals of the railway projects. The sole goal was to remove infrastructure bottlenecks in order to raise the average speed of trains.

1.3.2.5 Calculation of ENPV, ERR and other CBA indicators

Table 6:Results of the recalculations of three rail projects

	ENPV (5%)	ERR	BCR
	million euro		

PL	910.6	30.0%	10.5
SI	115.8	30.0%	11.4
IE	994.4	37.2%	16.1

In general, the three railway projects each yield high economic revenues. The reason is that in all three country groups the bottlenecks result in a relatively large loss of time. Hence existing users will gain large benefits. Moreover, the Cohesion countries are countries in a catching-up stage. The use of rail transport compared to road transport is large; hence the benefits will occur immediately after completion of the projects. However, demand for rail transport does not rise rapidly in the DGTREN scenarios. Demand for road transport rises faster. Thus the benefit of roads in Cohesion countries will be further away in the future. Moreover, the relative cost of road improvements is higher.

1.3.3 Port

Many investments in the extension and improvement of ports have been made throughout the last decades, despite the advance of air transport of passengers. Freight transport continues to play an important role in the supply of manufacturing activities. This affects demand analyses, since cargo estimations can be too optimistic following equally over-ambitious industrial projections.

Examples of port related investment project include the dredging of canals, creation of berths, increased cargo handling capacity, extension of land sites for ground transport, reinforcement of levees etc.

Port assessment is no exception to the general picture that institutes and authorities possess extensive knowledge about the evaluation of infrastructure related projects. Extensive manuals have been written about possible direct effects, indirect effects and externalities concerning waste water.

1.3.3.1 Demand analysis

Unlike the demand analysis for road and rail transport, the demand analysis for port infrastructure is only executed at the level of the project. The time horizon of the used ex-post analyses was such that actual revealed demand could be found in the CBA studies for a period of one decade. These increasing demands for port transportation were compared to EuroStat data on total gross weight of goods handled and total TEU, discerned to share of the studied ports in the national total. Some stated demand increases from the studies were reduced if the total demand of the particular project had a disproportionate share of the national total.

In the long term, a projection of future growth of population, GDP, GDP per capita, and growth of passengers and freight transport by rail is given by projections of DGTREN (*European Energy and Transport; trends to 2030: Update 2007*). These growth levels are given for ten-year periods between 1990 and 2030; actual growth levels were obtained from EuroStat. Demand for transport is given by EuroStat in passenger-kilometre and ton-kilometre (in millions). The projections by DGTREN provide stable future growth paths and demand for transport at the national level.

1.3.3.2 Total investment, operating costs and revenues

Investments in ports turn out to be underestimated in the ex-ante analysis. Operating costs are relatively high given the high amortization rate of stock and the continuous need for dredging. All studied projects include benefits referring to the reduction of required maintenance, which obviously doesn't mean that there is no need for maintenance. Direct revenues are acquired from harbour charges, but this is not the main source of benefits. Reduction of handling time for a limited number of different cargos is a major benefit.

1.3.3.3 Conversion of market to accounting prices

All port projects induce increased ship traffic, implying negative external effects. These effects are relatively small compared to the other societal effects. We can convert to accounting prices using a wide range of acknowledged shadow prices from HEATCO and the eco-invent database. Shadow prices are for instance expressed in the monetary value per kilogram, cost of emissions per ton-kilometre etc.

1.3.3.4 Monetisation of non-market impacts and inclusion of indirect effects

Indirect effects like land value, value added and job creation are relatively dominant benefits. Increased value added can be derived from (for instance) industries in the direct vicinity or value added logistics. This in turn raises land values for other spatial use since the supply of land becomes relatively smaller. The increased added value means in some cases that low and medium skilled jobs are created, with corresponding labour markets usually experiencing significant unemployment.

1.3.3.5 Calculation of ENPV, ERR and other CBA indicators

Key indicators are calculated based on investment costs, operation and management costs, revenues, indirect effects and some environmental external effects. Regardless of the length of the construction phase a time horizon of 30 years is assumed to decrease uncertainty. To calculate the Net Present Value and the Cost/Benefit ratio a social discount rate of 5% is used. The resulting rates of economic return are within the scope of average values for port projects on EU level.

1.3.4 Waste water

The improvement and/or extension of waste water facilities is a classical infrastructural investment. The actual projects contain the replacement and/or construction of pumping stations, sewers and related access points, pipelines, treatment works (filters, reservoirs) and natural filtering systems.

One of the first objectives of waste water systems is to increase hygiene in densely populated areas. But given the fact that sewers have been used for a long period in human history, and that the coverage of such networks is quite high, this objective is not mentioned in CBA studies dating from recent decades. Instead, projects aim to reduce the incidence of pollutants and increase efficiency.

The large majority of EPC sectors in the field of environmental improvements can be regarded as basic infrastructure. This implies that institutes and authorities have a profound knowledge about the evaluation of these projects. Extensive manuals have been written about possible direct effects, indirect effects and externalities concerning waste water.

1.3.4.1 Demand analysis

The demand for waste water treatment works is basically the result of demographic changes and standards for quality of life. Demand analyses from the studies are readily checked and all are used in our analysis. The related CBA studies also show that the total demand for wastewater is relatively predictable. Although some ex-post analyses state that demand has changed during the construction phase of project, this varies only very little. For that reason the number of litres per household and thereby the total waste water demands are applied as put forth by the CBA studies. In most cases initial demand, before implementation of the project, was given as well.

1.3.4.2 Total investment, operating costs and revenues

Total investments and cost for operations and maintenance are at the core of the financial analysis of every study, and therefore widely available.

First we have to appreciate a special feature of environmental infrastructure. In most cases demand will increase along with tariff increases. This is counter intuitive, but is explained by the increased standards of living: efficient and clean infrastructure can both meet new demand and allow for price increases.

As was already observed for the preceding types of infrastructure, two types of consumers are relevant for the calculation of monetised welfare change in terms of consumer surplus: existing users and new users. In case of replacement of old facilities it is possible that a project yields no new consumers. They will face the full effect of quality and tariff increase: rectangle A. In case of extension of infrastructural networks the rule of half applies, consumer surplus of new users are depicted by triangle B. If both replacements and extensions are relevant, than we can sum up both effects.

Tariff increases are based on expected returns needed to repay the investment and operational costs. They are given by the CBA studies in most cases, and rebased from another (neighbouring) country and base year if missing.

1.3.4.3 Conversion of market to accounting prices

In environmental related infrastructure, external effects are very important. Externalities in transactions are most common when we consider spatial planning and natural resources. We can convert to accounting prices with the use of shadow prices. For environmental studies, we used values based on Dutch governmental research (CE Delft, 2010). Shadow prices are expressed in monetary values per kilogram. Auxiliary sources confirm that there is an international consensus on the level of these prices. Nevertheless, numbers are rebased on the national level and base year of investment, because from our methodological point of view shadow prices are related to GDP per capita.

1.3.4.4 Monetisation of non-market impacts and inclusion of indirect effects

Cost-benefit manuals describing waste water project evaluation mention the following benefits from indirect or non-market effects: the number of unskilled and skilled/competitive jobs, the reduced amount of pollutants, increased land value, (residential and industrial) the re-use of purified water, the avoided depletion of groundwater and the residual value of investment.

The jobs and pollutants related benefits had an impact on the economic value of waste water projects. Other benefits were hardly mentioned in the studies and therefore disregarded in case they were not part of the project objectives.

1.3.4.5 Calculation of ENPV, ERR and other CBA indicators

Using the information above, the calculation exercise based on investment costs, operation and management costs, revenues, indirect effects and non-market effects can be performed. For both costs and benefits, yearly sums are discounted to express them in base year values.

1.3.5 Solid waste

The improvement and/or extension of solid waste treatment systems has gained attention throughout the last decades. Although waste collection has a long history in urban development, recycling and reducing emissions represent new requirements to waste treatment. The actual projects contain the creation of landfills, recycling centres/sorting facilities, improved furnaces, connections to heat and electricity networks as well as emission reduction measures.

Solid waste projects feature the most diverse set of objectives of all environmental projects. They aim at decreasing collection costs (mostly by preventing costs of alternative/obsolete solid waste treatment systems), reducing pollutants, producing energy and recycling materials.

The large majority of EPC sectors in the field of environmental improvements can be regarded as basic infrastructure. Again, this implies that institutes and authorities possess sound knowledge about the evaluation of these projects.

1.3.5.1 Demand analysis

The demand for solid waste treatment works is a complex result of demographic changes, technological and economic developments, energy prices and land value. Since it is unfeasible to check for all these factors, demand analyses from the studies are used in our analysis. Some ex-post analyses state that demand has changed during the construction phase of project, however they cannot predict demand during the operational phase.

1.3.5.2 Total investment, operating costs and revenues

Tariff increases, investment- and operational costs are available from the available studies. Solid waste treatment, like waste water, features the attribute that increased prices go alongside increased demand. For the application of the rule of half in this situation, see section 1.3.4.2. An additional aspect in the financial analysis is the re-use of energy and recycling materials. Estimates for these prices are available from both the related CBA studies and general sources.

1.3.5.3 Conversion of market to accounting prices

In environmentally related infrastructure, external effects are very important. Externalities in transactions are most common when we consider spatial planning and natural resources. See section 1.3.4.3 for an explanation of the applied shadow prices of pollutants.

1.3.5.4 Monetisation of non-market impacts and inclusion of indirect effects

Cost-benefit manuals on the subject of solid waste treatment mention the following benefits from indirect or non-market effects: the number of unskilled and skilled/competitive jobs, the reduced amount of pollutants, increased land value, (residential and industrial) factor for increased hygiene and the residual value of investment.

The jobs and pollutants related benefits had an impact on economical value of waste water projects. Other benefits were hardly mentioned in the studies and therefore disregarded in case they were not part of the project objectives.

1.3.5.5 Calculation of ENPV, ERR and other CBA indicators

Calculations were made similar to the method explained in section 1.3.4.5

1.3.6 Drinking water

Drinking water is a basic necessity of life, and therefore a highly predictable research variable once demographic changes are known. However, demand can be reduced if the general public is made aware of water saving measures that directly lead to lower household expenditure. The actual projects contain the replacement and/or construction of pumping stations, pipelines, treatment works (filters, reservoirs) that have a distinct use from waste water facilities and the training of workers.

Where other environmental services (solid waste collection, waste water treatment, risk prevention) are not always made available to households, drinking water has always closely followed demand. This resulted in a situation where extension of drinking water facilities is mainly driven by population growth. Very few projects evaluated during the last decades had the aim to connect households that were not enjoying drinking water supply from the network.

Like the other environmental sectors, the large majority of drinking water system improvements can be regarded as basic infrastructure. This means that institutes and authorities have profound knowledge about the evaluation of these projects. Extensive manuals have been written about possible direct effects, indirect effects and externalities concerning drinking water.

1.3.6.1 Demand analysis

The demand for extension of drinking water networks is basically the result of demographic changes. Demand analyses from the studies are readily checked and all are used in our analysis. The related CBA studies also show that the total demand for drinking water is relatively predictable. Some analyses mention a change in the demand for drinking water when people are informed about water saving measures. These changes on the household level can be significant (from 180 to 110 litres of water per person per day) and have an unpredictable effect on the revenues. In our studies we used the revealed demand as given by the ex-post studies.

1.3.6.2 Total investment, operating costs and revenues

Tariff increases as well as investment- and operational costs are available form the studies. Solid waste treatment, like preceding public amenities, features the attribute that an increased price goes alongside increased demand. See section 1.3.4.2. for the application of the rule of half in this situation. The unpredictability of demand on household level was discussed in the previous paragraph. For our revenue calculation there the best assumption was to use revealed demand.

1.3.6.3 Conversion of market to accounting prices

Unlike other environmental projects, drinking water projects are usually not directed at reducing pollutants. Therefore pollutants' shadow prices could not be applied. The only shadow price we could use was an expression of the societal value of improved quality of drinking water. This value was given by a Dutch study (PBL, 2009) and rebased to the appropriate year and geographical location.

1.3.6.4 Monetisation of non-market impacts and inclusion of indirect effects

Selected cost-benefit manuals on drinking water mention the following benefits from indirect or non-market effects: number of unskilled and skilled/competitive jobs, increased land value, (residential and industrial) added productivity from increased hygiene, avoided depletion of groundwater and the residual value of investment.

The jobs and improved quality related benefits impact on the economic value of waste water projects. Other benefits were hardly mentioned in the studies and therefore disregarded in case they were not part of the project objectives.

1.3.6.5 Calculation of ENPV, ERR and other CBA indicators

The calculation was made similar to the method explained in section 1.3.4.5.

1.3.7 Emissions and environmental protection

This sector has a miscellaneous character and features a wide range of environmental projects. The actual projects contain on the one hand improvement of air quality. The aim is a reduction of air pollution, related to energy production and transport. The projects show a strong focus on reducing emissions or concentrations of COx, (e.g. carbondioxide) SOx, NOx, PM10 (particulate matter) and O_3 (ozone). Environmental protection projects aim for programs such as forest fire risk reduction, expansion of forests, flood prevention, reduction of Ozone Depleting Substances, industrial safety, agricultural waste management and biodiversity stimulation.

Of all environmental sectors, these categories are the hardest when it comes to providing accurate demand analysis. Whereas other environmental services are closely related to demographic changes, these environmental investments are rather related to standards of living and thereby GDP per capita. There is also a huge political influence on demand, where both local awareness and incentives from the EU play a significant role.

Benefits of these investments are subject to on-going debate. This means that we closely follow evaluation of factors that are generally regarded as beneficial, and avoid valuation of uncertain effects.

1.3.7.1 Demand analysis

As mentioned previously, demand generally depends on the content of the project and the related objectives. However, the three studies involved have the following demand analysis. An air emission reduction project has its demand analysis based on international levels of mg per m^3 of certain substances (CO, PM_{10} etc.). A forest fire reduction evaluation bases its demand analysis on the total acreage of forest in the whole country, and the acreage of forest potentially lost in a single forest fire. The third study comprises of an ODS reduction programme. The demand analysis in this case is the general assumption that these substances needed to be totally phased out of the industrial process.

1.3.7.2 Total investment, operating costs and revenues

Only in case of reduced industrial risk (production value), flood protection (real estate value), and forest management (logging production) can actual market prices be used to calculate benefits. In all other cases, we only can use the studies to provide us with investment costs.

1.3.7.3 Conversion of market to accounting prices

If consumer surplus and tariffs do not justify an investment, the related external effects will become very important. For most air quality improvement and environmental risk reduction studies, we can use the values based on Dutch governmental research (CE Delft, 2010). Shadow prices are expressed in monetary values per kilogram, value of life, diverted cost per ha, recreational value per ha. Numbers are obviously rebased on the national level and base year of investment, because from our methodological point of view shadow prices are strongly related to GDP per capita.

1.3.7.4 Monetisation of non-market impacts and inclusion of indirect effects

No general cost-benefit manuals are available on these projects, but it is possible to assess the generally accepted indirect or non-market effects: number of unskilled and skilled/competitive jobs, increased land value (residential and industrial), reduction of pollutants and the residual value of investment.

The jobs, land value and pollutant related benefits have an impact on the economic value of air quality and on environmental risk reduction projects.

1.3.7.5 *Calculation of ENPV, ERR and other CBA indicators*

Calculations were performed similar to the method explained in section 1.3.4.5.

1.3.8 Energy

Energy investment projects aim at promoting the installation and development of new industrial plants and supporting the production and distribution of energy. Energy infrastructure can be distinguished into traditional energy sources and new and renewable energy sources including energy efficiency. The development of renewable energy is a central aim of the European Commission's energy policy, with the objective of reducing carbon dioxide (CO2) emissions, which is a major Community objective (in order to meet the Kyoto agreement). Increasing the share of renewable energy in the energy balance is one of the European community targets.

Documented cost and benefit analyses of energy investment projects are mostly found in the Baltic as well as in eastern European countries. The CBAs discussed in this section are based on the Klaipeda Geothermal Demonstration Project that uses low-temperature geothermal water as a renewable, indigenous energy resource in district heating systems in the Republic of Lithuania[5], and the municipal district heating (DH) enterprise in Krakow, Poland. These projects share a common objective to improve energy efficiency of heating systems in their respective jurisdictions. Obviously, these two projects differ in many aspects, including scale and total amount of investment. The aim here is to illuminate relevant contrasts with regard to the perceived benefits, including differences in their quantification and general methodology.

1.3.8.1 *Demand analysis*

The evaluated geothermal plant in Lithuania provides 41 MW of heat (41 percent from geothermal heat and 59 percent from boilers running on natural gas) to the district heating system, representing about 12 percent of Klaipeda's current heat demand (350 MW). It was expected at the time of project appraisal that the geothermal plant would provide 10 percent of the city's heat demand. However, a reduction in demand for heat combined with network efficiency improvements and a higher than expected heat output from the geothermal plant, have increased the percentage of Klaipeda's heat demand that the implementing agency EG is able to supply. If the installed boilers were operated at their maximum capacity during the winter season, EG's total capacity would amount to 68

[5] The Klaipėda Geothermal Demonstration Plant is a geothermal heating plant in Klaipeda, Lithuania, constructed during the late 1990s and early 2000s and financed by a loan from the World Bank (US$5.9 million) and a grant from the Global Environment Facility (US$6.9 million). The projects implementation completion report can be found in the World Bank document WB (2009).

MW, consisting of 17 MW geothermal energy, 48 MW from natural gas and 3 MW from economizers extracting energy from stack gases.

As for the municipal DH enterprise in Krakow, its number of customers increased by 47 percent from 3,308 in 2000 to 4,465 in 2008. About 1,000 customers, 25 percent of the total, are now served continuously with domestic hot water replacing inefficient individual heating in (mostly electric) water boilers. Accordingly, the primary energy consumption of the electric water boilers would have been more than five times higher than the incremental energy consumption for the DH system.

1.3.8.2 Total investment, operating costs and revenues

The total investments for these projects are available in their respective cost benefit analyses. Cost savings from the use of natural gas instead of heavy fuel oil used for heating (e.g., mazut) constitute part of the benefits. In turn, these reductions in fuel consumption are expected to have considerable environmental benefits by reducing carbon dioxide (CO2), sulphur dioxide (SO2), total particulate matter (TPM) and nitrogen oxides (NOX) emissions. Cost savings due to higher energy efficiency also contribute to the total benefits.

While environmental benefits account for no less than 75 percent of the total benefits in the geothermal (Lithuania) project, they represent only 6 percent of the total benefits in the municipal DH enterprise project in Krakow. Fuel efficiency increase accounts for most (65 percent) of total benefits. Improvements in productivity (reduction in staffing) and savings from maintenance cost also contribute to total benefits.

1.3.8.3 Conversion of market to accounting prices

No conversion is made to accounting prices.

1.3.8.4 Monetisation of non-market impacts and inclusion of indirect effects

It will be clear from the description above that total benefits from emission reduction and energy efficiency can be calculated by comparing the project with alternative traditional fossil fuel sources. In both projects, environmental benefits are recalculated using unit prices of the different environmental pollution (CO2, SO2, TPM and NOX) that were derived from the ExternE study.

1.3.8.5 Calculation of ENPV, ERR and other CBA indicators

Based on a cost savings calculated from emission reductions from consuming mazut and with corresponding environmental benefits computed based on a conservative scenario of taking the unit prices of environmental pollutants coming from a “low stack” as provided by ExternE, an ERR of 21 percent is obtained for the geothermal project. This is 6 percentage points higher compared to what was reported in the original study where a 12 year evaluation period was applied. The corresponding NPV based on a social discount rate of 5 percent is calculated to be US$ 18.2 mil.

For the Krakow municipal DH enterprise project, the time horizon of the cost benefit analysis is 24 years. The investment period spans the first seven years. The NPV is calculated to be 408 mil PLN based on a social discount rate of 10 percent. This amounts to 3,73 mil PLN if environmental benefits are not taken into account. The corresponding ERRs are 48 percent with environmental benefits and 43 percent without environmental benefits.

1.3.9 ICT

Telecommunication infrastructure investments are divided between the local and non-local scale. The benefits of telecommunication projects are mainly to be found in increasing efficiency and accessibility of the existing and additional services provided. Benefits can be calculated by the time saved for each communication and/or by calculating the willingness-to-pay for new additional services by the users. Investments in telecommunication can lead to positive externalities by network spill-overs and negative local environmental effects. Another important aspect is the flexibility and adaptability to future developments of telecom services.

The number of ICT projects in the database is limited. Ex-post CBAs of ICT projects consist of local scale telecommunication investments (7/8) that have been executed in Eastern Europe during the 1990s. All projects concern network expansion and congestion reduction. After the communist era telecom network coverage was limited, featuring waiting time for new users who wanted to become connected. Telecom in those years was mainly focused on business customers. Throughout the 1990s investments were made in Eastern Europe to catch up and supply demand. Although the number of projects is limited, the quality of the ex-post CBAs is good. The CBAs consist of well documented financial analyses of the assessed projects.

The main benefit is the increased network access through the provision of 220 thousand new lines, of which 213 thousand are supplied for business customers. The number of lines increased stepwise during the investment period.

About 85 percent of the project costs are spent on goods, such as new equipment, transmission systems and local networks. The other part of the investment costs is spent on management costs and transaction costs for custom duties and bank loans.

1.3.9.1 Demand analysis

The main benefit is the increased network access, expressed in the number of new connections. The benefits are reflected in the payments for additional telephone services because of the network expansion. The amount paid for subscription charges is a minimum indication of the willingness-to-pay of consumers for telecommunication (PWC, 2004).

1.3.9.2 Total investment, operating costs and revenues

In the financial analysis of the ex-post CBAs a well documented financial analysis is included. The financial analysis contains information on investment costs, operational costs and revenues and is available for most part of the evaluation period of 15 years. Future revenues and operational costs are set to the final year available.

About 85 percent of the investment costs are spent on goods, such as new equipment, transmission systems and local networks. The main sources of revenues are the usage and fixed costs fees paid by new business and residential customers.

1.3.9.3 Conversion of market to accounting prices

For the investment costs no conversion is made to accounting prices.

1.3.9.4 Monetisation of non-market impacts and inclusion of indirect effects

ICT technology contributes to economic growth and productivity of the total economy. Investments in ICT facilitate product innovations and process innovations leading to a more efficient production process and an increase of Total Factor Productivity growth. Network effects have an important role, partly captured by spill-over effects. Spill-over effects are benefits that are not fully internalised in the usage and fixed charges of business customers.

1.3.9.5 Calculation of ENPV, ERR and other CBA indicators

Based on the financial analysis of the ex-post CBAs, ERR and ENPV are calculated straightforward.

The time horizon for the evaluation of telecommunication infrastructures projects is 15 years. The investment period is five years. Maintenance costs occur in all project years. ENPV is calculated based on a social discount rate of 5 percent.

1.3.10 Social infrastructure

The Guide to Cost Benefit Analysis of Investment Projects (DG REGIO, 2008) correlates health infrastructure projects with the prevention and/or treatment of pathologies and refers to different categories of population. Accordingly, the overarching goals are increasing life expectancy and life quality.

The methodology described in this section is based on the CBA study of the Health Sector Reform Project in Romania.[6] The strategic purpose of this programme is increased health for the Romanian population, eventually yielding savings from restructuring and downsizing hospital facilities. The project is composed of three main components: maternity and neonatal care, emergency care services, and primary health care and rural medical services. Component 1 is intended to support the Government's programme to improve maternity and neonatal services throughout Romania. The programme aims to upgrade and improve health services for pregnant women, new-born children and their mothers. Component 2 helps to develop and implement integrated automated ambulance dispatch capability and upgrade hospital emergency areas. Both interventions are essential to maximizing the impact of the investments that have been made to date, and the effectiveness of the emergency medical services system generally. The objectives of component 3 are three-fold: to improve the quality of services of family doctors mainly through new initiatives in primary care (multipurpose health centres, group practice, practice association, mobile labouratory, community nurses, home care, ambulatory prescribed drugs) in rural areas and small urban localities; to increase the access to health services provided from multipurpose health centres by family doctors, ambulatory care specialists, community nurses, home care, social services; and to better integrate primary care with ambulatory and hospital services, consistent with the National Health Programs.

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[6] The Health Sector Reform Project is a US$80 mil World Bank-funded project to support the second phase of the health sector reform programme set out in 2000

1.3.10.1 Demand analysis

According to the DG REGIO CBA Guide, the benefits of the investments in health infrastructure can be derived primarily from morbidity and mortality changes, added quality of services or efficiency gains. These are reflected in the different components of the Romanian project (Table 7). It is assumed that the project-related changes in the health care system will target up to 80 percent of Romania's population under component 1, around 50 percent for component 2, and around 20 percent of the population for component 3.

Table 7: Assumptions used and perceived benefits by component

Component	Objectives	Benefits (indicators)	% Reduction	Target Population
1. Maternity and Neonatal Care	- Facility rehabilitation for maternity and neonatal care units	Reductions in		17.8 million (80%)
	- Technical assistance and training	- maternal mortality	15	
		- neonatal mortality	20	
		- number of low birth weight babies	20	
		- number of Caesarean sections	15	
2. Emergency Care Services	- upgrade hospital emergency areas	Reductions in		
	- integrated ambulance dispatch capability	- mortality from traffic accidents, injury and poisoning, ischemic heart disease and other external causes	10	11.1 million (50%)
3. Primary Health Care and Rural Medical Services	improving the accessibility and quality o f basic medical services:	Reductions in		4.4 million (20%)
	- Multipurpose Health Centres	- hospital discharges for infectious diseases	10	
		- infant mortality	20	

1.3.10.2 Total investment, operating costs and revenues

The total investments for the respective investment projects are given in the cost benefit analyses.

The benefits over a time horizon of 10 years are estimated for the three major project components: benefits accruing from the Maternal and Child Health component, the Emergency Medical Services Restructuring component and the Primary Health Care component. The benefits from component 1 are the expected benefits accruable to the project from a reduction in the number of maternal and infant deaths, the average length of stay following deliveries, the number of Caesarean sections, and low birth weight babies. For component 2, the analysis assumes a reduction in the number of deaths resulting from accidents, injury and poisoning, ischemic heart disease and other external factors. In the context of component 3, strengthening rural primary health care would be expected to reduce the incidence and duration of hospital stays, eliminate unnecessary admissions, reduce consultations and eventually yield savings from restructuring and downsizing hospital facilities. Direct benefits result from a reduction in the costs of provision of services. Indirect benefits are related to the potential life years saved by the project and the economic and financial value of increasing productivity.

In the original CBA set-up, it was estimated that the project will potentially save more than 4,700 lives as a result of applying the assumptions to the pattern of mortality in the country as reported in Table 7. The reduction in mortality was taken as the base line assumption to calculate the indirect benefits of the project. The estimates of reduced mortality are based on conservative estimates based on historical trends in Romania and international literature on cost-effectiveness.

1.3.10.3 Conversion of market to accounting prices

No conversion is made to accounting prices.

1.3.10.4 Monetisation of non-market impacts and inclusion of indirect effects

To calculate the indirect benefits, the discounted life years saved attributable to these reductions are then converted to monetary terms by using estimates of the discounted life time earnings lost from each death, as reflected by the use of average wage levels, adjusted for labour market participation, and the number of years of life lost for each death casualty.

To remain consistent with the methodology used in the other investment projects, we recalculate equivalent life years lost based on the calculated value of statistical life (VSL) using the estimated VSL equation that was reported in section 1.3.1.4. Specifically, a life-year lost in a particular period is the VSL for that period divided by the average life expectancy (in number of years). This implies that for the benefits due to reductions in neonatal and infant mortality, the full amount of the estimated VSL for that particular period is assumed for each number of lives saved. On the other hand, the benefits from reductions in maternal mortality are calculated from the life years lost for each life saved, which is based on national information about the fertility rate (1.4 per women), mean age at first birth (25 years old), and life expectancy of women (76 years old).

1.3.10.5 Calculation of ENPV, ERR and other CBA indicators

The investment period spans the first 10 project years. The first benefits occur during the third project year. We extend the time horizon for which benefits will be distributed to 28 years. We take a conservative assumption by taking half of the original reduction rates and target population across all components. The result is an ERR of 25 percent and an ENPV of US$ 231 mil based on a social discount rate of 5 percent.

1.3.11 Education

One of the determinants of economic growth is human capital. Investments in education contribute to future human capital (DG REGIO, 2008). Investments in education focus on basic education, vocational education, higher education or specific learning programmes for young, disabled and/or unemployed workers. The education projects are expected to have social economic impact on the labour market, resulting in higher earnings for participants in the education programme. Key issues for the evaluation are labour market opportunities with and without the education investments. Measuring the net impact of education is complex. By definition, the result of an alternative situation (the case without education) remains unobserved when an individual participates in an educative programme. Here, also the heterogeneity of people plays a role. Another issue is that compared to other expenditure categories, investments in education take a relatively long time span before economic returns can be enjoyed. For example, pupils who benefit from investments in primary education will be part of the labour market only after a period of ten to twenty years. This implies that potential economic returns of increased human capital will appear ten to twenty years after the project is completed. This explains why ERRs for investments in education are not calculated for all projects in the database.

Empirical results of economic effects of education are limited in the economic literature. One of the most common sources of rates of return estimates are Mincerian earnings functions (Mincer, 1974). These functions apply regression analysis to earnings data on a cross-section of individuals to relate people's earnings and to their level of schooling and their work experience. In the Mincerian method (Mincer 1974) the basic earning function is defined as:

$$\ln W_i = \alpha + \beta S_i + \gamma_1 EXP_i + \gamma_2 EXP_i^2 + \varepsilon_i \qquad (1.6)$$

where the natural logarithm of hourly wage (W) is estimated on the years of schooling (S), years of labour market experience (EXP) and its square (EXP2). The coefficient on years of schooling can be interpreted as the average private rate of return to one additional year of schooling (Jimenez and Patrinos, 2004). The coefficient of years of schooling is also called the Mincerian coefficient. The Mincerian coefficient varies by country and is on average 10 percent, based on a sample of over 100 countries (Psacharopoulos and Patrinos 2004). The Mincerian approach is often used to evaluate benefits from education from a private point of view. From a private point of view costs of education are the education fees and missed wages during the education period. Benefits are higher earnings after graduation. From a societal point of view, in addition, the extent to which education is financed publicly/privately and the externalities of education are important.

Returns of education are diminishing with income. For developed countries we observe comparably lower returns to education because human capital is less scarce than in developing countries. Furthermore, returns to education are declining over time. Jimenez and Patrinos (2004) indicate a decline of -0.6 percent in the period 1992-2004 due to increasing supply of education worldwide. This results in an increase in the number of years of schooling and a decrease in the returns. Psacharapoulos and Patrinos (2002) show updated results for Mincerian coefficients and number of years of schooling by country. This is an important literature source for the calculation of ERRs.

The Mincerian approach fits in the main benefits of education projects mentioned in the *Guide to Cost Benefit Analysis of Investment Projects* (DG REGIO, 2008). Here, three main types of benefits are identified:

- Number of pupils who found (or are expected to find) productive employment. Without investment they will be underemployed or unemployed;

- Expected increased income of students due to avoided under-employment and a better position on the labour market;

- Alternative method is willingness-to-pay, valuable as the average fee students would have to pay to take similar private courses. Not recommended.

Based on EU CBA guide 2002, ERRs of investments in schools, universities etc. are between 3.4 and 47.5 percent and have an average of 17.5 percent (and a standard deviation of 14.2 percent). Also they argue that long term studies in other countries can be used to quantify the impact on the labour market.

1.3.11.1 Demand analysis

Examples of indicators that are identified in cost benefit evaluations of education projects are the number of enrolments (or enrolment rates), drop-out rates, achievement rates of students, completion rates, graduation rates, number of schools to be built, boarding accommodations, the quality level of the teaching staff, etc.

Because we apply the Mincerian approach, we focus on CBAs in the database that provide information on the number of students (for example, the number of enrolments, completion rates etc.). If available for the country of the CBA, we apply the results of the Mincerian coefficient from Psacharapoulos and Patrinos (2002). Otherwise a comparable country is selected based on the number of years of schooling and GDP per capita.

1.3.11.2 Total investment, operating costs and revenues

Total investments of the education projects are given in the cost benefit analysis in the database by year. The investment period is usually around four years and refers to the period education is provided. Revenues are not mentioned in the cost benefit analysis and. An economic analysis of benefits is not available.

Part of the investments is in facilities and educating teachers. Future participants in education programmes can benefit from this increase in capital stock of the education sector. For simplicity we neglect these benefits and focus on the impact of the investments on students during the investment period.

1.3.11.3 Conversion of market to accounting prices

For the investment costs no conversion is made to accounting prices.

For the social returns of investments in education, it is important that earnings reflect the marginal productivity of labour (Mingat and Tan, 1996). The match between observed earnings and productivity is closest in competitive labour markets, but such markets may not always exist. To calculate the impact of education on future earnings by the Mincerian coefficient, we will use shadow wages.

1.3.11.4 Monetisation of non-market impacts and inclusion of indirect effects

Based on the Mincerian earning function private returns of education can be calculated as increased future income. However, this approach underestimates the social return because the positive externalities of education are omitted in the evaluation (Jimenez and

Patrinos, 2008). Education does not only lead to higher productivity of a single worker, but also of co-workers and/or productive industries. Also societal benefits could arise from more social cohesion and less crime. Another example is that parental education affects children's educational level child's health. Therefore CBA is not truly a practical tool for public decision-making for education project investments (Jimenez and Patrinos, 2004). To summarize, existing estimates of the social returns to investment in education typically fail to take account of externalities in the cost-benefit calculation.

1.3.11.5 Calculation of ENPV, ERR and other CBA indicators

The time horizon for the evaluation of education projects is 15 years. The investment period is around four years. ERR and ENPV are calculated using a social discount rate of 5 percent.

1.3.12 Labour market institutions

A large share (around 11 percent) of the total budget for the ECP expenditures over the 2007-2013 period is spent on labour market institutions. Investments in active labour market programmes (ALMPs hereafter) play an important role in many Eastern European countries. Investments in labour market institutions focus on accessibility to employment and adaptability of workers. Accessibility to employment contains investments in for example job counselling, self-employment assistance, employment and relocation services, and public employment programmes. Improvement of the labour market employability of workers can be attained by providing training and retraining programmes for the unemployed. Main benefits of labour market programmes are the reemployment of participants and the increase of future earnings of the participants. Also, labour market investments can have non market effects, for example on crime, health, social participation and the reduction of poverty.

In general, data on cost-effectiveness of active labour market programmes are not available. This is due to lack of data, a limited number of studies and the failure of use control groups (DG EMPL, 2006). Also by defining the impact of ALMPs possible deadweight losses, substitution and displacement effects are possible pitfalls. A central problem is the construction of counterfactuals on evaluating social labour programmes (Heckman, Lalonde and Smith, 1999). That is, what is the net impact of the labour market programmes on participants and the rest of society? A control group is missing in the projects in the database, which results in difficulties when measuring the net impact of the ALMP.

In the literature, the economic effects of ALMPs are evaluated using either a micro-economic macro-economic approach. The micro-economic approach focuses on the individuals that participated in the programme. The micro-economic approach is favourable in the literature but demanding in terms of data requirements. In order to evaluate the net impact of a labour programme participants have to be compared with a representative group of non-participants. These net impacts can be employment and/or increases in earnings. Based on a meta-analysis the net impact of reintegration projects on job opportunities is fairly small (De Koning, 2008), about 3 percent. For training and counselling only, the net impact tends to be higher, about 7 percent. The net impact of ALMPs is dependent on the social-economic situation and tends to be higher during a recession period. This is because the chance of finding a job anyway increases when unemployment rates are low. Public employment programmes tend to have a negative impact on future employability (see for example Rodriguez-Planas and Benus, 2006). Participating in public employment programmes can have a negative signalling function on future labour demand.

The macro approach evaluates at the societal level, including both positive and negative impacts of activation on overall employment. In the macro approach the focus is on the augmented matching function. The matching function is the relation between the stock of vacancies, number of unemployed and the number of outflows from unemployment to employment. In empirical studies at the macro level, many programmes do not exhibit a positive impact after accounting for indirect or aggregated effects but show positive results at the micro level (De Koning, 2001). Based on a micro-approach assessing the effect on individual participants they find strong positive effects of the labour market programme in the short run. Based on a macro approach where they estimate the augmented matching function only a small positive effect was found. Welfare effects at the aggregate level are not accounted for; the assumption is that participants of the programme find jobs that otherwise would have gone to a non-participant.

The project database on CBAs of labour market institution projects is very limited. Also, in none of the appraisals a CBA was calculated. Unfortunately, this also influences the data availability for these projects. Only one project could be evaluated in Romania.

1.3.12.1 Demand analysis

Main benefits of labour market programmes are the re-employment of participants and the increase of future earnings of the participants. The minimum requirement for the demand analysis is the number of participants of the programme, together with placement rates. In case of nationwide programmes unemployment rates of a country can be taken into account.

This gives an indication of the gross benefits of the investments. But these benefits can not be fully attributed to the investment. That would imply the unrealistic assumption that without the programme there would be no reemployment. In order to calculate the additionality of effects empirical research is needed.

For the case of Romania, the active labour market programme has been evaluated based on a rich sample (Rodriguez-Planas and Benus, 2006). The main findings imply that three types of programmes (training and retraining, self-employment assistance, employment and relocation services) are successful from a cost-benefit point of view for both individual participants and society as a whole. Public employment was found detrimental for future employment perspectives of participants. The focus of the evaluation was on the employment experiences and earning prospects of its participants compared to a control group. The control group consists of individuals that continued to search for a job openly as unemployed. The rich dataset of this study consists of a follow-up survey over a four-year period (1999-2002) of about 4,000 randomly chosen registered unemployed individuals in 1999. Participants participated in 1999 in at least one of the four types of programmes and were monitored for three years. About half of them were active in one of the four types of programmes, the others were not. The net impact of the programmes is estimated by the use of a kernel-based matching estimator on the conditional independence assumption (CIA). This is a valid approach because of the rich set of data including baseline information (for example, pre-programme earnings, employment history and experience).

The study focuses on two types of outcomes: reemployment probability and worker's earnings. Depending on the type of programme, the probability of being employed after two years is between 0 and 8.5 percent. The impact on future earnings is strong: between 0 and 58 percent (!) depending on the type of programme. The results on employability are in line with the meta-analysis studies (for example, De Koning, 2008). Welfare effects on an aggregated level are not taken into account.

1.3.12.2 Total investment, operating costs and revenues

Total investments of the labour market programme are given in the cost benefit analysis. All costs are made during the period when the unemployed participate in the programme, usually less than one year. Revenues of the programme are not available in the cost benefit analysis but can be estimated with the help of additional information from the empirical evaluation study of Rodriguez-Planas and Benus.

Benefits on reemployment are assumed only to take place in the short run. Benefits because of higher future earnings are taken into account for the short run (for all types of programmes) and the long run. Long run effects are assumed to occur only in case of training and retraining programmes. Based on the Mincerian earning coefficient and depreciation rate of human capital (see section 1.3.11 on education projects), long term effects are estimated. The duration of the training programmes is assumed to be 0.5 year for the Mincerian earning function.

1.3.12.3 Conversion of market to accounting prices

For the investment costs no conversion is made to accounting prices.

Future earnings and higher employment rates are calculated using shadow prices for Romania. For simplicity, shadow prices are assumed to be equal to the minimum wage in Romania derived from EuroStat.

Future growth rate of the shadow wages are assumed to be equal to the forecast of GDP growth in Romania (based on the baseline scenario of DG TREN for 2030).

1.3.12.4 Monetisation of non-market impacts and inclusion of indirect effects

Investments in labour market programmes can have non-market impacts because of less crime, higher social participation and higher quality of life. This influences health of participants and reduces poverty. Another effect is reduced deadweight losses due to reduces taxes required to pay for unemployment benefits. No empirical results are found in the literature to calculate these non-market effects, therefore non-market impacts are not taken into account in the evaluation.

1.3.12.5 Calculation of ENPV, ERR and other CBA indicators

The time horizon of the cost benefit analysis of labour market programmes is 30 years. The investment period is one year. All investment costs are allocated in the first year of the time horizon. Benefits arise after the investment period.

1.4 Evaluation of economic effects of RTD

Available CBA files or operational programmes document project costs and expenditures on R&D but do not make attempt to evaluate resulting returns on R&D. This is understandable, given the complexities of evaluating R&D impact which has not been completely resolved in the literature yet.

R&D investment is characterized by a very high uncertainty at the level of individual R&D investment projects. Thus it is very hard to arrive at a single estimate of return to R&D given this stochastic nature of R&D investment and highly skewed distribution of success with a small number of projects yielding the bulk of benefits. There are a number of case studies on individual technologies available in the literature starting back in 1950s, such as on agricultural research, a number of industrial innovations, computers, medical research and others (Griliches 1958, Huffman and Evenson 1993, Seldon 1987, Mansfield et al. 1977, Tewksbury et al. 1980, Bresnahan 1986, Wiesbrod 1971, Trajtenberg 1989). The studies generally show very high rates of return to investment on R&D in some cases about 100 percent (agricultural research) but in the minority of cases moderate rates of around 10 percent. National Institute of Standards and Technology (U.S.)

routinely calculates rates of return on a number of its programmes (NIST 2011), with very high rate of return estimates of NIST research programmes, often in excess of 100 percent. The overall impression from the case studies in the literature is that they tend to pick the winners. At the same time, we need to have an estimate of the average rate of return to R&D.

Studies of return of investment on large samples of firms provide a more balanced picture of returns to R&D, since large samples allow compensating for the skewness of distribution of benefits from research in evaluating the average rates of return. Hall et al. (2010) reviewed practically all studies on returns to R&D based on firm- or industry-level data published in the last 50 years geographically covering developed Europe as well as North America and East Asia. There are two principle techniques for evaluation of the rates of return to R&D – production-function approach and cost-function approach. The studies show a large variety of estimates of returns. However, the authors established that the majority of studies show rates of return from 10-20 percent in case of the cost function methodology and from 20-30 percent in case of the production function methodology.

Therefore, the best possible (conservative) estimate of the rates of return of R&D would be around 10 percent. We take this estimate for the evaluation of spill-over effects from investment in RTD.

The benefit/cost ratio associated with this rate of return follows from the standard specification of the equation used for the estimation of the rates of return in virtually all studies (Hall et. al, ibid.). The benefits of investment in R&D are modelled in this specification as the function of investment of the same period. Hence, the cost/benefit ratio equals one plus the rate of return.

2 Work Package 2. From Microeconomic to Macroeconomic Analysis: Relating Spill-over Elasticities to Benefits to Costs Ratios

This work package establishes the link between the micro-level analysis carried out in WP 1 and economy-wide assessment of spill-over effects of investments by sector of investment of the European Cohesion Policy. This is done by deriving in a General Equilibrium framework a set of theoretical formulas, which provide a link between the CBRs of CBA studies and spill-over elasticities. The formulas are quantified using the results of simulations with RHOMOLO and include all main general equilibrium effects and inter-sectoral input-output linkages.

This WP also includes supplementary statistical calculations, such as the estimation of capital stock, human capital stock and research and technological development stock. The estimates of these three types of stock are needed to express the magnitude of spill-over effects of the ECP in terms of percentage changes of underlying indicators. The estimates of capital stocks are used in the formulas for the aggregation of details spill-over elasticities to the level of details used in the HERMIN model.

2.1 GDP, total factor productivity, and inter-temporal effects of environmental externalities

2.1.1 Estimating the elasticity of substitution between capital and labour

The CES (constant elasticity of substitution) production function is an important building block in applied general equilibrium modelling. One of the key parameters is the elasticity of substitution between factors of production (Kemfert, 1998). In this section, we will survey literature on the estimation of the substitution elasticity between capital and labour. Both theoretical issues and empirical evidence will be discussed, considering various possibilities for specification and estimation. Based on empirical literature, we will present an overview of representative estimates for the elasticity of substitution, both at the aggregate and sector levels. An outline of data and approach for own empirical analysis, to be conducted for European countries, is given as well.

2.1.1.1 Specification of econometric equations

As argued by León-Ledesma et al. (2010), the value of the elasticity of substitution has important economic modelling implications. The aggregate substitution elasticity has been shown to affect equilibrium differences in factor returns and convergence, movements in income shares, trade and development patterns and the effectiveness of active labour market policies. For instance, the substitution elasticity between capital and labour in production may be as important as the savings rate or the growth rate of the labour force in determining the steady-state income level in dynamic growth models (Klum et al., 2007).[7] In the context of this project, the values of elasticities of substitution between capital and labour are important parameters within the production functions for the various sectors in the regional computable general equilibrium model.

Most of the empirical literature on substitution elasticities follows the framework of CES production functions. This framework applies some standard assumptions, which we will follow. Most notably, the elasticity is assumed to be time invariant. Although more flexible frameworks, such as VES (variable elasticity of substitution) and translog functions, allow time varying elasticities, empirical identification becomes problematic if time-varying estimates are sought for (León-Ledesma et al., 2010). Secondly, we need to take into account technological progress parameters. We follow standard assumptions on the functional specification of technological progress, which are necessary for identifiability. Whether technological progress is factor-augmenting (technical bias) or neutral, may affect the empirical estimation; not taking into account potential technical bias in the empirical specification may lead to omitted variable bias in estimating the elasticity of substitution.

The CES production function is specified as follows:

$$Y_t = F\left(A_t^K K_t, A_t^L L_t\right) = C\left(\phi\left(A_t^K K_t\right)^{\frac{\sigma-1}{\sigma}} + \left(1-\phi\right)\left(A_t^L L_t\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}. \tag{2.1}$$

Here, *Y* stands for gross domestic product. The primary inputs to production are capital (*K*) and labour (*L*). These can be expressed in efficiency units, using their factor-specific productivity parameters denoted by A^i (for *i* either *K* or *L*). The parameters in the model are interpreted as follows: *C* is an efficiency parameter (scalar); φ is a parameter related to capital intensity[8] of production technology. The parameter of most interest to us is σ: the elasticity of substitution between capital and labour.

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[7] Paraphrased based on a citation in León-Ledesma et al. (2010), p. 1334 ff.

[8] It is often denoted as a distribution parameter. Following Euler's law for linearly homogeneous (of degree one) production functions, related to the capital income share. This interpretation becomes direct if the production function is properly normalized (see León-Ledesma et al., 2010, for application of normalization in estimation).

The elasticity of substitution is defined as:

$$\sigma = \frac{d\ln\left(K/L\right)\big)}{d\ln\left(w/r\right)}. \tag{2.2}$$

It is point elasticity, relating the percentage change in factor proportions to the percentage change in the ratio of real factor prices (or ratio of physical marginal products). The easiest way to derive the elasticity, is to make use of the CES factor demand following from the cost-minimizing input choice subject to the production function constraint (assuming perfect competition on factor markets and output markets). Hence, determine the relevant first order conditions for minimizing total input costs. The least-cost combination condition, stating that each input is hired until its marginal product equals its factor price, reads (see Chiang and Wainwright, 2005, p. 398):

$$\frac{F_L}{F_K} = \frac{w}{r}.$$

Using the above, we find:

$$\frac{1-\phi}{\phi}\left(\frac{A^K}{A^L}\right)^{\frac{1-\sigma}{\sigma}}\left(\frac{K}{L}\right)^{\frac{1}{\sigma}} = \frac{w}{r} \leftrightarrow \frac{K}{L} = \left(\frac{\phi}{1-\phi}\right)^{\sigma}\left(\frac{w}{r}\right)^{\sigma}\left(\frac{A^L}{A^K}\right)^{1-\sigma}$$

Log-linearising this equilibrium equation and applying the definition of the elasticity, we can corroborate that the elasticity of substitution equals the parameter σ in the CES production function, which justifies the use of σ in equation (2.2):

$$\ln\left(\frac{K_t}{L_t}\right) = \alpha_0 + \sigma\ln\left(\frac{w_t}{r_t}\right) + \left(1-\sigma\right)\left(\gamma_L - \gamma_K\right)t, \tag{2.3}$$

where we define the technology parameters A^L and A^K to grow at a constant growth rate of γ_L and γ_K, respectively, and normalize A^L and A^K to the value one at t = 0. The final term on the right will be zero if σ = 1 (Cobb-Douglas production function), or if $\gamma_L = \gamma_K$ (Hicks neutral technological progress). In case of technical bias ($\gamma_L \neq \gamma_K$), the time trend is important to avoid potential omitted variables bias.

Alternatively, we can use the separate first order conditions (FOC) of profit maximizing input choice for capital and labour. These are (see León-Ledesma et al., 2010):

$$\ln\left(\frac{Y_t}{K_t}\right) = \alpha_1 + \sigma\ln\left(r_t\right) + \gamma_K\left(1-\sigma\right)t \tag{2.4}$$

$$\ln\left(\frac{Y_t}{L_t}\right) = \alpha_2 + \sigma\ln\left(w_t\right) + \gamma_L\left(1-\sigma\right)t \tag{2.5}$$

Hence, based on the first order conditions (FOC) of cost minimization, a reduced form equation can be derived for direct estimation of σ. Equation (2.3) opts for combining the first order conditions for both primary inputs. Alternatively, the estimation strategy may be to estimate one of the separate FOCs for either input (for example, because of data availability).

The general approach of using single input demand equations based on FOCs is a widely used empirical strategy (see Juselius, 2008 and León-Ledesma, 2010, for overviews). Alternatives are a systems approach (combining production function and input demand FOCs, discussed in León-Ledesma, 2010), and a cost function approach (most often based on translog cost functions, see Koetse et al., 2008). The cost function approach, as the FOC input demand function approach, relies on cost minimization.

In contrast to the FOC input demand function approach set out here, input price ratios are related to optimal cost shares for inputs instead of optimal factor proportions. As shown in Draper and Manders (1996), who follow a cost function approach, the so-called one-price-two-factor elasticity (Morishima elasticity) is a-symmetric. This elasticity is derived from cross-price and own-price elasticities of factor demand. We will consider direct estimates of σ, such as those based on the FOC input demand approach, which are in principle symmetric (although estimates may differ according to which FOC is estimated). Because of its focus on translog functions and Morishima elasticities, rather than CES functions, we will not discuss the cost function approach in detail. It may be clear, though, that both approaches are strongly related.

2.1.1.2 Overview of empirical evidence

In this section, we will briefly discuss existing evidence on the value of sigma across countries and industries.

The literature on the elasticity of substitution between capital and labour addresses a diversity of topics. These range from short-run elasticities to long-run elasticities, from a-symmetric (Morishima-) elasticities to symmetric elasticities, from aggregate elasticities to industry-specific elasticities.

Our focus will be on the elasticity estimates derived from CES production functions using a FOC input demand approach. This is a parameter that relates to technological substitution possibilities, hence it is a long-run measure. Adjustment costs of the capital stock do not play a role in the long run.

Interestingly, many studies estimate a single aggregate σ, based on single-country or cross-country data at the industry level, or even firm-level or plant-level panel data. Most of the literature (surveyed, e.g., in Chirinko, 2008) focuses on such aggregate σ, relevant for aggregate growth models. If anything, the consensus is that the elasticity may well be smaller than one, providing support for capital and labour being gross substitutes and against Cobb-Douglas unit elastic substitution. Based on León-Ledesma (2010, Table 1), a value of 0.6 – 0.7 for the U.S. is a reasonable depiction of the median estimate in the literature. Based on a wider set of estimates, including studies on for example U.K. and

Euro Area data, Chirinko (2008) concludes that σ is likely to be within the range 0.4 – 0.6. There is no clear difference depending on the country/countries used in the empirical analysis.

Implicit is the assumption that σ does not vary across industries or countries, or that countries do not differ too much in sector-structure. However, available explicit evidence on cross-country differences in σ shows considerable variation (Mallick, 2007, Tables 1 and A.4). The U.S. is estimated to have σ = 0.6 (with estimation standard error equal to 0.09). This is in line with evidence reported in León-Ledesma (2010). The average value over a sample of 90 countries, however, is 0.34 as is the OECD area average. Standard deviations of the estimates for all countries and the OECD are 0.38 and 0.31, respectively. Notably, some East-Asian countries are estimated to have much higher elasticities of factor substitution. According to recent insights, this might help explain their higher growth (de La Grandville, 2009).

A smaller set of studies estimate industry-specific σ's. Examples are recent economy-wide studies for the U.S. (Balistreri et al, 2003; and Young, 2010) and from cross-country data in manufacturing industries (Claro, 2003). These studies show considerable variation in industry-level elasticities.

2.1.1.3 Data and empirical results

Estimates for σ are presented below for three sectors: agriculture, manufacturing and energy, and services. Data are taken from Cambridge Econometrics (CE) database for 279 NUTS 2 regions in Europe. Data cover the period 1995-2008. We have estimated the equation for determining σ's for each of 23 European countries separately, for each of the three sectors. The choice of using CE data reflects a choice for using regional variation, allowing more precise estimation, and a choice for country detail above sector detail in estimation. This recently compiled database contains rich data on value added, capital stock, employment and labour remuneration. Wages were computed by dividing remuneration by employment. Value added and remuneration are in constant prices of 2000. Remuneration figures of CE needed to be deflated, using the same EuroStat deflators for the three sectors as indicated on the CE website for determining value added in real terms. Because no direct information on capital income was available, and the user cost of capital could not be determined on a reliable basis for the CE regional sample, we estimate equation(2.5): the FOC for labour.

The estimation approach is based on regional time series analysis, by country, for each of 3 industries. We have estimated equation (2.5) in logarithmic form. To avoid reverse causality between wages and labour productivity, we use wages lagged by one year in the estimates presented below. Results using contemporaneous wages as explanatory variable are comparable qualitatively, as well as in the vast majority of cases quantitatively. The results are presented in the following table.

Table 8: Estimates of the elasticity of substitution between capital and labour.

Country	Agriculture			Manufacturing			Services		
	Subst. Elasticity	t value	N	Subst. Elasticity	t value	N	Subst. Elasticity	t value	N
Austria	0.25	13.60	117	0.65	11.30	117	0.91	16.86	117
Belgium	0.13	3.76	143	0.97	15.43	143	0.80	29.32	143
Bulgaria	0.12	2.68	78	0.05	1.52	78	0.08	3.73	78
Switzerland	0.53	10.04	91	0.88	15.29	91	1.01	12.29	91
Czech Republic	0.14	1.16	104	0.75	9.84	104	0.77	15.44	104
Germany	0.12	5.90	507	0.84	51.00	507	1.25	31.78	507
Denmark	-0.45	-5.90	65	1.73	19.56	65	0.88	20.44	65
Spain	0.07	1.01	247	0.81	22.75	247	0.42	6.58	247
Finland	0.41	5.54	65	1.31	16.04	65	0.97	10.27	65
France	0.92	36.24	286	0.66	23.80	286	0.82	29.52	286
Greece	0.59	11.22	169	0.33	2.50	169	0.25	1.51	169
Hungary	0.24	2.98	91	0.72	8.43	91	0.72	10.94	91
Ireland	0.25	3.33	26	1.90	11.35	26	1.76	12.28	26
Italy	-0.05	-1.24	273	0.62	17.85	273	0.61	12.02	273
Netherlands	0.21	3.58	156	0.55	1.75	156	0.76	19.31	156
Norway	0.61	12.49	91	0.66	8.14	91	1.03	31.03	91
Poland	0.67	27.51	208	0.62	11.47	208	0.72	18.02	208
Portugal	0.89	22.50	65	1.08	20.72	65	0.65	12.58	65
Romania	0.39	10.76	104	0.12	2.62	104	0.24	7.25	104
Sweden	0.21	1.35	103	0.80	4.10	104	1.21	13.96	104
Slovenia	0.14	1.92	26	0.34	2.78	26	0.66	14.96	26
Slovak Republic	0.49	2.14	52	1.07	12.10	52	1.03	26.98	52
United Kingdom	0.82	18.24	478	0.53	16.74	481	0.75	22.66	481

Most of the estimated elasticities are within the reasonable range between 0 and 1. Some are larger than one (mostly in manufacturing), though not always statistically significantly. The only negative value that is statistically significant is the estimated σ for agriculture in Denmark.

2.1.2 Estimating Total Factor Productivity (TFP) regressions

Within the context of the present study the results of econometric analysis are used in order to validate the estimates of the spill-over elasticities based on the results of CBA analysis and modelling with the regional CGE model (RHOMOLO). Hence, econometric analysis is used for checking the robustness of the spill-over elasticities calculated using CBA and modelling.

The exact formulation of technical progress cannot be easily obtained from the HERMIN specification. From the interpretation of the relevant parameters all possible types of technical progress (Hicks-neutral, Harrod-neutral (labour-embodied) and autonomous) are applied together to different parts of demand equation. To derive the needed spill-over elasticities and to fully allow for the latest theoretical developments in economic growth theory and for empirical developments in the field, we will make growth regressions based on the present state-of-the-art.

Based on the extensive literature review, which took place in the beginning of the project, we will model the growth of total factor productivity (TFP) as a semi-endogenous growth with a catch-up mechanism.

In this case TFP growth is determined by region-specific investments in research and development (R&D), human capital and a sector and region-specific gap between a region and a technological leader. TFP levels were derived with the use of gross value added, capital stocks and employment from Cambridge Econometrics database. Technological leader in a base year is defined as a region with the highest level of TFP.

Infrastructure stock is an input to the production functions of the regional CGE model. Including it into the TFP equation will result in double counting of its effect and hence is not necessary to include it in the TFP.

In order to improve the fit and reliability of our econometric model we have used a pooled data for the EU 27. In order to capture country-specific effects we have used country dummies. The estimated econometric specification captures region and sector specific effects. This is due to region and sector-specific nature of explanatory variables: regional-specific investments into R&D, regional human capital and region and sector-specific technological gap. Given this rationale, using data over the EU 27 will improve rather than worsen the reliability of estimates with regards to using only the data for 18 countries. Then country-specific estimates are derived from RHOMOLO.

The specification was estimated separately for three aggregated sectors: agriculture, manufacturing and services. All the parameters turned out to have a positive effect on productivity growths as one could expect. Also all the parameters, except for R&D in agriculture, are significant determinants of TFP growth.

Results of econometric estimation of TFP regressions will be incorporated into RHOMOLO in order to improve its reliability and quality of its simulation results. Econometric estimates of production function and TFP regression parameters will represent the first best guess and the starting point for the estimation procedure based on the results of micro-level CBA studies. RHOMOLO parameters will be estimated and will be micro-founded. The estimated parameters in combination with the structure of RHOMOLO will provide the link between micro and macro level data and effects required within the context of this project. As a result, the impacts of investments in physical capital, human capital and RTD on TFP (output) and labour productivity (that is spill-over-elasticities) estimated by using RHOMOLO will be micro-founded as is requested by the terms of reference of the project.

In semi-endogenous growth models variation of total factor productivity (TFP) is assumed to be determined by variation in R&D stocks, human capital stocks, investments in education and R&D by households, firms and the government and distance of the country/region from the technological frontier. We make use of this type of model and estimate its parameters empirically. In general, our regression and simulation results are encouraging. Regression results seem in line with those in Benhabib and Spiegel (2005).

TFP levels by region are derived from a Cobb-Douglas production function with two factors production function using the growth accounting approach. We make use of the Cambridge Econometrics (CE) database, summer 2010 edition, to get region- (NUTS2) and sector-specific data on value of gross value added, employment and capital stocks. In order to derive factor (capital and labour) compensation shares in gross value added we address to EU KLEMS database. In growth accounting exercise we use average factor compensation shares across Europe. CE and EU KLEMS contain data on different level of sector disaggregation. We have to stick the more aggregated one, which is CE in this case. It provides data on the following three sectors: agriculture, manufacturing and services.

Human capital and research and development (R&D) data are derived from EuroStat. These data provided by EuroStat vary only between NUTS2 regions and so we are not able to observe sector-specific differences.

Human capital is measured as average number of schooling in the region. To calculate this measure we make use of the data on economically active population by the highest level of education. Average years of schooling are computed using the formula YS=6*PP+10*PS+14*PT, where PP is a proportion of active population with primary education as the highest one, PS – with secondary education and PT – with tertiary education.

As an R&D indicator we make use of percentage of total R&D expenditures in the region relative to gross value added in the region. Unfortunately, data on R&D expenditures from EuroStat are quite poor and have a lot of missing values. We take 1997 as a base year in TFP equation estimation. Data for this year is almost full for main European countries, except for UK. Missing value were interpolated either using values of preceding and following years in the same NUTS2 region, or average shares of NUTS2 regions in NUTS1 region derived from available years. It should be noted that both R&D and human capital measures are available only on regional level and thus their impact on specific sectors productivity growth will be interpreted as a combination of direct and inter-sector spill-overs effects.

Empirical results

In order to improve the fit and reliability of our econometric model we have used a pooled data for all regions of Europe. In order to capture country-specific effects we have used country dummies. The estimated econometric specification captures not only country but also region and sector specific effects. This is due to region and sector-specific nature of explanatory variables: regional-specific investments into R&D, regional human capital and region and sector-specific technological gap.

The results for different sectors are summarised in the table below. Regional research and development investments are insignificant in agricultural sector and thus results are reported for specification with omitted term. On contrary, impact of R&D intensity turns out to be significant with positive effect in manufacturing and service sectors. Effect of human capital is also positive and even more significant in all sector considered. Effect of interaction term of human capital and productivity gap is negative and also strongly significant. Negative coefficient of interaction term indicates that effects of human capital are higher in the regions lagging behind in terms of technological development, and thus catch-up pattern represented. One can easily show that overall effect of increased human capital is positively correlated with productivity growth since productivity gap term is limited between zero and one.

Standardised beta coefficients are also presented. These allow interpretation of comparative effects of different explanatory variables regardless of their units of measurement. The coefficients show the effect of one standard deviation change in independent variable on change in dependent variable also in terms of one standard deviation. Variation in human capital and catch-up term appears to have more impact on variation of productivity growth than R&D intensity does. Although beta-coefficients provide some insight in relative importance of independent variables they should be interpreted with caution. In real application one standard deviation changes in human capital and R&D intensity can imply completely different amount of policy measures and interpretation of one standard deviation change in interaction term could be even more complicated.

Table 9: Estimation results of the TFP equations

Sector	Intercept		lnH		R&D		lnH*GAP		R^2
	Coeff.	St.Err	Coeff.	St.Err	Coeff.	St.Err	Coeff.	St.Err	
Agriculture	-0.1244***	0.0439	0.0708*** *(0.2079)*	0.0196			-0.0309*** *(-0.4636)*	0.0038	0.24
Manufacturing	-0.1585***	0.0275	0.0844*** *(0.5083)*	0.0131	0.1312* *(0.1087)*	0.0752	-0.0226*** *(-0.5435)*	0.0044	0.27
Services	-0.1420***	0.0165	0.0682*** *(0.5937)*	0.0077	0.0854* *(0.1023)*	0.0477	-0.0092*** *(-0.2764)*	0.0020	0.40

The dependent variable in the regressions is an average annual growth rate of TFP over 1997-2008. R&D is a per cent of R&D expenditures in gross value added in 1997, H is a human capital measure as described above in 1999. Regressions are performed using OLS with robust errors.
Standardised beta coefficients in parenthesis.
*** - significant at 0.1.
* - significant at 0.01.

To summarise, all the sectors are apparently characterised by higher effect of human capital level and technology adoption and comparatively lower affect of R&D intensity. The model in service sector has the highest explanatory power. Effect of technological adoption from technological leader is the highest in manufacturing sector On the other hand, service sector is the one benefiting the most from human capital accumulation.

2.1.3 Estimation of relationship between investments, energy and emissions intensity

2.1.3.1 *Overview of main results of runs with E3ME*

The simulations necessary for the estimation of relations between investments and energy and emissions intensity was carried out using E3ME model. The E3ME model covers 29 European countries (EU27, Norway and Switzerland), 42 economic sectors, 19 energy users, 12 fuels, and 28 energy technologies. For more information on the E3ME model, including the online manual, see www.e3me.com. E3ME is a macro-econometric model which provides detailed sectoral and Member State (MS) level analysis. The model contains sector- and country-specific parameters and is capable of forecasting annual economic and environmental impacts at these levels for the period up to 2050, for which in this project we go up to 2030. E3ME is suitable for economy-energy-environment analysis in both the short and medium to long terms since the model contains both short and long-terms parameters as a result of its econometric specification.

E3ME's role in this study is to provide quantitative analysis of the possible environmental impacts of different types of ECP investment projects. Although the E3ME model is capable of providing detailed economic results, its role in this study focuses on its other 'Es': Energy and Environment. Figure 9 shows how the model is used in this study to provide environmental externalities.

The six categories agreed for the E3ME modelling are:

- Urban transport
- Promoting products and process
- Renewable energy: wind
- Renewable energy: solar
- Renewable energy: biomass
- Renewable energy: geothermal

In addition to the main six ECP expenditure scenarios, a sensitivity analysis was carried out for each scenario to ensure the robustness of the results. The sensitivity testing altered the value of the exogenous investment in each scenario from 5% additional investment in the main scenario to:

- 1%
- 3%
- 10%
- 25%

In Annex 2, a full description of the E3ME model, methodology and results is provided.

2.1.3.2 Estimation technique and results

Based on the E3ME, we can estimate functions these that depict the relation between the change in the ECP investment in a scenario, relative to the E3ME baseline, and the change in the so called *emission intensity as well* as *energy intensity.*

Emission intensity is the average emission rate from given source relative to the intensity of a specific activity, e.g. grams of CO_2 emission released per MJ of electricity produced. *Energy intensity* ($En\_Intensity$) is a measure of the energy efficiency of an economy. It is calculated as units of energy per unit of GDP (output). These two concepts can be described by the following formulas:

$$\text{Energy Intensity} = \frac{\text{Energy}}{\text{GDP}} \tag{2.6}$$

$$\text{Emission Intensity} = \frac{\text{Emission}}{\text{Energy}} \qquad (2.7)$$

The functions are estimated based on the E3ME results for the exogenous ECP investment scenarios in E3ME modelling. To do that we implement the simulation results from the E3ME runs. Recall that the E3ME results are derived by assuming additional investment of 1%, 5%, 3% and 10% in each ECP categories, to the existing investment in the relevant industry. We compute the percentage change in the Energy Intensity using the total fuel demands of EU27 in 2030 and the total GDP. For each of the six ECP scenarios, we then compute the percentage change of Energy Intensity relative to the E3ME baseline, for each of the additional exogenous investments in E3ME results. The percentage change in Emission Intensity relative to the E3ME baseline is calculated in the same way by using the percentage change in Emission Intensity of CO_2 for EU27.

Let's denote the percentage change in the energy intensity relative to the baseline by ΔENT , percentage change in emission intensity relative to the baseline by ΔEMT , and the alternation (in percent) of the value of exogenous investment by ΔI . The problem is to estimate the following functions:

$$\Delta ENT = f_{EN}(\Delta I) \quad \text{and} \quad \Delta ENT = f_{EM}(\Delta I) \qquad (2.8)$$

The the general form of the estimated function is the so called *Hill function*

$$f_i(x) = \frac{ax^n}{bx^n + c^n}, \text{ for } i \in \{EN, EM\} \qquad (2.9)$$

with $x \geq 0$ and parameters $a > 0$, $b > 0$, $c \geq 0$ and $n > 0$.

This function is always an increasing function ($f'(x) > 0$), with $f(0) = 0$. The latter property captures the fact that if there is no change in the exogenous investment of a certain ECP scenario, there will be also no change in the energy and emission intensities for that scenario. Moreover, The former property is the *law of positive returmn* that is the more the exogenous investment is inceased the more will be the increase in the enrgy and emission intensities. In addition to these properties, the function has a an aymptotic behaviour at infinity:

$$\lim_{x \to \infty} f(x) = \frac{a}{b} = \text{constant} \tag{2.10}$$

This means that for a relatively large increase in the exogenous investment, any additional invesment has no effect (or relatively very small positive effect) on the energy and emission intensity.

Depending on the value of the parameters, function f can be either convex (Figure 3) or concave-convex (Figure 4). If f is convex. i.e. satisfies the *diminishing marginal return law*, increasing more the exogenous investment (in percentage) at some point yield lower (percentage) change in energy and emission intencities. However, if f is concave-convex , for relatively low investment change (%) relative to the baseline, the marginal return to the change in the energy and emission intensities are increasing, but for high investment change, these marginal returns diminish.

Figure 3: $y = f(x) = \dfrac{x^{0.9}}{1+x^{0.9}}$

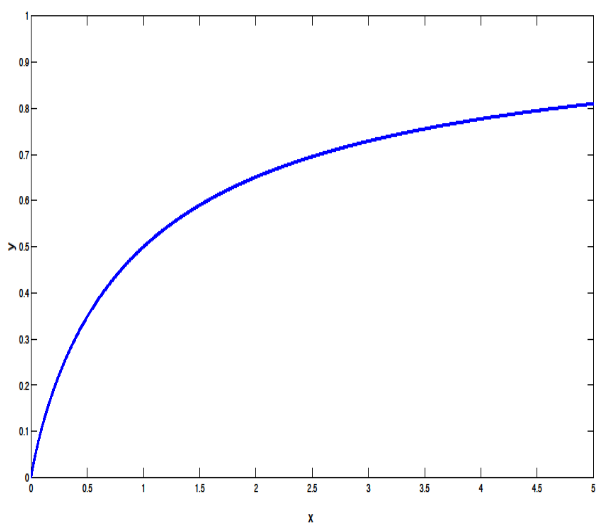
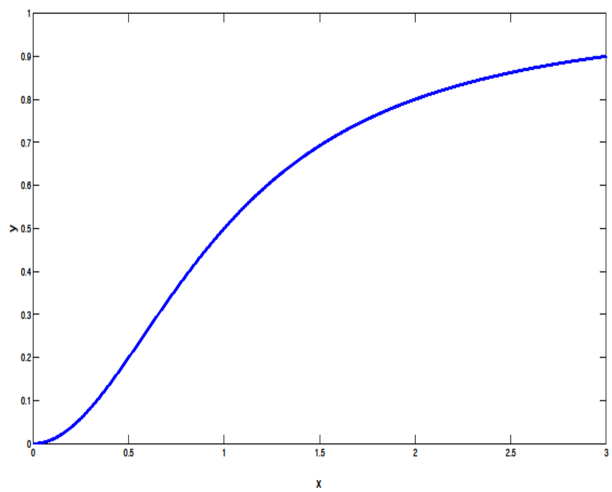


Figure 4: $y = f(x) = \dfrac{x^2}{1+x^2}$



As an example, by using the result of E3ME runs, as described in the beginning of the section, for the E3ME category Urban Transport, function f_{EN} is well approximated as below

$$\Delta ENT = f_{EN}(\Delta I) = \frac{a \cdot \Delta I^n}{b \cdot \Delta I^n + c^n} \tag{2.11}$$

with parameter values $a = 0.1295$, $b = 1.082$, $c = 0.4068$, and $n = 0.9613$ (see Figure 5).

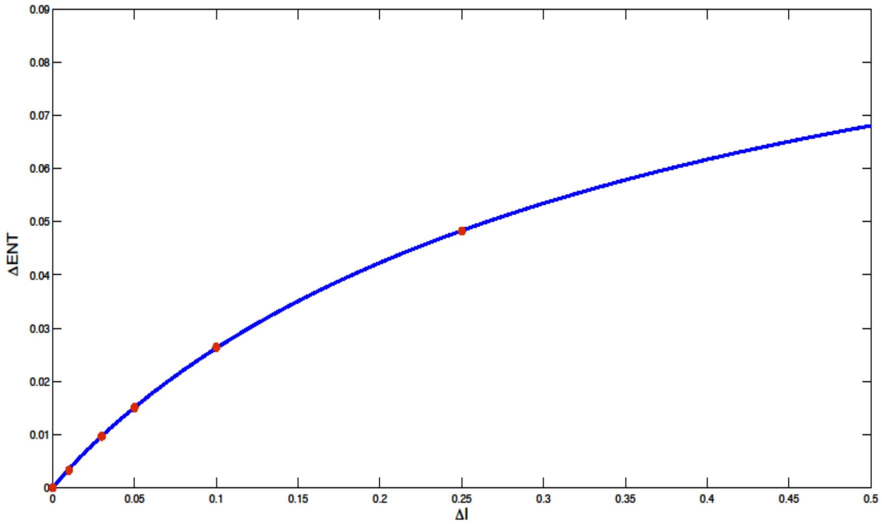


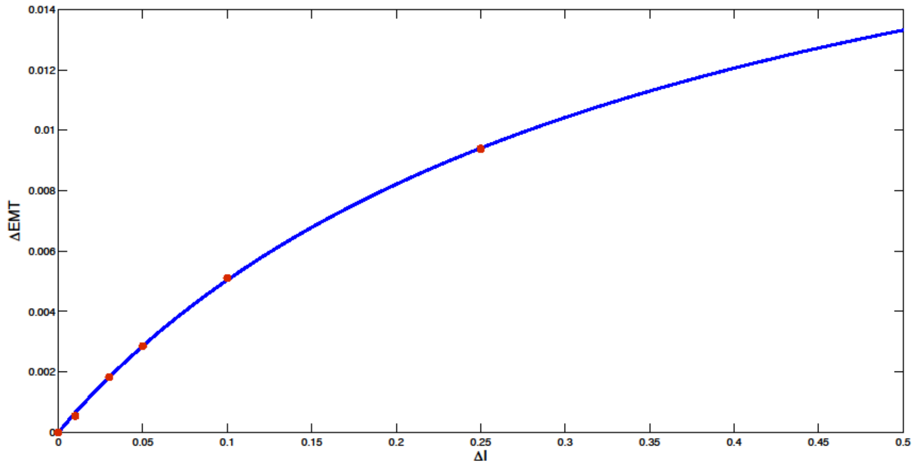
Figure 5: The red points (dots) are computed based on E3ME run for Urban Transport category and the solid line is the graph of f_{EN} *that is approximated for these points.*

In a similar way, function f_{EM} is well approximated as below

$$\Delta EMT = f_{EM}(\Delta I) = \frac{a \cdot \Delta I^n}{b \cdot \Delta I^n + c^n} \quad (2.12)$$

with parameter values a = 0.02562, b =1.105, c =0.4083, and n = 0.981 (see Figure 6)

Figure 6: The red points (dots) are computed based on E3ME run for Urban Transport category and the solid line is the graph of f_{EM} that is approximated for these points.



As seen in Figure 5 and Figure 6, the more the exogenous investment is increased the more will be the increase in the energy and emission intensities for this category of investment. Moreover, for a large increase in the exogenous ECP investment, any additional investment has almost no effect on the energy and emission intensity. Moreover, both functions, f_{EN} and f_{EM} satisfy the diminishing marginal return law.

2.1.4 Representation of inter-temporal effects of externalities on GDP

2.1.4.1 Overview of main inter-temporal effects

When analysing the costs of negative externalities, the focus is usually on the impact on welfare and utility. However, negative externalities can also impose costs on market-based indicators, such as income and productivity[9]. A textbook example is the impact of the pollution of a river on the fisheries industry further downstream. In addition, impacts that we would usually regard as imposing costs mainly on welfare can also impose costs on market indicators, especially in the long-term. For example, a poisoned water supply will damage the labour force's health which will, in turn, make them less productive workers.

This short survey focuses on the literature on the impacts of externalities on the long-run GDP of the macro-economy, rather than the short-run industry-specific example of the fishery downstream from a pollution source. This means that the impacts of externalities need to be aggregated across the whole economy, and the interdependencies between in-

[9] Which will, incidentally, have knock-on impacts on welfare and utility

dustries, both those directly affected and unaffected by the externality, need to be considered. We also focus on 'dynamic' long-run analyses of GDP growth, rather than 'static' analyses of the short-run impact of externalities on the level of GDP.

We first discuss how the issue has been dealt by in long-run growth models, which project capital accumulation, labour productivity and income growth over the very long-term equilibrium trend. These models tend to lack sectoral detail, so we then turn to 'bottom-up' analyses, which examine specific externalities and sectors in detail, but tend to lack a full analysis of long-run dynamics. Finally, we look at attempts to draw the two strands of methodology together.

2.1.4.2 Long-run growth models

In the very long-run, GDP levels and growth in GDP is usually modelled using derivatives of the seminal Solow model that was originally developed in the 1950s[10]. Under this framework, exogenous productivity growth, that is, productivity growth determined outside of the model and unaffected by the variables in the model is the sole source of growth in per capita GDP[11]. In the 1980s and 1990s, this model was further developed to incorporate *endogenous* productivity growth[12], that is, productivity growth is partly determined by variables inside the model such as saving and investment. This provides an opportunity to integrate negative externalities into the analysis. Ricci (2007) gives a simple example in which aggregate production (Y) is the product of a function of capital (K) and pollution (P) (because pollution is generated when producing goods and services), and total factor productivity (A). Total factor productivity is itself a function of environmental quality.

Pollution, or the activity that causes it, has a positive effect, through its impact on the production function, but the externality itself has a negative effect, through its impact on total factor productivity. Capital accumulation and pollution are determined simultaneously: pollution can be thought of as a side effect of capital accumulation[13]. The latter part of the equation shows how pollution abatement directly reduces the productivity of capital, since capital must be reallocated to activities that produce less pollution instead of those that maximise income. On the other hand, the subsequent lower levels of pollution bring environmental benefits that ultimately enhance the productivity of capital. For

[10] i.e. Solow (1957)

[11] Total GDP growth is due to the same technological growth, and also due to population growth

[12] Ricci (2007)

[13] Since pollution carries no private cost, producers are indifferent to how much pollution they generate as a side effect of their other activity.

example, if fossil fuel-fired power stations are forced to remove all particulates from their exhaust gases, they will need to dedicate considerable resources to doing so; and this will *reduce* their output and productivity[14]. However, the subsequent improvement in air quality will improve the health of workers throughout the economy, including at the same power stations, and this will *improve* their productivity and output[15].

Ricci's (2007) survey notes several studies that have modelled the impact of environmental pollution on long-run growth using a technique similar to this, including Bovenberg and Smulders (1995), Smulders and Gradus (1996), Smulders (1995), Rosendahl (1996), Rubio and Aznar (2000). The later studies find that, at high levels of pollution, a fall in pollution would increase GDP, since pollution levels are very sensitive to a reduction or reallocation in capital accumulation[16]. However, at low levels of pollution, a fall in pollution would reduce GDP, since the fall requires a large reduction or reallocation in capital accumulation[17].

A feature common to these models is that the externalities and their effects can be very generalised and abstract – a generic economy-wide 'pollution' externality affects economy-wide total factor productivity. Ricci (2007) notes that this approach makes most sense when describing an economy that is heavily reliant on natural resources, where a general impact of pollution might be expected, but less so for a varied industrialised economy, where the impact of pollution might vary across sectors. A slightly more specific branch of the literature use growth models that include investment in human capital[18] to model the impact on GDP growth of the damage to human health caused by pollution. In Ricci (2007)'s example, households decide how much to invest in their human capital based on a trade-off between foregone consumption and lifetime earnings from increased productivity. Pollution reduces the potential earnings from human capital, therefore households invest less in it and are less productive workers, with knock-on effects for GDP growth.

As a further example, Pautrel (2009) takes a slightly different approach to modelling the effects of environmental damage to human health, still within the endogenous growth model framework. In his model, finitely-lived households smooth their consumption over time, based on taxes and the return to savings. A crucial factor in GDP is the extent

[14] It isn't all a deadweight loss to the entire economy; the manufacturers of emissions abatement technology will benefit for example. However, there will be an aggregate net deadweight loss if the economy was originally at the output-maximising allocation of resources.

[15] In the language of the Solow growth models, the long-term impact is that both the steady-state level of capital accumulation and long-term income growth are lower.

[16] The results are dependent upon standard assumptions about constant returns to scale.

[17] Note, however, that consumer utility is always improved by a reduction in pollution in this model.

[18] In this context, a worker's productivity

to which younger households invest their wealth in order to increase consumption in the future. The effect of environmental damage to health is modelled as a reduction in life expectancy. This reduces investment by young households, since they have less time to enjoy consumption in later life, and in turn damages GDP growth. Pautrel thereby identifies a further channel through which externalities can affect long-term GDP growth, although it relies on some strong assumptions about the far-sighted nature of households.

2.1.4.3 'Bottom-up' modelling

The models discussed so far have the advantage that, being very general, they can be adapted to suit more-or-less any negative externality that affects all, or a significant part, of the economy. However, this carries the disadvantage that the models are not particularly closely related to any real-world externality, which limits their empirical usefulness, beyond some fairly abstract scenario work. A major reason for this is the enormous difficulty in understanding and estimating the effects of externalities and how these are transmitted to the economy[19], most notably in the case of climate change (see below), which makes such estimation a major task in itself. In addition, while the science of externalities needs considerable sectoral detail, growth models of the sort discussed above tend to be very 'top down' and lacking in sectoral detail.

Therefore, there is a different branch of literature that makes detailed estimates of the impacts of externalities at the regional and sectoral level, and then aggregates these to the whole economy and projects them forwards, but without the more detailed treatment of productivity and capital accumulation seen in the growth models. The approach is closer to cost-benefit analysis rather than a model of long-term GDP. There is a considerable amount of work on the effects of climate change in this area, although that literature tends to focus on the welfare costs of the externality, rather than the GDP cost itself[20].

For example, Tol (2002) draws together data from a large number of other studies on five key areas: agriculture, forestry, water-level rises, human health, and energy consumption and water resources. However, only some of the costs are measured as a loss in GDP or GVA, including agriculture and forestry, others are measured in a variety of ways, such as the number of deaths from poor health, converted to a monetary valuation. The input studies are all based on 'General Circulation Models', a method of modelling the global climate, and are normalised to a global temperature rise of 1ºC. Tol notes some of the difficulties in aggregated regional results to the global level, not least that deaths measured in terms of willingness to pay are worth more in rich countries than poor countries,

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[19] Stern (2007)

[20] For good reasons – GDP can be a very misleading indicator in the case of climate change since spending on climate change mitigation measures, such as flood barriers, registers as a boost to GDP, but clearly consumers would be better off if the climate change threat was removed and that expenditure were shifted to consumer goods (Stern Review).

but these are usually less of a problem for GDP growth. Tol has followed up his own work in several further studies (Tol (2005), Bosello et al (2007), Tol (2009)[21]).

The EU's ExternE project[22], which has been running since 1991, is a major effort to assess the external costs and impacts of many categories of health and environmental damage. The coverage is extensive and detailed, calculating the external cost of many different pollutants on human health, building materials, crops, global warming, noise and ecosystems, among others. The methodology, which ExternE calls the 'impact pathway approach', is very much rooted in the bottom-up scientific tradition. The steps include: calculating the types and sources of emissions; the geographic spread of those emissions; the physical impacts across that geographic spread; and finally a monetary valuation. For the monetary valuations, the focus is strongly on consumer preferences and welfare, mainly in terms of 'willingness-to-pay' (i.e. the amount a consumer would pay in order to avoid environmental damage). Therefore, the market price and income impacts are only used when they are thought to coincide with willingness-to-pay, which is the case for the agriculture and building materials sectors. The estimates are of limited use for calculating GDP impacts.

The Stern Review surveys a number of estimates of the costs of climate change of a similar type[23], including Tol (2002), and notes that they omit several factors that could have a large impact on both GDP and non-market variables[24]. This includes the risk of sudden environmental disasters, such as major floods or storms, which is only addressed in a minority of studies[25], while the rest assume that the climate follows a smooth path towards a global temperature rise. The other common omissions noted by Stern are indirect impacts including, as discussed above, the lack of a dynamic treatment of saving and capital accumulation, and also the lack of interaction between sectors. Stern uses the PAGE2002 model, which has the advantage that it produces thousands of results based on randomly varying climate parameters (a 'Monte Carlo' simulation), which are combined to produce a probability distribution of results. However, it still does not address the problem of indirect impacts[26].

[21] Bosello et al (2007) is a little different, modelling the impact of sea-level rises in a general equilibrium model of the entire economy, but this is a static 'snapshot' model, without a dynamic treatment of investment and capital accumulation.

[22] See http://www.externe.info/ and http://www.externe.info/brussels/methup05a.pdf

[23] Many of which are drawn from the IPCC's Third Assessment Report (2001), including Mendelsohn et al (1998), Nordhaus and Boyer (2000) and Tol (2002).

[24] Part II, Chapter 6.

[25] Such as Nordhaus and Boyer (2000).

[26] Stern's estimate of the average loss in global GDP per capita in 2200 range between 5.3% to 13.8% but this includes welfare costs.

Weil (2007) carries out this type of analysis in the context of human health, with a much stronger focus on GDP growth. However, he treats health itself as the externality, without discussing the externalities that might damage health. He estimates the effect of health at the micro-economic level by regressing data on wages against health indicators including average heights and the Adult Survival Rate (the proportion of 15 year olds expected to live to 60). The health indicators are selected to be, as much as possible, proxies for overall health. Weil begins the task of relating this back to the long-run GDP growth methodology by using a growth accounting framework and cross-country data to estimate the impact of general health levels on the productivity residual[27]. Weil concludes from his results that eliminating the gap in health outcomes between countries could reduce the income gap between countries in the 90th percentile of the income distribution and those in the 10th percentile by over 12%.

2.1.4.4 Drawing together the different methodologies

Finally, more recently there have been some attempts to draw together the strands of the literature, by combining these detailed estimates of the micro-impacts of climate change and poor health with the very long-term dynamic growth models discussed earlier. An interesting example is Hallegatte et al (2007), who devise a 'Non-Equilibrium Dynamic Model' that is similar to a Solow-style growth model in the long-run, with the crucial difference that it allows non-equilibrium results[28] in response to major external shocks, such as an environmental disaster, to the economy[29]. Environment disasters are implemented through sudden reductions in the capital stock, which leads to a prolonged period of depressed growth, and a permanent step-change in GDP, due to rigidities in the investment and labour markets. The reductions in the capital stock can be calibrated to estimates of the economic costs of widespread natural disasters, and Hallegatte et al calculate an 'amplification ratio' between the immediate natural disaster and the consequent effect on GDP. The model also includes an adjustable probability distribution to project the frequency of future random natural disasters. However, this model continues to have no sectoral detail, and climate change is an exogenous input.

Ashraf et al (2008) build a long-term growth model that includes the impact of human health, calibrated to the micro-economic estimates in Weil (2007), 'years lost due to disability data' from the World Health Organisation, and other data. Again, health itself is the externality, and the causes of ill-health are not included. The model used is an en-

[27] The productivity, or Solow, residual, is the part of GDP growth that cannot be explained by a rise in capital or labour – it is assumed to proxy the total factor productivity.

[28] The model includes an inventory-building equation, which kicks in when supply does not equal demand in the goods market.

[29] Therefore, it also goes some way to addressing the criticisms of Stern (2007), above.

dogenous growth model including a treatment of human capital, in which the effects of health are transmitted through the impacts on worker productivity, educational attainment and the demographic make-up of the population. Interestingly, Ashraf et al find that even a major shock to health has a relatively small impact on economic growth, although they examine the impact improvements in health than those of reductions in health. Furthermore, income per capita decreases initially after a major positive health shock, up to around thirty years, due to the increase in population.

Summary

The Solow and endogenous growth models are the dominant methods of looking at the key factors, namely capital accumulation and labour productivity, which determine an economy's income and GDP growth over the very long term. As we have discussed, the endogenous models can be adapted to model how a negative externality interacts with these factors and ultimately affects growth (as distinct from the wider welfare implications). The effect on growth can be positive or negative.

However, these growth models tend to be very top-down and abstract, with little sectoral detail. This can make it difficult to model empirically an externality in any depth, especially in the case of climate change, where the effects are region and sector specific and highly uncertain. Hence, there is a different literature, less focused on growth and more on broader welfare, which attempts to make detailed bottom-up estimates of the impact of negative externalities. However, much of the understanding of the dynamic processes behind capital accumulation and labour productivity is lost.

To some extent, there have been attempts to combine the two strands of methodologies, although there are significant challenges involved, and separation has its benefits. At present, this trend seems to be more advanced in the treatment of health externalities, where Weil (2007) has demonstrated a method of using micro-econometric health indicators to analyse the difference in total factor productivity between countries.

2.1.4.5 Overview

The environmental effects are not explicitly modelled in HERMIN, hence one has to use an alternative model to evaluate them. We will use RHOMOLO for the evaluation of major environmental effects of all ECP sectors of investment. RHOMOLO includes the explicit representation of GHG and non-GHG emissions, pollution due to waste and waste water. These environmental impacts are monetized in terms of inter-temporal impact on GDP. This monetization is done based on the existing environmental studies such as for example ExternE. The overall modelling is hence able to assess both negative and positive external effects of all ECP sectors of investment. Within the present project the structure of RHOMOLO includes the relations, which provide the link between several types of ECP investments and the reduction energy use and pollution coefficients (amount of pollution per unit of energy use). These relations are calculated using the runs with the

E3ME model and done for a set of ECP categories which have a direct impact upon the change in production technology of the sectors. The runs with E3ME have been designed in such a way that we can easily derive the functional form of the relations: that is simulations have been done for 1%, 3%, 10% and 25% increase in current investments by relevant ECP category. The table below summarises information about the coverage of environmental externalities by RHOMOLO and E3ME as well as gives information about which environmental effects are monetised in terms of inter-temporal effect on GDP:

Table 10: Coverage of environmental externalities by RHOMOLO and E3ME

Environmental effects covered in RHOMOLO	Environmental effects covered in E3ME	Environmental effects which are monetised in terms of inter-temporal effect on GDP
GHG emissions	GHG emissions	GHG emissions
Non-GHG emissions		Non-GHG emissions
Solid waste		Solid waste
Waste water		Waste water

These environmental effects include impacts of GHG and non-GHG air pollutions, impacts of waste water and solid waste. RHOMOLO includes an explicit modelling of all main types of GHG emissions based on IEA database and of all main types of non-GHG emissions based on EMEP database. Emissions in RHOMOLO are associated with either output or energy consumption of various production sectors. Environmental damage of GHG and non-GHG pollutants is based on the ExternE estimates. These estimates include main impacts of pollution on health and environment including negative effects of pollutants on human health, building materials, crops, global warming, noise and ecosystems, among others.

Waste in RHOMOLO is of two types: hazardous and non-hazardous. Waste in RHOMOLO can be treated in different ways and its damage in monetary terms depends on the way it is treated. Waste is produced by production sectors and households. Waste water in the model is associated with production of the water sector and each litre of waste water is associated with the certain environmental damage valued in money. Utility of households in RHOMOLO is negatively influenced by environmental externalities which in its turn affects their decision to leave in a particular region of the country. Change in the population of the region due to migration has effect upon the real estate prices in this area. Hence, RHOMOLO takes into account that environmental externalities have negative impact upon real estate prices.

The evaluation of inter-temporal environmental externalities associated with energy- and environment-related ECP sectors of investment, which specifically target air emission reduction, will be carried out as a two-step procedure. As the first step, we derive the relations, which represent the relationship between the amount of ECP investment and the change in emissions coefficient and/or energy intensity, with the help of specialised economic environmental model E3ME. This model has a detailed description of production technologies related to energy use and their environmental effects. The relations between investment and energy and emissions intensity estimated on the basis of E3ME runs will be incorporated into RHOMOLO in order to evaluate the inter-temporal environmental effects.

Both RHOMOLO and E3ME use consistently the same set of monetary values of pollutions. RHOMOLO is a recursive-dynamic model and the shock of the ECP investments by sector propagates through all markets. Resulting output changes and associated environmental costs affect inter-temporal social welfare function and well as GDP.

2.1.4.6 Available empirical studies and parameterisation of the model

The ExternE/Ecosense data provides estimates for different pollutants, effects and countries on a consistent basis. The consistency of the different estimates is important for the robustness of the type of analysis we are carrying out. The estimates (see ExternE 2005 methodology publication for more details) identify different types of impact, such as through impacts on mortality, morbidity, on production of crops, and in the deterioration of buildings etc. In valuing health impacts the ExternE/Ecosense estimates use a value for immediate loss of life expectancy of €75000 per life year loss. The ExternE number was carefully derived after an extensive research, using the WTP method taking into account the issue of chronic air pollution-induced mortality (slowly losing life years and sometime non-measurable). In discussing the estimate ExternE explain that their estimate may be more conservative than some others in the literature, they consider it more robust and reliable.

The damage coefficients produced by ExternE/Ecosense consider the direct impact of emissions on particular factors (health, crops etc). They omit some of the indirect, often more long-term impacts. For example, the negative impact of pollution on the fabric of buildings (e.g., erosion) is included in the damage coefficients produced. However, if not addressed, then over time the cumulative impact on the built environment could have a detrimental impact on tourism. Such impacts are less ‘robust’ than the effects included in the damage coefficients, and would also vary considerably from area to area (the physical impact of pollution on a building may be the same in two areas, but any long-term impact on tourism will depend on the type of economy/assets it has.

DROPS[30] research project considered the impacts that heavy metal pollutants had on additional health costs, additional education costs from loss of IQ, and losses of labour productivity, with impacts feeding back into the determination of economic activity in subsequent years. The study found that the substantial time lags between pollution and the effects being felt meant that the impact against a baseline during the 20-year horizon of the scenarios being developed was small.

2.2 Linking Benefits to Costs Ratio and Economic Rates of Return with spill-over elasticities

In this section the standard measure of cost-benefit analysis Benefits to Costs Ratio (*BCR*) as well as Economic Rate of Returns (*ERR*) are linked to the spill-over elasticities. We demonstrate the derivation of such a link in a formal general equilibrium model.

2.2.1 *Structure of theoretical general equilibrium model*

Here we introduce a formal general equilibrium model of a single (representative) consumer, n-good economy. Goods are denoted by $i \in I = \{1,...,n\}$ with price p_i. The market factors that are used in production of n goods are physical capital K with rental price r and labour L with wage rate w. In this model we shall assume that each good is produced by one production sector, private or public, with good s produced by sector i, $i \in I$. Investment in this model is traced with an exogenous change in the capital. In addition, it is assumed that in the model there are intermediate consumptions from the sector's outputs.

Before presenting the equations of the general equilibrium model we set out the notation which will be used throughout the section. For each $s \in S$:

C_i^p represents private consumption of good or service s

G_i represents the real government consumption expenditure of good or service s

C_i represents the total consumption of good or service s

$U(C_1, C_2, ..., C_n)$ represents the utility function of the consumer

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30 http://drops.nilu.no/ 2007, DG Research, European Commission.

Q_i represents production of good s by sector s

K_i represents the demand for the composite capital by sector s

L_i represents the demand for labour by sector s

$\overline{K}, \overline{L}$ represent the total endowments of capital and labour

p_i represents the price of good s

r_i and w represent the rental on capital and wage respectively (we assume that $w_i = w, \forall i$)

tc_i represent consumption tax rate for good or service i

tk and tl represent capital income and labour income tax rates resp.

Y represents the consumer's income

$\Omega = [IO_{ij}]_{n \times n}$ represents the matrix of input-output coefficients IO_{ij}

In this model it is assumed that there is substitutability (or complementarity) in the utility function between private consumption and government consumption expenditure therefore:

$C_i = C_i^p + \mu G_i$, for $\forall i \in I$

Here the parameter μ captures the substitutability or complementarity between private consumption C_i^p and the public consumption G_i of good or service i (see Ashauer (1985) and Ashauer (1985)). The model does not include the government budget constraint for simplicity. We take tax rates directly from the data without imposing any stringent restriction on government budget (i.e. the budget can be balanced or not).

Underlying the general equilibrium model is the optimising behaviour assumption by the economic agents. The behaviour of the consumer is based on the utility-maximisation principle. The consumer solves a static one period optimisation problem, where the optimal consumption bundle is determined in order to maximise the instantaneous utility function. The utility function is maximised given one period consumption budget constraint of the households. The maximisation problem is solved under the assumption that the whole consumption budget constraint is used each period of time to buy various goods and services.

We shall assume that the consumer's utility function is a Cobb-Douglass utility function:

$$U = \prod_i C_i^{\beta_i}, \tag{2.13}$$

with $C_i \geq 0$, $0 < \beta_i < 1$ *and* $\sum_i \beta_i = 1$.

The Cobb-Douglas function is chosen for its mathematical simplicity that is needed to derive the complex formulas linking spill-over elasticities with change in welfare in this study. The Cobb-Douglas preferences are homothetic this implies that the income elasticities for all goods are unitary and the budget shares are independent of income level of the consumer. Note also that the demand for each good is independent of the prices of the other commodities, implying zero cross-price elasticities. Given these assumptions, we believe that the representation of utilities by Cobb-Douglas function is adequate for the purposes of this analysis.

In the model the household budget constraint (*B*) of a particular household type in a region is as follows

$$B = \sum_i p_i \cdot (1 + tc_i) \cdot C_i, \tag{2.14}$$

where $p = (p_1, p_2, ..., p_n)$ is the commodity price bundle; and tc the product tax rate.

The consumer spends its consumption budget on services and goods in order to maximise its satisfaction from the chosen consumption bundle. Consumer has substitution possibilities between different consumption commodities. In the model these substitution possibilities are captured by Cobb-Douglas utility function.

The amounts of the goods and services bought by the consumer are determined according to a static utility-maximisation problem of the consumer that is described by the following constrained optimisation problem:

$$\max U(C) = \prod_i C_i^{\beta_i},$$

subject to (2.15)

$$\sum_i p_i \cdot (1 + tc_i) \cdot C_i = Y$$

where p_i and tc_i are the price and the consumption tax rate of the commodity i, and Y is the consumer's income. In order to solve this maximisation problem we need to form the Lagrangian:

$$\mathbf{L}(C,\lambda) = \prod_i C_i^{\beta_i} + \lambda(Y - \sum_i p_i \cdot (1+tc_i) \cdot C_i) \tag{2.16}$$

The First Order Conditions (FOCs) are:

$$\frac{\partial \mathbf{L}}{\partial C} = \beta_i \cdot \prod_i C_i^{\beta_i} - \lambda \cdot p_i \cdot (1+tc_i) = 0 \tag{2.17}$$

$$\frac{\partial \mathbf{L}}{\partial \lambda} = B - \sum_i (p_i \cdot (1+tc_i) \cdot C_i) = 0 \tag{2.18}$$

Then the first order conditions (FOCs)are obtained as follows:

$$\frac{\beta_i}{C_i} \cdot U = \lambda \cdot p_i \cdot (1+tc_i) \tag{2.19}$$

$$\frac{\partial \mathbf{L}}{\partial C} = \frac{\beta_i}{C_i} \cdot \prod_i C_i^{\beta_i} - \lambda \cdot p_i \cdot (1+tc_i) = 0 \tag{2.20}$$

$$Y = \sum_i p_i \cdot (1+tc_i) \cdot C_i \tag{2.21}$$

Finally the above equations are solved to obtain the demand function as follows:

$$C_i = C(p_i, Y) = \frac{\beta_i Y}{p_i \cdot (1+tc_i)}, \forall i \in I \tag{2.22}$$

Moreover, the indirect utility function $v(p,Y)$ is obtained by replacing the C_i in the utility function (2.13) with demand function(2.22):

$$v(p_i, Y) = \prod_i \left(\frac{\beta_i Y}{p_i \cdot (1+tc_i)} \right)^{\beta_i}, \forall i \tag{2.23}$$

The indirect utility function will be used in the derivation of the formulas linking BCR to spill-over elasticities later in this section.

1.1.1.1 Firms' behaviour

Production costs of each sector in the model include labour costs and (composite) capital costs. The sector's technological constraint describes the production technology of each sector. It provides information on how many of different units of labour and sector-specific capital are necessary for the production of one unit of the sectoral output.

The production technology of the firm is represented by a production function of the general form:

$$X_i = A_i . f(K_i, L_i) \tag{2.24}$$

Here X denotes the total production and A the *total factor productivity (TFP).*

Solution of the system of the first order conditions associated to the cost minimisation problem are the demand functions for the production inputs:

$$K_i = K(X_i, r_i, w) \tag{2.25}$$

and

$$L_i = L(X_i, r_i, w) \tag{2.26}$$

1.1.1.2 The full general equilibrium model

The full general equilibrium model consist of the demand and supply equations, which have been derived in the previous subsections, in all markets in the economy, together with the market clearing equations (or equilibrium conditions) and the equations defining the budget constraints of each of the agents in the economy. The full set of equations is presented below.

Service and commodity market:

Demand

$$C_i = C(p_i, Y), \forall i \in I \tag{2.27}$$

$$\sum_i C_i \cdot p_i \cdot (1 + tc_i) = Y \tag{2.28}$$

Supply

$$X_i = X_i(p_{1,\dots,}p_n, r_i, w) \tag{2.29}$$

Market clearing

$$C_i = X_i \tag{2.30}$$

$$p_i \cdot X_i - r_i \cdot K_i - w \cdot L_i - \sum_{j=1}^{n} IO_{j,i} \cdot X_i \cdot p_i = 0 \tag{2.31}$$

Factor markets:

Demand

$$\begin{aligned} K_i &= K(X_i, r_i, w) \\ L_i &= L(X_i, r_i, w) \end{aligned} \tag{2.32}$$

Market clearing

$$\begin{aligned} \sum_i K_i &= \overline{K} \\ \sum_i L_i &= \overline{L} \end{aligned} \tag{2.33}$$

Income equations:

$$\begin{aligned} Y &= \sum_i (wL_i(1-tl) + r_i K_i(1-tk)) \\ &= w\overline{L}(1-tl) + \sum_i r_i K_i (1-tk) \end{aligned} \tag{2.34}$$

2.2.2 Methodology of linking BCR with spill-over elasticities

Here a set of formula linking the change of welfare ΔW , as a determinant of ENPV, with spill-over elasticities are derived. These formulas are derived by starting with what Dinwiddy and Teal (1966) describes as the structural form of the welfare measure. The change in welfare is then captured by the *Compensating Variation* (CV) measure, i.e. $\Delta W = CV$. Finally in the context of the formal general equilibrium model, the formula linking CV and hence ΔW with spill-over elasticities are derived.

2.2.2.1 Welfare evaluation of economic change

In the model we make a distinction between utility and welfare functions of the consumer. The utility functions of the consumer cannot be measured in money and is only used to derive optimal demands of the households given a certain budget constraint.

Here the welfare of society can be identified with the welfare of the representative consumer, W (see Dinwiddy and Teal (1996: chapter 5) formerly[31]). Given the consumer's utility function U, the change in welfare is measured by the differential of U that is

$$dU = \sum_i \frac{\partial U}{\partial C_i} \cdot dC_i \qquad (2.35)$$

Following Dinwiddy and Teal (1996), the change in welfare is defined as the change in household's utility divided by the marginal utility of income (λ) (structural form of the welfare measure):

$$\Delta W \approx dW = \frac{dU(C_1, C_2, ..., C_n)}{\lambda} \qquad (2.36)$$

Note that under utility maximisation problem, the ratio of the marginal utility of every good i to its price is equal to the marginal utility of income

$$\frac{\partial U / \partial C_i}{p_i} = \lambda, \forall i \qquad (2.37)$$

From the above expression it follows that for each good or service i, the willingness to pay of the household is equal to the market price

$$\frac{\partial U / \partial C_i}{\lambda} = p_i, \forall i \qquad (2.38)$$

Consequently the relation the change in welfare can be reformulated as

$$dW = \sum_i p_i \cdot dC_i \qquad (2.39)$$

Hence change in welfare is the change in utility measured in monetary units.

[31] Dinwiddy, C. and F. Teal (1996), Principles of Cost-Benefit Analysis for Developing Countries, Cambridge University Press.

The component $\sum_i p_i dC_i$ of the welfare change represents the change in welfare of the consumer that is change in its utility measured in monetary units. In this study, however, we capture the change in welfare by the *Compensating Variation* (CV) measure, i.e. $\Delta W = CV$. Compensating Variation is a measure of welfare change introduced by John Hicks and it gives the amount of income which have to be given (taken away) from the household in order for it to stay on its old level of utility after a certain change in policy control variables. This measure is based on money metric indirect utility function $m(p,v)$ that measures the income needed to attain utility level v at the vector of price p.

In order to derive the formula for the compensating variation in the model, it is first needed to calculate the money metric utility function by Solving equation (2.23) for Y:

$$m(p_i, v) = \prod_i \left(\frac{p_i \cdot (1 + tc_i)}{\beta_i} \right)^{\beta_i} v, \forall i \tag{2.40}$$

The compensating variation CV is a welfare measure based on the money metric indirect utility function using the post policy prices. Suppose that the initially the price vector and nominal income level were p^0 and Y^0 respectively. After some policy change, new price vector p^l and nominal income Y^l are observed. The compensation variation is given by the following expression:

$$CV = m(p_i^l, v(p_i^l, Y^l)) - m(p_i^l, v(p_i^0, Y^0)) = Y^l - m(p_i^l, v(p_i^0, Y^0)) \tag{2.41}$$

For the Cobb-Douglas utility function and by using Equations (2.23) and (2.40):

$$\Delta W = CV = Y^l - \prod_i \left(\frac{p_i^l}{p_i^0} \right)^{\beta_i} Y^0 \tag{2.42}$$

See Annex 3 for detailed derivation of Equation (2.42)

To investigate the marginal effects we shall assume, as we will in the next subsection, that $p_i^l \to p_i^0$, then in the limit the formula (2.42) reads as follows,

$$dW \approx \Delta W = Y^l - Y^0 = \Delta Y \tag{2.43}$$

The reader can consult Varian (2003) Chapter 10 for more details.

2.2.3 Formulas linking the change in welfare with spill-over elasticities

In the context of the formal general equilibrium model, which was introduced in the previous subsections, we derive the formulas linking CV (and consequently dW) with spill-over elasticities E_{X_i,K_j} , i.e. the spill-over elasticity of output X_i with respect to the composite capital K_j .

As mentioned before, in this model investment in a particular sector is traced with an exogenous change in the composite capital of the sector. Suppose that the initial equilibrium allocation and price vector in this model are denoted by superscript 0 (e.g. K_i^0 denotes the initial capital). In the general equilibrium model, any exogenous change in capital, lead to a new equilibrium allocation and price vector that are denoted by superscript l (e.g. K_i^l denotes the new capital). Moreover, let

$$\Delta K_i := K_i^l - K_i^0 \ \& \ \Delta X_i := X_i^l - X_i^0 .$$

The following formula links the output spill-over elasticity of capital for a sector $m \in I$, $E_{X_{\%}K_{\%}}$, with the change in welfare, ΔW , given that the exogenous change in capital happens only in sector m in the economy, i.e. $\Delta K_i = 0$, for $\forall i \neq \mathrm{m}$:

$$E_{X_m,K_m} = \frac{K_m^0}{\varphi_m \cdot \Delta K_m} \cdot \Delta W - \frac{\psi_m \cdot K_m^0}{\varphi_m \cdot \Delta K_m} \tag{2.44}$$

where coefficients φ_m (*modified value added)*, and ψ_m are defined as follows,

$$\varphi_m = \sum_i [\eta_{m,i} \cdot X_i^0 - \sum_j (IO_{ij} \cdot \eta_{m,j} \cdot X_j^0)] \cdot p_i^l \cdot (1 + tc_i)$$

and (2.45)

$$\psi_m = \sum_i [(X_i^0 - \sum_j (IO_{ij} \cdot X_j^0)] \cdot (p_i^l - p_i^0 \cdot \frac{pcv^l}{pcv^0})(1 + tc_i)$$

Here the parameter $\eta_{i,j}$, *elasticity coefficient*, is defined as:

$$\eta_{i,j} = \frac{\partial X_j / \partial K_i}{\partial X_i / \partial X_i} \cdot \frac{X_i}{X_j} \quad (2.46)$$

For any sector i, if the exogenous change in capital is small enough then there will be a very small change in the equilibrium price vectors. In this case the above expression can be even further simplified by assuming that for any $\varepsilon > 0$, $\left| p_i^l - p_i^0 \right| \le \varepsilon$. Using the formulation of equation (2.44), as $p_i^l \to p_i^0$, $\psi_m \to 0$. Hence in the limit the formula can be written as:

$$E_{X_m, K_m} = \frac{K_m^0}{\varphi_m \cdot dK_m} \cdot dW \quad (2.47)$$

where

$$\varphi_m = \sum_i [\eta_{m,i} \cdot X_i^0 - \sum_j (IO_{ij} \cdot \eta_{m,j} \cdot X_j^0)] \cdot p_i^l \cdot (1 + tc_i) \quad (2.48)$$

In the course of the present study this is the main formula that is used to link the output spill-over elasticity of capital for a sector m, E_{X_m, K_m}, to the marginal change of the welfare, dW. Its economic meaning can be seen as follows. The variable φ_m from equation (2.49) represents modified value added of sector *m*. Indeed, the first term in the brackets is the gross output (multiplied by the ratio of own- to cross-elasticity). The second term in the brackets represents intermediate product used to produce gross output modified in similar manner (i.e. by multiplying by the same ratio). The term after the brackets is in fact price term which turns the whole expression into purchaser prices.

$\frac{K_m^0}{dK_m}$ in equation (2.48) is the inverse of the percentage change in the capital stock of sector *m* as a result of the ECP investment. Hence, the output elasticity is proportionally related to the change in social welfare with the coefficient of proportionality inversely related to sectoral (modified) value added and percent change in the capital stock.

Moreover, the cross-sectoral spill-over elasticity, i.e. the spill-over elasticity of output of a sector j with respect to the capital of a sector i, can be determined using the following formula:

$$E_{X_j, K_i} = \eta_{i,j} \cdot E_{X_i, K_i} \quad (2.49)$$

This relation enable us to link cross-sectoral spill-over elasticity E_{X_j,K_i} to the change in welfare through the main formula (2.47) (simply multiply by factor $\eta_{i,j}$).

The full mathematical derivations of formulas (2.44) and (2.47), are presented in Annex 3A of the report.

2.2.4 Formulas linking the BCR and ERR with spill-over elasticities

Here we consider a *recursive-dynamic model* that is used to model an economy with ECP. By the recursive-dynamic model we mean, multi-period general equilibrium model in which results are computed one-period-at-a-time based on the formal general equilibrium model, which is discussed in this section. In contrast, for fully inter-temporal models, results are computed simultaneously for all periods. Here in the context of this model the change in welfare dW is linked to the BCR (Benefit Cost Ratio) and consequently to the ERR (Economic Rate of Return).

We assume that there are T time periods with the following structure of the cost-benefit stream structure. There is just a one-period investment in a project (cost of the project) at time 0, which is set to $I^0 = dK^0$. Then at each time period $1 \le t \le T$ there is benefit $B^t = dW^t$ for the project. Hence the cost-benefit structure of an ECP project in this economy has the following structure:

$$dK^0; dW^1, dW^2, ..., dW^T$$

The spill-over elasticity at each time period t is denoted by E^t, change in welfare by dW^t, and the *modified value-added coefficient* (defined in Equation (2.47)) by φ^t. Here, we assume that the spill-over elasticities are constant over time that is $E^t = E$ for $1 \le t \le T$.

In this setting, by using the definition of the BCR and that $B^t = dW^t$ we have:

$$BCR = \frac{\sum_{t=1}^{T} \frac{dW^t}{(1+r)^{t-1}}}{dK^0} \qquad (2.50)$$

Where r is the discount rate.

Then by using formula (2.47) the spill-over elasticity, *E*, and Benefit-Cost Ratio of a project, BCR, can be linked through the following formula:

$$E = \frac{K^0}{\sum_{t=1}^{T} \frac{\varphi^t}{(1+r)^{t-1}}} \cdot BCR \tag{2.51}$$

Here the elasticity is proportional to BCR and the modified capital-output ratio. In order to see this, notice that the denominator of equation (2.52) represents yet another modification of sectoral value added before ECP intervention (this time, represented as discounted flow over T years) while the numerator is the initial capital stock..

Recall that Economic Rate of Returns of a project, i.e. ERR, can be derived by solving the equation $BCR = 1$ for r. That is ERR is the solution of the following equation:

$$\frac{\sum_{t=1}^{T} \frac{dW^t}{(1+r)^{t-1}}}{I^0} = 1 \xrightarrow[\text{Solve for } r]{} r^* = ERR$$

Therfore by using equation (2.51), the spill-over elasticity E can be linked to the ERR in the following formula:

$$E = \frac{K^0}{\sum_{t=1}^{T} \frac{\varphi^t}{(1+ERR)^{t-1}}} \tag{2.52}$$

Thus elasticity equals the modified capital-output ratio under the assumption of equal costs and benefits (i.e. BCR = 1).

The full mathematical derivation of formulas (2.51) and (2.52) are presented in Annex 3.

2.2.5 Illustrative Example

Here a worked example is provided to present the overall rationale of the formulas and illustrate the main theoretical results that are derived in this section.

Consider the model, which was described in the previous subsection (2.2.4), with two aggregated economic sectors: *Manufacturing* (MF) and *Market Services* (MS) that is:

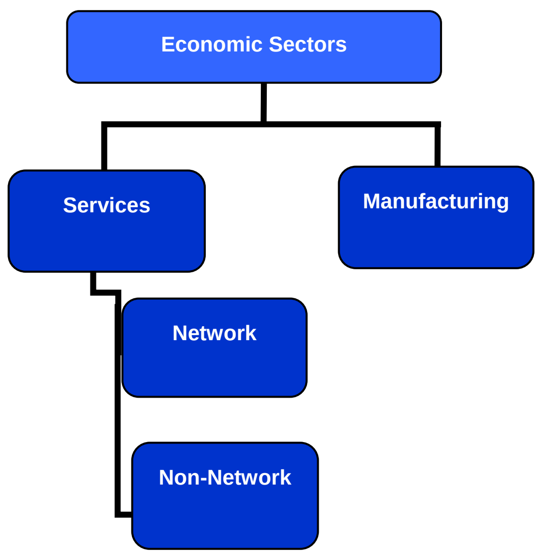
$$I = \{MF, MS\}$$

In which *Market Services* has two economic subsectors: *Network* (MS_1) (e.g. transport, electricity) and *Non-Network* (MS_2) (e.g. R&D):

$$MS = \{MS_1, MS_2\}$$

This situation is depicted in Table 10

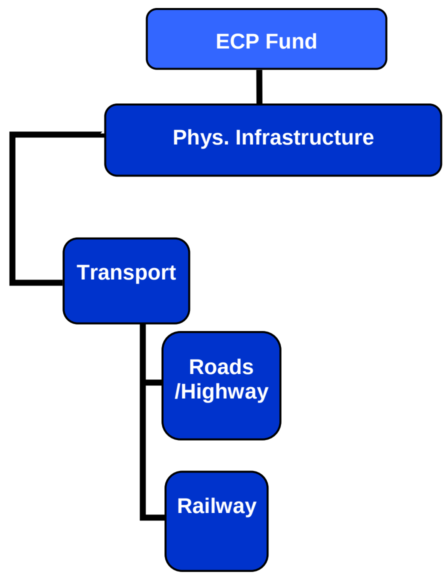
Table 11: Economic sectors



Now suppose that the ECP fund with the following structure is included in this economy.

There is one category of expenditure, *Physical Infrastructure* (INF), with one ECP sector of investment, *Transport* (TR), and two ECP subsectors of investments: *Road* (RD) and *Railway* (RL):

Table 12: ECP Sectors



Suppose that the benefit-cost flow for the project *Railway* over 30 years, $\{dK_{RW}^{0}, B_{RW}^{1}, ..., B_{RW}^{30}\}$, and the modified value added (coefficient) flow, $\{A_{RW}^{t}\}_{t=1}^{30}$, are given (as described in the previous subsection).

Then, for instance, the output elasticity of *Network Market Services* with respect to capital *Railway*, $E_{X_{MS_1}, K_{RW}}$, is linked to benefit-cost ratio of *Railway* project, BCR_{RW}, by

$$E_{X_{MS_1}, K_{RW}} = \frac{K_{RW}^{0}}{\sum_{t=1}^{30} \frac{\varphi_{RW}^{t}}{(1+r)^{t-1}}} \cdot BCR_{RW}, \qquad (2.53)$$

where φ_{RW}^{t} is the modified value added of *Railway* project at time *t* defined as Equation (2.48), K_{RW}^{0} is the initial capital stock of ECP subsector of investment "*Railway*", and *r* is the discount rate.

Here the elasticity of output of "*Network Market Service"* with respect to capital of ECP subsector of investment "Railway" is proportional to benefit-cost ratio of *Railway* project and the modified capital-output ratio. In order to see this, notice that the denominator of equation (2.52) represents yet another modification of sectoral value added before ECP intervention (this time, represented as discounted flow over 30 years) while the numerator is the initial capital stock..

Moreover, elasticity of output of "*Network Market Service"* with respect to capital of ECP subsector of investment "Railway", $E_{X_{MS_1},K_{RW}}$, can be linked to the Economic Rate of Returns of *Railway* project, ERR_{RW}, using:

$$E_{X_{MS_1},K_{RW}} = \frac{K_{RW}^{0}}{\sum_{t=1}^{30} \frac{\varphi_{RW}^{t}}{(1+ERR_{RW})^{t-1}}}$$

Here the elasticity of output of "*Network Market Service"* with respect to capital of ECP subsector of investment "*Railway*" equals the modified capital-output ratio under the assumption of equal costs and benefits of *Railway* project (i.e. $BCR_{RW} = 1$).

2.3 Capital Stock for Sectors of Investment

2.3.1 The need for estimation and use of capital stocks within the study

Spill-over elasticities are expressed as percentage change in a variable (such as output, total factor productivity and labour-embodied technical change) as a result of a percentage change in one type of the capital stock (such as the physical capital stock, human capital stock, and R&D stock). These elasticities shall be evaluated at the ECP sector of investment level and then aggregated to the higher, category of expenditure level. In order to perform both the evaluation and aggregation tasks, we need to evaluate in the base year the stock of these three factors – physical capital, human capital and R&D. Thus we need the estimates of these three types of capital stocks on two levels – ECP subsector of investment and expenditure category for the 16 cohesion countries and two macro regions (East German Lander and South Italy) for the period 1995-2007.

Estimation of stocks of physical capital

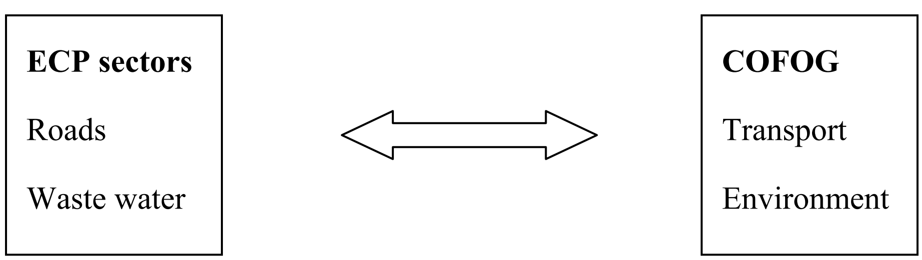
The difficulty of such an assessment is that the ECP sectors differ from the standard statistical sectoral classifications and data on capital stock by ECP sector are unavailable. Therefore, we have to construct these data ourselves. The data sources include, among others, the COFOG dataset (General Government Expenditure by function) government capital stock estimates by Cambridge Econometrics, data on physical infrastructure stock, valuation data. We used two primary methods of estimating capital stock by ECP subsector of investment.

Method 1: Physical measures of capital stock and its valuation

This method is applied to transport infrastructure subsectors (such as highway, rail roads, ports) and ICT. National statistical Institutes have data on capital stock by sector measured in physical units for transport infrastructure and computer equipment, such as the length of roads of certain type in kilometres, available computer equipment. Our task is then to valorise these stocks. This is done by using model countries for which unit price is available (Spain) and correcting the unit prices for other countries in line with purchasing power parity.

Method 2: COFOG data

The COFOG (General Government Expenditure by function) dataset gives a clear insight in the yearly capital formation of EU governments. With COFOG it is determined how much is invested in the different ECP sectors over the years. Some COFOG sectors are similar to those of ECP. These include education and all environmental subsectors of investment.



To arrive at the capital stock at subsector of investment, we applied the average shares of COFOG sectoral flows over 10 years to total government national stock estimated by Cambridge Econometrics.

2.3.2 Estimation of stocks of R&D capital

The R&D stocks were constructed with the use of the Perpetual Inventory Method (PIM) based on yearly expenses in the field of R&D. This is consistent with the method used by EU KLEMS. What we need beside the abovementioned R&D data is an assumed annual depreciation and a set of deflators.

We dataset used was the GERD database, which consists of total intramural spending on R&D per nation in current prices. Deflators were taken from the AMECO 2006 data. The methodology is based on the choice for 1) a base year for constant prices, 2) on the choice for annual depreciation and 3) the calculation of the initial stock (in 1995), as follows:

1) All R&D is estimated in constant prices by using 2000 as base year.

2) The depreciation is set to 12% annually resulting in a hyperbolic curve; it takes about 18 years to reduce an investment to 10% of its value.

3) The initial stock in 1995 is calculated by adding and depreciating annual R&D investments from 1987 up to and including 1994. Using the GERD database, this resulted in R&D capital stocks that are consistent with the EU KLEMS data.

From 1995 on, R&D capital stock is calculated by adding R&D annual investments and depreciating all previous investments along the hyperbolic curve.

The result of the methodology is a constantly increasing R&D capital stock for every single country, since the total depreciation of all previous investments was always smaller than the new investments during the period of 1995 to 2007 throughout Europe.

2.3.3 Estimation of stocks of human capital

Overview of estimation methodology and main assumptions

Human capital refers to the total of knowledge, competence, experience and personal attributes and skills. Human capital is a factor in the explanation of GDP per capita, the growth of labour productivity, wages and the wealth of nations. Research on human capital dates back into the 1950s and 1960s (Lewis 1954, Mincer 1958 and Becker 1954). In this project, data on human capital stock are not readily available, so data on the value of human capital stock are calculated. Without going into current complicated debate on appropriate definition and measurement of human capital debate, we apply a traditional approach to estimation of human capital via a modification of perpetual inventory method, taking into account a starting value, annual expenditures, and a depreciation rate.

Annual expenditures

The calculation of human capital is based on data from COFOG (general government expenditure by function) from EUROSTAT. The intangible component of human capital is thereby not taken into consideration; it is only the monetary expenditure. This source gives the annual monetary public expenditure on primary, secondary and tertiary education from 1980 on. Missing years are interpolated with the ratio expenditure on education/GDP of the nearest known years. Private expenditures are not included. For European countries this is not problematic, since education is mainly a public task. Like physical capital, the human capital stock is accumulating each year by this annual investment in education.

Starting value

Human capital stock has a starting value, given as a level. This level represents the human capital stock as a result from expenditures the preceding period. Since sources on this are lacking, this value is estimated with the assumption that the development of the growth of human capital in the past has been generally the same as in the future.

Starting value human capital 1980 = expenditure education 1980/

average growth expenditure + depreciation rate

This results into a starting value of human capital 12,8 times as large as the public expenditure on education in 1980.

Deprecation rate

Accordingly, human capital is depreciating due to renewal of knowledge. This depreciation value is subject to debate. The question is that on the one hand, young people entering the labour market have the newest human capital but no experience. During their lifetime, they gain experience and enjoy higher wages. So, their human capital is not decreasing due to depreciation, but increasing due to more experience. Later on in their lifetime, their relative productivity decreases, due to renewal of knowledge embodied in younger people, and depreciation occurs. At the end of the lifetime of human capital, the retirement age, the human capital is not zero; they just leave the work force and the stock of human capital.

Based on several sources, the average number of working years of working persons is assessed in each country. This is the difference between the retirement age and the average age of entering the labour market. The depreciation rate is calculated as follows:

Depreciation rate = ((100/number of working years)/100) * 2

The factor 2 is a reflection of double decline depreciation. This depreciation not only captures linear depreciation, but also non-linearity. Over the lifetime of a working person, depreciation accelerates. Besides, this formula also incorporates that early retirement age results in a higher depreciation rate.

2.3.4 Structure and content of the Excel file with the capital stock data

In section 2.5.1, we described the outline of the methodology to estimate the capital stock for different ECP sectors. This resulted in the MS Excel file named "Capital stock per ECP sector.xls".

The excel file contains three worksheets. Two sheets display the results of the methodological steps in yearly Gross Capital Formation (GCF) for all relevant countries in 2000 and 2007. The most relevant sheet is named "CS_for _ECP_sectors" that displays the capital stock for ECP sectors.

The "CS_for_ECP_sectors" sheet appears as follows:

- In column A the regions (countries) are named, in column B are the years from 1995 to 2007 given and column C displays the five different asset types.
- In column D the actual data from Cambridge Econometrics for capital stock is shown.
- From column E to column V the totals from column D are distributed using the RAS matrix results from the sheets named "2000 flows" and "2007 flows". These are the actual ECP capital stock estimates. This is only done for Cohesion countries, so for other EU countries these cells will appear empty.
- All the data is displayed from row 2 to row 1756.

The totals for ECP sectors over different asset types can easily be obtained by summing the 5 different asset types.

2.4 Identification of spill-over elasticities for each sector of investment

2.4.1 Theoretical definition of spill-over elasticities for each sector of investment

Recall that in the HERMIN model we use the definition of spill-over as being any indirect effect of public expenditure. Concerning supply-side effects per se, the so-called *spill-over elasticities* must be identified. The value assumed by spill-over elasticities assesses the added value of the Cohesion Policy as compared to a cash-transfer policy.

More specifically, spill-over elasticity measures the impact of over a variable, for instance, sector GDP due to a percentage change of expenditure in specific sectors of investment (e.g., physical capital). The mathematical notion of the spill-over elasticity of output Y with repect to factor X is defind as

$$E_{Y,X} = \frac{\partial \ln Y}{\partial \ln X} = \frac{\partial Y}{\partial X}\frac{X}{Y} \approx \frac{\%\Delta Y}{\%\Delta X} \tag{2.54}$$

2.4.2 Spill-over elasticities in the HERMIN model

In order to calculate the spill-over elasticities used in the HERMIN model, we have to first understand their economic meaning and interpretation. In order to be able to do that we have studied in details the user manual of the HERMIN model including its technical Annexes. HERMIN model uses two types of spill-over elasticities:

- Output spill-over elasticity
- Productivity spill-over elasticity

The later spill-over elasticity includes the labour productivity elasticity and the TFP elasticity. The effects of human capital investments are modelled via the labour productivity spill-over elasticity whereas the effects of RTD and infrastructure investments are modelled via the TFP spill-over elasticity.

The output spill-over elasticity enters the HERMIN model via the hybrid demand-supply equation and represents the effects of investment on demand and supply in the new market equilibrium point. In the new market equilibrium point demand is equal supply. The output spill-over elasticity captures the effects of inter-sectoral input-output linkages as well as increase in productivity in a sector resulting form a particular investment. For example, additional investments into the transport infrastructure will increase the productivity of the transport sector (direct effect) and at the same time have impact through input-output linkages on the other sectors of the economy (indirect effect). Both of these effects are captured by the output spill-over elasticity.

The productivity spill-over elasticity enters the HERMIN model via the CES demand functions for labour and investments. The amount of investments and labour necessary to produce one unit of output depends on the productivity spill-over elasticities and can be influenced by additional investments into physical infrastructure, human capital and RTD. This spill-over productivity only captures the effect of investments in the sector where they have been done. These additional investments lead to reduction in production costs per unit of output.

Below we present the table with the spill-over elasticities which need to be calculated for the HERMIN model. Besides the presented elasticities we also need to calculate the environmental effects of different ECP investments. This is done with the use of environmental spill-over elasticity which is defined as the percentage change in total environmental costs as an effect of one percent change in physical infrastructure, human or RTD capital stocks.

Table 13: HERMIN Spill-Over Elasticities

	Manufacturing output	**Manufacturing productivity**	**Market Services output**	**Market Services productivity**
Physical infrastructure	Output/ infrastructure	Total Factor Productivity/ infrastructure	Output/ infrastructure	Total Factor Productivity/ infrastructure
Human resources	Output/human capital	Labour embodied technical change/ human capital	Output/human capital	Labour embodied technical change/ human capital
RTD	Output/RTD	Total Factor Productivity /RTD	Output/RTD	Total Factor Productivity /RTD

We also present a table with the correspondence between the HERMIN sectoral classification and NACE Rev 1.0 classification of EuroStat. Please notice that economic sectors with the highest share of ECP infrastructure investments such as transport, telecommunications and water supply are included into the "Market services" sector of the HERMIN model.

Based on the economic meaning of output and productivity spill-over elasticities in HERMIN and the correspondence between NACE and NERMIN sectors we can make some conclusions about the relative values of the spill-over elasticities to be calculated. Given that the output spill-over elasticities include both sector-specific effect as well as the effects related to inter-sectoral linkages in the economy we would expect the values of these elasticities will be higher then the values of the productivity spill-over elasticities.

Based on the mapping between the HERMIN and NACE sectors we would expect that the effect of physical infrastructure investments on "Market services" will be higher then its effect on "Manufacturing". This is because "Market services" includes transport, telecommunications and water supply sectors. Hence, the output spill-over elasticities of physical infrastructure for "Market services" will be higher then the same output spill-over elasticity for "Manufacturing".

In case of the productivity spill-over, given that the sector "Manufacturing" does not include any economic sectors where large ECP infrastructure investments, it will not be directly affected by these investments. It will only be affected by them via the inter-sectoral input-output linkages. Hence, we expect that the productivity spill-over of "Manufacturing" with respect to physical infrastructure should be rather small. Since "Market services" includes economic sectors with relatively high shares of high-skilled labour we would expect that the impact of investments into human resources will be higher for "Market services" then for "Manufacturing". In case of RTD the result can be ambiguous, since both "Market services" and "Manufacturing" included economic sectors with relatively high RTD intensity.

Table 14: The correspondence between sectors in HERMIN and the NACE classification.

HERMIN sectors	Economic sectors	NACE classification code
Agriculture	Agriculture, hunting and forestry	A
	Fishing	B
Manufacturing	Food, beverage and tobacco	DA
	Textiles and clothing	DB
	Fuels, chemical, rubber and plastic	DF, DG, DH
	Electronics	DL
	Transport equipment	DM
	Other manufacturing	DC, DD, DE, DI, DJ, DK, DN
Building and Construction	Constructions	F
Market services	Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods	G
	Hotels and restaurants	H
	Transport and storage	IA60, IA61, IA62, IA63
	Post and telecommunications	IA64
	Financial intermediation	J
	Real state, renting and other business activities	KA70, KA71, KA72, KA74
	Research and development	KA73
	Water supply	EA40.3
	Electricity and gas	EA40.1, EA40.2
	Mining and quarrying	C
Non-market services	Public administration and defence, compulsory social security	L
	Education	M

HERMIN sectors	Economic sectors	NACE classification code
	Health and social work	N

From the user manual of HERMIN model it does not become clear what is the basis for the choice of present values of the spill-over elasticities and on which concrete econometric/other studies they are based. Below we present a table with the present values of the HERMIN model spill-over elasticities and a short overview of literature review presented in the user manual of the HERMIN model.

Table 15: Present values of HERMIN Spill-Over Elasticities (based on the user manual)

	Manufacturing output	Manufacturing productivity	Market Services output	Market Services productivity
Physical infrastructure	*0.2*	*0.1*	*0.05*	*0.05*
Human resources	*0.2*	*0.1*	*0.05*	*0.05*
RTD	*0.05*	*0.05*	*0.01*	*0.025*

On infrastructure capital, studies reviewed in HERMIN description and operating manual (see Table 6.1 on pp. 87-90) are macroeconomic by nature and link the infrastructure capital with GDP rather than manufacturing and market services. According to the aggregation formula for output elasticities with respect to infrastructure, equal sectoral elasticities will yield a lower aggregate elasticity; thus assumption of the GDP elasticity equal to sectoral elasticities appears not very convincing. Still a larger problem coming out from the reviewed studies is that there appears to be an extremely wide range of elasticity estimates available in the literature ranging from negative to, in a couple of cases, higher than one, with the estimate of 0.2 used in HERMIN being on the high side.

As to the elasticity with respect to R&D, the HERMIN description and operating manual correctly notes that the empirical findings on R&D impact are still in experimental stage are even less robust than those of infrastructure capital. It goes on that the solution would be to adopt "very low values" (section 6.5 of the HERMIN manual, p. 98), not further specified in the manual. The value in the actual model is set to 0.05. Thus we cannot really view this value as a hard benchmark.

It is not clear to us (given the economic interpretation of HERMIN spill-over elasticities and mapping between NACE sectors and HERMIN sectors), why the output elasticity of manufacturing with respect to physical infrastructure is much higher then the same spill-over elasticity for market services. It is surprising because the sector market services includes such important infrastructure sectors as transport, water supply, telecommunications and electricity and gas.

According to the present values investment into human capital have much higher impact upon the manufacturing sector despite the fact that market services sector includes a number of sectors where human capital plays a large role such as research and development, financial intermediation and other business activities. Manufacturing is in general more capital intensive then services and one would expect that the human capital plays less important role in case of manufacturing.

The above discussion on the economic meaning and present values of the HERMIN spill-over elasticities is meant to become a part of explanation why it should not come as a surprise that the values of spill-over elasticities estimated in the present study are somewhat different from the present values of the spill-over elasticities.

2.4.3 Calibration of RHOMOLO parameters using the results of micro-level CBA studies

In order to improve the reliability of RHOMOLO model we will calibrate its parameters based on a set of micro-level data of the CBA studies. The main idea behind the calibration of RHOMOLO parameters is to make sure that the main results of CBA studies including ERR and benefits to costs (BCR) ratios are reproduced during the simulations with the model. For the purpose of this study we group ECP into the following investment sectors:

- Road
- Rail
- Port
- Waste water
- Solid waste
- Drinking water
- Air emissions and environmental protection
- Energy
- ICT
- Social infrastructure
- Education
- Labour market institutions
- RTD (including aid to productive sectors related to RTD)

According to the sampling methodology of the study, we have to do three ex-post CBA studies covering different Cohesion Countries for each of the thirteen types of ECP investment sectors (39 CBA studies in total). In order to be able to reproduce the main outcomes of CBA studies per type of ECP investment, we have implemented a simulation setup for each type of ECP separately in RHOMOLO.

In order to create these simulation setups we have used information not only about economic but also about physical indicators from the CBA studies. For example in case of investments in roads we have used available data on saved lives, time savings and additional generated traffic. Information about physical indicators of CBA studies has helped us to translate information on investment costs of the project into the respective changes in the parameters of RHOMOLO.

By running simulations with RHOMOLO until 2050 we are able to calculate ERR and BCR for each CBA study of the project separately. In case when the deviations of the CBA outcomes calculated with the model were significantly different from the results of CBA projects, we have to change one or multiple parameters of RHOMOLO in order to reduce the gap between two types of outcomes. For each type of ECP investment we have identified a separate set of model parameters which have to be adjusted during this iterative procedure.

Calibration of RHOMOLO on the results of CBA studies by hand requires a lot of effort and time. In order to make the calibration more efficient we have programmed an automated procedure n GAMS in order to be able to calibrate the model in an efficient way. This is essential for meeting the deadlines of the final report of this study.

2.4.4 Calculation of spill-over elasticities for Cohesion Countries based on the results of ex-post CBA studies

The calculation of spill-over elasticities is based on the theoretical formula which links the Benefits to Costs Ratio (BCR) with the own and cross-sectoral output elasticities with respect to capital stock. Details of the derivation of these formulas are presented in section 2.2 of this report. In order to implement the derived formulas we need some additional data and parameters. This includes the data on outputs and intermediate inputs by type of economic sector as well as the ratios between the own and cross-sectoral output elasticity with respect to capital stock. These ratios allows us to derive elasticity of output of sector X with respect to the capital stock of sector Y, given that we know own elasticity of output with respect to capital stock of sector Y. The above mentioned ratios have been calculated by using RHOMOLO model for eighteen Cohesion Countries and capture all general equilibrium effects and inter-sectoral input-output linkages between the economic sectors. Besides these ratios we also use the database of RHOMOLO for the year 2007 as a basis for the calculation of spill-over elasticities.

In order to calculate the output, productivity and environmental spill-over elasticities for the HERMIN model we proceed as follows:

Step I: Based on the ex-post CBA studies prepare the data on BCR and the ratio of the discounted environmental effects to the discounted investment costs.

Step II: Prepare the database for spill-over calculations: (1) Calculate the discounted flow of total environmental costs over 30 years. (2) For each economic sector of RHOMOLO calculate the discounted flow of the sector-specific indicator derived in section 2.2 over 30 years. This sector specific indicator allows one to calculate the own output elasticity based on the information about CBR by type of ECP investment.

Step III: Using the theoretical formulas derived in section 2.2 calculate the own and cross-sectoral output elasticities for all economic sectors of RHOMOLO for each of thirteen types of ECP investments. Own elasticities correspond to HERMIN's productivity spill-over elasticities whereas cross-sectoral elasticities correspond to HERMIN's output spill-over elasticities. The result was two matrices (for productivity and output spill-over elasticities) of dimension 13 X 23 plus a vector with 13 elements (for environmental spill-over elasticity) for each of eighteen Cohesion Countries.

3 Work Package 3. Macroeconomic Analysis: Relating Spill-over Elasticities at Different Level of Aggregation

Spill-over elasticities need to be assessed at three consecutive levels of aggregation in order be used in HERMIN. For instance, in case of a road project, the first-level will be the highways sector, the second-level will be the transport sector, and the third-level sector/category of expenditure will be physical infrastructure including also non-transport sectors. These estimates should be made separately for each Member State. The present WP devires the formulae used to carry out this aggregation procedure.

The final estimates of spill-over elasticities are differentiated by country, covering all Cohesion Policy countries, and by broad categories of expenditure. These estimates are prepared by implementing a set of theoretical formulas in an Excel file.Besides the calculation of the present values of spill-over elasticities based on the results of CBAs, ths file also allows for simulations and prediction of the future values of the spill-over elasticities depending on a set of economic assumptions.

The prediciton of spill-over elasticities takes into account Cohesion Policy expenditures and the co-financing scheme. As a result, the HERMIN model used by DG REGIO will be able to carry out Cohesion Policy variant simulations, to obtain a ranking of alternatives, or to achieve (sub-) optimization.

3.1 Motivation and rationale

Spill-over elasticity measures the impact over a variable (e.g., sector output) due to a percentage change variation of expenditure in specific sectors of investment (e.g., physical capital). Spill-over elasticities strongly influence the ECP impact over Member States economies and they reflect its supply-side effects. The spill-over elasticities used in the HERMIN model are identical for all countries but this study shall produce the estimates of these elasticities varying over country and sector of investment. It is the objective of this WP (and of the study in general) to identify elasticities for the main categories of expenditure (infrastructure, human capital, R&D) on manufacturing and marketing output as well as on corresponding total factor productivity.

Spill-over elasticities are being assessed at three consecutive levels of aggregation in order to be used in HERMIN. For instance, in case of a road project, the first-level will be the highways sector, the second-level will be the transport sector, and the third-level sector/category of expenditure will be physical infrastructure including also non-transport sectors. These estimates should be made separately for each Member State. We will derive and test the formulae to carry out this aggregation procedure.

As alternative budget allocations to different categories of ECP expenditure need to be assessed, aggregation formulae take into account the composition of the ECP, as is shown in the next section.

An Excel worksheet allowing for the calculation of elasticities at different levels of aggregation is prepared. This worksheet is linked to other worksheets containing all necessary information for such aggregation procedures. To this end, it is also worth noting that the Excel worksheet includes relevant the indicators which can be readily used in HERMIN.

3.2 Derivation of aggregation formulas

3.2.1 Methodology and aggregation formulas

Consider an economy in which the technological constraint of a production sector $i \in I = \{1, 2, .., n\}$ is described by the production function F as below:

$$X_i = F(K_i, L_i) = A(K_i) \cdot f(K_i, L_i) \qquad (3.1)$$

In this equation X_i represents the production of good i by sector i, K_i camposit capital (consist of physical capital, education, and RTD) and L_i labour. Function A describes the *total factor productivity* (TFP). Given this general form of the production function the impact of subsectors of investment on economic sector output where the subsector belongs to the same sector can be derived as follows.

Suppose that the set of production sectors in the economy, I, is partitioned into m categories (aggregate sectors) $I_m \subset I$. That is each production sector $i \in I$ in the economy belongs to an aggregate sector I_j for $1 \leq j \leq m$. In mathematical notation, set I is a disjoint union of $I_j \subseteq I$:

$$I = \bigcup_{j}^{g} I_j \qquad (3.2)$$

Now consider a sector aggregate I_j and for the simplicity denote the output, the capital and TFP of aggregated sector I_j by X, K and A respectively (drop the indices). Based on the discussion on the previous subsection suppose that $K = \sum_{i \in I_j} K_i$ and $X = \sum_{i \in I_j} X_i$. Now define the weight coefficient w_i as

$$w_i = \frac{X_i / K_i}{X / K} \cdot \frac{dK_i}{dK}, \forall i \in I_j \tag{3.3}$$

Then, the spill-over elasticity of output with respect to the capital for the aggregated sector I_j is the sum of the output spill-over elasticity of the capital for the subsectors i's in I_j, multiplied by the weighting parameter w_i:

$$E_{X,K} = \sum_{i \in I_j} w_i \cdot E_{X_i,K_i} \tag{3.4}$$

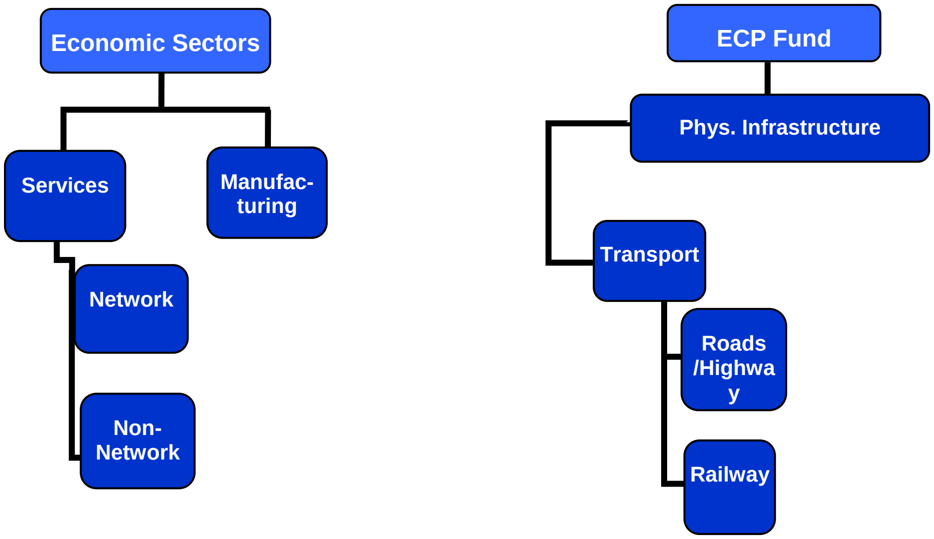
The intuition about w_i is as follows. An exogenous burst of investment in sector I_j, i.e. dK, impacts the output of this sector via the following channels. First, it impacts the capital stock in the subsector $i \in I_j$ belonging to this sector. This explains $\frac{dK_i}{dK}$. Next, how much the output of the sector aggregate, I_j, will be impacted depends on the relative output/capital ratio of the aggregated sector I_j in it's subsector i, which is the term $\frac{X_i / K_i}{X / K}$.

The full mathematical derivation of the aggregation formulas are discussed in Annex 3.

3.2.2 Illustrative example

In this subsection the worked example which is described in section 2.2.5 is used again to present the overall rationale of the aggregation formulas and illustrate the main theoretical results that are derived in this section.

Recall the structure of the Economic and ECP sectors in the economy:



Suppose that the benefit-cost ratio of *Railway* project, BCR_{RW} , and the benefit-cost ratio of *Road/Highway* project, BCR_{RD} , are given. Using formula (2.51) the output elasticity of *Network Market Services* (MS_1) with respect to capital of ECP subsector of investment "*Railway*", $E_{SW_1,RW}$, and with respect to capital of ECP subsector of investment "*Road*", $E_{SW_1,RD}$, are calculated . Moreover, by using formula (3.3) and (3.4) the following spill-over elasticities are derived (cross-sectoral spill-over elasticities):

$E_{MS_2,RW}$: *Output elasticity of non-network market services with respect to capitalof* ECP subsector of investment "*Railway*"

$E_{MS_2,RD}$: *Output elasticity of non-network market services with respect to capital of* ECP subsector of investment "*Road*"

$E_{MF,RW}$: *Output elasticity of manufacturing with respect to capital of* ECP subsector of investment "*Railway*"

$E_{MF,RD}$: *Output elasticity of manufacturing with respect to capital of* ECP subsector of investment "*Road*"

Now the problem is the calculation of the following aggregated spill-over elasticities:

$E_{MS,INF}$: *Output elasticity of Market Services with respect to Infrastructure*

$E_{MF,INF}$: *Output elasticity of Manufacturing with respect to Infrastructure*

Step 1. Aggregation of Economic Sectors Network and Non-Network Market Services to Market Services:

Output elasticity of Market Services with respect to Rail, $E_{MS,RW}$ *,* is derived by using formula (3.4) as follows,

$$E_{MS,RW} = w_1 \cdot E_{MS_1,RW} + w_2 \cdot E_{MS_2,RW} \tag{3.5}$$

with

$$w_1 = \frac{X_{MS_1}}{X_{MS}} \qquad \text{and} \qquad w_2 = \frac{X_{MS_2}}{X_{MS}}$$

Note that $X_{MS} = X_{MS_1} + X_{MS_2}$.

The intuition about w_1 (or w_2) is as follows. An exogenous burst of investment in sector Market Services impacts the output of this sector via the relative output of the aggregated sector Market Services in its subsector Network market Services (or Non-Network Market Services) which is the term $\frac{X_{MS_1}}{X_{MS}}$ (or $\frac{X_{MS_2}}{X_{MS}}$).

In the similar way $E_{MS,RD}$ is calculated.

Step 2. Aggregation of ECP sectors:

Given that $E_{MS,RD}$ and $E_{MS,RD}$ were calculated in Step 1. the output elasticity of *Market Services* with respect to capital infrastructures, $E_{MS,INF}$ can be derived:

$$E_{MS,INF} = w_1 \cdot E_{MS,RW} + w_2 \cdot E_{MS,RD} \tag{3.6}$$

with

$$w_1 = \frac{K_{INF}}{K_{RW}} \cdot \frac{dK_{RW}}{dK_{INF}} \qquad \text{and} \qquad w_1 = \frac{K_{INF}}{K_{RD}} \cdot \frac{dK_{RD}}{K_{INF}}$$

Note that here $K_{INF} = K_{RW} + X_{RD}$.

The intuition about w_1 is that an exogenous burst of investment in *Railway*s, i.e. dK_{RW}, impacts the output of sector Market Services via the following channels. First, it impacts the capital stock in the ECP subsector Railway which belongs to infrastructure. This explains $\frac{dK_{RW}}{dK_{INF}}$. Next, depends on the relative capital of the aggregated *ECP* sector infrastructures in its ECP subsector *Railways*, which is the term $\frac{K_{INF}}{K_{RW}}$. The same applies to w_2 for *Road*.

In the similar way the aggregated elasticity $E_{MF,INF}$ can be calculated.

3.3 Aggregation of spill-over elasticities

3.3.1 Implementation of aggregation formulas

In section 2.4 we have presented the description of the derivation of detailed productivity, output and environmental spill-over elasticities for thirteen types of ECP investment sectors and twenty-three types of economic sectors (according to RHOMOLO classification). The result was two matrices (for productivity and output spill-over elasticities) of dimension 13 X 23 plus a vector with 13 elements (for environmental spill-over elasticity) for each of eighteen Cohesion Countries.

These detailed results have to be aggregated to the level of details used in the HERMIN model. Aggregation of spill-over elasticities is based on the theoretical formulas for aggregation derived in section 3.2. Aggregation procedure is split into two steps: (1) aggregate economic sectors of RHOMOLO to HERMIN economic sectors and (2) aggregate thirteen types of ECP investment sectors into three types used in the HERMIN model. The aggregation procedure is implemented as follows:

Step I: Calculate the aggregation weights for the first step of aggregation as the share of value added of the sector in the total value added of the HERMIN economic sector to which it belongs.

Step II: Aggregate the economic RHOMOLO sectors into the HERMIN model sectors (manufacturing and market services).

Step III: Calculate the aggregation weights for the second step of aggregation as the share of ECP investment sector in the total capital stock of the HERMIN ECP investment sector to which it belongs.

Step IV: Aggregate the thirteen ECP investment sectors into the HERMIN model ECP investment sectors (infrastructure, human capital and RTD).

3.3.2 Overview of main results

Table below presents the calculated values of spill-over elasticities for the HERMIN model for all eighteen Cohesion Countries estimated on the basis of the results from ex-post CBA studies. These include the productivity, output and environmental spill-over elasticities. Our average over countries elasticities are similar to those reported in the HERMIN Manual for manufacturing output with respect to physical infrastructure, market services output with respect to RTD and market services productivity with respect to human resources. Our averaged estimates are higher for market services output with respect to physical infrastructure, for market services output with respect to human resources, and for market services productivity with respect to physical infrastructure.

And, finally, our averaged estimates are lower for manufacturing output with respect to human resources, manufacturing output with respect to RTD, manufacturing productivity with respect to physical infrastructure and manufacturing productivity with respect to human resources. This is not surprising in the light of results of econometric studies which have been reviewed in the HERMIN use manual (see section 2.4.2 for more details). These studies in general report the values of elasticities of manufacturing as being lower than the ones presently being used in HERMIN.

Our estimates for output and productivity spill-over for market services are higher then for manufacturing which is explained by the mapping between economic NACE sectors and the HERMIN sectors. According to the present mapping all main infrastructure sectors such as transport, telecommunications, water, electricity and gas are a part of the market services sector of the HERMIN model. Hence it is logical to expect that the effect of investment into infrastructure will have higher effects on this particular sector of HERMIN. The effect of infrastructure investments on manufacturing sector is lower.

Average spill-over elasticities of human capital are roughly the same in case of market services and manufacturing. Average spill-over elasticities of RTD are higher on manufacturing output and productivity than on market services. Impact of RTD on productivity and output is lower than the impact of human capital.

Environmental spill-over elasticities are negative in case of physical infrastructure and zero in case of human capital and RTD. Negative values of environmental spill-over elasticities reflect the present composition of ECP investments. The present share of investments into cleaner technologies and environmental protection is relatively low. If this share will increase in the future the values of this spill-over elasticity will become positive.

The variation of spill-over elasticities between the countries is mostly explained by the following two factors: value of CBR and the ratio between ECP capital stock and the corresponding economic indicator presented in section 2.2.3. The main essence of this indicator is the discounted flow of value added of an economic sector which corresponds to the particular type of ECP investment. For example road transport corresponds to the transport sector. Water supply corresponds to the water supply sector. In case of other types of ECP such as RTD and education, the whole economy is being affected rather than a particular sector. The effect of RTD and education on different sectors of the economic varies depending on their RTD and labour intensity.

In general if two countries have the same values of CBR and the economic indicator, the country with the higher ECP capital stock has the higher values of the spill-over elasticities. This reflects the fact that in case of a higher capital stock on a country one percent change in it requires larger investments and hence will have a higher impact.

In case the two countries have the same ratios of ECP capital stock to the economic indicator, the country with higher CBR has the higher values of the spill-over elasticities. This indicates that one country is more efficient than the other one in making investments.

If both CBR and ECP capital stocks of the countries are equal, the country with the higher values of the economic indicator has a lower value of the spill-over elasticities. This reflects the fact that in this country an ECP investment has an influence upon a larger part of the economy, hence its influence is spread and impact an on individual economic sector becomes smaller.

Table 16: The values of spill-over elasticities for the HERMIN model calculated on the basis of ex-post CBA studies

Type of ECP investment	HERMIN sector	BG	CY	CZ	DE	EE	ES	GR	HU	IE	IT	LT	LV	MT	PL	PT	RO	SI	SK	Ave
Physical infrastructure	Manufacturing output	0.0444	0.0194	0.1135	0.2171	0.1148	0.1689	-0.0248	0.1135	0.1496	0.3335	0.0483	0.1841	0.0982	0.0661	0.2335	0.0921	0.1447	0.0560	0.19
Physical infrastructure	Market services output	0.1937	0.0939	0.2069	0.3349	0.3049	0.3711	0.5416	0.1678	0.2822	0.3911	0.1176	0.4307	0.3420	0.1582	0.5126	0.1845	0.2883	0.1030	0.32
Human resources	Manufacturing output	0.0094	0.0081	0.0048	0.1546	0.0161	0.0124	0.0098	0.0043	0.0179	0.0568	0.0056	0.0064	0.0072	0.0055	0.0276	0.0057	0.0255	0.0035	0.09
Human resources	Market services output	0.0143	0.0090	0.0051	0.1160	0.0137	0.0137	0.0124	0.0052	0.0262	0.1508	0.0054	0.0118	0.0163	0.0105	0.0220	0.0095	0.0189	0.0030	0.09
RTD	Manufacturing output	0.0069	0.0107	0.0030	0.0414	0.0073	0.0184	0.0205	0.0073	0.0104	0.0334	0.0099	0.0276	0.0299	0.0043	0.0094	0.0029	0.0240	0.0120	0.03
RTD	Market services output	0.0082	0.0123	0.0035	0.0046	0.0136	0.0181	0.0157	0.0023	0.0027	0.0116	0.0047	0.0132	0.0086	0.0046	0.0112	0.0020	0.0052	0.0141	0.00
Physical infrastructure	Manufacturing productivity	0.0038	0.0026	0.0041	0.0060	0.0017	0.0148	0.0373	0.0040	0.0053	0.0059	0.0081	0.0112	0.0076	0.0021	0.0073	0.0047	0.0043	0.0054	0.00
Physical infrastructure	Market services productivity	0.0606	0.0296	0.0723	0.1179	0.1050	0.1050	0.2400	0.0515	0.0955	0.1264	0.0414	0.1202	0.1025	0.0416	0.1301	0.0466	0.0839	0.0423	0.10
Human resources	Manufacturing productivity	0.0057	0.0056	0.0033	0.1132	0.0071	0.0077	0.0053	0.0023	0.0108	0.0206	0.0026	0.0037	0.0051	0.0020	0.0087	0.0029	0.0106	0.0020	0.06
Human resources	Market services productivity	0.0050	0.0059	0.0032	0.0778	0.0098	0.0085	0.0076	0.0027	0.0195	0.0813	0.0026	0.0035	0.0113	0.0026	0.0116	0.0024	0.0103	0.0017	0.05
RTD	Manufacturing productivity	0.0057	0.0107	0.0032	0.0406	0.0053	0.0155	0.0180	0.0070	0.0101	0.0300	0.0089	0.0276	0.0299	0.0022	0.0090	0.0024	0.0216	0.0078	0.02
RTD	Market services productivity	0.0065	0.0123	0.0017	0.0036	0.0112	0.0122	0.0110	0.0019	0.0012	0.0081	0.0027	0.0130	0.0086	0.0022	0.0106	0.0013	0.0029	0.0078	0.00

3.4 Sensitivity analysis

In the general formula, the value of the elasticities depends on the value of the capital stock and the BCR of the projects. This makes clear that the resulting elasticities are dependent form assumptions made in the CBAs on the projects and on the assumptions made in the calculation of the capital stock by ECP sector. Changes in these assumptions have an influence on the resulting elasticities. We investigate in this section to what extent the elasticities change as a consequence of a change in the values of the BCRs and capital stock.

Assumption 1: growth rate of GDP in the future halved

Regarding the BCRs, their value is highly dependent on the GDP growth projections over the remainder of the 30 year horizon. GDP growth directly impacts demand (via income growth) and some shadow prices such as the value of statistical life, value of time, demand for passenger and freight transport, and the valuation of externalities in the future. The overall ERR and BCR will therefore change.

Since the projections by DG TREN are already highly optimistic, in the sensitivity analysis we only trim them down. More specifically, we assume that the growth rate of GDP in the future will be half projected rates. This formulated our alternative scenario.

Assumption 2: Variation in capital stock

As was explained earlier, capital stock by ECP sector is constructed based on data from Cambridge Econometrics and information from COFOG and stock of infrastructure in physical units. The errors in capital stock estimation arise, in the former case, from differences in flow-type COFOG data and stock estimations. In the latter, the errors can come from possible insufficient differentiation of unit costs per country. Therefore, we give a generous margin of error in capital stock estimate of +/- 20 percent. Thus we have two alternative scenarios.

With two scenarios on the BCR and three scenarios on the capital stock, we will have six different alternatives for each of which we calculated a set of elasticities:

	CS baseline	CS +20 %	CS -20%
BCR baseline	Baseline	MAX	
BCR slow growth			MIN

According to the elasticity calculation formulae, we will have minimal elasticity estimates under the scenario of BCR baseline with 20 percent increase in capital stock. The minimal values of elasticities result from scenario with BCR under slow growth and 20 percent reduction in capital stock.

Next, the elasticity estimates for the lowest level of sectoral aggregation are consequently aggregated to two higher levels of aggregation. Aggregation formulae presented in section 3.3 stipulate that aggregate elasticity is the weighted average of the elasticities at the lower level of aggregation. These formulae are similar in both aggregation steps – the one from the subsectors of investment to the sector of investment, and another from the sector of investment to the category of expenditure. The low and high bounds for the aggregate elasticities are obtained on the basis of the low and the high bounds for the elasticities at the lower levels via the aggregation formula.

The relative difference between the maximum and minimum estimates can be calculated for each elasticity as:

$$D = (E_{max} - E_{min}) / E_{min} \quad (3.7)$$

The average relative difference across all elasticity estimates at the aggregated level amounted to 28.9%, with a standard deviation of 6.3%..

In a fourth step, we raised the BCRs by 20%, simulatiug non-marginal effects. The average difference related to the minimum value, this resulted into an average difference of 53. 9 % with a standard deviation of 10.2%. The tables below give the range of elasticities (minimum and maximum values) obtained in this sensitivity analysis exercise.

Table 17: Maximum bound of elasticities by category of expenditure and country

Type of ECP investment	HERMIN sector	BG	CY	CZ	DE	EE	ES	GR	HU	IE	IT	LT	LV	MT	PL	PT	RO	SI	SK
Physical infrastructure	Manufacturing output	0.0533	0.0232	0.1362	0.2605	0.1378	0.2027	-0.0298	0.1362	0.1795	0.4002	0.0580	0.2209	0.1178	0.0793	0.2803	0.1105	0.1736	0.0672
Physical infrastructure	Market services output	0.2325	0.1127	0.2483	0.4019	0.3659	0.4453	0.6499	0.2014	0.3387	0.4693	0.1412	0.5168	0.4104	0.1898	0.6151	0.2214	0.3460	0.1236
Human resources	Manufacturing output	0.0113	0.0097	0.0058	0.1855	0.0194	0.0148	0.0117	0.0051	0.0215	0.0681	0.0068	0.0077	0.0086	0.0066	0.0331	0.0068	0.0306	0.0041
Human resources	Market services output	0.0172	0.0108	0.0061	0.1392	0.0165	0.0165	0.0149	0.0062	0.0314	0.1810	0.0064	0.0142	0.0195	0.0126	0.0264	0.0114	0.0227	0.0036
RTD	Manufacturing output	0.0083	0.0128	0.0036	0.0497	0.0088	0.0220	0.0246	0.0087	0.0125	0.0401	0.0119	0.0331	0.0358	0.0051	0.0113	0.0034	0.0288	0.0144
RTD	Market services output	0.0099	0.0148	0.0042	0.0055	0.0163	0.0217	0.0188	0.0027	0.0033	0.0140	0.0057	0.0158	0.0103	0.0056	0.0134	0.0024	0.0063	0.0170
Physical infrastructure	Manufacturing productivity	0.0045	0.0031	0.0050	0.0072	0.0021	0.0178	0.0448	0.0049	0.0064	0.0071	0.0098	0.0134	0.0091	0.0025	0.0088	0.0056	0.0051	0.0065
Physical infrastructure	Market services productivity	0.0727	0.0355	0.0868	0.1414	0.1260	0.1259	0.2880	0.0617	0.1145	0.1517	0.0497	0.1442	0.1230	0.0500	0.1561	0.0560	0.1007	0.0507
Human resources	Manufacturing productivity	0.0069	0.0067	0.0040	0.1358	0.0085	0.0092	0.0063	0.0028	0.0130	0.0247	0.0031	0.0044	0.0061	0.0024	0.0104	0.0035	0.0127	0.0024
Human resources	Market services productivity	0.0060	0.0071	0.0039	0.0934	0.0118	0.0102	0.0092	0.0033	0.0234	0.0976	0.0032	0.0042	0.0136	0.0032	0.0139	0.0028	0.0123	0.0020
RTD	Manufacturing productivity	0.0068	0.0128	0.0038	0.0487	0.0064	0.0186	0.0216	0.0084	0.0122	0.0360	0.0107	0.0331	0.0358	0.0026	0.0108	0.0029	0.0259	0.0094
RTD	Market services productivity	0.0078	0.0148	0.0021	0.0043	0.0134	0.0147	0.0131	0.0023	0.0014	0.0097	0.0033	0.0156	0.0103	0.0027	0.0127	0.0016	0.0035	0.0094

Table 18: Minimum bound of elasticities by category of expenditure and country

Type of ECP investment	HERMIN sector	BG	CY	CZ	DE	EE	ES	GR	HU	IE	IT	LT	LV	MT	PL	PT	RO	SI	SK
Physical infrastructure	Manufacturing output	0.0421	0.0164	0.0998	0.1821	0.1001	0.1492	-0.0220	0.1027	0.1243	0.3131	0.0437	0.1667	0.0795	0.0612	0.2001	0.0884	0.1284	0.0506
Physical infrastructure	Market services output	0.1838	0.0760	0.1816	0.2798	0.2651	0.3260	0.4969	0.1519	0.2330	0.3672	0.1061	0.3906	0.2747	0.1465	0.4373	0.1771	0.2553	0.0926
Human resources	Manufacturing output	0.0090	0.0078	0.0046	0.1474	0.0154	0.0119	0.0094	0.0041	0.0172	0.0545	0.0052	0.0060	0.0069	0.0052	0.0265	0.0055	0.0243	0.0033
Human resources	Market services output	0.0137	0.0087	0.0049	0.1106	0.0131	0.0132	0.0119	0.0049	0.0251	0.1448	0.0049	0.0110	0.0156	0.0099	0.0211	0.0091	0.0181	0.0028
RTD	Manufacturing output	0.0066	0.0103	0.0029	0.0397	0.0070	0.0176	0.0197	0.0070	0.0100	0.0321	0.0095	0.0265	0.0287	0.0041	0.0090	0.0028	0.0230	0.0115
RTD	Market services output	0.0079	0.0118	0.0033	0.0044	0.0130	0.0174	0.0150	0.0022	0.0026	0.0112	0.0046	0.0126	0.0083	0.0045	0.0107	0.0019	0.0050	0.0136
Physical infrastructure	Manufacturing productivity	0.0036	0.0023	0.0036	0.0052	0.0015	0.0131	0.0345	0.0036	0.0043	0.0051	0.0073	0.0100	0.0066	0.0019	0.0063	0.0045	0.0038	0.0050
Physical infrastructure	Market services productivity	0.0575	0.0237	0.0634	0.0982	0.0909	0.0917	0.2197	0.0464	0.0780	0.1182	0.0373	0.1089	0.0811	0.0384	0.1108	0.0447	0.0741	0.0379
Human resources	Manufacturing productivity	0.0055	0.0054	0.0032	0.1079	0.0067	0.0074	0.0051	0.0022	0.0104	0.0198	0.0024	0.0035	0.0049	0.0019	0.0083	0.0028	0.0101	0.0019
Human resources	Market services productivity	0.0047	0.0057	0.0031	0.0742	0.0094	0.0082	0.0073	0.0026	0.0187	0.0780	0.0024	0.0032	0.0109	0.0025	0.0111	0.0023	0.0098	0.0016
RTD	Manufacturing productivity	0.0054	0.0103	0.0031	0.0390	0.0051	0.0149	0.0173	0.0067	0.0097	0.0288	0.0085	0.0265	0.0287	0.0021	0.0087	0.0023	0.0207	0.0075
RTD	Market services productivity	0.0062	0.0118	0.0016	0.0034	0.0107	0.0117	0.0105	0.0019	0.0012	0.0078	0.0026	0.0125	0.0083	0.0021	0.0102	0.0013	0.0028	0.0075

Non-marginal elasticities

We have performed an experimental exercise on assessing the possible change in elasticities under assumption of very large investment shocks, which can be characteristic for programmes, with the use of RHOMOLO. We start with calibrating RHOMOLO so that the CBR obtained in the model coincide with the actually observed CBRs of projects. In order to reproduce CBR calculated in CBA studies with RHOMOLO, we have to calibrate fourteen investment efficiency parameters. These efficiency parameters are specific for each aggregated type of ECP investment and are incorporated in different parts of the model.

For instance, in case of "road transport", the calibrated efficiency parameter is a part of the congestion function implemented in RHOMOLO. This parameter allows us to translate investments in monetary units into additional capacity of road transport per region. Road capacity together with the flow of road transport (both passenger and freight) determines the level of congestion in a region and hence identifies an average travel time. Increase in road capacity leads to lower travel times and hence results in positive consumer surplus and welfare benefits.

We have chosen the studies from different countries which cover the following categories of ECP: (1) road; (2) education; (3) energy and (4) social infrastructure. Once the correct values of the investment efficiency parameters have been identified, we have run RHOMOLO in order to simulate the effect of the same type investment with the budget of 10 and 100 times higher than the initial one reported in the CBA files.

In total we have run about 10-15 simulations with RHOMOLO per project in order to calibrate the model on the results of CBA studies. Two additional simulations have been done for sensitivity analysis (10- and 100-times increase in investment budget). In total we have done about 60 simulations with RHOMOLO for this part of sensitivity analysis.

As we can see from the table below, increase in the investment budget results in CBR increase of 1% to 10% in comparison with the original CBR. Variation depends on the type of the project and the country of its implementation. In general we can see that increase in investment budget for infrastructure projects (transport and energy) does not result in high variation of CBR. On average, CBR increases by 4% as a result of 100 times increase in the investment budget. In case of investment in education we see a slight decrease in CBR resulting from an increase in the investment budget. This is explained by the nature of investments in education. Educated labour is complementary to RTD and physical capital in the production functions, which means that further investments in education without the accompanying investments into the other production factors exhibit decreasing returns to scale. Finally, increase in investment into social infrastructure leads to 15% increase in CBR in case of 100-time increase in investment. Social infrastructure is one of the important production factors for the sectors like education, health and social services. It improves their production capacity and allows more people to become employed in those sectors. Given that cohesion countries have relatively high level of unemployment, increase in capital stock of several important economic sectors exhibits increasing returns to scale. This will be the case until the pool of unemployed is not fully used.

Table 19 : Effects of scaling up ECP investments on BCR

Country	Type of ECP	Times	Investment size in mil euros	Calculated BCR	BCR from CBA	Ratio to original BCR
CY	**Road**		**114,00**	**1,51**	**1,50**	
		10,00	1140,00	1,53		1,01
		100,00	11400,00	1,53		1,02
GR	**Education**		**17,50**	**0,98**	**0,92**	
		10,00	175,00	0,95		0,97
		100,00	1750,00	0,95		0,97
PL	**Energy**		100,00	2,40	2,29	
		10,00	1000,00	2,61		1,09
		100,00	10000,00	2,58		1,08
IT	**Social infrastructure**		1,00	1,06	1,18	
		10,00	10,00	1,16		1,10
		100,00	100,00	1,22		1,15

Given that the time costs for this part of sensitivity analysis were quite high, we could only investigate four types of ECP investments in four countries. This gives only very modest degree of certainty over the impact of investment scaling-up on BCRs and consequently elasticities. We find it reasonable to believe that investment scaling-up could lead to increase in BCRs from 0 to 10 percent. Since there is a proportional relationship between BCRs and elasticities, this will also lead to increase in elasticities from 0 to 10 percent.

4 *Structure and content of Excel file used for calculation and aggregation of spill-over elasticities*

4.1 Main structure of the file

The Excel file called “Spill-over elasticities HERMIN” is the main output of this research project. This file allows both for calculation and for prediction of spill-over elasticities. Calculation of detailed elasticities are done on the basis of data form CBA studies and coefficients calculated with RHOMOLO model. The detailed spill-over elasticities are further aggregated in two steps to the level of details of the HERMIN model.

This file has a complex structure and consists of multiple linked work sheets. The list of the sheets is given below and their content is explained in details. All economic variables are given in millions of euro in the Excel file. Initial input data in the Excel file are highlighted with *light green colour*. The rest of the data is being calculated inside the Excel file.

- **Sheet “ERR”:** contains Economic Rates of Return (ERR) of the ex-post CBA studies done during this research project. Measured in %.
- **Sheet “Benefits to costs ratio”:** contains Benefits to Costs Ratios (BCR) of the ex-post CBA studies done during this research project.
- **Sheet “Ratio of env eff to inv costs”:** contains ratios of discounted environmental effects to discounted flow of investment costs of the ex-post CBA studies done during this research project.
- **Sheet “Capital stocks ECP”:** contains the estimated capital stocks of physical capital, human capital and RTD by thirteen types of ECP investment sectors. Measured in millions of Euros for the year 2007.
- **Sheet “Sectoral data”:** contains the initial data and parameters from RHOMOLO as well as the calculations of the indicator necessary to derive the own elasticity of output with respect to capital stock. The calculated indicator is derived on the basis of the theoretical formulas for linking CBR with the spill-over elasticities. The formulas use the data on sectoral outputs, intermediate consumption, consumption

taxes and the relationships between own and cross-sectoral output elasticity with respect to the capital stock. Both the data and the relationships between own and cross-sectoral elasticities are derived from RHOMOLO.

- **Sheet "Input into calculations":** contains all the data necessary for the calculation of detailed spill-over elasticities based on CBR from ex-post CBA studies. This includes the indicator calculated in sheet "Sectoral data", data on share of low and high-skilled labour in employment of a sector, RTD expenditure of a sector as % of country GDP, energy intensity, share of sector-specific emissions and waste in the total country emissions and waste and finally the relationships between own and cross-sectoral output elasticity with respect to the capital stock.

- **Sheet "Spill-over calculation":** contains the calculations of detailed productivity, output and environmental spill-over elasticities based on the theoretical formula linking CBR and spill-over elasticities.

- **Sheet "Sectoral data for aggregation":** contains the data on wages, returns to capital and capital stocks of the economic sectors of RHOMOLO, which are used for the derivation of weights.

- **Sheet "HERMIN data":** contains the data on wages, returns to capital and capital stocks of the economic sectors of HERMIN, which are used for the derivation of aggregation weights. The data in this sheet is derived as an aggregation of the data in sheet "Sectoral data for aggregation".

- **Sheet "Step I weights":** contains the derivation of aggregation weights for the first step of the aggregation (from detailed economic sectors to HERMIN economic sectors).

- **Sheet "Step I results":** contains the spill-over elasticities resulting from the first aggregation step.

- **Sheet "Step II weights":** contains the derivation of aggregation weights for the second step of the aggregation (from detailed ECP sectors of investment to HERMIN ECP sectors).

- **Sheet "HERMIN spill-over elasticities":** contains the spill-over elasticities resulting from the second aggregation step. <u>This sheet contains the final productivity, output and environmental spill-over elasticities to be used in the HERMIN model.</u>

- **Sheet "Simulation assumptions":** contains assumption used for deriving new values of spill-over elasticities based on certain simulation assumptions. Scenario assumptions are highlighted with *light yellow colour* and include assumptions about the composition of ECP investments, co-financing rates and alternative annual growth rates of the Cohesion Countries.

- **Sheet "Step II weights sim":** contains preliminary calculations of second step weights used to derive simulation results.

- **Sheet "Simulation results":** contains two types of simulation results (i.e. new values of spill-over elasticities to be used in the HERMIN model), the first one without taking into account alternative economic growth assumption and the second one is with taking into account alternative assumptions about the economic growth rate.

4.2 Implementation of formulas linking spill-over elasticities and BCR

The main formula giving the relationship between BCR and spill-over elasticities was presented in Section 2.2.4:

$$E = \frac{K^0}{\sum_{t=1}^{T} \frac{\varphi^t}{(1+r)^{t-1}}} \cdot BCR \qquad (4.1)$$

Where

$$\varphi^t = \sum_i [\eta_{m,i} \cdot X_i^t - \sum_j (IO_{ij}^{\ t} \cdot \eta_{m,j} \cdot X_j^t)] \cdot p_i^l \cdot (1+tc_i)$$

Exactly this formula is being implemented in the Excel file. The time horizon T is taken at 30 years, as in the CBAs. The sources of information for all other variables are threefold:

(i) Capital stock K^0 is our own estimate.
(ii) The ratio of own- to cross-elasticity $\eta_{m,i}$ is calculated in RHOMOLO.

Other parts of the second equation are taken from the use tables in purchaser prices. Indeed, $\sum_i X_i^t p_i^l \cdot (1+tc_i)$ is the output is purchaser prices (projected for the 30-year period with a baseline growth rate assumption; and $\sum_j IO_{ij}^{\ t} \cdot \eta_{m,j} \cdot X_j^t \cdot p_i^l \cdot (1+tc_i)$ is the intermediate product in the use table in purchaser prices.

4.3 Implementation of aggregation formulas

In order to aggregate the spill-over elasticities we need to know the mapping between RHOMOLO sectors and the production sectors of HERMIN. It should be noted that although the HERMIN model include five economic sectors, spill-over mechanism is only assumed in Manufacturing and Market Services as these sectors are direct beneficiary of output and productivity enhancing spill-overs. In Table 20, the correspondence between sectors in HERMIN, sectors in RHOMOLO, and the NACE classification are shown.

Table 20: The correspondence between sectors in HERMIN, sectors in RHOMOLO, and the NACE classification.

HERMIN sectors	RHOMOLO sectors	NACE classification code
Agriculture	Agriculture, hunting and forestry	A
	Fishing	B
Manufacturing	Food, beverage and tobacco	DA
	Textiles and clothing	DB
	Fuels, chemical, rubber and plastic	DF, DG, DH
	Electronics	DL
	Transport equipments	DM
	Other manufacturing	DC, DD, DE, DI, DJ, DK, DN
Building and Construction	Constructions	F
Market services	Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods	G
	Hotels and restaurants	H
	Transport and storage	IA60, IA61, IA62, IA63
	Post and telecommunications	IA64
	Financial intermediation	J
	Real state, renting and other business activities	KA70, KA71, KA72, KA74
	Research and development	KA73

HERMIN sectors	RHOMOLO sectors	NACE classification code
	Water supply	EA40.3
	Electricity and gas	EA40.1, EA40.2
	Mining and quarrying	C
Non-market services	Public administration and defence, compulsory social security	L
	Education	M
	Health and social work	N

Source: EuroStat, Statistical Classification of Economic Activities in the European Community, Rev. 1.1 (2002),

Accordingly, the two models differ in sectoral aggregation but there is a clear correspondence between sectoral definitions of both models, since both are based on NACE classification. Hence HERMIN sectors can be obtained by aggregating RHOMOLO sectors following the mapping presented at the table above.

The aggregation of 23 RHOMOLO production sectors into the sectors of HERMIN can be done using the weights calculated according to the aggregation formula in section 3.2. The weights are calculated on the basis of data received from the database of RHOMOLO model.

In order to implement the second step of aggregation we need to map the thirteen ECP sectors of investment with the three investment types used in HERMIN model. Table below provides details on the mapping which was used.

Table 21: Correspondence between ECP sectors of investment and investment types in HERMIN model

ECP investment sector	HERMIN type of investment
Road	Physical infrastructure
Rail	Physical infrastructure
Port	Physical infrastructure
Waste water	Physical infrastructure
Solid waste	Physical infrastructure
Drinking water	Physical infrastructure

Air emissions and environmental protection	Physical infrastructure
Energy	Physical infrastructure
ICT	Physical infrastructure
Social infrastructure	Physical infrastructure
Education	Human capital
Labour market institutions	Human capital
RTD and aid to productive sectors	RTD

At the second step of aggregation we again calculate the weights according to the theoretical formulas using the data on capital stocks by ECP sector of investment. We aggregate thirteen types of investments into three types used in the HERMIN model.

4.4 Predicting spill-over elasticities

Prediction of the values of HERMIN spill-over elasticities is based on a set of the assumptions to be specified in the Excel sheet "Simulation assumptions":

- The mix of investments done into different ECP sectors by thirteen types of investments. This has to be specified in millions of Euros for all Cohesion Countries.
- Co-financing rates of the European Commission by type of ECP investment have to be specified as a share for all Cohesion Countries.
- Alternative assumptions about the long-term annual growth rates of the Cohesion Countries have to be specified if necessary. At the present moment we are using the official forecasts of Energy Outlook published by the European Commission.

Once these assumptions have been specified the new values of the spill-over elasticities will be calculated and displayed in the sheet "Simulation results". Excel file produces two sets of simulation results: (1) without taking into account alternative economic growth assumptions and (2) taking into account alternative economic growth assumptions.

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Annexes

Annex 1. Allowing for HERMIN features

Preamble

Annex 1 is concerned with identifying the appropriate approach to derive spill-over elasticities for HERMIN model. As noted in the Commission's comment, a Computable General Equilibrium (CGE) model is necessary to derive micro-founded spill-over elasticities by using data on real investment projects. This is done "In order to adequately consider the characteristics of the economies by taking into account less aggregated approaches". The main challenge and essence of the present study is to make a link between micro-level data on various CBA studies and macro-level spill-over elasticities used as input to HERMIN model.

No macro-econometric model such HERMIN could be used in this regard. In addition, the model used for deriving spill-over elasticities should not be identical to HERMIN, simply because in HERMIN spill-over elasticities are exogenous (they cannot be calculated by using HERMIN). Therefore, the model used to derive elasticities should necessarily be different from HERMIN. However, where relevant the differences will be reduced at the minimum to ensure that we derive the best consistent spill-over elasticities to be used in HERMIN.

The methodological approach, which will allow us to link micro and macro levels of analysis within the context of this study, is the regional CGE framework. This framework represents the meso (sectoral and regional) level of analysis. CGE model is the only type of economic methodology, which can provide us with the framework that includes both micro and macro-economic elements in a theoretically consistent way. Hence, it is indispensible to this study given the objectives presented in the terms of reference: to estimate spill-over elasticities based on the micro-level data of investment projects.

In order to explain in more details the approach used for estimation of spill-over elasticities for HERMIN, this annex describes:

1. HERMIN model main features and specifications, which are most relevant for the spill-over elasticities (functional forms adopted for the output and production function);
2. Sector correspondence between HERMIN, RHOMOLO and NACE95 classification of EuroStat, which ensures that capital stocks from Cambridge Econometrics database and spill-over elasticities derived using RHOMOLO are consistent with HERMIN;

3. The correspondence between the ECP broad categories of expenditure included in HERMIN (physical infrastructure, human resources, direct aid to the productive sector, the latter being split into RTD and non RTD expenditure) and the aggregation of the expenditure adopted in this study.

4. Explaining how the results of econometric estimation of the production function parameters for RHOMOLO (including substitution elasticities and TFP regressions) will be used to evaluate the coefficients capturing the impact of investments in physical capital, human capital and RTD (i) on TFP (output) and (ii) on labour productivity in HERMIN;

5. TFP specification tested until now. The specification is based on the endogenous growth models of economic growth and catch-up that are widely used in the literature on a leader-follower context of economic development (e.g., see Barro and Sala-i-Martin 1995; 1997; Howitt 2000). In this framework, productivity growth is generated through own innovations, knowledge spill-overs and technology adoption (catching-up).. The most important elements to model semi-endogenous growth are technological knowledge, R&D stocks, human capital stocks, and investments in education and R&D by households, firms and the government.

Overall structure of HERMIN model

The overall structure of HERMIN model is described through its three main blocks: a supply block, an absorption block and an income distribution block. These are schematically described in

Figure 7 as provided in the operating manual of The COHESION System of HERMIN country and regional models.

Figure 7: ***The HERMIN Model Scheme***

Supply aspects

Manufacturing Sector (mainly tradable goods)

Output = f_1(World Demand, Domestic Demand, Competitiveness, t)

Employment = f_2(Output, Relative Factor Price Ratio, t)

Investment = f_3(Output, Relative Factor Price Ratio, t)

Capital Stock = Investment + (1-δ) Capital Stock$_{t-1}$

*Output Price = f_4(World Price * Exchange Rate, Unit Labour Costs)*

Wage Rate = f_5(Output Price, Tax Wedge, Unemployment, Productivity)

Competitiveness = National/World Output Prices

Building and Construction Sector (mainly non-tradable)

Output = f_6(Total Investment in Construction)

Employment = f_7(Output, Relative Factor Price Ratio, t)

Investment = f_8(Output, Relative Factor Price Ratio, t)

Capital Stock = Investment + (1-δ)Capital Stock$_{t-1}$

Output Price = Mark-Up On Unit Labour Costs

Wage Inflation = Manufacturing Sector Wage Inflation

Market Service Sector (mainly non-tradable)

Output = f_6(Domestic Demand, World Demand)

Employment = f_7(Output, Relative Factor Price Ratio, t)

Investment = f_8(Output, Relative Factor Price Ratio, t)

Capital Stock = Investment + (1-δ)Capital Stock$_{t-1}$

Output Price = Mark-Up On Unit Labour Costs

Wage Inflation = Manufacturing Sector Wage Inflation

Agriculture and Non-Market Services: mainly exogenous and/or instrumental

Demographics and Labour Supply

Population Growth = f_9(Natural Growth, Migration)

Labour Force = f_{10}(Population, Labour Force Participation Rate)

Unemployment = Labour Force – Total Employment

Migration = f_{11}(Relative expected wage)

Demand (absorption) aspects

Consumption = f_{12}(Personal Disposable Income)

Domestic Demand = Private and Public Consumption + Investment + Stock changes

Net Trade Surplus = Total Output - Domestic Demand

Income distribution aspects

Expenditure prices = f_{13}(Output prices, Import prices, Indirect tax rates))

Income = Total Output

Personal Disposable Income = Income + Transfers - Direct Taxes

Current Account = Net Trade Surplus + Net Factor Income From Abroad

*Public Sector Borrowing = Public Expenditure - Tax Rate * Tax Base*

Public Sector Debt = (1 + Interest Rate) $Debt_{t-1}$ + Public Sector Borrowing

Key Exogenous Variables

External: World output and prices; exchange rates; interest rates;

Domestic: Public expenditure; tax rates.

Source: Bradley and Untiedt (2008)

The supply aspect describes the production component of the five economic sectors in the model, viz. manufacturing, market services, building and construction, agriculture and non-market services. The manufacturing output is determined in HERMIN by a combination of world and domestic demand, together with price and cost competitiveness terms. In both the manufacturing and market service sectors, factor demands are derived on the basis of cost minimisation subject to given output yielding a joint factor demand equation system.

When subject to a demand shock, expenditure and income distribution sub-components generate fairly standard income-expenditure mechanisms. For example, the implementation phase of cohesion policy has a demand component, as public expenditure is increased, but longer-term supply side benefits have not yet appeared.

But the HERMIN model also has many neoclassical features in the longer term. Thus, output in manufacturing is not simply driven by demand. It is also influenced by price and cost competitiveness, where firms seek out minimum cost locations for production (Bradley and FitzGerald, 1988). In addition, factor demands in manufacturing and market services are derived on the assumption of cost minimization, using a CES production function constraint, where the capital/labour ratio is sensitive to relative factor prices. The incorporation of a structural Phillips curve mechanism in the wage bargaining mechanism introduces further relative price effects.

For the case of agriculture, output is determined from a time-trended labour productivity relationship. Unlike the cases of manufacturing and services, no production function is imposed. The view is taken that low productivity in the sector is partially caused by under-employment. For the market services, output is measured mainly by wage inputs but also includes a non-wage element.

Population growth is endogenised through a “natural” growth rate, corrected for net additions or subtractions due to migration. Population is treated in terms of three age cohorts: pre-working age; working age; and post-working age. In all three cases, a natural growth mechanism is specified where the rate of growth/decline is obtained from data. Net out-migration is linked only to the working age group. The labour force participation rate is treated as a single aggregate

The determination of household consumption is determined partially by real personal disposable income. Public consumption is determined primarily by public employment, which is (effectively) a constrained policy instrument. Private investment is determined within production sectors as the investment part of the sectoral factor demand systems. Public investment is a constrained policy instrument.

Table 22 below summarizes the main features of the HERMIN model and contrasts them with the RHOMOLO model. The RHOMOLO model is a Spatial Computable General Equilibrium (SCGE) whish is also being built to for the purpose of evaluating the EU Cohesion policy. Both models are based on Keynesian theory. This ensures that the models are consistent at the macro-level. The macro-economic closure of RHOMOLO is also quite similar to the closure which is used in HERMIN. Unlike the HERMIN model which is at the national level, the RHOMOLO is based on regional level.

Table 22: HERMIN model features in comparison with RHOMOLO

Model features	**HERMIN**	**RHOMOLO**
Overall methodology	Macro-econometric	Spatial Computable General Equilibrium
Geographical disaggregation	Country-level	NUTS2
Production functions	Constant Elasticity of Substitution	Constant Elasticity of Substitution
Technological progress	Hicks neutral technical progress	Hicks neutral technical progress
Macro-closure	Keynesian closure, which allows for unemployment and wages to be different from the marginal product of labour..	Neo-Keynesian/Kaldorian closure, which allows for wage to be different from the marginal product of labour and brings investments to equality with savings.
Sectoral classification	NACE 5 sectors	NACE 23 sectors
Wage identification	Bargaining mechanism	Bargaining mechanism

Sector Correspondence

It should be noted that although the HERMIN model include 5 economic sectors, spill-over mechanism is only assumed in Manufacturing and Market Services as these sectors are direct beneficiary of output and productivity enhancing spill-overs. In Table 20, the correspondence between sectors in HERMIN, sectors in RHOMOLO, and the NACE classification are shown.

Table 23: The correspondence between sectors in HERMIN, sectors in RHOMOLO, and the NACE classification.

HERMIN sectors	**RHOMOLO sectors**	**NACE classification code**
Agriculture	Agriculture, hunting and forestry	A
	Fishing	B
Manufacturing	Food, beverage and tobacco	DA
	Textiles and clothing	DB
	Fuels, chemical, rubber and plastic	DF, DG, DH
	Electronics	DL
	Transport equipment	DM
	Other manufacturing	DC, DD, DE, DI, DJ, DK, DN
Building and Construction	Constructions	F
Market services	Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods	G
	Hotels and restaurants	H
	Transport and storage	IA60, IA61, IA62, IA63
	Post and telecommunications	IA64
	Financial intermediation	J
	Real state, renting and other business activities	KA70, KA71, KA72, KA74

HERMIN sectors	RHOMOLO sectors	NACE classification code
	Research and development	KA73
	Water supply	EA40.3
	Electricity and gas	EA40.1, EA40.2
	Mining and quarrying	C
Non-market services	Public administration and defence, compulsory social security	L
	Education	M
	Health and social work	N

Source: EuroStat, Statistical Classification of Economic Activities in the European Community, Rev. 1.1 (2002),

Accordingly, the two models differ in sectoral aggregation but there is a clear correspondence between sectoral definitions of both models, since both are based on NACE classification. Hence HERMIN sectors can be obtained by aggregating RHOMOLO sectors.

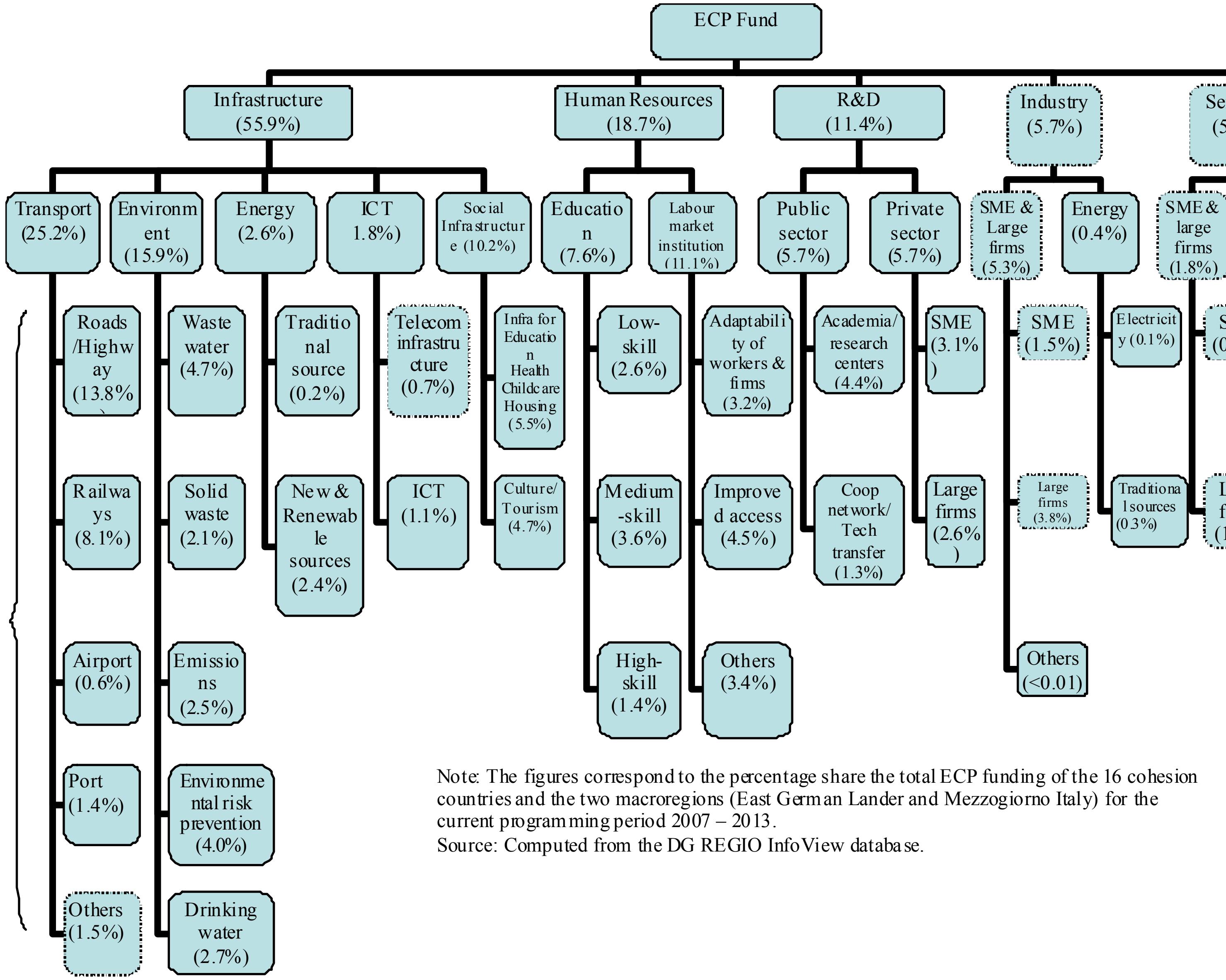
From the table of correspondence between HERMIN sectors and NACE classification, presented above, it is clear how the coherence between HERMIN and NACE sectoral classifications is ensured. In addition, in HERMIN also energy, gas and water (E), and mining sectors (C) is a part of "Market services". This does not create any problem for aggregation of elasticities calculated with RHOMOLO. It is only a question of correct mapping of detailed RHOMOLO sectors to the sectors of HERMIN.

The capital stock data from Cambridge Econometrics database is available for the following NACE sectors: (1) Agriculture that includes NACE sectors A and B; (2) Manufacturing that includes NACE sectors C to F; (3) Services that include NACE sectors G to P. As regards the capital stock data, this will be taken from Cambridge Econometrics which estimates capital stock as a whole for manufacturing sector which includes NACE sectors C to F. In order to resolve this problem we can make use of EU-KLEMS data on capital stocks, which is available at detailed NACE disaggregation at the country level. This auxiliary information will allow us to separate the capital stock of E and C sectors from manufacturing sector and add it to sector "Market services" in HERMIN.

Categories of expenditure

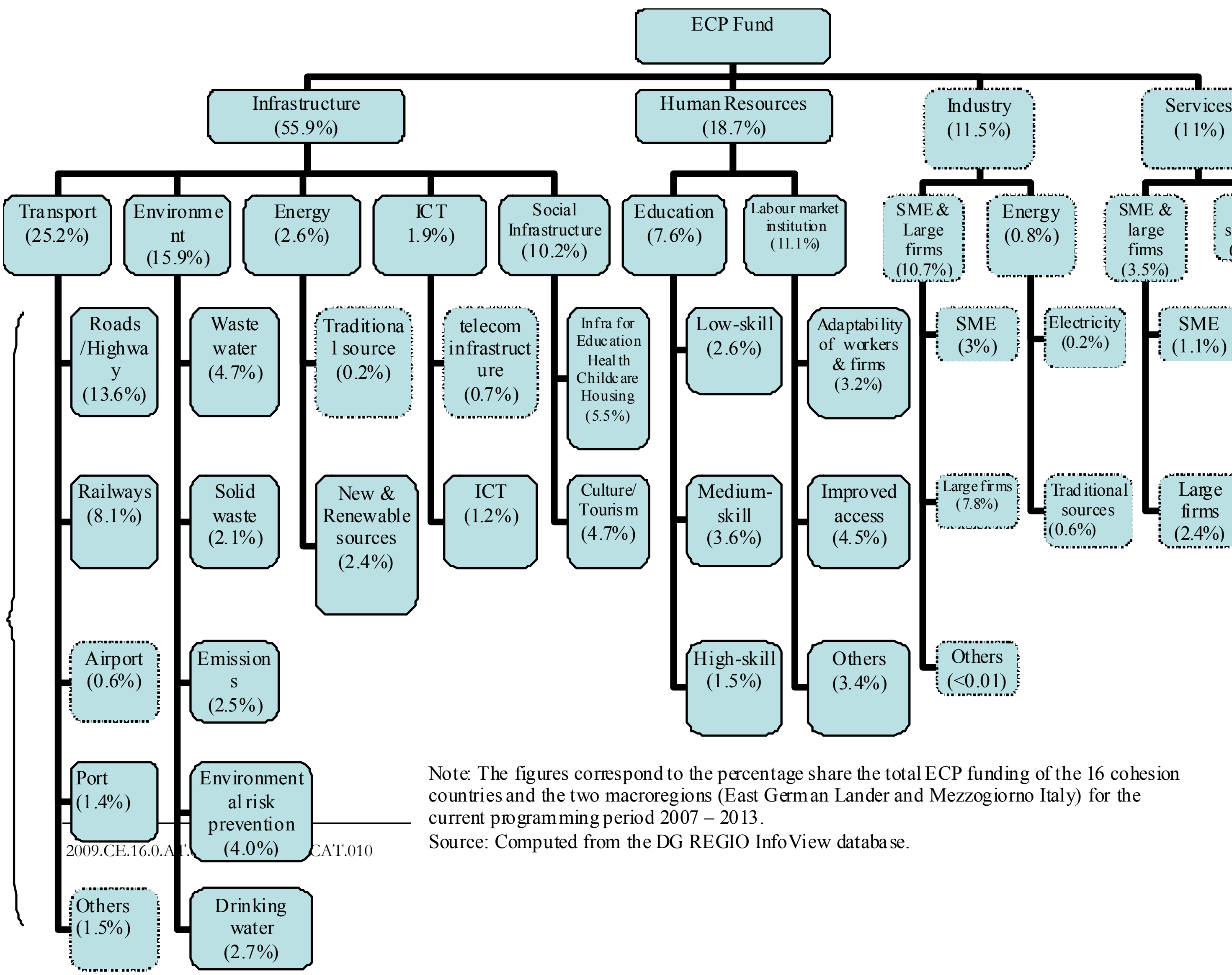
Presented here are the schematic diagrams of the categorization of ECP thematic dimensions taking into account the InfoViews' categorization. Diagram 1 depicts the diagram in which the 86 ECP thematic dimensions is grouped into 5 expenditure categories where in aid to productive sector is split into R&D, industry and services. It can be seen that R&D expenditure accounts more or less for 50% of the total aid to productive sector of the 16 cohesion countries plus the 2 macro-regions under investigation. In these countries, aid to production sector accounts 22.5% of the total ECP expenditure. In Diagram 2, R&D is contained partly in industry and partly in services on the pro rata basis, as it can be done in HERMIN. Therefore, Diagram 2 is equivalent to the classification of the sectors of investment of HERMIN. RHOMOLO will use this particular this classification.

Diagram 1: Levels of Sectoral Aggregation and Budgetary Relevance, infoView.



Note: The figures correspond to the percentage share the total ECP funding of the 16 cohesion countries and the two macroregions (East German Lander and Mezzogiorno Italy) for the current programming period 2007 – 2013.
Source: Computed from the DG REGIO InfoView database.

Diagram 2: Levels of Sectoral Aggregation and Budgetary Relevance, HERMIN.



Note: The figures correspond to the percentage share the total ECP funding of the 16 cohesion countries and the two macroregions (East German Lander and Mezzogiorno Italy) for the current programming period 2007 – 2013.
Source: Computed from the DG REGIO InfoView database.

Production functions of HERMIN

In this sub-section we focus on the supply side of the HERMIN model in which spill-over elasticises are specified. The HERMIN specification of the production function described in the main part of HERMIN manual (Bradley and Untiedt, 2008) follows a CES form of the added value production function and imposes it on the manufacturing (T), the market service (M) and the building and construction (B) sectors:

$$O = A \cdot \exp(\lambda t) \cdot \left[\delta L^{-\rho} + (1-\delta) K^{-\rho} \right]^{-\frac{1}{\rho}} \qquad (4.1)$$

In this equation, *O, L* and *K* are added value, employment and the capital stock, respectively, *A* is a scale parameter, ρ is related to the constant elasticity of substitution, δ is a factor intensity parameter, *t* is time, and λ is the rate of Hicks neutral technical progress, acting as a proxy for the sector's autonomous expansion.

It should be noted, however, that in the actual code of the HERMIN model (presented in the Annex A3: Sample model listing: HEE5.TXT), the capital flow, that is, investment (I), is incorporated in the production function and not the stock of capital, (K). If this assumption is made, then from the cost-minimisation, investment (*I*) and labour demand (*L*) are derived, using a CES production function with constant returns to scale. This leads to a two factor demand system (Bradley and Untiedt, 2008):

$$I = O \cdot \exp\left(-\ln(AX) - \lambda \cdot t + \frac{\sigma}{(1-\sigma)} \cdot \ln\left((1-\delta) + \frac{\sigma}{(1-\sigma)} \cdot \ln\left(\frac{\delta}{1-\delta}\right)^{\sigma} \cdot ERFP^{(1-\sigma)} + 1 \right) + TRI \right) \quad (4.2$$

$$L = O \cdot \exp\left(\begin{array}{l} -(D_H \cdot \eta_H) \cdot \ln(KTRNR) - \ln(AX) - \lambda \cdot t + \\ \frac{\sigma}{(1-\sigma)} \cdot \ln\delta + \frac{\sigma}{(1-\sigma)} \cdot \ln\left(\left(\frac{\delta}{1-\delta}\right)^{-\sigma} \cdot ERFP^{(\sigma-1)} + 1 \right) \end{array} \right)$$

where *ERFP* is the expected relative factor price ratio. *KTRNR* is a training stock ratio dependent on training investment (i.e., increase in stock of trained labour). η_H is the labour productivity spill-over of human capital, and the D_H is the corresponding exogenous variable relating "phase-in" mechanisms that "permit one to take account of the fact that some multi-year investment programmes may only yield supply-side benefits after a lag".[32] The effective input of labour $\lambda \cdot \left(KTRNR\right)^{D_H \cdot \eta_H}$ is equivalent to augmenting the labour-embodied technical progress term, $\lambda_L \cdot t$. Hence, human capital is embodied in labour and the returns to increases in human capital are internalised.

The term *TRI* in the investment demand equation is direct aid to productive sectors (i.e., sectoral share of total APS), which is included as a boost to the sectors' (industry or services) investment. Hence, during the implementation phase of any cohesion policy programme, there is a Keynesian boost to the economy, operating through an exogenous increase in the sectors' investment. This vanishes after the programme is terminated. In contrast, the R&D element continues to have supply-side spill-over impacts that operate as TFP externality. Similarly, infrastructure investments have the same TFP externality effect mechanism in the production function. These externality effects of R&D and infrastructure are operationalized in the scale parameter (*A*):

$$AX = A \cdot \left(K_{IF}\right)^{D_{IF} \cdot \eta_{IF}} \cdot \left(K_{RD}\right)^{D_{RD} \cdot \eta_{RD}} \qquad (4.3)$$

where K_{IF} and K_{RD} are the increase in stock of physical infrastructure and R&D, respectively. η_{IF} and η_{RD} are the corresponding labour productivity spill-over of infrastructure and RD, and the D_{IF} and D_{RD} are exogenous variables relating "phase-in" mechanisms.

The capital stock is recovered using the standard perpetual inventory method (PIM) formula with an assumption that there is no difference in efficiency between old and new vintages of capital:

$$K_t = I_t + \left(1 - \lambda_K\right) \cdot K_{t-1} \qquad (4.4)$$

where λ_K is the depreciation rate set equal to 8%.

On the other hand, the measure of human capital (*H*) is based on the average number of years of formal education and training that the labour force has achieved which is converted into a number of man-years. Specifically, the number of cohesion policy-funded

[32] Accordingly, these variables are set so as to phase in the supply-side impacts uniformly over a five-year period. In other words, the full impact of the spill-over benefit, as quantified by the spill-over elasticity and the size of the increase in the underlying stock, only comes on stream after five years. As more information comes available on the actual progress of the investment programmes, these "phase-in" variables can be reset to reflect reality.

trainees (measured in trainee-years) is accumulated into a 'stock' by means of a PIM, with a ‘depreciation’ rate of 5%.[33]

$$K_{Ht} = ST_t + \left(1 - \lambda_H\right) \cdot K_{Ht-1} \tag{4.5}$$

where H_t is an approximate number of extra trainees per year that can be funded from cohesion policy for a given total expenditure on human resources, which takes into account the following considerations, (i) income of the trainee or participant taken to be a specified fraction of the average industrial wage, (ii) the wage of the wage of the instructor, (iii) overhead on total wage costs to take account of buildings, equipment, materials, and (iv) a trainee-instructor ratio.

The initial stock of human capital is computed as:

$$K_{H0} = \sum_s Y_s \cdot F_s \cdot D_s \tag{4.6}$$

where the subscript *s* refers to the 4 education levels (i) primary and lower secondary, higher secondary, non-university tertiary and university tertiary. *Y* is standardised number of years. *F* is fraction of population with *s* cycle education. *D* is the corresponding “discount” factor for years of the *s* cycle.[34]

In the HERMIN model, a common value of the elasticity of substitution of 0.5 is imposed in all sectors and countries except Bulgaria and Mezzogiorno where it is set to 0.8. Both are rather ad hoc assumptions not supported by available econometric evidence.

Since the stock of capital cannot be approximated with an investment, we will estimate econometrically a standard CES production function with capital stock and labour as factor inputs. In addition to econometric estimation of CES production function we will also estimate the TFP regression, which will become an integral part of production functions in RHOMOLO. The specification of TFP regression will be based on the latest advance-

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[33] As noted by Bradley and Untiedt (2008), if the HR programmes are badly designed and ineffective, obviously the raw stock proxy, K_H will be a poor guide to future benefits. However, that can be handled by imposing low, or zero spill-over benefits.

[34] Bradley and Untiedt (2008) provides a motivation for including a “discount” factor which is as follows. “Although many studies assume that a single year of primary cycle education adds as much to human capital (and is as valuable a contribution as an input to productive working activity), as one year of university education, this is very unlikely to be true in practice. Adding up the years of education without weighting them is likely to bias the level of human capital upwards. For example, since primary and lower secondary level education are becoming the norm throughout the EU, we might discount these years relative to years of higher secondary, tertiary non-university and tertiary university education. If one sets the discount factor to zero, this is equivalent to assuming that primary and lower secondary education is a prerequisite for acquiring human capital, and not a part of productivity-enhancing human capital. However, this is a rather extreme assumption.”

ments in growth theory and empirics. This is necessary to ensure high quality of the elasticity spill-overs for HERMIN, which will be estimated using RHOMOLO model. Simulations with RHOMOLO will be used in order to estimate the impact of investments in physical capital, human capital and RTD on TFP (output) and labour productivity. This is the best way to achieve two goals: allow RHOMOLO to be consistent with HERMIN and integrate in it the elements which are lacking in HERMIN and do not allow for calculating spill-over elasticities. The latter should be in fact derived by considering those additional modelling aspects not included in HERMIN.

TFP specifications

The exact formulation of technical progress cannot be easily obtained from the HERMIN specification. From the interpretation of the relevant parameters all possible types of technical progress (Hicks-neutral, Harrod-neutral (labour-embodied) and autonomous) are applied together to different parts of demand equation. To derive the needed spill-over elasticities and to fully allow for the latest theoretical developments in economic growth theory and for empirical developments in the field, we will make growth regressions based on the present state-of-the-art. This will ensure the quality of the spill-over elasticities for HERMIN evaluated with the use of RHOMOLO model, where the model parameters are estimated on the micro-level data of CBA studies.

Based on the extensive literature review, which took place in the beginning of the project we will model the growth of total factor productivity (TFP) as a semi-endogenous growth with a catch-up mechanism. In this case TFP growth is determined by investments in research and development (R&D), human capital and a gap between a region and a technological leader. TFP levels were derived with the use of gross value added, capital stocks and employment from Cambridge Econometrics database. Technological leader in a base year is defined as a region with the highest level of TFP.

In the final specification the average TFP growth evaluated over ten years depends on human capital, R&D intensity and the interaction term of human capital and TFP gap in the base year. TFP growth is averaged over several years in order to smooth business cycle fluctuations. The specification was estimated separately for three aggregated sectors: agriculture, manufacturing and services. All the parameters turned out to have a positive effect on productivity growths as one could expect. Also all the parameters, except for R&D in agriculture, are significant determinants of TFP growth. We got plausible simulation results of estimated specification as well. One-off human capital and R&D intensity increase leads to stably higher TFP growth path with the half life of 20 years for agriculture and manufacturing and 50 year for services (for details, see Work Package 2 section 1.5.2 of the report).

Results of econometric estimation of TFP regressions will be incorporated into RHOMOLO in order to improve its reliability and quality of its simulation results. Econometric estimates of production function and TFP regression parameters will represent the first best guess and the starting point for the estimation procedure based on the results of micro-level CBA studies. RHOMOLO parameters will be estimated based on the procedure described in the next section of the Annex and will be micro-founded. The estimated parameters in combination with the structure of RHOMOLO will provide the link between micro and macro level data and effects required within the context of this project. As a result, the impacts of investments in physical capital, human capital and RTD on TFP (output) and labour productivity (that is spill-over-elasticities) estimated by using RHOMOLO will be micro-founded as is requested by the terms of reference of the project. Thus the impact of increases in the stock of physical capital, of R&D and of human capital on output and labour productivity will be evaluated with the help of econometrics.

Again this is the best approach to proceed: considering on the one hand HERMIN specifications, and on the other hand the lack in it of key aspects which are fundamental to derive the needed spill-over elasticities. In other words, as in HERMIN spill-over elasticities are exogenous they should include those key determinants (for the spill-over elasticities themselves) which are lacking in HERMIN.

Estimation and calibration of economic models

In the classical literature of applied CGE modelling (see Scarf and Shoven (2008)), model parameters are not estimated but rather calibrated on the dataset for one year. Approach for parameters calibration is relatively simple and consists of solving analytically system demand or supply equations with respect to model parameters under assumption that one knows all quantities and prices in the base year. The base year here is the year for which one has the data for the model. In some cases (like in the case of CES demand functions) one has more unknown model parameters then known quantities. This means that the system of equations does not have a unique solution and one needs to fix a number of parameters based on some assumptions or literature estimates. In case of CES functions one normally uses a literature estimate for the elasticity of substitution and finds analytically the share and scaling parameters of the function.

Estimation of parameters of CGE models is a very new field which is presently under development. Only a couple of small applied models so far have been estimated rather then calibrated. The difficulty of estimation of parameters of an applied CGE model is two-fold: firstly, one needs to have a series of sector-level observations to do that and this was not available until very recently and, secondly, one needs to have a method to estimate a large system of non-linear equations. Most of existing econometric software is not quite able to handle this challenge.

As one knows from econometrics one should use maximum likelihood approach in order to estimate the system of non-linear equations. The same method has also been proposed for estimation of CGE models (see Draganska and Dipak (2001)). However, implementation of this method proved to be quite difficult and it requires quite some computer power. An alternative is to use the entropy approach (see Arndt, Sherman and Tarp (2001)).

The good thing about this alternative is that in its essence it is very close to the maximum likelihood approach. In fact they give identical results under certain conditions.

We propose to follow the maximum entropy approach in order to estimate the parameters of CGE model in the present project. It will be used in order to evaluate the parameters of RHOMOLO based on a set of micro-level data of the CBA studies. Implementation of this approach will require us to programme it in GAMS in parallel with the RHOMOLO code. The code for the estimation of RHOMOLO parameters based on the maximum entropy approach is already under development.

Conclusions

Comparing the main features of HERMIN and RHOMOLO models, the fundamental difference between these models stems from the fact that RHOMOLO is a CGE model while HERMIN is a macroeconomic model with exogenous elasticities (that is, they cannot be calculated within HERMIN). Both models are built to for the purpose of evaluating the EU Cohesion policy and based on Keynesian theory. This ensures that the models are consistent at the macro-level. The macro-economic closure of RHOMOLO is also quite similar to the closure which is used in HERMIN. Unlike the HERMIN model which is at the national level, the RHOMOLO is based on regional level.

The two models differ in sectoral aggregation but there is a clear correspondence between sectoral definitions of both models, since both are based on NACE classification. Hence HERMIN sectors can be obtained by aggregating RHOMOLO sectors. In addition, the nomenclatures of ECP sectors of investment in both models are the same.

Since we believe that approximating stock of capital with an investment flow is incorrect, we will not estimate the demand equations of HERMIN specification presented above. Instead, we will estimate econometrically a standard CES production function with capital stock and labour as factor inputs. Econometrically estimated parameters of CES production function will be used in order to improve the reliability and quality of RHOMOLO model. This is necessary to ensure high quality of the elasticity spill-overs for HERMIN, which will be estimated using RHOMOLO model. Simulations with RHOMOLO will be used in order to estimate the impact of investments in physical capital, human capital and RTD on TFP (output) and labour productivity.

Since the exact formulation of technical progress cannot be easily obtained from the HERMIN specification, we have chosen to investigate the latest theoretical and empirical developments in the field and construct our growth regressions based on the present state-of-the-art. This will ensure the quality of the spill-over elasticities for HERMIN evaluated with the use of RHOMOLO model, where the model parameters are estimated on the micro-level data of CBA studies. Based on the extensive literature review, which took place in the beginning of the project we have decided to model the growth of total factor productivity (TFP) as a semi-endogenous growth with a catch-up mechanism. In this case

TFP growth is determined by investments in research and development (R&D), human capital and a gap between a region and a technological leader.

Annex 2. Overview of simulation results with E3ME model

Overview

The environmental effects are completely absent from HERMIN, hence one needs to use an alternative model to evaluate them. We will use RHOMOLO for the evaluation of major environmental effects of all ECP sectors of investment. RHOMOLO includes the representation of GHG and non-GHG emissions, pollution due to waste and waste water. These environmental impacts are monetized in terms of inter-temporal impact on GDP. This monetization is done based on the existing environmental studies such as for example ExternE. The monetization of the different environmental impacts will also be included in RHOMOLO and presented in the draft final report to ensure that those impacts are comprehensively taken into account and monetized. The overall modelling is hence able to assess both negative and positive external effects of all ECP sectors of investment. Within the present project the structure of RHOMOLO will be improved by including the relations, which provide the link between several types of ECP investments and the reduction energy use and pollution coefficients (amount of pollution per unit of energy use). These relations are calculated using the runs with the E3ME model and done only for a set of ECP categories which have a direct impact upon the change in production technology of the sectors. The runs with E3ME have been deigned in such a way that we can easily derive the functional form of the relations between investments and energy and emissions intensity: that is simulations have been done for 1%, 3%, 10% and 25% increase in current investments by relevant ECP category. The table below summarises information about the coverage of environmental externalities by RHOMOLO and E3ME as well as gives information about which environmental effects are monetised in terms of inter-temporal effect on GDP:

Table 24: Coverage of environmental externalities by RHOMOLO and E3ME

Environmental effects covered in RHOMOLO	Environmental effects covered in E3ME	Environmental effects which are monetised in terms of inter-temporal effect on GDP
GHG emissions	GHG emissions	GHG emissions
Non-GHG emissions		Non-GHG emissions
Solid waste		Solid waste
Waste water		Waste water

These environmental effects include impacts of GHG and non-GHG air pollutions, impacts of waste water and solid waste. RHOMOLO includes modelling of all main types of GHG emissions based on IEA database and of all main types of non-GHG emissions based on EMEP database. Emissions in RHOMOLO are associated with either output or energy consumption of various production sectors. Environmental damage of GHG and non-GHG pollutants is based on the ExternE estimates. These estimates include main impacts of pollution on health and environment including negative effects of pollutants on human health, building materials, crops, global warming, noise and ecosystems, among others.

Waste in RHOMOLO is of two types: hazardous and non-hazardous. Waste in RHOMOLO can be treated in different ways and its damage in monetary terms depends on the way it is treated. Waste is produced by production sectors and households. Waste water in the model is associated with production of the water sector and each litre of waste water is associated with the certain environmental damage valued in money. Utility of households in RHOMOLO is negatively influenced by environmental externalities which in its turn affects their decision to leave in a particular region of the country. Change in the population of the region due to migration has effect upon the real estate prices in this area. Hence, RHOMOLO takes into account that environmental externalities have negative impact upon real estate prices.

The evaluation of inter-temporal environmental externalities associated with energy- and environment-related ECP sectors of investment, which specifically target air emission reduction, will be carried out as a two-step procedure. As the first step, we will derive the relations, which represent the relationship between the amount of ECP investment and the change in emissions coefficient and/or energy intensity, with the help of specialised economic environmental model E3ME. This model has a detailed description of production technologies related to energy use and their environmental effects. The relations between investments and energy and emissions intensity estimated on the basis of E3ME runs will be incorporated into RHOMOLO in order to evaluate the inter-temporal environmental effects.

E3ME is described in detail in the following section. Both RHOMOLO and E3ME use consistently the same set of monetary values of pollutions. RHOMOLO is a recursive-dynamic model and the shock of the ECP investments by sector propagates through all markets. Resulting output changes and associated environmental costs affect inter-temporal social welfare function and well as GDP.

The E3ME Model

Introduction

The simulations necessary for the estimation of relations between investments and energy and emissions intensity was carried out using E3ME model. The E3ME model covers 29

European countries (EU27, Norway and Switzerland), 42 economic sectors, 19 energy users, 12 fuels, and 28 energy technologies. For more information on the E3ME model, including the online manual, see www.e3me.com. E3ME is a macro-econometric model which provides detailed sectoral and Member State (MS) level analysis. The model contains sector and country-specific parameters and is capable of forecasting annual economic and environmental impacts at these levels for the period up to 2050, for which in this project we go up to 2030. E3ME is suitable for economy-energy-environment analysis in both the short and medium to long terms since the model contains both short and long-terms parameters as a result of its econometric specification.

The E3ME model has been widely used for analysis of the economic impacts of environmental policies. Examples of European Commission studies that use E3ME to analyse economic impacts of environmental policies include contributions to Impact Assessments for the Review of the EU ETS (DG Environment), the Energy Taxation Directive (DG TAXUD) and the possible establishment of EU-wide emissions trading of NOx and/or SO2 (DG Environment).

E3ME has also previously been used to assess the environmental impacts of R&D and technological progress in a number of European studies. These include using E3ME to provide an assessment of the EU's Lisbon targets for R&D spending (DG JRC-IPTS), an assessment of using tax revenues to boost low-carbon investment (DG Research, Anglo-German foundation) and the analysis of the impacts of ICT spending (SEAMATE, DG InfoSoc).

The full references for the above projects and other examples of E3ME applications can be found at www.e3me.com.

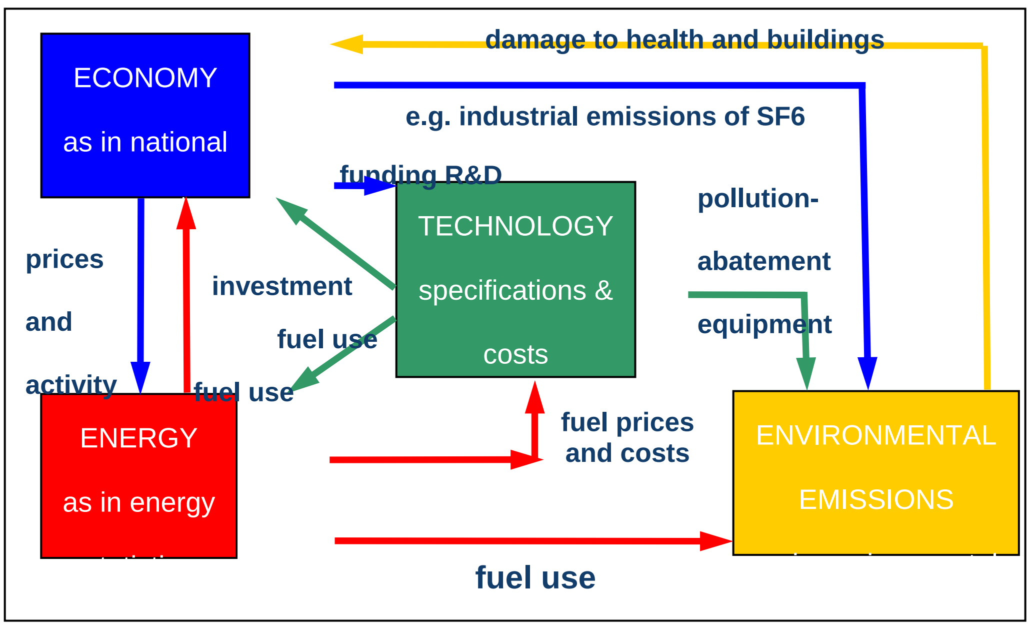
The E3ME baseline

E3ME's baseline forecast is calibrated to be consistent with the projection in the latest version of the 'PRIMES' baseline, published in *Energy and Transport: Trends to 2030*, by DG TREN. The current E3ME baseline uses the 2007 update of these projections.

Economic-Energy-Environmental links in E3ME

Table 9 shows how the three components of the model - energy, environment and economy - fit together. Each component is shown in its own box and utilises its own units of account and sources of data. Each data set has been constructed by statistical offices to conform to accounting conventions. Exogenous factors coming from outside the modelling framework are shown as inputs into each component on the outside edge of the chart. For the regional economy, these factors are economic activity and prices in other world areas and economic policy (including tax rates, growth in government expenditure, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of energy industries). For the environment component, exogenous factors include policies such as reduction in SO2 emissions from large combustion plants. The linkages between the components of the model are shown explicitly with arrows showing which values are transmitted between components.

Figure 8: E3 Interactions in E3ME



The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides a comprehensive treatment of energy demand and associated emissions of the main air pollutants, which are inputs to the environment module. The environmental module considers *selected* damages arising from different pollutants, specifically on human health (mortality and morbidity), agricultural production and on buildings and the built environment. The economy module also provides measures of population stress (numbers of households, demands for water etc) to the environment module, which in turn will give an indication of the extent to which global temperatures are expected to rise in different long-term scenarios (this linkage is also not yet included in the model). The energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

The key features E3ME provides for E3 analysis are the feedback links between economy, energy and environment. The model has been widely used in Europe for general policy assessment, as well as more focused impact analysis of policies relating to greenhouse gas mitigation (EU ETS, Carbon Taxation), incentives for industrial energy efficiency and sustainable household consumption. The link between emissions to economy in E3ME is currently to do with the impact of emission taxation on the economy (where model is commonly used to assess the impacts). Although we have in the past carried out a study to incorporated damages to heaths and buildings as a result of heavy pollutant (DROPS), the effects to the economy were too small to show up within the time scope of the models (2030). This finding is also common among other macroeconomic models and by no mean is a disadvantage. The E3ME model remains one of the most commonly used models for Impact Assessment in Europe when it comes to E3 analysis

Further details regarding E3ME are available at www.e3me.com.

The role of investment in E3ME's energy demand equations

E3ME contains both total energy demand equations (aggregate) and fuel substitution equations for coal, heavy oil, gas and electricity (disaggregate). Investment and R&D appear as explanatory factors in both aggregate and disaggregate energy demand equations.

The measures of investment in E3ME's aggregate energy demand equation capture the effect of new ways of decreasing energy demand (energy-saving technical progress) and the elimination of inefficient technologies, such as energy-saving techniques replacing old inefficient uses of energy. Investment and R&D variables in the equation are grouped into the 19 fuel users in each country. Moreover, there are two further R&D expenditure variables, R&D in machinery and R&D in transport, which are the sum of all EU27 regions' expenditure and are included in the aggregate energy demand equation to take into account spill-over effects. These spill-over terms reflect the international nature of European car manufacturers and, to a lesser extent, equipment firms, with developments in one country being put into products in other countries. Other variables in E3ME's fuel demand equation include economic activity, energy prices, and a dummy variable for Germany unification.

The disaggregated energy demand equations (coal, oil, gas, and electricity) contain the same R&D and investment variables, although the measure of transport R&D is only applied in the equation for liquid fuels. These equations are intended to allow substitution between these energy carriers by users on the basis of relative prices, although overall fuel use and the technological variables are allowed to affect the choice. Since the substitution equations cover only four of the twelve fuels, the remaining fuels are determined as fixed ratios to similar fuels or to aggregate energy use. The final set of fuels used must then be scaled to ensure that they add up to the aggregate energy demand (for each fuel user and each region).

Investment impacts on the energy technology submodel

Investment also plays an important role in the E3ME's Energy Technology (ETM) sub-model[35]. The ETM models the process of substitution of energy sources within power generation. The substitution process allows the non-carbon energy sources to meet a larger part of European energy demand as the prices of these sources decrease with investment, learning-by-doing and innovation. However, this substitution is conditional to the possibility of supply of various energy sources.

New technologies are brought forward by investment decisions related to their relative costs compared to the marker technology (a technology or fuel 'of choice', usually gas). In E3ME's ETM, the investment decision is represented as one taken institutionally by a social planner following the rules promoting efficiency under social, economic and political restrictions. Desired capacity will determine the size of the investment, and will depend on load factors, desired generation and the ratio between maximum generation and average generation. Since there is a considerable lag between the decision to invest and the investment coming on stream (a lag of up to ten years is allowed in E3ME), desired capacity and therefore desired generation have to be projected.

The key factor driving the investment decision is cost minimisation over the first eleven years of the project. It is assumed that decisions are decentralised, while economic instruments are included to provide incentives for different technologies. Capital costs, including the spill-over learning-by-doing and economies-of-scale effects, are a key component of this cost calculation. The logarithmic specification allows the costs of new technologies to fall over time as more efficient production methods are found.

Methodology

Objective and overviews

E3ME's role in this study is to provide quantitative analysis of the possible environmental impacts of different types of ECP investment projects. Although the E3ME model

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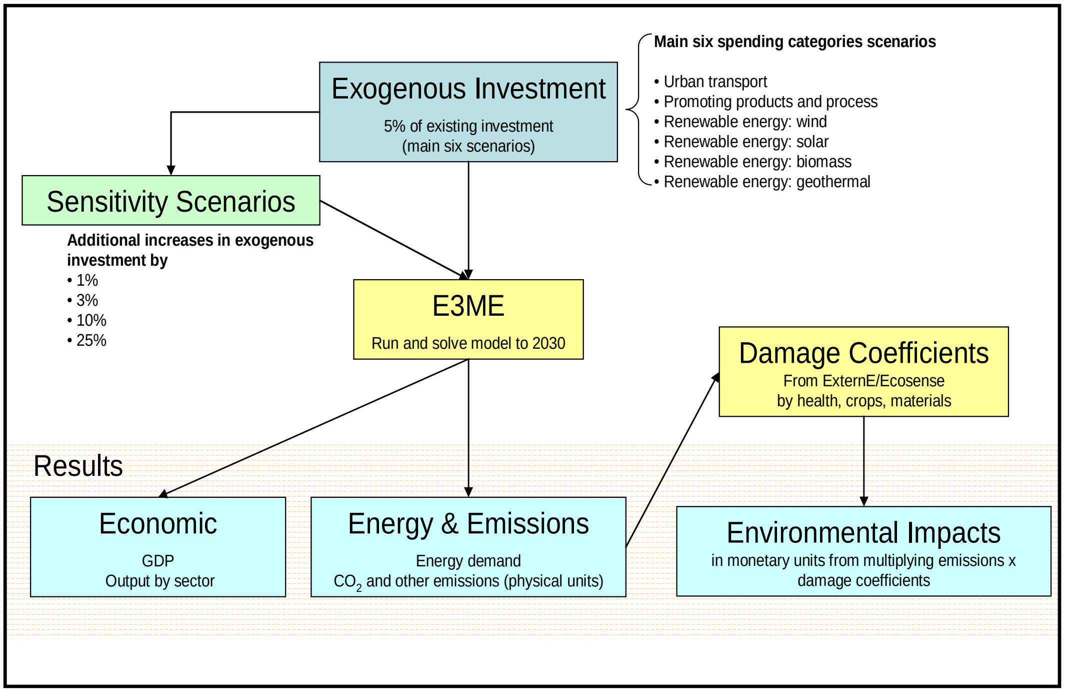
[35] Barker, Terry, Ole Lofsnaes and Hector Pollitt (2007) 'The ETM in E3ME43', Cambridge Econometrics.

http://94.76.226.154/Libraries/Downloadable_Files/ETM.sflb.ashx is capable of providing detailed economic results, its role in this study focuses on its other 'Es': Energy and Environment. Figure 9 shows how the model is used in this study to provide environmental externalities.

Figure 9: Summary of methodology



Estimating environmental impacts

It should be noted that the scope of pollutants in E3ME is restricted to air-borne emissions. Moreover, the model only provides causality from the environment to the economy in terms of environment taxation (e.g. CO_2 taxation and the EU ETS). In the current version of E3ME, there is no causality from the environment to the economy in terms of the environmental damages. Cleary this is a limitation but this is the standard treatment in economic models which, in this sense, tend to view the economy as an isolated system. However, due to the issue of environmental impacts in this study, it is inevitable that this relationship must be established. For this reason, we make use of the emission damage coefficients from the ExternE/Ecosense[36] database. Some of these coefficients were already included in the E3ME model but only at an aggregated level; the methodology for extending the scope of the damage-coefficient analysis is given below in Task 3.

[36] http://ecoweb.ier.uni-stuttgart.de/ecosense_web/ecosensele_web/frame.php

ExternE/Ecosense data

The ExternE/Ecosense data provides estimates for different pollutants, effects and countries on a consistent basis. The consistency of the different estimates is important for the robustness of the type of analysis we are carrying out. The estimates (see ExternE 2005 methodology publication) for more details) identify different types of impact, such as through impacts on mortality, morbidity, on production of crops, and in the deterioration of buildings etc. In valuing health impacts the ExternE/Ecosense estimates use a value for immediate loss of life expectancy of €75000 per life year loss[37]. The ExternE number was carefully derived after an extensive research, using the WTP method taking into account the issue of chronic air pollution-induced mortality (slowly losing life years and sometime non-measurable). In discussing the estimate ExternE explain that their estimate may be more conservative than some others in the literature, they consider it more robust and reliable[38].

The damage coefficients produced by ExternE/Ecosense consider the direct impact of emissions on particular factors (health, crops etc). They omit some of the indirect, often more long-term impacts. For example, the negative impact of pollution on the fabric of buildings (e.g. erosion) is included in the damage coefficients produced. However, if not addressed, then over time the cumulative impact on the built environment could have a detrimental impact on tourism. Such impacts are less 'robust' than the effects included in the damage coefficients, and would also vary considerably from area to area (the physical impact of pollution on a building may be the same in two areas, but any long-term impact on tourism will depend on the type of economy/assets it has.

Scope of the E3ME analysis

The scope of pollutants in E3ME is restricted to air-borne emissions, so the analysis does not include the potential externality of other physical pollutants, such as chemical waste. However, it should be noted that the scope of the damages caused by these types of pollutants is believed to be beyond the time horizon that the E3ME model covers. These potential impacts have been studied by Cambridge Econometrics using E3ME as part of a FP-6 funded project, DROPS[39]. This substantial research project considered the impacts that heavy metal pollutants had on additional health costs, additional education costs from

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[37] ExternE's standard value of €75,000 life year loss (VOLY) is derived from a statistical life of €1m - see methodology publication (2005) from http://www.externe.info/ for more detail

[38] The DG REGIO guide to cost benefit analysis (July 2008) does not explicitly specify a value a statistical life to be used. It does suggest (p.125 however that the two approach used to estimate statistical life is a) human capital approach and b) WTP (more widely accepted)–which ExternE is using.

[39] http://drops.nilu.no/ 2007, DG Research, European Commission.

loss of IQ, and losses of labour productivity, with impacts feeding back into the determination of economic activity in subsequent years. The study found that the substantial time lags between pollution and the effects being felt meant that the impact against a baseline during the 20-year horizon of the scenarios being developed was small. The development of E3ME undertaken for the DROPS project is described in Annex I. It also provides a recommendation for how the environmental costs results from WP2 can be used in the RHOMOLO model to link the inter-temporal impacts of environment to the economy. However, extending the DROPS approach to a wider range of pollutants considered here is beyond the resources of this study and, given the findings from DROPS, the omission has only a small impact on the modelling results.

Modelling wider environmental spill-overs in RHOMOLO

As water pollutants are concerned, environmental externalities associated with water treatment/sewage are present in RHOMOLO. They include damage coefficients for five principal water-based pollutants: biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), Phosphorus (P) and Nitrogen (N). Shadow prices for one kilogram of undesirable output of the above substances are taken from the literature and appear as an exogenous input into RHOMOLO. In addition, RHOMOLO contains a detailed breakdown of the waste treatment sector into the following subsectors: Deposit onto or into land; Land treatment and release into water bodies; Disposal; Incineration; Recovery and Energy recovery.

The following sections describe the tasks for this study in more detail.

Task 1: Identified ECP categories to model

Table 25: Summary energy and environment related categories of expenditures

ECP expenditure categories	Descriptions

39	Renewable energy: wind
40	Renewable energy: solar
41	Renewable energy: biomass
42	Renewable energy: hydroelectric, geothermal and other
43	Energy efficiency, co-generation, energy management
47	Air quality
48	Integrated prevention and pollution control
49	Mitigation and adaptation to climate change
52	Promotion of clean urban transport

Source(s): Commission Regulation (EC) No 1828/2006 of 8 December 2006.

The resource within the project that available for E3ME modelling limits the number of alternative investment scenarios that can be carried. As the results of the E3ME analysis will be an input to the final model structure, it is important that the limited resources available to the task are used to best effect (from the perspective of 'useful' information for the subsequent modelling tasks.)

Of the categories listed in Table 25, categories 47, 48 and 49 are considered to be too broad to be able to clearly model the transmission mechanism from investment activity to emission impact. It was also believed that some of the energy and environment-related categories are somewhat overlapping the same topics. For example, promotion of clean urban transport (52) should automatically improve air quality (47) and most of the categories can also be considered as the mitigation and adaptation to climate change (49).

The nine categories of expenditure assessed with the use of E3ME include only the categories of ECO investment which have direct impact upon the choice of technology of the production sectors. The reason for this is that the simulations with E3ME are only used in order to estimate the relations between investments and energy and emissions intensity to be used in RHOMOLO. Out of the nine categories of expenditure directly related to the choice of the production technology only six could be modelled with E3ME. The remaining categories will be modelled and included in RHOMOLO.

Of the categories listed in Table 25, categories 47, 48 and 49 are considered to be too broad to be able to clearly model the transmission mechanism from investment activity to emission impact. It was also believed that some of the energy and environment-related categories are somewhat overlapping the same topics. For example, promotion of clean urban transport (52) should automatically improve air quality (47) and most of the categories can also be considered as the mitigation and adaptation to climate change (49).

The final six categories agreed for the E3ME modelling are:

- Urban transport
- Promoting products and process
- Renewable energy: wind
- Renewable energy: solar
- Renewable energy: biomass
- Renewable energy: geothermal

The rationale for the six selected categories is given below.

Urban transport

The *Urban Transport* expenditure category looked at the impacts of investment in transport equipment on energy demand and emissions. The urban transport spending category is intended to cover the ECP expenditure: *52 Promotion of clean urban transport*. The measures of investment expenditure in E3ME's aggregated and disaggregated energy demand equations capture the effect of new ways of decreasing energy demand (energy-saving technical progress) and the elimination of inefficient technologies, such as energy-saving techniques, replacing old inefficient uses of energy. Investment variables in the equation are grouped into the 19 fuel users (see annex 2)

) in each country. It should be noted that some of the exogenous investment on machinery will feed through to R&D that also get included in the E3ME energy demand equations. The R&D spill-over variable for transport equipment is included to reflect the international nature of European transport manufacturers with development in one country being put into products in other countries.

Promoting products and processes

The broad '*Promoting Products and Processes*' expenditure group was introduced to cover ECP expenditure: *43 Energy efficiency, co-generation, and energy management*. Within this expenditure group, energy efficiency is achieved by promoting investment spending in machinery in the electronics and engineering sectors. The R&D in machinery variable in the energy demand equations takes into account both domestic R&D and spill-over R&D from other countries in Europe. We would expect increases in investment expenditure on machinery to lower demand for energy, and in turn, to lower air-borne emissions (other things being equal). The magnitude of the energy-efficiency gain as a result of extra investment in machinery for an energy user in a country depends on the estimated parameters from historical data.

Four renewable energy categories

From the ECP expenditure categories (see Table 25), it may be obvious that one possible grouping is to combine all the renewable energy expenditure categories together. However, we believed that it does not make sense to do this as each technology has different average load factors (generation to capacity ratio), different costs and different characteristics. For example, the characteristics of biomass capacity can be very different to the characteristics of solar technologies. It is therefore, in theory, better to keep the distinction between technologies so that the impacts of each renewable technology can be distinguished. In practice, however, this distinction will also depend on the modelling capacity. E3ME, fortunately, has a detailed treatment of the power generation sector (in its Energy Technology sub-Model: see Section 2.5) and is able to model possible impacts of investment in these renewable energy technologies separately.

Transport infrastructure

As regards transport infrastructure, it is considered not under the transport sector in RHOMOLO. The model assesses full set of environmental externalities associated with the development of transport infrastructure.

Task 2: Create exogenous investment assumptions

To implement a scenario for any one investment category, it is necessary to link that category to E3ME's industry classification and to identify the scale of the exogenous investment. Originally, it was anticipated that the project-based information gathered in WP1 would be able to inform the assumptions made. However, changes to the project work plan have led to WP1 and WP2 had to be carried out simultaneously. Decisions about the scale of exogenous investments to be modelled have been taken in discussion with TNO to ensure the results of the E3ME analysis are appropriate to how they will be subsequently used. The main scenario for each investment category modelled involves a 5% increase on the existing investment profile for that sector. We have also provided sensitivity scenarios, using exogenous investment impacts of 1%, 3%, 10% and 25% (see Task 5). Table 26 summarises the exogenous investments that were introduced for the scenarios.

Table 26 : Summary of exogenous investment in the six scenarios

Scenario	Sectors that make additional investment
S1:Urban Transport	Land transport
S2:Promoting Product and Processes	Engineering: -Mechanical engineering -Electronics -Electrical Engineering & Instruments
S3: Renewable Energy – Wind	Electricity – translated to extra investment in Wind technology in Power Generation
S4: Renewable Energy - Solar	Electricity – translated to extra investment in Solar technology in Power Generation
S5: Renewable Energy -Biomass	Electricity – translated to extra investment in Biomass technology in Power Generation
S6: Renewable Energy - Geothermal	– translated to extra investment in Geothermal technology in Power Generation

For the four renewable scenarios, additional investment was assumed to come from the electricity (power generation) sector. The monetary value of the investment was translated to exogenous physical (MWe) increases of the desired technology in power generation by using cost information shown in Table 27.

Table 27: Investment costs for different technologies in power generation

Scenario	Investment cost ($/kWe)	Investment lags (years)
S3: Renewable Energy - Wind	500	2
S4: Renewable Energy - Solar	6000	2
S5: Renewable Energy - Biomass	2300	4
S6: Renewable Energy - Geothermal	2000	3

Source(s): 4CMR, University of Cambridge

Task 3: Set up and run scenarios

The third task was to set up and solve E3ME for each of the ECP investment scenarios. The setting up of the model required some modifications to the existing E3ME source code to take into account the additional exogenous variables (e.g. the exogenous investment variable in the Energy Technology sub-Model). The model solves annually up to 2030. The largest part of this task, however, is in checking the detailed model outputs to assure that results are sensible and in line with expectations.

Task 4: Calculate inter-temporal environmental impacts on GDP

As mentioned previously, E3ME does not provide causality from the environment to the economy in terms of environmental damages (it does provides causation to the economy in terms of the impacts of environmental taxation). The previous version of E3ME, however, provided some monetary costs for some pollutants, namely SO2, NOX, PM10 and VOC by applying damage coefficients from ExternE/Ecosense to the model's emissions results. These emissions damage coefficients were, however, incorporated in E3ME only at aggregate level (i.e. total costs).

For this study, Cambridge Econometrics expanded on the previous treatment to take into account more detailed damage coefficients to cover the breakdown of emission costs by crops, materials and health (morbidity and mortality). The coefficients were used to calculate the long-term external (non-economic) costs of emissions (in constant prices) of different pollutants from the different countries modelled in E3ME. This breakdown allowed the analysis to cover the intertemporal effects on production (e.g. crops and building materials), investment and consumption (through impacts on health morbidity and mortality), and allocated costs to year of incidence using ExternE's discount rates.

The ExternE/Ecosense database only covers the EU25 (although data for Malta and Cyprus are zero). The results did not cover Norway and Switzerland since they are not affected by the EU Cohesion Policy.

The following sub-tasks were carried out to process and analyse the damage coefficients:

- download detailed damage coefficient data (by type and by country) from ExternE/Ecosense for each available pollutant: SO2, NOX, PM10 and VOC
- process the data to the format required by E3ME (19 fuel users by country)
- create new model code to take into account the more detailed treatment
- apply the coefficients to the emissions results from the E3ME model

The ExternE/Ecosense database allows different options for each pollutant before the damage coefficients are calculated. The following table shows how these options were selected in order to match the coefficients to the E3ME 19 fuel users classification.

Table 28: ExternE/Ecosense options mapping to E3ME

E3ME Fuel User	**High Stack / Low Release**	**Source (industry/ ground-level/ domestic heating)**	**Local Environment (city/ rural/ agglomeration)**
Power Generation	HS	Industry	Rural
Other own use	HS	Industry	Rural
Iron and Steel	HS	Industry	City
Non-Ferrous Metals	HS	Industry	City
Chemicals	HS	Industry	City
Non-Metallics	HS	Industry	City
Ore extraction	HS	Industry	City
Food etc	HS	Industry	City
Textiles	HS	Industry	City
Paper and Pulp	HS	Industry	City
Engineering etc	HS	Industry	City
Other Industry	HS	Industry	City
Rail Transport	LR	Ground Level	Rural
Road Transport	LR	Ground Level	City
Air Transport	HS	-	Rural

E3ME Fuel User	High Stack / Low Release	Source (industry/ ground-level/ domestic heating)	Local Environment (city/ rural/ agglomeration)
Other Transport	LR	Ground Level	Rural
Households	LR	Domestic	City
Other Final Use	LR	Ground Level	City
Non-Energy Use	LR	Ground Level	City

From the above table, the following assumptions were made:

- all industries and services sectors are based in cities
- all power generation is based in rural areas or small towns
- all transport is at ground level (except Air Transport)
- road transport pollution is in cities while air, rail and other transport (other) is rural
- all household pollution is in cities

The long-term external cost (or benefit) of the additional (or reduced) emissions from one year was calculated by applying these damage coefficients to the additional (or reduced) emissions. It should be noted that the damage costs do not have feedbacks to E3ME's determination of economic activity in subsequent years.

GHG damage coefficients

The same analysis was not done for the GHG emissions (CO_2, CH4, and N2O). This is because these GHG do not have any impacts other than through global warming and depletion of the ozone layer. The externalities associated with them are beyond the timescale of E3ME.

Other air-borne emissions

There are no available data from the ExternE/Ecosense database for other greenhouse gases (HFCs, PFCs and SF6) or other non-GHG pollutants such as CFCs, carbon monoxide or lead emissions to air. It was therefore, not possible to carry out the same analysis for these pollutants.

Task 5: Sensitivities analysis

In addition to the main six ECP expenditure scenarios, a

analysis was carried out for each scenario to ensure the robustness of the results. The sensitivity testing altered the value of the exogenous investment in each scenario from 5% additional investment in the main scenario to:

- 1%
- 3%
- 10%
- 25%

The sensitivity analysis followed the same path as the main scenarios (Task 2 to Task 4).

Task 6: Prepare results to be used in the RHOMOLO model

The main strength of using E3ME in this analysis is its ability to provide detailed environmental impacts for each of the investment categories. Investment and R&D in E3ME have impacts on both overall energy demand and the composition of the fuel types that meet the total demand. As a result, the impacts from each of the six ECP spending scenarios generated different energy and environment profiles (e.g. different composition of GHG results) and in turn indicated which spending category generates the biggest environmental costs (or benefits).

The results from this task are environment elasticities by cost types by countries (presented in terms of emissions costs (or benefits) in euros per euro of exogenous investment in each of the six expenditure categories. These are provided alongside environmental and energy results in physical units and the main economic results so that they can be incorporated into the RHOMOLO model for further analysis on environmental externalities on the economy, and the inter-temporal impacts on the economy.

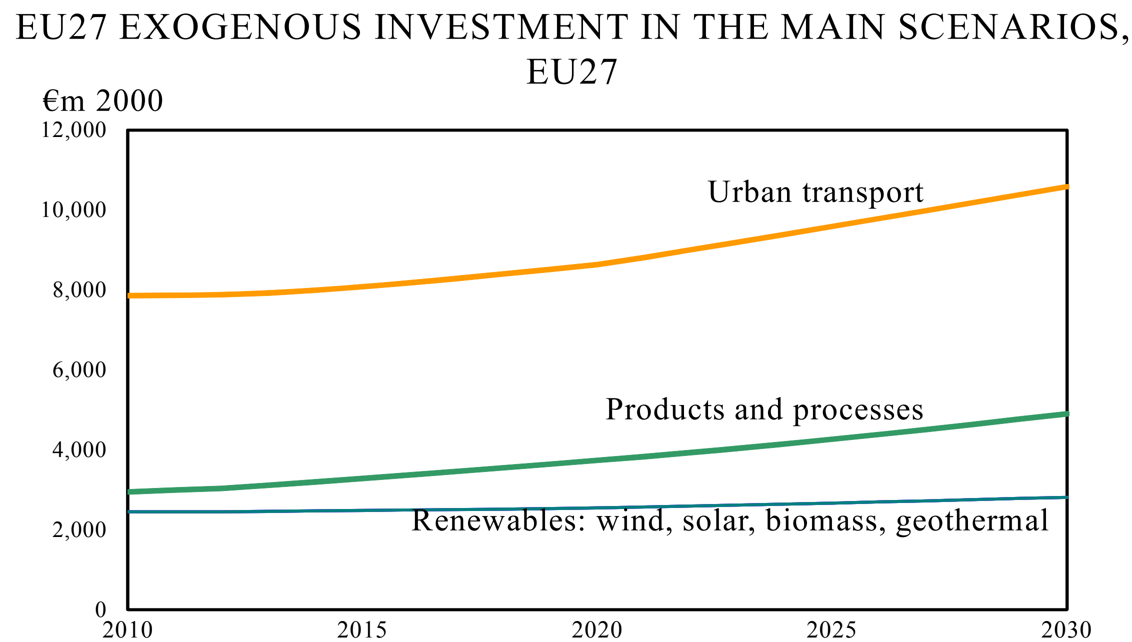
Modelling Results: Main Scenarios

Introduction

Since environmental externalities *per se* are absent from HERMIN, the environmental impact on GDP will be accounted for through the output elasticities which enter the HERMIN structure as exogenous parameters. The modelling results are provided separately to this report in a form of in an excel spreadsheet. Users are advised to be cautious when using the detailed disaggregated results from the spreadsheet. This is because E3ME is (in economic terms) a bottom-up model and each individual result in E3ME is dependent on the parameters estimated. In some cases, individual results may be driven by a single estimated parameter, which in turn depends on the quality and availability of historical data. Although in theory we could check individual results, in practice this task is very resource-intensive (e.g. 33 stochastic functions x 42 sectors x 29 regions x 6 scenarios x 5 sensitivity analysis). The common practice is to provide the main macro results from the E3ME model as in the remaining sections of this report.

Exogenous investment assumptions

The key input to the scenarios was the exogenous investment. The model solved all the equations simultaneously each year, linking between economy, energy and environment at sectoral and country level with this exogenous investment. As discussed previously, for the main scenarios this is assumed to be 5% additional to the existing investment between 2010 and 2020 in the baseline in the relevant sector. This means that the actual level of exogenous investment depends on the size of investment that is already expected in a sector (and a country). Figure 10shows how the magnitudes of investment differed between the main six ECP scenarios at EU27 level. The approach to modelling the exogenous investment, we assume the funds are made available to industry by the government from the Cohesion Fund. No view is taken as to how the additional funds are raised (i.e. there are not compensating tax increases, nor is other public spending reduced, so we are effectively assuming the additional investment is financed by debt).



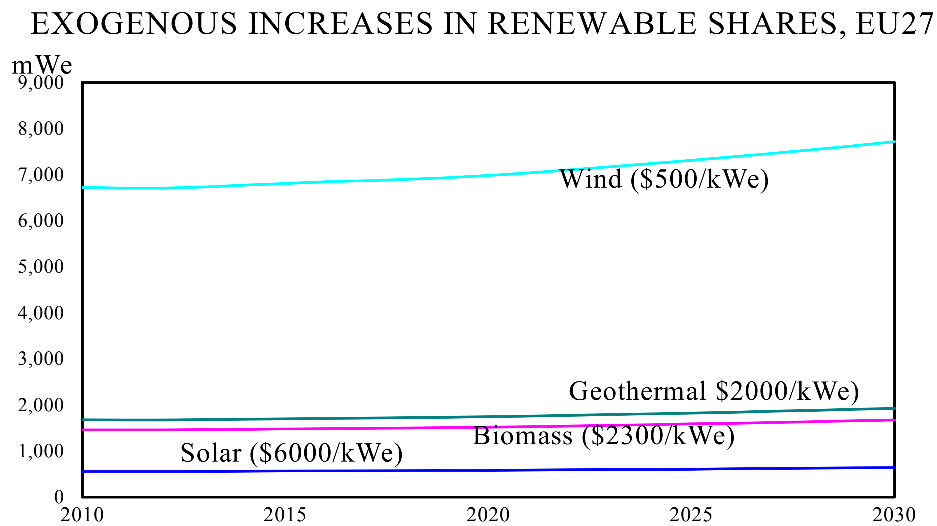
Note(s) : Chart shows exogenous investment assumption in the main ECP scenarios (5% of existing investment in the sector, sum across EU27 regions).
Source(s) : E3ME, Cambridge Econometrics.

Figure 10: EU27 Exogenous investment in the main scenarios, EU27

In the different renewables categories (Wind, Solar, Biomass and Geothermal), the electricity industry is assumed to make the investment in various renewable power generation technologies.

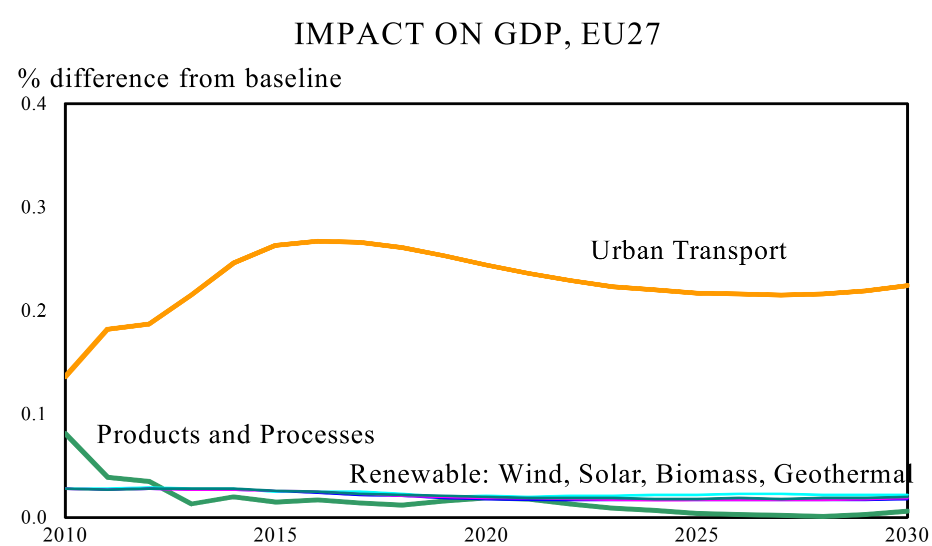
The costs of renewable technologies are different depending on its characteristics. This means that for the same investment from the electricity sector (i.e. 5% additional), the additional extra capacity that it generates in physical units (mWe) is different depending on the costs of generating the new technologies (see Figure 11). The assumption of investment costs information of the different technologies was based on the study '*The Technical and Economic Characteristics of Electricity Technologies'* carried out by Cambridge Centre for Climate Change and Mitigation Research (4CMR), University of Cambridge.

Figure 11: Exogenous increases in renewable shares, EU27



Note(s) : Chart shows exogenous increases in renewable shares at EU27 level in terms of mWe as a result of a 5% increase in investment from the electricity sector. Numbers in parentheses are investment cost for the renewable in US$ per kWe.

Source(s) : E3ME, Cambridge Econometrics.
4CMR, University of Cambridge



Note(s) : Chart shows EU27 GDP in terms of percentage difference from baseline.

Source(s) : E3ME, Cambridge Econometrics.

Economic Results

The impacts on GDP from the exogenous investments are shown in Figure 12. It is clear from the chart Urban Transport investment provides the greatest overall impacts on GDP and that Products and Processes investment has the least impact. The different types of investment in renewables produced similar impacts on GDP. These results are partly explained by the assumed levels of additional investment in each category. The assumption in each investment scenario is that the same percentage increase in investment occurs (i.e. 5%), but because the current level of investment in, say, urban transport is higher than that in solar renewable energy then this means the absolute increase in investment in each investment scenario differs. As investment is a major component of GDP, then it is not surprising that the different investments produce vastly different GDP impacts.

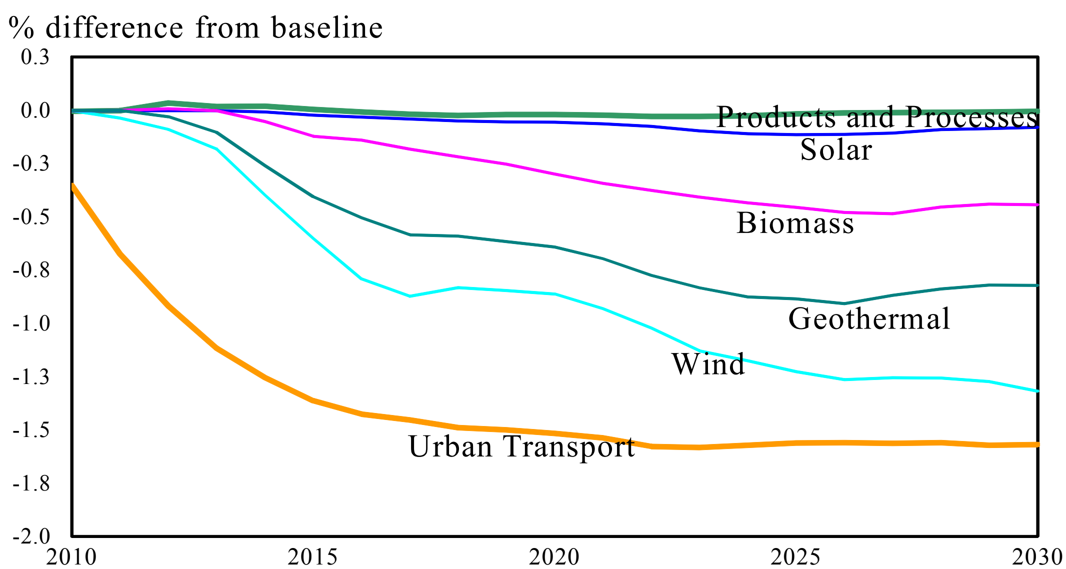
Additional investment in Products and Processes, despite having the second-largest level of exogenous investment, produced the lowest impacts on GDP. This is because investment in engineering sectors is often linked to labour-saving technologies. The estimated parameters for the investment terms in the E3ME employment equations suggested that this is the case for the engineering sectors. As a result, exogenous investment of this type produced some negative GDP impacts from the initial positive shock of exogenous investment through reduction in labour demand which in turn leads to reduction in income and consumer spending. However, these effects are small and the balance is that, in Europe as a whole, the effects are positive.

The GDP impacts from investment in different types of renewables were very similar because they all had the same level exogenous investment assumptions (5% additional investment by the electricity sector).

E3ME results provide interesting insights to the economic impacts of exogenous investment including how it affects the different components of demand and competitiveness.

However for the purpose of this study, the results reported here focus on the energy and environmental results.

IMPACT ON CO2, EU27



Note(s) : Chart shows EU27 CO2 emissions in terms of percentage difference from baseline.

Source(s) : E3ME, Cambridge Econometrics.

The emissions results from the main six ECP scenarios are shown in Figure 13. The most effective investment for reducing CO_2 emissions is Urban Transport where 5% additional exogenous investment in the land transport sector is relatively large. The parameters for land transport also suggested that investments and R&D are strongly linked to reductions in energy demand via increased energy efficiency. Products and Processes investments, despite having the second largest level of exogenous investment, the parameters suggested that there are less established links between increases in investment and reductions in energy used.

An interesting comparison is between the CO_2 impacts in the separate renewable energy investments. The four different investment types had the same level of exogenous investment (5% additional in electricity sector) but produced different levels of CO_2 reduction. Since different renewable technologies have different characteristics, they behaved differently to investment. E3ME is able to provide a detailed treatment for different power generation technologies in its ETM sub-model (see Section 1.5.2.5). The two main explanations for the differences in renewable scenarios are the investment costs and the lag years in which the investments take to build the necessary infrastructure. From the results, the most effective renewable investment was wind technology. Not only does wind technology have the lowest investment cost per kWe, it also has one of the shortest investment periods out of the four renewable technologies. By referring to Table 29, the results can be explained by the combination of these factors; Solar being the most expensive in terms of cost per kWe, had the least environmental impacts. The differences CO_2 impacts between Biomass and Geothermal, are due to the combination of investment cost for biomass being 15% more expensive and the different length of investment required (4 years for biomass plants compared to 3 years for geothermal).

Environmental impact by fuel user

Table 29 reveals the CO_2 reductions on the fuel users that were directly affected from the additional investment. It also reveals how other fuel users were affected through secondary impacts. As expected, the impacts were greater in the sectors that the scenario was designed for i.e. urban transport (land based), engineering benefit most in Products and Processes investment, and Power generation from investment in renewables. The secondary impacts on other energy users came from both higher economic activity as a result of investment made by the main sectors and from its own investment as a result of higher economic activity (other factors include prices and R&D). These secondary impacts came mostly from the economic relationship where sectors are linked by input-output relationships and regions are linked through international trades. In general, the results show considerable environmental gains in the main sectors and only small impacts, both positive and negative, in the other sectors.

Table 29 : EU27 CO2 Impacts by energy users in 2030, % difference from baseline

	Urban Transport	**Products and Processes**	**Renewable: Wind**	**Renewable: Solar**	**Renewable: Biomass**	**Renewable: Geothermal**
1 Power own use & trans.	0.0	0.0	**-4.3**	**-0.3**	**-1.5**	**-2.7**
2 Energy own use & tra	0.1	0.0	0.0	0.0	0.0	0.0
3 Iron & steel	0.1	0.0	0.0	0.0	0.0	0.0
4 Non-ferrous metals	-0.1	0.0	0.1	0.0	0.0	0.0
5 Chemicals	0.1	0.0	0.1	0.0	0.0	0.0
6 Non-metallics nes	0.0	0.0	0.0	0.0	0.0	0.0
7 Ore-extra.(non-energy)	0.0	0.0	0.0	0.0	-0.1	-0.1
8 Food, drink & tob.	0.0	0.0	0.1	0.0	0.0	0.0
9 Tex., cloth. & footw.	0.1	0.0	-0.1	0.0	-0.1	-0.1
10 Paper & pulp	0.2	0.0	0.0	0.0	0.0	0.0
11 Engineering etc	0.1	**-0.9**	0.1	0.0	0.1	0.1
12 Other industry	0.0	0.1	0.2	0.0	0.1	0.1
13 Rail transport	**-1.8**	0.0	-0.3	0.0	-0.1	-0.2
14 Road transport	**-6.8**	0.0	0.0	0.0	0.0	0.0
15 Air transport	**0.0**	0.0	0.0	0.0	0.0	0.0
16 Other transp. serv.	**-1.6**	0.0	0.0	0.0	0.0	0.0

	Urban Transport	Products and Processes	Renewable: Wind	Renewable: Solar	Renewable: Biomass	Renewable: Geothermal
17 Households	0.1	0.1	-0.1	0.0	0.0	0.0
18 Other final use	-0.1	0.0	0.1	0.0	0.0	0.1
19 Non-energy use	0.0	0.0	0.0	0.0	0.0	0.0
Total	**-1.6**	**0.0**	**-1.3**	**-0.1**	**-0.4**	**-0.8**

Note(s): Table shows CO2 impacts in 2030 in term of differences from baseline in EU27.

Source(s): E3ME, Cambridge Econometrics.

Environmental impact by country

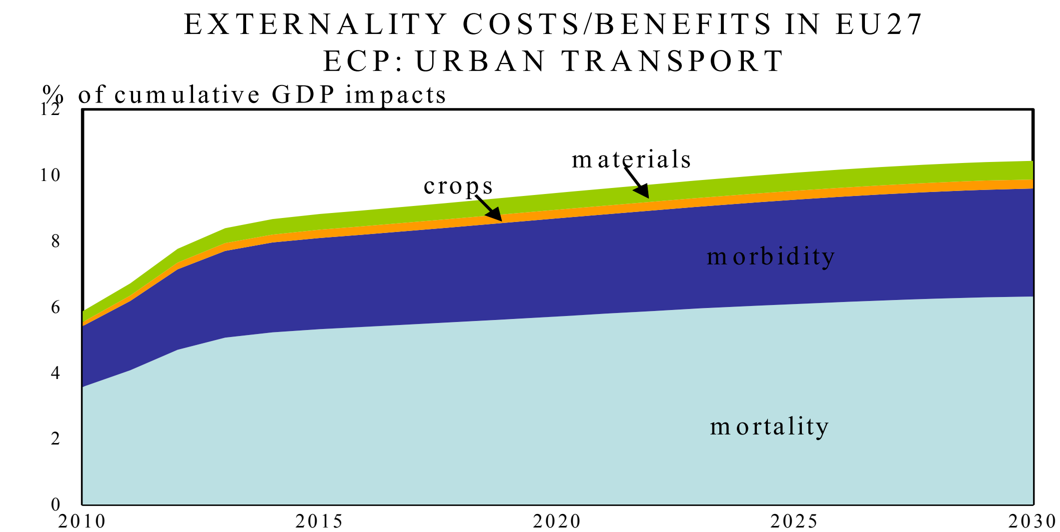
The CO_2 results by country are shown in Table 30. Noticeably, there are countries that were more responsive to investment than others. Under additional investment in Urban Transport, France, Netherlands and Denmark are the most responsive while with investment in renewables the New Member States were more responsive to the additional ECP investment.

Table 30: CO2 impacts by country in 2030, % difference from baseline

	Urban Transport	Products and Processes	Renewable: Wind	Renewable: Solar	Renewable: Biomass	Renewable: Geothermal
Belgium	0.6	0.0	0.0	-0.2	-0.5	-2.1
Denmark	-5.0	0.0	-0.2	0.0	-0.1	-0.3

Germany	-0.3	0.0	-0.1	0.0	-0.2	-0.4
Greece	-0.1	-0.1	-1.9	0.0	-0.2	-0.6
Spain	-0.3	0.0	-1.1	0.0	-0.2	-0.6
France	-9.1	0.0	0.1	0.0	-0.1	0.0
Ireland	-0.2	-0.1	-1.1	-0.1	-0.8	-1.3
Italy	-0.3	0.0	-3.4	0.0	-0.3	-1.3
Luxembourg	-0.6	-0.1	-0.5	0.0	-0.1	-0.3
Netherlands	-8.2	-0.1	-1.2	-0.1	-0.6	-0.8
Austria	-0.2	0.2	-5.3	-0.2	0.4	-2.8
Portugal	-0.9	-0.1	-0.6	-0.2	-0.6	-0.4
Finland	-0.4	-0.1	-4.1	-0.3	-1.2	-2.6
Sweden	-0.2	0.0	-0.9	0.0	-0.3	-0.7
UK	-0.3	0.0	-1.1	0.0	-0.3	-0.4
Czech Rep.	-0.8	-0.4	-1.1	-0.1	-0.6	-1.0
Estonia	-0.2	0.0	-2.4	0.0	-0.2	-0.4
Cyprus	-0.4	0.0	0.0	0.0	0.0	0.0
Latvia	-0.3	0.3	2.2	-0.2	-4.0	-4.7
Lithuania	-4.4	-0.1	-1.5	-0.1	-0.8	-1.9
Hungary	-0.2	0.9	-1.3	0.3	-4.0	0.2
Malta	-0.3	0.0	0.0	0.0	0.0	0.0
Poland	-0.3	-0.1	-3.8	-0.7	-1.6	-2.4
Slovenia	-0.4	0.2	-0.1	0.0	0.0	-0.1
Slovakia	-0.1	0.0	-1.1	0.0	-0.3	-0.6

Bulgaria	-0.2	0.0	-1.9	0.0	-0.2	-0.4
						.7
						.8



Note(s) : Chart shows EU27 cumulative externality impacts as a percentage of cumulative GDP impacts in ECP: Urban Transport (Scenario 1).

Source(s) : E3ME, Cambridge Econometrics.

mental benefits as shares of the cumulative impacts on GDP for each scenario. For example, Figure 14 shows that by 2030, the externality benefits (crops, health and material) from Urban Transport investment are accumulated to account for around 10% of accumulated positive impacts on GDP over 20 years.

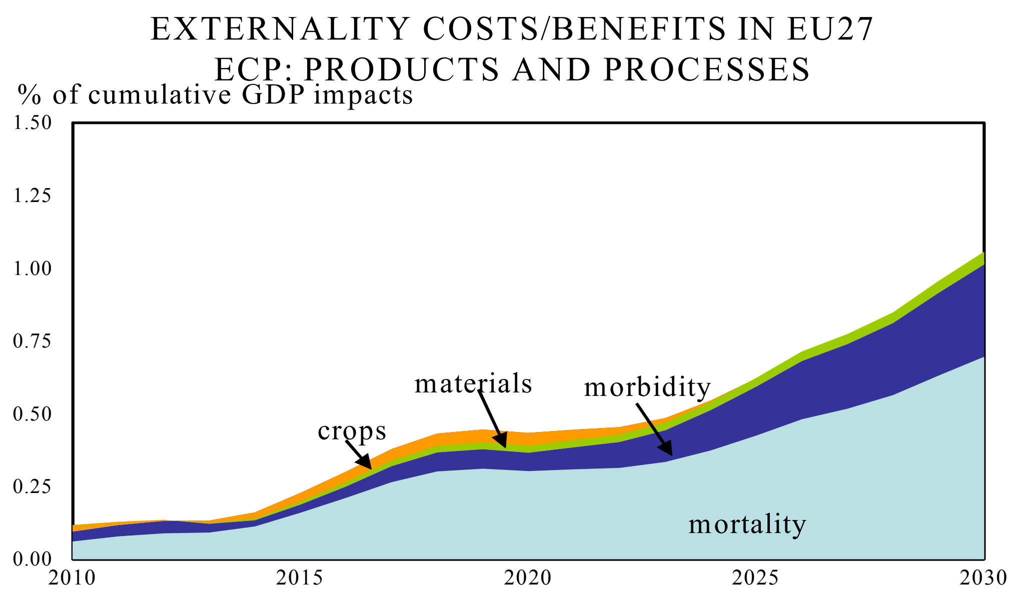
The charts show that in the renewable scenarios (Wind and Geothermal), the percentage share of cumulative externalities benefits in the cumulative GDP impacts were higher. This is because SO2 and NOX emissions are usually associated with conventional thermal power plants. The switch to renewable sources as a result of ECP investment reduced these emissions considerably.

The Urban Transport scenario, despite having the biggest CO_2 reduction, had less positive externalities in the overall GDP impacts. Again this is to do with the fact that CO_2 (and other GHG emissions) do not have any impacts other than through global warming and depletion of the ozone layer and therefore the externalities associated with them are beyond the timescale of E3ME.

Figure 14: Externality costs/benefits in EU27 from ECP Urban Transport

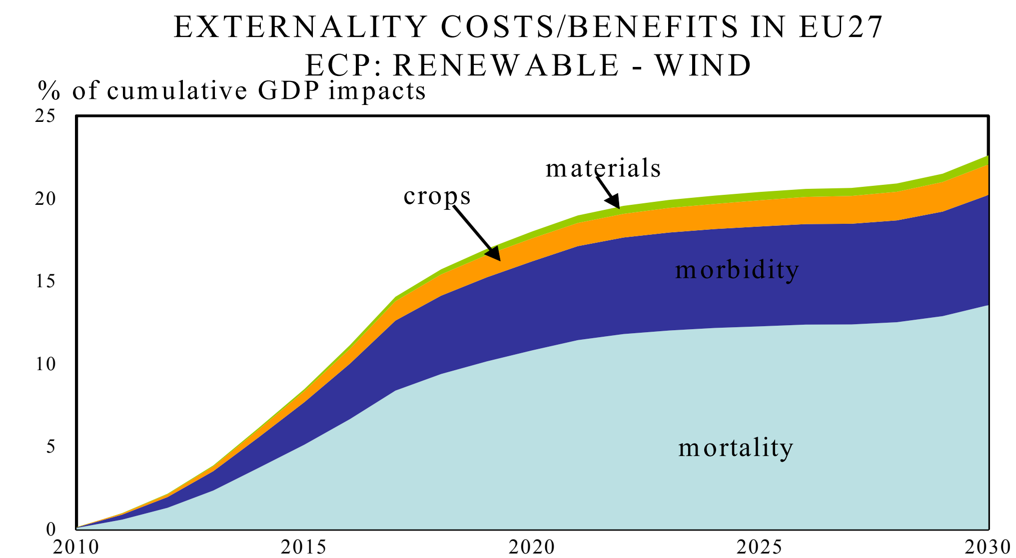
Figure 15: Externality costs/benefits in EU27 from ECP Products and Processes

Figure 16: Externality costs/benefits in EU27 from ECP renewables - Wind



Note(s) : Chart shows EU27 cumulative externality impacts as a percentage of cumulative GDP impacts in ECP: Products and Processes (Scenario 2).

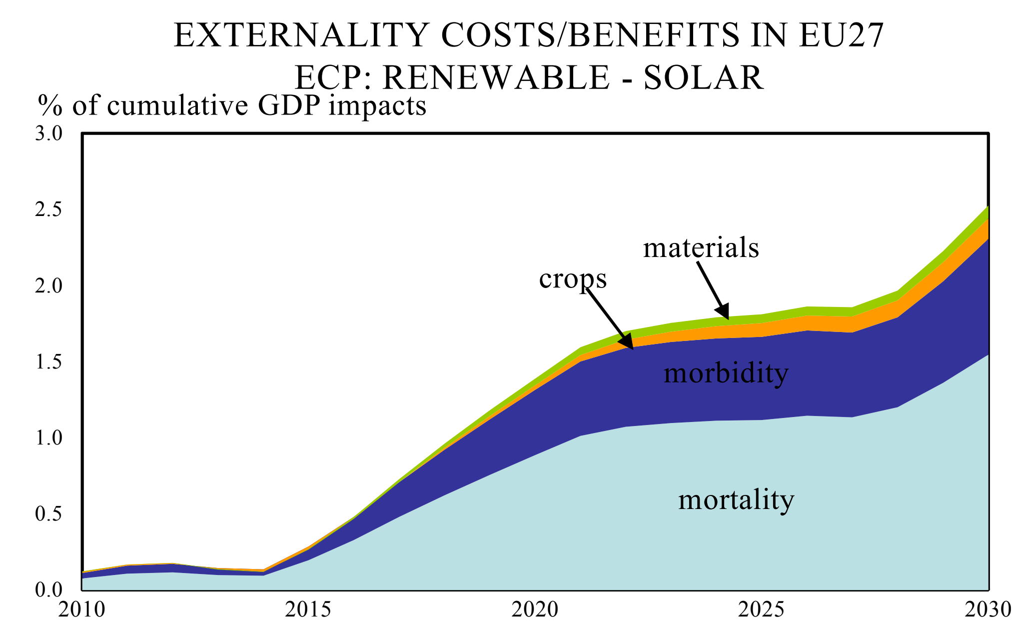
Source(s) : E3ME, Cambridge Econometrics.



Note(s) : Chart shows EU27 cumulative externality impacts as a percentage of cumulative GDP impacts in ECP: Renewable – Wind (Scenario 3).

Source(s) : E3ME, Cambridge Econometrics.

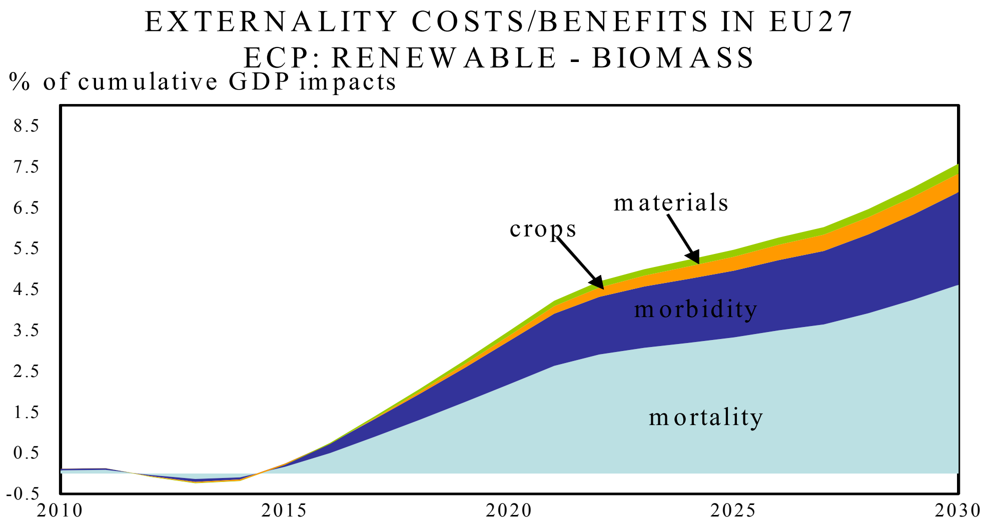
Figure 17: Externality costs/benefits in EU27 from ECP renewables - Solar



Note(s) : Chart shows EU27 cumulative externality impacts as a percentage of cumulative GDP impacts in ECP: Renewable – Solar (Scenario 4).

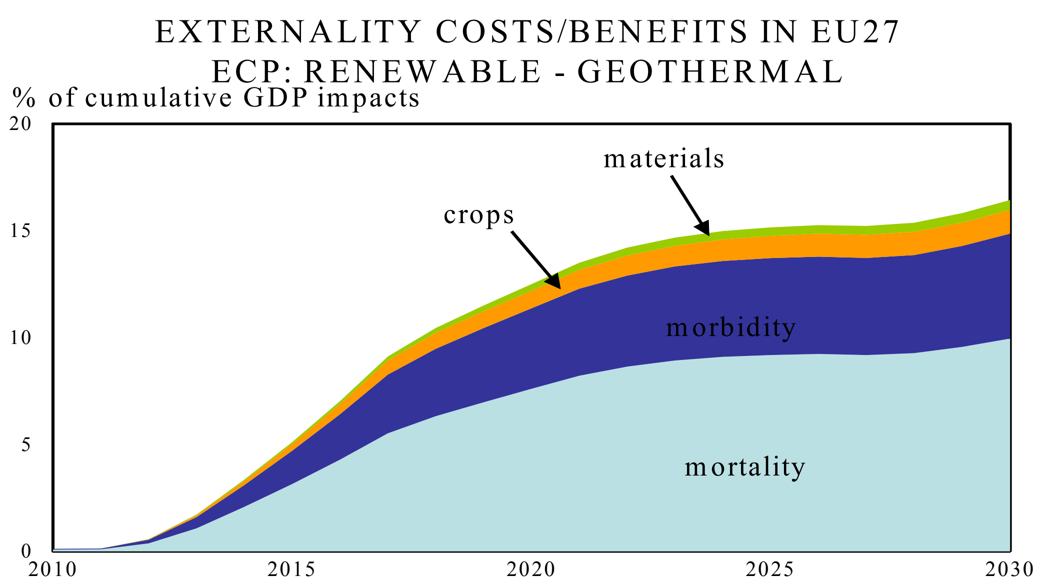
Source(s) : E3ME, Cambridge Econometrics.

Figure 18: Externality costs/benefits in EU27 from ECP renewables - Biomass



Note(s) : Chart shows EU27 cumulative externality impacts as a percentage of cumulative GDP impacts in ECP: Renewable – Biomass (Scenario 5).

Source(s) : E3ME, Cambridge Econometrics.



Note(s) : Chart shows EU27 cumulative externality impacts as a percentage of cumulative GDP impacts in ECP: Renewable - Geothermal (Scenario 6).

Source(s) : E3ME, Cambridge Econometrics.

Overall net impact

Figure 14 - Figure 19 shows the impacts on GDP for the main ECP scenarios when environmental externalities are taken into account. In particular it shows the cumulative impacts on GDP (€m 2000), with and without the environmental externality impacts per additional euro of investment over 2010-2020.

It should be noted that *Figure 14* - Figure 19 is intended for providing a rough idea how the positive impacts from ECP investment would be if positive externalities from pollution reduction are included. In the ExternE database damages to crops, material, and health are referring to yields loss, maintenance costs and value of life year loss (estimated from WTP method) respectively. From this we made the following assumptions;

- yields loss can be translated to reduction in GDP through higher import, lower export, or reduction in profit

- maintenance costs also have an impacts on GDP through reduction in profit

- VOLY is assumed to have be related to income[40] and all income is assumed to spend on consumption which directly feed through to GDP[41]

For example, in the ECP Urban Transport Scenario a €1m exogenous investment over 2010-2020 resulted in +€3.26m cumulative GDP impact. When environmental externalities are included (i.e. impact on health, crops and materials) the impacts rises to +€3.6m. Since the six ECP scenarios here are those that generate positive environmental impacts,

---

[40] ExternE (2005) study found that income is significantly related to WTP

[41] Even if we assumed less than one to one relationship between WTP and income and income and consumption, the ranking of spill-over impacts that included externalities between ECP scenarios would still be the same.

it is not surprising that when taken into account of environmental externalities, the impacts on GDP are higher. Figure 13 also reveals that the ECP Urban Transport produced the highest spill-overs impacts (GDP gains per exogenous investment), both before and after externalities are taken into account and the ranking of the spill-over impacts between scenario does not changed in both cases. For the ECP Products and Processes scenario, the cumulative impact on GDP per investment ratio is less than one. Looking more closely at the E3ME results suggests that in the short run the GDP/Investment ratio for this ECP is high (+2.8 in 2010) but over time investment in Products and Processes also reduced worker demand (due to labour-saving technologies) and consequently lower GDP through reduction in income and consumption.

Modelling Results: Sensitivity Analysis

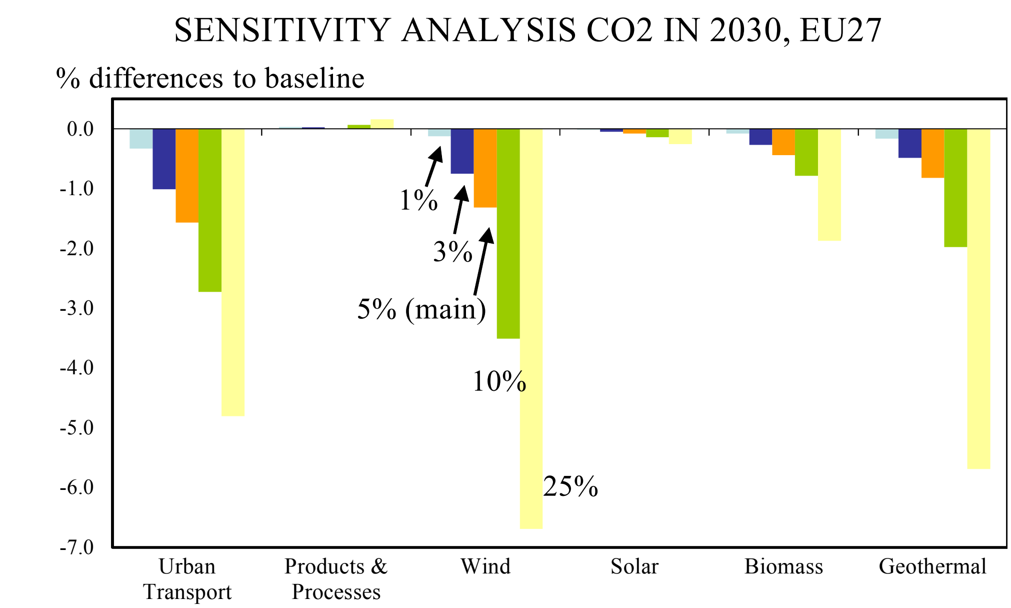
As described above, the effect of the six types of ECP investment were examined under different assumptions for the scale of investment; with exogenous increases of 1%, 3%, 10% and 25% of baseline investment. The results are shown in Figure 20 and Figure 21.

Sensitivity analysis results

GDP impacts

The GDP results from the sensitivity analysis were as expected (see Figure 20); higher investments lead to bigger positive impacts on GDP. The differences between the investment types still holding, with Urban Transport investment generating greater impacts on GDP than the other scenarios because existing investment in the transport sector was already relatively large. All renewable scenarios generated almost identical GDP results as they all had the same exogenous investment assumption (from electricity sector).

Figure 20: Sensitivity analysis: GDP in 2030, EU27



Note(s) : Chart shows EU27 CO2 in 2030 as a percentage difference from baseline for the main (5% additional investment) and sensitivities scenarios.

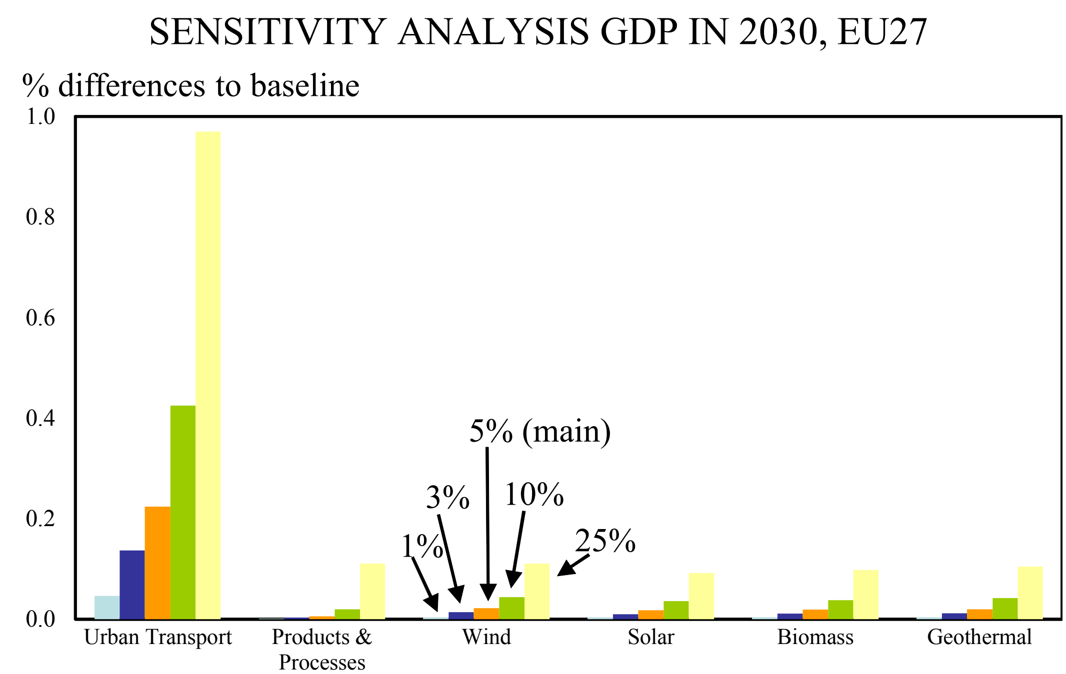
Source(s) : E3ME, Cambridge Econometrics.

CO_2 impacts

Figure 21 shows the CO_2 impacts in the sensitivity scenarios. Interestingly, the effectiveness of different ECP spending in reducing CO_2 emissions varies with the level of investment. In the main scenarios where exogenous investment was increased by 5%, Urban Transport investment was the most effective in reducing the CO_2 impacts. As investment levels increased, however, the ECP investment on renewables (especially Wind and Geothermal) became more cost-effective as renewable capacities rise with investment and average costs of additional production fall due to scale and learning effects. This made renewable sources more attractive to conventional sources. These conventional sources were the main sources of CO_2 emissions and therefore by switching from them CO_2 emissions are reduced considerably. The differences described above between the results for investment in different types of renewables remain in the sensitivity analysis in that the rate of effectiveness depends upon the costs of the technology and how long the new investment is required (e.g. to build a new plant).

With Products and Processes investment, CO_2 increases slightly due to higher economic activities (although small) that generate greater energy demands (and emissions). These effects outweighed the benefits from investment in new technologies.

Figure 21: Sensitivity analysis: CO2 in 2030, EU27



Note(s) : Chart shows EU27 GDP in 2030 as a percentage difference from baseline for the main (5% additional investment) and sensitivities scenarios.

Source(s) : E3ME, Cambridge Econometrics.

Summary

As set out in the Inception Report and the progress report, E3ME has been used to quantify the environmental implications of certain types of investment project in terms of emissions of air-borne pollutants and the associated damage costs on health, buildings and crops. The modelling results are inputs to the RHOMOLO model which will provide the integrated modelling framework for this study.

The six ECP spending categories that have been assessed are;

- Urban transport
- Promoting products and processes
- Renewable energy: wind
- Renewable energy: solar
- Renewable energy: biomass
- Renewable energy: geothermal

Each of the six types of investment has been assess under a range of assumptions for the scale of investment. The central assumption is an increase of 5% of base projections, with alternatives of 1%, 3%, 10% and 25% also examined.

Exogenous environment-related investment on its own should generate more energy-efficient technologies and in turn reduced the amount of energy demand and emissions. Energy demand, however, is also dependent on economic activities, prices and R&D spill-overs in E3ME. Since the model automatically captures these rebound effects, it was not necessarily the case that higher investment led to a larger reduction in energy demand. The magnitude and direction of changes in energy demand depended on the combination of these estimated relationships (at sector and country level).

Despite having the same level of exogenous investment from the electricity sector, the four renewable ECP scenarios produced different emissions results. This is because different renewable technologies have different characteristics. This includes the costs of investment or the time that it takes for the investment to come into effect. Data from the ExternE/Ecosenses database have been used to quantify the externality cost/benefit that changes in emissions of SO2, VOC and NOX resulting from the investments will have on health (due to mortality and morbidity), crops and materials. The outcome of this analysis provided some insights to the monetary benefits of ECP spending in the environment-related categories. The results in general were as expected, higher investment leads to bigger reduction in energy demand (and emissions) and therefore generated more external benefits.

More detailed results (full time series by country and by sectors) are available and will form inputs to the eventual RHOMOLO modelling. It should be noted, however, that the results at this detailed level should be used with caution. Each of E3ME's detailed results (over 1.2 million i.e. 33 equations x 29 regions x 42 industries x 6 scenarios x 5 sensitivities) were based on estimated relationships. Inevitably there are some equations that are more poorly fitted than others. The economic component of the E3ME model is intended to be bottom-up and the results are usually presented at macro-level.

Annex 3. Detailed derivation of the main formulas

Derivation of the formula Linking change in welfare to spill-over elasticities

In the context of the formal general equilibrium model, which was introduced in section 2.2.1, here we present the full derivation of the formulas linking CV (and consequently dW) with spill-over elasticities E_{X_i,K_j}, i.e. the spill-over elasticity of output X_i with respect to the composite capital K_j. Moreover, detailed derivation of the formulas linking BCR and ERR to the spill-over elasticities are also discussed.

As mentioned before, in the formal general equilibrium model investment in a particular sector is traced with an exogenous change in the composite capital of the sector. Suppose that the initial equilibrium allocation and price vector in this model are denoted by superscript 0 (e.g. K_i^0 denotes the initial capital). In the general equilibrium model, any exogenous change in capital, lead to a new equilibrium allocation and price vector that are denoted by superscript l (e.g. K_i^l denotes the new capital). Moreover, let $\Delta K_i := K_i^l - K_i^0$ and $\Delta X_i := X_i^l - X_i^0$, then by definition

$$E_{X_j,K_i} = \frac{X_j^l - X_j^0}{K_i^l - K_i^0} \cdot \frac{K_j^0}{X_i^0} = \frac{\Delta X_j}{\Delta K_i} \cdot \frac{K_i^0}{X_j^0} \tag{4.7}$$

Recall the formula (2.42):

$$\Delta W = CV = Y^l - \prod_i \left(\frac{p_i^l}{p_i^0} \right)^{\beta_i} Y^0$$

First add $0 = -Y^0 + Y^0$ to the right hand of this equation to obtain:

$$\Delta W = Y^l - Y^0 + Y^0 - \prod_i \left(\frac{p_i^l}{p_i^0} \right)^{\beta_i} Y^0$$

Let $\Delta Y := Y^l - Y^0$ then we have

$$\Delta W = \Delta Y + Y^0 (1 - \prod_i \left(\frac{p_i^l}{p_i^0} \right)^{\beta_i})$$

$$= \Delta Y + Y^0 (1 - \frac{\prod_i (p_i^l)^{\beta_i}}{\prod_i (p_i^0)^{\beta_i}})$$

Define the price indices $pcv^l = \prod_i (p_i^l)^{\beta_s}$ and $pcv^0 = \prod_i (p_i^0)^{\beta_i}$ and substitute them in the above formula:

$$\Delta W = \Delta Y + Y^0 (1 - \frac{pcv}{pcv^0})$$

Given that

$$1 - \frac{pcv}{pcv^0} = \frac{pcv^0 - pcv}{pcv^0},$$

we can derive:

$$CV = \Delta Y + Y^0 (\frac{pcv^0 - pcv}{pcv^0}) \qquad (4.8)$$

Substituting Y from the equilibrium condition (2.31)into the above expression yields to:

$$CV = \sum_i [(X_i^l - \sum_j IO_{ij} \cdot X_j^l) \cdot p_i^l (1 + tc_i)]$$
$$- \sum_i [(X_i^0 - \sum_j IO_{ij} \cdot X_j^0) \cdot p_i^0 (1 + tc_i)] \qquad (4.9)$$
$$+ Y^0 (\frac{pcv^0 - pcv^l}{pcv^0})$$

Recall that

$$E_{X,K} = \frac{\partial X}{\partial K} \cdot \frac{K}{X}$$

hence , CV can be rewritten as a function of E_{X_m,K_m} , for sector $m \in I$, given that the exogenous change in capital happens only in sector m in the economy, i.e. $\Delta K_i = 0$, for $\forall i \neq \mathrm{m}$:

$$CV = \sum_i [X_i^0 (p_i^l - p_i^0 \cdot \frac{pcv^l}{pcv^0})(1 + tc_i)]$$
$$- \sum_i \sum_j [IO_{ij} \cdot X_j^0 (p_i^l - p_i^0 \cdot \frac{pcv^l}{pcv^0})(1 + tc_i)]$$
$$+ E_{X_m,K_m} \cdot \frac{\Delta K_m}{K_m^0} \times [\sum_i \eta_{m,i} \cdot X_i^0 \cdot p_i^l \cdot (1 + tc_i) \qquad (4.10)$$
$$- \sum_i \sum_j (IO_{ij} \cdot \eta_{m,j} \cdot X_j^0 \cdot p_i^l \cdot (1 + tc_i))],$$

where the (elasticity) coefficient $\eta_{i,j}$ is defined as

$$\eta_{i,j} = \frac{\partial X_j / \partial K_i}{\partial X_i / \partial X_i} \cdot \frac{X_i}{X_j} \qquad (4.11)$$

Finally equation (4.10) can be solved for E_{X_m,K_m} to express the elasticity as function of $CV = \Delta W$:

$$E_{X_m,K_m} = \frac{K_m^0}{\Delta K_m} \times \frac{\Delta W - (\sum_i [(X_i^0 - \sum_j (IO_{ij} \cdot X_j^0)] \cdot (p_i^l - p_i^0 \cdot \frac{pcv^l}{pcv^0})(1+tc_i))}{\sum_i [\eta_{m,i} \cdot X_i^0 - \sum_j (IO_{ij} \cdot \eta_{m,j} \cdot X_j^0)] \cdot p_i^l \cdot (1+tc_i)} \qquad (4.12)$$

This expression can be written in an elegant form:

$$E_{X_m,K_m} = \frac{K_m^0}{\varphi_m \cdot \Delta K_m} \cdot \Delta W - \frac{\psi_m \cdot K_m^0}{\varphi_m \cdot \Delta K_m}$$

(4.13)

where coefficients φ_m, which is called here as *modified value added*, and ψ_m are defined as follows,

$$\varphi_m = \sum_i \left(\eta_{m,i} \cdot X_i^0 - \sum_j \left(IO_{ij} \cdot \eta_{m,j} \cdot X_j^0 \right) \right) \cdot p_i^l \cdot \left(1+tc_i\right)$$

and (4.14)

$$\psi_m = \sum_i \left(X_i^0 - \sum_j \left(IO_{ij} \cdot X_j^0 \right) \right) \cdot \left(p_i^l - p_i^0 \cdot \frac{pcv^l}{pcv^0} \right) \left(1+tc_i\right)$$

The own spill-over elasticities were linked to the change in welfare through formula (4.13). In the following we explain how with the help of parameter $\eta_{i,j}$ the cross-sectoral spill-over elasticities can be also linked to ΔW .

Recall that

$$\eta_{i,j} = \frac{\partial X_j / \partial K_i}{\partial X_i / \partial X_i} \cdot \frac{X_i}{X_j}$$

Multiplying both sides by $1=\frac{K_i}{K_i}$ we obtain

$$\eta_{i,j}\cdot 1=\frac{\partial X_j / \partial K_i}{\partial X_i / \partial X_i}\cdot\frac{X_i}{X_j}\cdot\frac{K_i}{K_i}=\frac{\partial X_j / \partial K_i}{\partial X_i / \partial X_i}\cdot\frac{K_i / X_j}{K_i / X_i}$$

But by the mathematical definition of the spill-over elasticity:

$$\eta_{i,j}=\frac{E_{X_j,K_i}}{E_{X_i,K_i}}$$

which is the cross-sectoral /own elasticity ratio.

This finally yields to

$$E_{X_j,K_i}=\eta_{i,j}\cdot E_{X_i,K_i} \tag{4.15}$$

This relation enable us to link cross-sectoral spill-over elasticity E_{X_j,K_i} to the change in welfare through the main formula (4.13) (simply multiply by factor $\eta_{i,j}$).

For any sector i, if the exogenous change in capital is small enough, that is $|\Delta K_i|<\varepsilon,$ for an arbitrary $0<\varepsilon = 1$, then there will be a very small change in the equilibrium price vectors. In this case the above expression can be even further simplified by assuming that $\left|p_i^l-p_i^0\right|\le\varepsilon$. In this case by eemploying the formulation of (2.44), as $p_i^l\to p_i^0$, then $\psi_m\to 0$. Therefore, in the limit the formula can be written as:

$$E_{X_m,K_m}=\frac{K_m^0}{\varphi_m\cdot dK_m}\cdot dW \tag{4.16}$$

Derivation of the formula Linking BCR and ERR to spill-over elasticities

Recall the structure of the *recursive-dynamic model* that is used to model an economy with ECP in section 2.4. Note that by the recursive-dynamic model we mean, multi-period general equilibrium model in which results are computed one-period-at-a-time based on the formal general equilibrium model, which is discussed in this section. In contrast, for fully inter-temporal models, results are computed simultaneously for all periods. Here in the context of this model the change in welfare dW is linked to the BCR (Benefit Cost Ratio) and consequently to the ERR (Economic Rate of Return).

Asume that there are T time periods. Denote the spill-over elasticity at each time period t by E^t, change in welfare by dW^t, and the *modified value-added* (coefficient) in the equation (2.47) by φ^t. Here, we assume that the spill-over elasticities are constant over time that is $E^t = E$ for $1 \le t \le T$. The following structure of the cost-benefit stream structure is assumed. There is just a one-period investment in a project (cost of the project) at time 0, which is set to I^0 with $I^0 = dK^0$. Then at each time period $1 \le t \le T$ there is benefit B^t with $B^t = dW^t$ for the project. Hence the cost-benefit structure of an ECP project in this economy has the following structure:

$$I^0, dW^1, dW^2, ..., dW^T$$

In this setting, by using the definition of the BCR:

$$BCR = \frac{\sum_{t=1}^{T} \frac{dW^t}{(1+r)^{t-1}}}{dK^0} \qquad (4.17)$$

Where r is the discount rate.

Using the general formula(2.44), at each time-period $1 \le t \le T$ (non-marginal effects) we have,

$$E^t \cdot \varphi^t = K^0 \cdot \frac{dW^t}{dK^0} \qquad (4.18)$$

Now by the assumption that $E^t = E$ for $1 \le t \le T$:

$$E \cdot \sum_{t=1}^{T} \frac{\varphi^t}{(1-r)^{t-1}} = K^0 \cdot \frac{\sum_{t=1}^{T} \frac{dW^t}{(1-r)^{t-1}}}{dK^0}$$

And by dividing both sides by $\sum_{t=1}^{T} \frac{\varphi^t}{(1-r)^{t-1}}$ we have

$$E = \frac{K^0}{\sum_{t=1}^{T} \frac{\varphi^t}{(1-r)^{t-1}}} \cdot \frac{\sum_{t=1}^{T} \frac{dW^t}{(1-r)^{t-1}}}{dK^0}$$

Recall that by definition

$$BCR = \frac{\sum_{t=1}^{T} \frac{dW^t}{(1-r)^{t-1}}}{dK^0}$$

Then by using the formula (4.18) the following formula can be derived which describes the link between the spill-over elasticities and BCR :

$$E = \frac{K^0}{\sum_{t=1}^{T} \frac{\varphi^t}{(1+r)^{t-1}}} \cdot BCR \qquad (4.19)$$

In order to link ERR spill-over elasticities first recall that ERR can be derived by solving the equation $BCR = 1$ for r . That is ERR is the solution of the following equation:

$$\frac{\sum_{t=1}^{T} \frac{dW^t}{(1+r)^{t-1}}}{I^0} = 1 \xrightarrow{\text{Solve for } r} r^* = ERR$$

Then by using (4.19) with $BCR = 1$ and $r = ERR$, the spill-over elasticity E can be linked to the ERR as follows:

$$E = \frac{K^0}{\sum_{t=1}^{T} \frac{\varphi^t}{(1+ERR)^{t-1}}} \tag{4.20}$$

Detailed derivation of the aggregation formulas

Here we present the full mathematical derivation of the aggregation formula for E_{X_i,K_i} is presented. The other formulas are derived in the same way.

Since the aggregation of spill-over elasticities for a sector aggregate I_j only applies to E_{X_i,K_i}, E_{A,K_i}, $E_{X_i,ED}$, and $E_{X_i,R}$

Recall that equation (3.1) describes the technological constraint of a sector $i \in I_j$. This equation can be expressed in the following general form

$$X_i = F(K_i, L_i, R, ED) \tag{4.21}$$

where $F(K_i, L_i) \equiv A(K_i) \cdot f(K_i, L_i)$.

The full differential of X_i is

$$dX_i = \frac{\partial X_i}{\partial K_i} \cdot dK_i + \frac{\partial X_i}{\partial L_i} \cdot dL_i \tag{4.22}$$

Recall that each production sector is denoted by $i \in I$ and that I is a disjoint union of $I_j \subset S$:

$$I = \bigcup_{j}^{g} I_j \tag{4.23}$$

Moreover, $K = \sum_{i \in I_i} K_i$, hence

$$dX = \sum_{i \in I_j} \frac{\partial X}{\partial K} \cdot \frac{\partial K}{\partial K_i} \cdot dK_i + \frac{\partial X}{\partial L} \cdot dL \qquad (4.24)$$

Subtracting (4.24) from (4.22) yields to

$$0 = \frac{\partial X}{\partial K} \cdot dK - \sum_{i \in I_j} \frac{\partial X}{\partial K} \cdot \frac{\partial K}{\partial K_i} \cdot dK_i \qquad (4.25)$$

And then

$$\frac{\partial X}{\partial K} \cdot dK = \sum_{i \in I_j} \frac{\partial X}{\partial K_i} \cdot dK_i \qquad (4.26)$$

Moreover, from $X = \sum_{i \in I_j} X_i$, we can find that $\frac{\partial X}{\partial K_i} = \frac{\partial X_i}{\partial K_i}$ .Taking this relation into (4.26) we obtain

$$\frac{\partial X}{\partial K} \cdot dK = \sum_{i \in I_j} \frac{\partial X_i}{\partial K_i} \cdot dK_i \qquad (4.27)$$

From the mathematical definition of the spill-over elasticity, we have that

$$\frac{\partial X}{\partial K} = E_{X,K} \cdot \frac{X}{K}$$

We then substitute the above relation into (4.27)

$$E_{X,K} \cdot \frac{X}{K} \cdot dK = \sum_{i \in I_j} E_{X_i,K_i} \cdot \frac{X_i}{K_i} dK_i \qquad (4.28)$$

And finally from this expression we derive the aggregation formula corresponding to this spill-over elasticity:

$$E_{X,K} = \sum_{i \in I_j} \frac{X_i}{X} \cdot \frac{K}{K_i} \cdot \frac{dK_i}{dK} \cdot E_{X_i,K_i} \qquad (4.29)$$

This proves the claim.

Annex 4. Database of CBA projects and its development

Projects in the database have been selected based on their quality of information and characteristics. Good quality of information means that the correct quantitative indicators that are necessary to calculate NPV, ERR and spill-over elasticities are present, either in ex-ante or preferably in ex-post project documentation. In order to calculate a project's NPV and ERR information on the following aspects is required: the lifetime of the project, the discount rate and individual costs and benefits over the time period (in prices times quantities). Each project that we find is screened for meeting these criteria. This means that mainly relatively large projects are considered as small projects often don't carry out a comprehensive CBA analysis.

The overview of the CBA studies is given in Table 31. It shows the amount of projects files per subsector of investment and by type (ex-ante or ex-post) currently in the database. A few of the (sub)sectors of investment have been omitted in the grouping process because the category is too small in terms of total ECP expenditure..

Table 31: *Overview of the amount of project evaluations by type*

Sectors if investment	Subsectors of investment	Ex-ante	Ex-post	Total
Infrastructure	1.1 Transport	60	26	86
	1.1.1Road	*42*	*9*	*51*
	1.1.2Rail	*12*	*10*	*22*
	1.13-1.1.1.5 Air-, waterways and other	*6*	*7*	*13*
	1.2 Environment	110	38	148
	1.2.1 Waste water	*62*	*12*	*74*
	1.2.2Solid waste	*25*	*3*	*28*
	1.2.3Emissions	*0*	*3*	*3*
	1.2.4 Environmental risk prevention	*3*	*10*	*13*
	1.2.5 Drinking water	*20*	*10*	*30*
	1.2 Energy	15	24	39
	1.3 ICT	1	7	8
	1.4 Social Infrastructure	9	14	23
2. Human resources	2.1 Education	4	9	13
	2.2 Labour market institution	3	7	10
3. R&D	3.1 Public sector			0
	3.2 Private sector	3	22	25
4. Aid to productive investments	4.1 Industry	2	7	9
	4.2 Services	1		1
	Total	208	154	362

Source: TNO

The table below gives an overview of researched data sources.

Source	Description

DG REGIO CD-ROMs	All but one CD's are examined and some ex-ante studies are added. The CD's do not contain studies for thinly covered sectors.
National Contact Points	No further action was taken from the 8-step programme presented in the last report
World Bank	The richest source of data
EU Regional Policy database	Possible extension of database for labour market institutions, human resources and R&D.

From the World Bank's website access to project documents can be gained for all Cohesion countries, except Germany. The World Bank made a complete sequence of project documents available to the public, from Project Information reports to Project Implementation and Completion reports. The subsectors of investments of the World Bank differ somewhat from the ECP expenditure categories. However, the bridge to the ECP classifications is made quite easily.

Annex 5 Overview of RHOMOLO model

Overall structure of the model

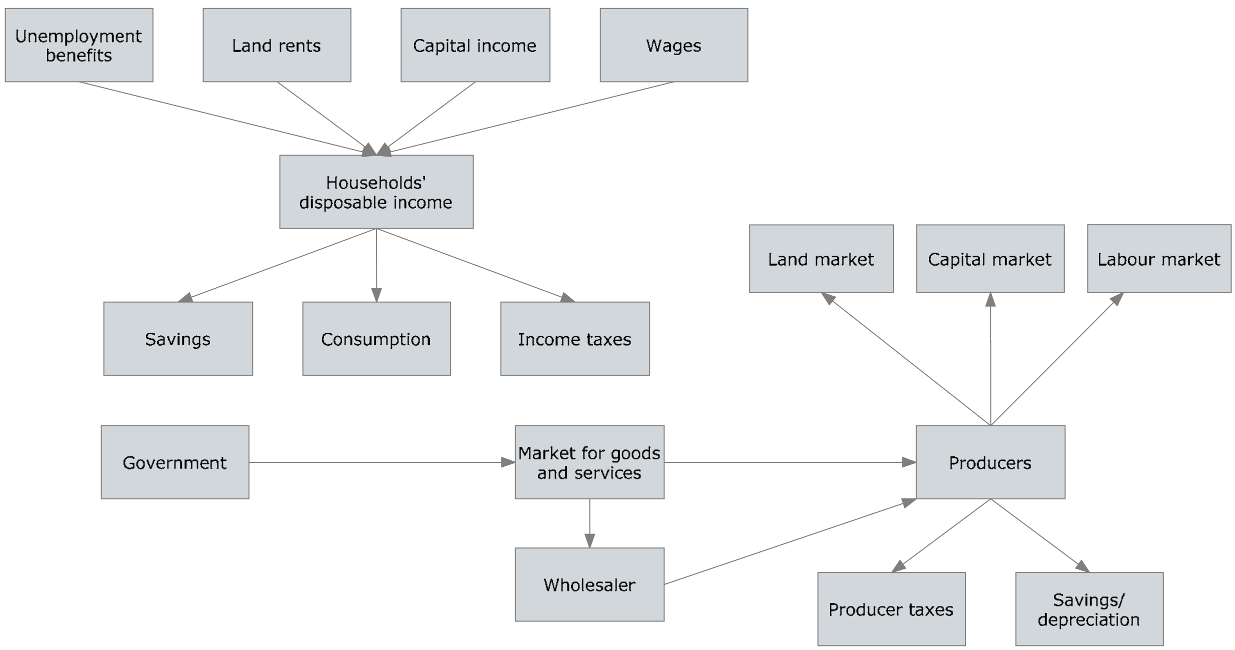
The main objective of the RHOMOLO model is to develop a system of regional models for a chosen set of European regions. The RHOMOLO model incorporates state-of-the-art theories of both theoretical and applied regional economic modelling. Therefore, the model contains features of the New Economic Geography (NEG) and endogenous growth theory. Furthermore, for application purposes, it is essential the model incorporates public sector interventions and a multi-level governance system.

The system of regional models is constructed using the Spatial Computable General Equilibrium (SCGE) framework, which takes as a basis the notion of the Walrasian equilibrium. Walrasian equilibrium is one of the foundations of the modern microeconomics theory. SCGE models typically are comparative static equilibrium models of interregional trade and location choice based on microeconomics, using utility and production functions with substitution between inputs. The RHOMOLO model is able to model (dis)economies of scale, external economies of spatial clusters of activity, continuous substitution between capital, labour, energy and material inputs in the case of firms, and between different consumption goods in the case of households. Moreover, monopolistic competition of the Dixit-Stiglitz type allows for heterogeneous products implying variety, and therefore allows for cross hauling of close substitutes of products between regions.

The model utilizes the notion of the representative economic agent. They represent the behaviour of the whole population group or of the whole industrial sector as the behaviour of one single representative agent. It is further assumed that the behaviour of each such representative agent is driven by certain optimization criteria such as maximisation of utility or minimization of costs.

The model is a dynamic, recursive over time, involving dynamics of physical and human capital accumulation and technology progress, stock and flow relationships and adaptive expectations. A recursive dynamic is a structure composed of a sequence of several temporary equilibriums. The first equilibrium in the sequence is given by the benchmark year. In each time period, the model is solved for an equilibrium given the exogenous conditions assumed for that particular period. The equilibria are connected to each other through physical and human capital accumulation.

Figure 22 Static structure of the model



Consumer behaviour

Behaviour of the households is based on the utility-maximisation principle. Household's utility is associated with the level and structure of its consumption and the level of emissions, waste and waste water. Households cannot influence environmental quality by their decisions. Each period of time the households solve a static one period optimization problem, where they determine their optimal consumption bundle in order to maximise their instantaneous utility function. The instantaneous utility function is maximised given one period consumption budget constraint of the households. The maximisation problem is solved under the assumption that the whole consumption budget constraint is used each period of time to buy various goods and services.

In the model substitution possibilities between different consumption commodities are captured by Stone-Geary utility function, which corresponds to the Linear Expenditure System (LES) of demands. According to the Stone-Geary utility function household derives its utility only from the amount of consumption, which is higher than the minimum subsistence amount and the elasticity of substitution between commodities is equal to one.

In each region the utility maximisation problem of a particular household type can be written in the following simplified way. Maximise the Stone-Gray utility function:

$$U = A \cdot \prod_i (C_i - \mu H_i)^{\alpha H_i}, \tag{4.30}$$

subject to the budget constraint:

$$B = \sum_i (p_i \cdot (1 - sc_i + tc_i) \cdot C_i) \tag{4.31}$$

Here A is a scaling parameter, C is the demand for consumer goods and services and μH is subsistence consumption level; p is the commodity price; sc and tc the product subsidy and tax rates.

Solution of the system of the first order conditions gives demand equations:

$$\begin{aligned} & p_i \cdot (1 - sc_i + tc_i) \cdot C_i \\ & = p_i \cdot (1 - sc_i + tc_i) \cdot \mu H_i + \alpha H_i (B - \sum_j (\mu H_j \cdot p_i \cdot (1 - sc_j + tc_j))) \end{aligned} \tag{4.32}$$

Producer behaviour

Behaviour of the production sectors is based on the profit-maximisation principle. The behaviour of each sector is captured by the behaviour of the representative firm. At each time period, the instantaneous behaviour of the sectors is based on the minimization of the production costs for a given output level under the sector's technological constraint. Production costs of each sector in the model include labour costs, energy costs, capital costs, land costs and the costs of intermediate inputs. The sector's technological constraint describes the production technology of each sector. It provides information on how many of different units of labour, energy, sector-specific capital, land and commodities, are necessary for the production of one unit of the sectoral output.

All production sectors are divided into traditional and modern sectors. Traditional sectors operate under constant returns to scale and perfect competition. Their pricing are equal to marginal production costs. Modern sectors operate under increasing returns to scale and monopolistic competition. Under the assumption of monopolistic competition the total sectoral production costs consist of the variable costs and of the fixed costs.

The production technology of the firm is represented by the nested Constant Elasticity of Substitution (CES) functions. The nested CES function is quite flexible and allows for different assumptions about the degree of substitutability between the production inputs.

Inputs which are easier to substitute with one another are put into the same nest. Inputs which are more difficult to substitute in the production process are put into different nests. The existence of the technological substitution possibilities is an important feature of the production process and cannot be neglected while modelling sectoral production.

In order to calculate the general formula for the demands of the intermediate inputs corresponding to the CES production function we start from the general CES production function:

$$Y = A \cdot \left(\sum_i a_i \cdot X_i^{\rho} \right)^{1/\rho} \tag{4.33}$$

where Y is the production output, A is the scaling parameter of the production function, X_i the intermediate inputs, a_i the share parameters of the CES function and $\rho = (\sigma - 1)/\sigma$,where σ is the elasticity of substitution between production inputs.

Cost minimization problem reads as:

$$\sum_i p_i \cdot X_i \Rightarrow \min_{X_i} \tag{4.34}$$

Solution of the system of the first order conditions gives demand equations for production inputs:

$$X_j = Y \cdot \left(\frac{a_j}{p_j} \right)^{\sigma} \cdot pY^{\sigma} \cdot A^{\sigma-1} \tag{4.35}$$

New Economic Geography and endogenous growth features

One of the main contributions of the spatial and regional economics literature, and the New Economic Geography (NEG) literature in particular, that the model tries to capture is that economic agents are spatially interconnected and interrelated. The essential contribution of NEG is that interregional linkages can be self- reinforcing due agglomeration and spreading effects.

The following main spatial effects can be distinguished from the model.

1 The market-access effect. Monopolistic firms will try to locate them-selves in a big market and export to small markets. In this way they minimize transport costs and are the most competitive in all regions.

2. The variety effect. Monopolistic firms (and consumers) will try to locate themselves in a big market with the most varieties to gain in productivity (and utility for consumers) via a larger variety of intermediate inputs.

3. The cost of living effect. Goods tend to be cheaper in a region with more economic activity since consumers in this region import less and reduce their transport costs. This attracts consumers.

4. The market-crowding effect. Monopolistic firms have an incentive to locate themselves in regions with few competitors to avoid strong competition.

While the first three effects are agglomeration forces, as they encourage agglomeration in the model, the last effect is a dispersion force. Trade costs and the regional availability of land determine the relative strength of these forces.

The RHOMOLO enables to link regions also via technological and knowledge spill-overs. The model structure extends to include endogenous total factor productivity (TFP) growth elements such as technological progress and human capital accumulation. The specification of endogenous growth in the model is based on models of economic growth and catch-up. In this framework, productivity growth is generated through own innovations, knowledge spill-overs and technology adoption (catching-up). The TFP equation takes the form:

$$gr\_TFP_{r,s} = a_{0,s} + a_{1,s} LnH_r + a_{2,s} RD_r + b_s LnH_r \left(\frac{TFP_{r,s}}{TFP^*_{r,s}} \right) + \varepsilon_{r,s} \tag{4.36}$$

This equation states that productivity growth of sector *s* in region *r* depends on some exogenous sector-specific parameter, human capital stocks (*H*), intensity of R&D investments (*RD*) and on the *TFP* level relative to the frontier (indicated by an asterisk, where the frontier relevant to region *r* by definition satisfies the condition: $TFP^*_r \geq TFP_r \; \forall s$). The last term of the above equation represents the technology adoption function comprising of technology transfer and absorptive capacity and hence it makes the term b endogenous. This term indicates that in addition to innovative capacity role of human capital, improvement in human capital enhances the closing of technology gap between the technology leader and follower.

External effects and representation of the government

All production activities in the model are associated with emissions and environmental damage. The model incorporates the representation of all major greenhouse gas (GHG) and non-greenhouse gas (non-GHG) emissions. In general GHG emissions are associated with the energy inputs whereas other emissions are associated with the total outputs of the sectors.

Changes in GHG and non-GHG emissions influence the regional households in a different way. GHG emissions have global character, which means that the households living in a particular EU region is negatively influenced by increase in GHG emission in the whole EU. Non-GHG emissions have local character and influence only the households living the region from where these emissions originate.

Besides pollution the model also incorporates waste and waste water. Waste can be treated in various ways and this will result in either positive or negative effects. In particular the use of waste in order to produce energy is associated with positive environmental effect, whereas deposit of waste into land results in negative influence. Waste water is also associated with the negative costs to the environment.

The model incorporates the representation of multi-level governance system: the federal and regional governments. The governmental sector collects taxes, pays subsidies and makes transfers to households, production sectors and to the RoW. Tax revenues are shared by the national and regional governments according to the certain rates determined from the base year data. The federal and regional governments consume a number of commodities and services, where the optimal governmental demand is determined according to the maximisation of the governmental consumption utility function. We use a Cobb-Douglas utility function in the model. Its maximisation results in the demand rules, which says that the expenditure share of different commodities and services purchases by the government stay constant over time. The model incorporates the governmental budget constraint. According to this constraint the total governmental tax revenues are spend on subsidies, transfers, governmental savings and consumption.

General equilibrium and Walras law

The model closure follows the two standard rules of a CGE model. First, on the product market the output of each regional sector equals its total demand from the own region plus demand from other regions. Second, on the factor market demand and supply of capital, land and labour are equalized. For capital, in each period the total stock of sector-specific capital is fixed and its market is cleared by the return on capital. The same holds for land, of which the total supply is exogenous in each period. The labour market is closed through the determination of the real wage.

Another general rule in a CGE model is that the market demands should satisfy the Walras law. In general, Walras law states that the value of market demands equals the value of the economy's endowments, that is,

$$\sum_i p_i(X_i(p)) = \sum_i p_i W_i, \quad \text{(4.37}$$

or the value of market excess demand (Z) equals zero at all prices,

$$\sum_i Z_i(p) = \sum_i p_i(X_i(p) - W)) = 0 \quad \text{(4.38)}$$

For any set of prices, regardless of being equilibrium prices or not, this condition must hold. Walras law is an important check on any equilibrium system; if it does not hold, as the model violates the sum of individual budget constraints, a misspecification is usually present in the model.

Welfare function

In the model we make a distinction between utility and welfare functions of the households. The utility functions of the households cannot be measured in money and is only used to derive optimal demands of the households given a certain budget constraint. Welfare function represents the change in welfare as change in the utility measured in monetary units. It is captured in RHOMOLO by the Compensating Variation (CV) measure. Compensating Variation is a measure of welfare change introduced by John Hicks and it gives the amount of income which have to be given (taken away) from the household in order for it to stay on its old level of utility after a certain change in policy control variables.

Compensating Variation is calculated on the basis of expenditure function in the following way:

$$CV = e(p_1, U_1) - e(p_1, U_0) = e(p_0, U_0) - e(p_1, U_0) \tag{4.39}$$

The change in the social welfare function (*dW*) in RHOMOLO is calculated as the sum of compensating variations of all household types in each region. In order to account in the welfare function for the negative impacts of emissions, waste and waste water we add additional term ($EnvBenefits_{th,r}$) to the compensating variations of the households. This term represents environmental damage in monetary terms:

$$dW = \sum_{th,r} \left(CV_{th,r} + EnvBenefits_{th,r} \right) \tag{4.40}$$

We account for the following types of environmental damage: health, building materials, crops, global warming, noise and ecosystems.

Implementation of RHOMOLO model for eighteen cohesion countries

The Cohesion System of HERMIN models (CSHM) is a set of macroeconomic models designed to assess the impact of Cohesion Policy at national level on eighteen EU Member States (BG, DE, CY, CZ, EL, EE, IE, ES, HU, IT, LT, LV, MT, PL, PT, RO, SK, SI). The *objective* of this study is to improve the current CSHM by identifying elasticities for the main categories of ECP expenditure. In order to be able to estimate with the help of RHOMOLO model spill-over elasticities for all EU Member States of HERMIN model, we need to extend the database of the model from five countries of the prototype model constructed by TNO consortium (DE, SK, PL, HU and CZ) to eighteen countries of HERMIN model States (BG, DE, CY, CZ, EL, EE, IE, ES, HU, IT, LT, LV, MT, PL, PT, RO, SK, SI).

In order to accomplish this difficult task within the deadlines of the project we have used a set of databases already available at TNO through our completed research projects. The main database which has been used is the database of our RAEM-Europe model. Both the model and the database have been constructed during one of our internal projects and is a property of TNO. Model database includes detailed production, employment, value added, number of firms and labour compensation data for NUTS2 regions of EU-27 in NACE Rev 2 sectoral specification (99 types of sectors). The starting point for this database is EuroStat data together with CE database and other more detailed sources. Database of RAEM-Europe model is constructed for 2007 and has provided us with the necessary detailed data on production side of the economy, migration, incomes and consumption of regional households.

Another database which we have used is the database of our EDIP model for Europe. This model is implemented at the national level and includes various external effects such as GHG and non-GHG pollution and waste. The latest database for EDIP model is for 2007 and gives us data on all national SAMs for European countries as well as the level of energy use, GHG and non-GHG emissions and waste. EDIP model database also contains information about sectoral employment by three levels of education.

The only data which was missing after we have put together these two databases was the data on the two levels of the government: regional and federal. We had to construct these data using EuroStat data and some regression analysis which has been done by us for RHOMOLO project.

In order to satisfy the needs of the HERMIN elasticities project we had to construct during a short time span of a couple of months the regional database for additional thirteen European countries (five we already had from RHOMOLO project) and calibrate RHOMOLO model on this extended database. The constructed database of RHOMOLO for eighteen Cohesion Countries has been put together using TNO databases and resources and is the property of TNO.

Annex 6. Results of shadow price estimations

Table 32 Shadow prices in Euros for the year 2007 as calculated with RHOMOLO model

Education level	Low isced0_2	Medium isced3_4	High isced5_6
BG	744	1250	2015
CY	3581	8141	9463
CZ	1343	5228	14278
DE	11288	14602	21798
EE	1340	4210	8545
ES	6480	9605	14930
GR	1367	5444	8527
HU	1367	2298	5841
IE	6157	14591	26122
IT	4645	7742	10431
LT	1226	1743	4026
LV	912	3134	5622
MT	1059	4219	6607
PL	856	1439	3538
PT	4131	7423	14217
RO	920	3582	4673
SI	1088	4237	9475
SK	808	4279	9480

Annex 7. Sheets with completed ex-post CBA studies

Road

<u>*Project information*</u>

Project name:	Third Road Maintenance and Rehabilitation Project
Country and region:	Poland (national)
Short description of the project:	Acceleration in investment in the road network to improve business climate. General project to rehabilitate highways and improve safety in the entire country
ECP programming period:	World Bank/European Investment Bank finances
Period of implementation:	2006-2008
Period of exploitation:	2009-2035

<u>*General CBA information:*</u>

Number of years for CBA analysis:	30
Social discount rate:	5%
Shadow price of labour:	Shadow price of time:
	Business: 12,87 passenger E/hour, 2002 prices (factor cost)
	Other: 5,07 passenger E/hour, 2002 prices (factor cost)
	Freight: 1,92 ton E/hour, 2002 prices (factor cost)
	Value of Statistical Life: 341.000 Euro/fatality, 2002 prices (factor cost)
Price level	2006, other base years are given

<u>*Demand analysis*</u>

Present level of annual demand (by type):	Business: 2193 million passkm
	Other: 3733 million passkm

Freight: 12509 million tonkm

Average annual generated demand (by type):Business 28 million PKM

Other 48 PKM

Freight 181 TKM

Change in prices for present level of demand (by type, due to investment)

Business -1.3%

Other -1.3%

Freight -1.3%

Financial analysis

Total investment costs: 312 million Euro

Total private investment costs:-

Total public investment costs: 312 million Euro

Average annual revenues/benefits:-

Discounted flow of revenue/benefits:-

Net present value (NPV): -

Internal Rate of Return (IRR): -

Socio-economic analysis

Average annual social benefits by type: Business 5.1 million

Other 3.5 million

Freight 4.7 million

Fatalities 7.0 million

Average annual environmental benefits by type 5.8 million Euro

Discounted social benefits by type

Business 132.2 million

Other 90.7

Freight 122.4

Fatalities 182,6

Discounted environmental benefits by type 150.6 million Euro

Economic net present value (ENPV): 44 million

Economic rate of return (ERR): 6,1%

Benefit/Cost ratio (BCR): 1.16

Project information

Project name: Fourth Highway Project

Country and region: Cyprus

Short description of the project: Easing critical bottlenecks, rehabilitation sub-standard roads serving agricultural areas, making tourist resort better accessible, improving maintenance, provision of consulting services

ECP programming period: World Bank finances

Period of implementation: 1988-1994

Period of exploitation: 1995-2017

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Shadow price of time (value of time), 2002 prices factor cost

Business 21.08 E/hour PKM

Other 8,32 E/hour PKM

Freight 2.73E/hour TKM

Demand analysis

Present level of annual demand (by type) Business 135 million PKM

Other 79 PKM

Freight 12 TKM

Average annual generated demand (by type) Business 4.8 PKM

Other 2.8 PKM

Freight 0,21 TKM

Change in prices for present level of demand (by type, due to investment)

Business -10%

Other -10%

Freight -10%

Financial analysis

Total investment costs: 114 million Euro (prices 2000)

Total private investment costs: -

Total public investment costs: -

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR): -

Socio-economic analysis

Average annual social benefits by type: Business 4.9 million Euro (2000 prices)

Other 1.1 million Euro (2000 prices)

Freight 0,04 million Euro

Average annual environmental benefits by type: Emissions: 0,6 million Euro

Discounted social benefits by type Business 113 million Euro (prices 2000)

Other 2.6 million Euro (prices 2000)

Freight 1 million Euro (prices 2000)

Discounted environmental benefits by type: 56

Economic net present value (ENPV): 5.74 million Euro (prices 2000)

Economic rate of return (ERR): 5.42%

Benefit/Cost ratio (BCR): 1.51

Project information

Project name: New road A14 from Magdeburg to Wismar (A20)

Country and region: Germany, former East Germany

Short description of the project: Construction of a highway in order to bring down time losses on a north-south connection (now a provincial road)

ECP programming period: EFRE Bund 2007-2013

Period of implementation: 2011-2016

Period of exploitation: 2017-2040

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: (value of time) Business 21.8 Euro/hour (2008 prices)

Other 9.8 Euro/hour (2008 prices)

Freight 3.1 Euro/ton (2008 prices)

Demand analysis

Present level of annual demand (by type) Business 554 PKM (passenger kilometre, million)

Other 326 PKM

Freight 205 TKM

Average annual generated demand (by type) Business 139 PKM

Other 82 PKM

Freight 58 TKM

Change in prices for present level of demand (by type, due to investment) -27% (passengers), -22% freight

Financial analysis

Total investment costs: 1174 million Euro 2008 prices

Total private investment costs:-

Total public investment costs: -

Average annual revenues/benefits:-

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR): -

Socio-economic analysis

Average annual social benefits by type: Business 56.1 mio Euro (2008 prices)

Other 14.8 mio Euro (2008 prices)

Freight 3.4 mio Euro (2008 prices)

Mazut 16.6 mio Euro (2008 prices)

Safety 2.9 mio Euro (2008 prices)

Average annual environmental benefits by type Environment passengers -8.5 mio Euro (2008 prices)

Environment Freight -2.4 mio Euro (2008 prices)

Discounted social benefits by type Business 1347 mio Euro, 2008 prices

Other 355 mio Euro, 2008 prices

	Freight 6.2 mio Euro, 2008 prices
	Mazut 399 mio euro, 2008 prices
	Safety 69 mio Euro, 2008 prices
Discounted environmental benefits by type	Passengers -204 mio Euro, 2008 prices
	Freight -58 mio Euro, 2008 prices

Economic net present value (ENPV): 467 mio Euro, 2008 prices

Economic rate of return (ERR): 8.01%

Benefit/Cost ratio (BCR): 1.46

Rail

Project information

Project name: Improvement of the railway structure in Poland

Country and region: Poland, several railway sections across the country

Short description of the project: bottlenecks limit train speed to a large extent, rehabilitation of parts on railway lines to increase average speed to speeds according to timetables

ECP programming period: -

Period of implementation:2002-2005 (four years)

Period of exploitation: 2005-2031

General CBA information:

Number of years for CBA analysis:30

Social discount rate: 5%

Shadow price of labour: (time)	Business 13,5 Euro/hour (2006 prices)
	Other 5,2 Euro/hour
	Freight 0,78 Euro/hour

Demand analysis

Present level of annual demand (by type): Business

Other 317 million PKM

Freight 2260 million TKM

Average annual generated demand (by type) Business 35 million PKM

Other 269,7 million PKM

Freight 17.3 million TKM

Change in prices for present level of demand (by type, due to investment)

Business -20.3 %

Other -20.3 %

Freight -20.3 %

Financial analysis

Total investment costs: 135 million (2006 euro)

Total private investment costs: -

Total public investment costs:-

Average annual revenues/benefits:-

Discounted flow of revenue/benefits:-

Net present value (NPV):-

Internal Rate of Return (IRR):-

Socio-economic analysis

Average annual social benefits by type Business

Other 2.7 million E

Freight 7 million E

Average annual environmental benefits by type -1.4 million E

Discounted social benefits by type Business

Other 70 million E

Freight 182 million E

Discounted environmental benefits by type 3.6

Economic net present value (ENPV): 43.96 million E

Economic rate of return (ERR): 9.22%

Benefit/Cost ratio (BCR): 1.71

Project information

Project name: Heuston Terminal / South West Rail corridor Development

Country and region: Ireland, Dublin, South, West Ireland

Short description of the project: Upgrading Heuston Station

ECP programming period: EU Commission Decision 2000

Period of implementation: 1999-2004

Period of exploitation: 2005-2028

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Business 28 Euro/hour (prices 1999)

Other 8.8 Euro/hour

Freight 1,32 Euro/hour

Demand analysis

Present level of annual demand (by type) Business -

Other 641 million PKM

Freight 146 million TKM

Average annual generated demand (by type) Business

Other 81 million pkm

Freight 19 million tkm

Change in prices for present level of demand (by type, due to investment)

Business -10.5

Other -10.5

Freight -10.5

Financial analysis

Total investment costs: 106.8 million E

Total private investment costs:-

Total public investment costs: -

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR): -

Socio-economic analysis

Average annual social benefits by type Business

Other 7.1 million E

Freight 0.26 million E

Average annual environmental benefits by type -0.01 million E

Discounted social benefits by type Business 170 million E

Other 6.4 million E

Freight 9.1 million E

Discounted environmental benefits by type 1.7 million E

Economic net present value (ENPV): 40.4 mio E

Economic rate of return (ERR): 8.11%

Benefit/Cost ratio (BCR): 1.45

Project information

Project name: Renewal of the cut Krizni with renewal of railway section on the line Zidani Most – Maribor

Country and region: Slovenia

Short description of the project: Upgrading of railway section and removal shortcut to increase average speed

ECP programming period: 2000

Period of implementation: 2001-2006

Period of exploitation: 2007-2030

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Business 18.5

Other 8.4

Freight 1.03

Demand analysis

Present level of annual demand (by type) Business

Other 38 million PKM

Freight 236 million TKM

Average annual generated demand (by type) Business

Other 10.4

Freight 64

Change in prices for present level of demand (by type, due to investment) -21.4

Financial analysis

Total investment costs: 18.1 million Euro

Total private investment costs:

Total public investment costs:

Average annual revenues/benefits:

Discounted flow of revenue/benefits:

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type	Business
	Other 0.75 million E
	Freight 0.4 million E

Average annual environmental benefits by type -0.04 million E

Discounted social benefits by type	Business 9.1 million E
	Other 17.8 million E
	Freight 9.1 million E

Discounted environmental benefits by type 0.04 million E

Economic net present value (ENPV): 3.9 million E

Economic rate of return (ERR): 6.7%

Benefit/Cost ratio (BCR): 1.25

Port

Project information

Project name: SZCZECIN-SWINOUJSCIE SEAWAY

Country and region: Poland, Pomorskie

Short description of the project: An improvement of harbour facilities, located in a poor Eastern Europe country. The project aimed to improve the canal, (time savings, lower maintenance, less incidents) to reduce handling time for “roll on – roll off” shipping, and to increase the amount of used, that is leased, land.

ECP programming period:

Period of implementation: 1995 -2002

Period of exploitation: 2003 - 2025

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: 920 EUR

Demand analysis

Present level of annual demand (by type) 7200 passages yearly

Average annual generated demand (by type) 89 > annual rate of 3% in passages

Change in prices for present level of demand (by type, due to investment) 68% tariff increase

Financial analysis

Total undiscounted investment costs: 66,2mio EUR

Total private investment costs: 0 mio EUR

Total public investment costs: 66,2mio EUR

Average annual revenues/benefits: time savings, 0,225 mio EUR, o&m savings, 0,092 mio EUR, reduced handling time terminal, 2,083 mio EUR, increased cargo/VA, 0,575, increase in emissions, 0,5 mio/year

Discounted flow of revenue/benefits: 130,7mio EUR

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type: land value increase, 0,5 mio EUR

Average annual environmental benefits by type:

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 33.14 mio EUR

Economic rate of return (ERR): 9.31%

Benefit/Cost ratio (BCR): 1.46

Project information

Project name: Spain second port project

Country and region: Spain, Andalusia, Mallorca, pays del Basco

Short description of the project: A improvement and expansion of seaports, all located in a Mediterranean country. Aim is to reduce handling time, to increase docking capacity and to decrease the yearly o&m costs. Some minor investments in a number of other ports were included in the project as well, but these did not yield clear benefits.

Period of implementation: 1974 - 1981

Period of exploitation: 1982 - 2003

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Creation of jobs was not an project objective

Demand analysis

Present level of annual demand (by type) > 6,4 mio tons

Average annual generated demand (by type) >

Change in prices for present level of demand (by type, due to investment) 6,3 tons increase

Financial analysis

Total undiscounted investment costs: 98,7mio EUR

Total private investment costs: 0 mio EUR

Total public investment costs: 98,7mio EUR

Average annual revenues/benefits: time savings, 0, 23 mio EUR, o&m savings, 0,337mio EUR, reduced handling time terminal, 0,79mio EUR, increased cargo/VA, 6,048, increase in emissions, 0,2mio/year

Discounted flow of revenue/benefits: 134,7mio EUR

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type:

Average annual environmental benefits by type:

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 40.49 mio EUR

Economic rate of return (ERR): 8.86%

Benefit/Cost ratio (BCR): 1.44

Project information

Project name: GESAMTWIRTSCHAFTLICHE BEWERTUNGDES NEUBAUS DES SCHIFFSHEBE-WERKS NIEDERFINOW NORD

Country and region: Germany, Brandenburg

Short description of the project: Construction of a ship elevator for an inland shipping harbour, located in a rich Eastern Europe country. Aim is to create a lift for ships in order to reach the harbour of Niederfinow, in order to create a large expansion of inland shipping vessels to reach the Berlin area.

ECP programming period:

Period of implementation: 2007 -2013

Period of exploitation: 2014 - 2036

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: not an objective of the study

Demand analysis

Present level of annual demand (by type) 1,7tons yearly

Average annual generated demand (by type) 89 > annual rate of 1,5% in tons

Change in prices for present level of demand (by type, due to investment)

Financial analysis

Total undiscounted investment costs: 234,0mio EUR

Total private investment costs: 0 mio EUR

Total public investment costs: 234,0mio EUR

Average annual revenues/benefits: time savings, 0,29 mio EUR, reduced handling time terminal, 15,3 mio EUR, increased cargo/VA, 2,39, rest value of 7,1 mio EUR (not annual), increase in emissions, 0,35mio/year

Discounted flow of revenue/benefits: 268,33mio EUR

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type: land value increase, 1,7 mio EUR

Average annual environmental benefits by type:

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 51.38mio EUR

Economic rate of return (ERR): 7.26%

Benefit/Cost ratio (BCR): 1.26

Waste water

Project information

Project name: Bielsko-Biala Water and Wastewater project

Country and region: Poland

Short description of the project: An extension of the waste water capacity, located in a poor Eastern Europe country. Aim is to improve service, upgrade existing plants and reduce leakage by installing detecting systems. Parts of the project that address drinking water improvements are disregarded.

ECP programming period:

Period of implementation: 1995 -2002

Period of exploitation: 2003 - 2025

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 1439EUR/y

Demand analysis

Present level of annual demand (by type)

Average annual generated demand (by type) 89 > 92% service region

Change in prices for present level of demand (by type, due to investment) 68% tariff increase

Financial analysis

Total investment costs: 22,73mio EUR

Total private investment costs: 1,50mioEUR

Total public investment costs: 21,23mio EUR

Average annual revenues/benefits:

Discounted flow of revenue/benefits: 9.78mio EUR

Net present value (NPV): -15.6mio EUR

Internal Rate of Return (IRR): -6.7%

Socio-economic analysis

Average annual social benefits by type: loss unskilled jobs, -0,054mio EUR

Average annual environmental benefits by type: reduction of pollutants, 1,205mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 8.19mio EUR

Economic rate of return (ERR): 8.21%

Benefit/Cost ratio (BCR): 1.31

Project information

Project name: 14 components wastewater project North Portugal

Country and region: Portugal

Short description of the project: An refurbishment of 14 waste water capacities, located in a poor region of a Mediterranean country. Aim is to improve service and upgrade existing plants.

ECP programming period:

Period of implementation: 2001 - 2008

Period of exploitation: 2009 - 2031

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour:

Demand analysis

Present level of annual demand: (by type) 77404 households

Average annual generated demand (by type)

Change in prices for present level of demand (by type, due to investment) 6,88EUR increase per household

Financial analysis

Total investment costs: 58,48mio EUR

Total private investment costs: 0mioEUR

Total public investment costs: 58,48mio EUR

Average annual revenues/benefits:

Discounted flow of revenue/benefits: 8.45mio EUR

Net present value (NPV): -58.3mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type:

Average annual environmental benefits by type: reduction of pollutants, 4,63mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 5,81mio EUR

Economic rate of return (ERR): 6.03%

Benefit/Cost ratio (BCR): 1.09

Project information

Project name: Tolny Duriec Waste Water program

Country and region: Slovakia, Martin

Short description of the project: An refurbishment of the waste water capacity, located in a rich Eastern Europe country. Aim is to extend (replace septic tanks) and improve the sewerage network in a medium sized town service and creation of an extensive number of jobs to be fulfilled by unskilled workers.

ECP programming period:

Period of implementation: 2002 -2005

Period of exploitation: 2006 - 2032

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: employment creation discarded

Demand analysis

Present level of annual demand (by type)

Average annual generated demand (by type) 4% of total regional demand

Change in prices for present level of demand (by type, due to investment) 2,32EUR per household

Financial analysis

Total investment costs: 14.21mio EUR

Total private investment costs: 3.1mioEUR

Total public investment costs: 11.11mio EUR

Average annual revenues/benefits: 0.03mio EUR

Discounted flow of revenue/benefits: 40.92mio EUR

Net present value (NPV): -15.3mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type: loss unskilled jobs, 0 mio EUR

Average annual environmental benefits by type: reduction of pollutants, 1.512mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 18.99mio EUR

Economic rate of return (ERR): 13.96%

Benefit/Cost ratio (BCR): 2.10

Solid waste

Project information

Project name: Krakow, solid waste treatment

Country and region: Poland, Krakow

Short description of the project: An extension of the solid waste landfill capacity, located in a poor Eastern Europe country. Aim is to extend the capacity, to reduce pollutants and to use the waste for energy production.

ECP programming period:

Period of implementation: 1990 -1997

Period of exploitation: 1998 - 2020

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 1331EUR/y

Demand analysis

Present level of annual demand: (by type) 234000 ton/y

Average annual generated demand: (by type) 26000 ton/y

Change in prices for present level of demand (by type, due to investment) increase of 0,5% of household income

Financial analysis

Total investment costs: 23.56mio EUR

Total private investment costs: 14.0mioEUR

Total public investment costs: 9.56mio EUR

Average annual revenues/benefits: 0.29mio EUR

Discounted flow of revenue/benefits: 85.38mio EUR

Net present value (NPV): -30.9mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type: 0.005mio EUR job creation

Average annual environmental benefits by type: reduction of pollutants, 3.114mio EUR, energy creation 0.005mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 42.09mio EUR

Economic rate of return (ERR): 16,22%

Benefit/Cost ratio (BCR): 2.09

Project information

Project name: Planta de Tratamiento de residuos urbanos

Country and region: Spain, Alicante

Short description of the project: An extension of the solid waste landfill capacity and processing capital stock located in a Mediterranean country. A well documented study, with detailed description of reduced pollutants and recycling benefits.

ECP programming period:

Period of implementation: 2004 -2007

Period of exploitation: 2008 - 2034

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 4130EUR/y

Demand analysis

Present level of annual demand: (by type) 95000 ton/y

Average annual generated demand: (by type) 97500 ton/y

Change in prices for present level of demand (by type, due to investment) increase of 74EUR per household

Financial analysis

Total investment costs: 13.75mio EUR

Total private investment costs: 0mioEUR

Total public investment costs: 13.75mio EUR

Average annual revenues/benefits: 0.16mio EUR

Discounted flow of revenue/benefits: 4.86mio EUR

Net present value (NPV): -42.7mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type: 0,413mio EUR job creation

Average annual environmental benefits by type: reduction of pollutants, 2,906mio EUR, energy creation 0,008mio EUR, recycling 0,002mio EUR, avoided costs of nitrate emission reduction 0,437 EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 8.17mio EUR

Economic rate of return (ERR): 10.09%

Benefit/Cost ratio (BCR): 1.17

Project information

Project name: Waste management Brno

Country and region: Czech Republic, Brno

Short description of the project: A rehabilitation of the solid waste processing capacity located in a Mediterranean country. The study clearly states that the old plant didn't meet any technical standards, and would be put out of use.

ECP programming period:

Period of implementation: 2003 -2006

Period of exploitation: 2007 - 2033

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 2975EUR/y

Demand analysis

Present level of annual demand: (by type) 94076 ton/y

Average annual generated demand: (by type) 219000 ton/y

Change in prices for present level of demand (by type, due to investment) decrease of 9EUR per household

Financial analysis

Total investment costs: 70,48mio EUR

Total private investment costs: 43mioEUR

Total public investment costs: 27,48mio EUR

Average annual revenues/benefits: -0.23mio EUR

Discounted flow of revenue/benefits: -6.9mio EUR

Net present value (NPV): -168.33mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type: 0,081mio EUR job creation

Average annual environmental benefits by type: reduction of pollutants, 6,5mio EUR, energy creation 0,703mio EUR, recycling 0,142mio EUR, avoided cost of soil cleanup 0,28mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 8.18mio EUR

Economic rate of return (ERR): 6.02%

Benefit/Cost ratio (BCR): 1.06

Drinking water

Project information

Project name: Modern water supply

Country and region: Poland, Swietokrzyskie

Short description of the project: An extension of the drinking water capacity, located in a poor Eastern Europe country. Aim is to extend the water supply in a remote area with cultural and touristic value.

ECP programming period:

Period of implementation: 2005 -2007

Period of exploitation: 2008 - 2035

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 900EUR/y

Demand analysis

Present level of annual demand (by type) no connection

Average annual generated demand: (by type) 336 extra households

Change in prices for present level of demand (by type, due to investment) 2,01EUR per household

Financial analysis

Total investment costs: 0.38mio EUR

Total private investment costs: 0.0mioEUR

Total public investment costs: 0.38mio EUR

Average annual revenues/benefits: 0.022mio EUR

Discounted flow of revenue/benefits: 0.02mio EUR

Net present value (NPV): -1.94mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type: 0.092mio EUR land value increase, 0.009 employment creation

Average annual environmental benefits by type: hygiene factor, 0.003mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 0.44mio EUR

Economic rate of return (ERR): 12.66%

Benefit/Cost ratio (BCR): 1.23

Project information

Project name: Lisbon region water supply project

Country and region: Portugal, Lisbon

Short description of the project: An expansion of the drinking water capacity, located in a Mediterranean country. The base year is one of the oldest and from a period where the country was still considered poor. Aim is to expand capacity in a big city, with no mentioning of other objectives.

ECP programming period:

Period of implementation: 1979 -1985

Period of exploitation: 1986 - 2009

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 1300EUR/y

Demand analysis

Present level of annual demand: (by type) 440000m3/day

Average annual generated demand: (by type) 250000m3/day

Change in prices for present level of demand (by type, due to investment) 14% annual price increase during construction

Financial analysis

Total investment costs: 102.02mio EUR

Total private investment costs: 34.8mioEUR

Total public investment costs: 67.2mio EUR

Average annual revenues/benefits: 1.72mio EUR

Discounted flow of revenue/benefits: 51.64mio EUR

Net present value (NPV): -63.51

Internal Rate of Return (IRR): -4.5%

Socio-economic analysis

Average annual social benefits by type: 0.092mio EUR job creation

Average annual environmental benefits by type: hygiene factor, 6.327mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 34,32mio EUR

Economic rate of return (ERR): 8,29%

Benefit/Cost ratio (BCR): 1.31

Project information

Project name: Slovene coast water project

Country and region: Slovenia, Istria

Short description of the project: An expansion of the drinking water capacity, located in a rich Eastern Europe country. Aim is to meet the demand for the tourist industry. The first years of the construction phase saw the outbreak of the Yugoslavian civil war.

ECP programming period:

Period of implementation: 1990 -1997

Period of exploitation: 1998 - 2020

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 1350EUR/y

Demand analysis

Present level of annual demand: (by type) 92.1% to 96.4% increase of population served

Average annual generated demand: (by type) 51mio m3/y

Change in prices for present level of demand (by type, due to investment) 4cents/m3 price increase

Financial analysis

Total investment costs: 65.02mio EUR

Total private investment costs: 58.1mioEUR

Total public investment costs: 6.9mio EUR

Average annual revenues/benefits: 1.30mio EUR

Discounted flow of revenue/benefits: 38.94mio EUR

Net present value (NPV): -20.44mio EUR

Internal Rate of Return (IRR): 0.7%

Socio-economic analysis

Average annual social benefits by type: 0,016mio EUR job creation, 0,045mio EUR land value increase

Average annual environmental benefits by type: hygiene factor, 2,149mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 16,35mio EUR

Economic rate of return (ERR): 7,65%

Benefit/Cost ratio (BCR): 1.27

Emissions and environmental protection

Project information

Project name: Integrated forestry Greece

Country and region: Greece, various locations

Short description of the project: The Integrated Forestry Development Project, located in continental western and north-western Greece and the Peloponnesus was designed to increase wood production, improve forest protection, and involve communities with forest maintenance. Investment cost includes hiring locals.

ECP programming period:

Period of implementation: 1979 -1984

Period of exploitation: 1985 - 2009

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour: Unskilled labour assumed to be worth 366EUR/y

Demand analysis

Present level of annual demand: (by type) 2.5mio hectares

Average annual generated demand: (by type) 0.68 hectares

Change in prices for present level of demand (by type, due to investment) 5EUR per hectare increased production

Financial analysis

Total investment costs: 104.04mio EUR

Total private investment costs: 42.6mioEUR

Total public investment costs: 61.44mio EUR

Average annual revenues/benefits: 1.79mio EUR

Discounted flow of revenue/benefits: 53.83mio EUR

Net present value (NPV): -65.2mio EUR

Internal Rate of Return (IRR): -4.1%

Socio-economic analysis

Average annual social benefits by type: 6.195mio EUR job creation, 0.006 land value increase, 0.214mio EUR from retained population threshold from halted emigration

Average annual environmental benefits by type: reduction of pollutants, 1.825mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 17.5 EUR

Economic rate of return (ERR): 6.77%

Benefit/Cost ratio (BCR): 1.17

Project information

Project name: environment project

Country and region: Slovenia, major cities

Short description of the project: One of the few projects completely focused on the reduction of air emissions, located in a rich Eastern European country. The focus was to stimulate households and small scale energy producing companies to switch to electricity and natural gas instead of low quality coal.

ECP programming period:

Period of implementation: 1992 -1999

Period of exploitation: 2000 - 2022

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5%

Shadow price of labour:

Demand analysis

Present level of annual demand: (by type) 400mg/m3 PM during peak hours

Average annual generated demand: (by type) 50mg/m3 PM during peak hours

Change in prices for present level of demand (by type, due to investment) shadow prices only

Financial analysis

Total investment costs: 30.0mio EUR

Total private investment costs: 2.7mioEUR

Total public investment costs: 27.3mio EUR

Average annual revenues/benefits: 0.00mio EUR

Discounted flow of revenue/benefits: 0.00mio EUR

Net present value (NPV): -25.9mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type:

Average annual environmental benefits by type: reduction of pollutants, 1.83mio EUR

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 7.01mio EUR

Economic rate of return (ERR): 7.36%

Benefit/Cost ratio (BCR): 1.27

Energy

Project information

Project name: THE MUNICIPAL DISTRICT HEATING ENTERPRISE OF KRAKOW

Country and region: Poland, Krakow

Short description of the project: The project objective is to improve energy efficiency of the heating systems which would be achieved by: (a) continuing the modernization programme for the City's district heating systems; (b) helping consumers decrease their heat energy consumption by improving the energy efficiency at the end-user level; and (c) developing in Krakow the knowledge and mechanisms necessary for financiers to fund end-user energy efficiency projects.

ECP programming period: 2000-2006

Period of implementation: 2002-2008

Period of exploitation: 2002 – 2025

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5

Shadow price of labour:

Demand analysis

Present level of annual demand (by type): 3,308 customers

Average annual generated demand (by type): an increased by 47% from 3,308 in 2000 to 4,465 in 2008.

Change in prices for present level of demand (by type, due to investment)

Financial analysis(Direct Heating component)

Total investment costs: 99.8mio EUR

Total private investment costs:

Total public investment costs:

Average annual revenues/benefits: 7.04mio EUR

Discounted flow of revenue/benefits: 211.15

Net present value (NPV): -27.42mio EUR

Internal Rate of Return (IRR): 1.93%

Socio-economic analysis

Average annual social benefits by type

Average annual environmental benefits by type: 4.22 EUR/kg because of saved emissions

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 104.25mio EUR

Economic rate of return (ERR): 13.22%

Benefit/Cost ratio (BCR): 2.09

Project information

Project name: Power and Environmental Improvement Project

Country and region: Madeira, PT

Short description of the project: Installation of equipment, modernization, and operational improvements of power stations, gas desulfurization, electrostatic precipitators as well as consulting services and staff training.

ECP programming period: 2000-2006

Period of implementation: 2004-2007

Period of exploitation: 2007-2033

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5

Shadow price of labour:

Demand analysis

Present level of annual demand (by type): 44 MWh / per day

Average annual generated demand (by type): .54 GWh and another 24 GWh from wind generators

Change in prices for present level of demand (by type, due to investment): No direct impact on the electricity price for the consumer due to the fact that Portugal has a fixed, regulated national tariff for electricity.

Financial analysis(Direct Heating component)

Total investment costs: 293.7mio EUR

Total private investment costs: 155.4mio EUR

Total public investment costs: 134.4mio EUR

Average annual revenues/benefits: -4.41mio EUR

Discounted flow of revenue/benefits: 132.61mio EUR

Net present value (NPV): -136.46mio EUR

Internal Rate of Return (IRR): N/A

Socio-economic analysis

Average annual social benefits by type

Average annual environmental benefits by type

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 24.67 mio EUR

Economic rate of return (ERR): 5.9%

Benefit/Cost ratio (BCR): 1.09

Project information

Project name: Power and Environmental Improvement Project

Country and region: CZ

Short description of the project: Installation of equipment, modernization, and operational improvements of power stations, gas desulfurization, electrostatic precipitators as well as consulting services and staff training.

ECP programming period: 1990-1998

Period of implementation: 1991-1997

Period of exploitation: 1993-2020

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5

Shadow price of labour:

Demand analysis

Present level of annual demand (by type):

Average annual generated demand (by type):

Change in prices for present level of demand (by type, due to investment)

Financial analysis(Direct Heating component)

Total investment costs: 34.7mio EUR

Total private investment costs: 17.3mio EUR

Total public investment costs: 17.4mio EUR

Average annual revenues/benefits: 2.9mio EUR

Discounted flow of revenue/benefits:

Net present value (NPV): -7.86mio EUR

Internal Rate of Return (IRR): 2.53%

Socio-economic analysis

Average annual social benefits by type

Average annual environmental benefits by type: reduced emissions of PM, So2, NOx and CO

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 1.93 mio EUR

Economic rate of return (ERR): 5.58%

Benefit/Cost ratio (BCR) 1.05

ICT

Project information

Project name: Telecommunication project

Country and region: Bulgaria

Short description of the project: The state owned telecommunication company provided services for domestic and international telephony, fixed telephone network and lines, telex, telegraphy, radio and television transmission and data transmission. Services provided were limited and of poor quality. Project objective is to modernize the telecommunication sector by increasing the number of lines and reducing the waiting list for subscriptions, especially for business customers. Another objective was to the corporate development of the state owned telecommunication company by increasing financial performance, modernize management practice and encourage private investments.

ECP programming period: -

Period of implementation: 1994-1999 (5 years)

Period of exploitation: 1994-2008 (15 years)

General CBA information:

Number of years for CBA analysis: 15 years

Social discount rate: 5%

Shadow price of labour: -

Demand analysis

Present level of annual demand (by type):

Average annual generated demand (by type): 220,000 new telephone lines, mainly for business customers

Change in prices for present level of demand (by type, due to investment)

Financial analysis

Total investment costs: 235mio EUR

Total private investment costs: 103mio EUR (44%)

Total public investment costs: 132mio EUR (56%)

Average annual revenues/benefits:

Discounted flow of revenue/benefits:

Net present value (NPV):

Internal Rate of Return (IRR): 24%

Socio-economic analysis

Average annual social benefits by type: EUR 28,5 M (revenues from new telephone services (charges + services)

Average annual environmental benefits by type: -

Discounted social benefits by type:

Discounted environmental benefits by type: -

Economic net present value (ENPV): 103.27mio EUR at a 5 % social discount rate

B/C Ratio of 1.58 at 5 % social discount rate

Economic rate of return (ERR): 21,28 %

Project information

Project name: Telecommunication project

Country and region: Spain

Short description of the project:

The objective of the project is to close the digital gap between urban and rural inhabitants by offering broadband internet in cities with less than 10,000 inhabitants in Andalusia. The aim is that rural areas can integrate in the Knowledge Society. Citizens and firms located in rural areas will become familiar and make use of ICTs in the broadest sense. Besides network access, also support and training is provided by staff. Driving force is social inclusion and providing equal digital opportunities for all economic, social and geographical groups. More than 600 centres are built in small cities where inhabitants have free access to high speed internet.

ECP programming period:

Period of implementation: 2002-2009 (7 years)

Period of exploitation: 2002-2009 (7 years)

The network is enrolled in four phases.

General CBA information:

Number of years for CBA analysis: 15 years

Social discount rate: 5%

Shadow price of labour: -

Demand analysis

Present level of annual demand (by type):

Average annual generated demand (by type): 400,000 registered users in rural areas in Andalusia (24% of the total rural populations have made use of the Guadalinfo internet services in 2009).

800,000 training hours offered.

Change in prices for present level of demand (by type, due to investment)

Financial analysis

Total investment costs: 71.4mio EUR

Total private investment costs: -

Total public investment costs: 71.4mio EUR (100%)

Average annual revenues/benefits:

Discounted flow of revenue/benefits:

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type: 12mio EUR (400,000 x 30)

Benefits are not calculated. Aim of the project was to have digital social inclusion in rural areas. Internet access in more than 600 centres is free, so no direct benefits. Value of free access is set to average month subscription of broadband internet (30 euros).

Average annual environmental benefits by type: -

Discounted social benefits by type: 0

Discounted environmental benefits by type: 119mio EUR

Economic net present value (ENPV): 50.62mio EUR at 5% social discount rate.

B/C ratio is 1.67

Economic rate of return (ERR): 16.64%

Project information

Project name: Telecommunication project

Country and region: Czech Republic

Short description of the project: The state owned telecommunication company provided services for domestic and international telephony, fixed telephone network and lines, telex, telegraphy, radio and television transmission and data transmission. Services provided were limited and of poor quality. Project objective is to expand and digitalize the telecommunication network and reduce congestion at key network elements. This includes modernization of the entire network and provision of modern digital communications for business customers. Another objective was to make institutional and policy improvements aimed to increase efficiency and the quality of service. This must lead to a transition towards a full commercial operation.

ECP programming period: -

Period of implementation: 1993-1996 (4 years)

Period of exploitation: 1994-2007 (14 years)

General CBA information:

Number of years for CBA analysis: 15 years

Social discount rate: 5%

Shadow price of labour: -

Demand analysis

Present level of annual demand (by type):

Average annual generated demand (by type): 1.1 million new telephone lines, mainly for business customers.

Quality of service increased due to a decrease of 50 percent of the fault rate.

Change in prices for present level of demand (by type, due to investment)

Financial analysis

Total investment costs: EUR 996 M

Total private investment costs: EUR 452 M (45%)

Total public investment costs: EUR 544 M (55%)

Average annual revenues/benefits:

Discounted flow of revenue/benefits:

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type: EUR 409 M (revenues from new telephone services (charges + services)

Average annual environmental benefits by type: -

Discounted social benefits by type:

Discounted environmental benefits by type: -

Economic net present value (ENPV): EUR 1787.02 M at a 5 % social discount rate

B/C Ratio of 1,74 at 5 % social discount rate

Economic rate of return (ERR): 27.55 %

Social infrastructure

Project information

Project name: HEALTH SECTOR REFORM PROJECT Phase 2

Country and region: Romania

Short description of the project: The project is implemented over a four year, seven month period and financed civil works, goods, technical assistance, training and incremental operating costs, with an overall aim of a "healthy Romania- lower morbidity and fewer premature deaths, equitable access to health services, and improved efficiency of the health system.

ECP programming period: 2000 – 2006, 2007 – 2013

Period of implementation: 2004 – 2008

Period of exploitation: 2006 – 2015

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5 %

Shadow price of labour:

Demand analysis

Table 33: Project Components

Component	Objectives	Benefits (indicators)	% Reduction	Target Population
(A) Maternity and Neonatal Care	- Facility rehabilitation for maternity and neonatal care units	Reductions in		17.8 million (80%)
	- Technical assistance and training	- maternal mortality	15	
		- neonatal mortality	20	
		- number o f low birth weight babies	20	
		- number o f Caesarean sections	15	
(B) Emergency Care Services	- upgrade hospital emergency areas	Reductions in		
	- integrated ambulance dispatch capability	- mortality from traffic accidents, injury and poisoning, ischemic heart disease and other external causes	10	11.1 million (50%)
(C) Primary Health Care and Rural Medical Services	improving the accessibility and quality o f basic medical services:	Reductions in		4.4 million (20%)
	- Multipurpose Health Centres	- hospital discharges for infectious diseases	10	
	- Sub-loans for family doctors	- hospital discharges for infectious diseases	15	
		- infant mortality	20	

Present level of annual demand (by type)

Average annual generated demand (by type)

Change in prices for present level of demand (by type, due to investment):

Financial analysis

Total investment costs: 53.3mioEUR

Total private investment costs:

Total public investment costs: 53.3mioEUR

Average annual revenues/benefits:

Discounted flow of revenue/benefits:

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type

Average annual environmental benefits by type

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 115.37 mio EUR

Economic rate of return (ERR): 13.88%

Benefit/Cost ratio (BCR): 1.47

Project information

Project name: Don Bosco Research Library

Country and region: IT

Short description of the project: The project objective is to provide for information and knowledge background for lifelong learning of citizens, improving child care facilities, business improvement and youth education.

ECP programming period: 2000-2006

Period of implementation: 2000-2006

Period of exploitation: 2007-2030

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5

Shadow price of labour: not part of project

Demand analysis

Present level of annual demand (by type):

Average annual generated demand (by type):

Change in prices for present level of demand (by type, due to investment)

Financial analysis(Direct Heating component)

Total investment costs: 19.2mio EUR

Total private investment costs:

Total public investment costs:

Average annual revenues/benefits:

Discounted flow of revenue/benefits:

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type

Average annual environmental benefits by type

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 0.19mio EUR

Economic rate of return (ERR): 9.52%

Benefit/Cost ratio (BCR): 1.26

Project information

Project name: Health Service Restructuring

Country and region: LSL

Short description of the project: The project comprises two phases. Phase I introduces the definitions, technical standards, institutional arrangements, training and pilot tests necessary to implement an initial set of health reforms and conduct pilots for an integrated National Health Information System. Phase II, based on pilot evaluations, will implement a national roll-out of health information systems.

ECP programming period: 2000-2007

Period of implementation: 2000-2007

Period of exploitation: 2008-2030

General CBA information:

Number of years for CBA analysis: 30

Social discount rate: 5

Shadow price of labour:

Demand analysis

Present level of annual demand (by type):

Average annual generated demand (by type):

Change in prices for present level of demand (by type, due to investment)

Financial analysis(Direct Heating component)

Total investment costs: 46.2mio EUR

Total private investment costs: 0

Total public investment costs: 46.2mio EUR

Average annual revenues/benefits: 7.8mio EUR

Discounted flow of revenue/benefits:

Net present value (NPV):

Internal Rate of Return (IRR):

Socio-economic analysis

Average annual social benefits by type

Average annual environmental benefits by type

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): 15.76mio EUR

Economic rate of return (ERR): 14.19%

Benefit/Cost ratio (BCR): 1.43

Education

Project information

Project name: Primary and lower secondary education project

Country and region: Romania, poor Eastern Europe country

Short description of the project: Second chance programme for people who have not participated in compulsory education and beyond the legal age for enrolling in mainstream school. Participants are mainly from ethnic minority groups.

ECP programming period: -

Period of implementation: 2008/2009 (1 year)

Period of exploitation: 1 year

General CBA information:

Number of years for CBA analysis: 20 years

Social discount rate: 5%

Shadow price of labour: 1916 EUR/y (taken from the CBA)

Demand analysis

Total participants: 10,000 participants

Graduation rate: 75%

Employment rate: 65% (it is assumed that the net impact of education on the employment at the aggregate level is 0 because of high unemployment rate of low skilled labour in Romania)

Change in prices for present level of demand (by type, due to investment):

Mincerian earning coefficient: +7% (only applies to graduated participants)

Financial analysis

Total investment costs: EUR 6 M

Total private investment costs: 0

Total public investment costs: : EUR 6 M

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR):-

Socio-economic analysis

Average annual social benefits by type

EUR 0.65 M

The following additional assumptions were made:

No net impact on employment rates

Earnings effects apply to graduated participants who found a job (75% x 65 %)

Non market benefits (less crime, less poverty, higher social participation etc) not calculated

Average annual environmental benefits by type: -

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): EUR 1,81 M, based on a 5% social discount rate

B/C Ratio is 1,38 based on a 5% social discount rate

Economic rate of return (ERR): 8.64 percent

Project information

Project name: High skilled education project

Country and region: Greece, Mediterranean country

Short description of the project: First step in reform programme of education system in Greece. Facilities and quality of teachers for technical education are inadequate. The project should lead to more enrolments in higher technical education in Greece offered by public education.

ECP programming period: -

Period of implementation: 1972-1974 (5 year)

Period of exploitation: 20 year

General CBA information:

Number of years for CBA analysis: 20 years

Social discount rate: 5%

Shadow price of labour: 8527 EUR/y (shadow price of high skilled labour in 2007 from the model)

Price is deflated to 1975 based on yearly average deflation of gross value added in Greece in 1990-2007 of 3.2 percent (source: AMECO 2006).

Demand analysis

Total participants: 6,660 enrolments per year

The study takes three years, 2350 output per year

Change in prices for present level of demand (by type, due to investment):

Mincerian earning coefficient: +7.6% (based on 1993 study in Greece (Psacharopoulos and Patrinos (2002))

Financial analysis

Total investment costs: EUR 17.5 M

Total private investment costs: 0

Total public investment costs: : EUR 17.5 M

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR):-

Socio-economic analysis

Average annual social benefits by type

EUR 1,52 M

The following additional assumptions were made:

All enrolments will be employed because of huge shortage of skilled labour

Earnings effects apply to enrolments and are calculated by school year

Non market benefits (less crime, less poverty, higher social participation etc) not calculated

Average annual environmental benefits by type: -

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): EUR -1.82 M, based on a 5% social discount rate

B/C ratio is 0.92 based on a 5% social discount rate

Economic rate of return (ERR): 4.02 percent

Project information

Project name: Higher education project

Country and region: Hungary, rich Eastern Europe country (ex-ante evaluation project)

Short description of the project: Reform programme to increase the cost-effectiveness of high education in Hungary. The objective of the reform is to increase capacity of higher education, increase cost-efficiency and create incentives for a better respond of the education system to skill requirements for workers in a market economy.

ECP programming period: -

Period of implementation: 1998-1999 (2 year)

Period of exploitation: 20 year

General CBA information:

Number of years for CBA analysis: 20 years

Social discount rate: 5%

Shadow price of labour: 4500 EUR/y (equal to shadow price of high skilled labour in Hungary from the model (discounted to 1998))

Demand analysis

Increase in number of students per teacher from 7.7 to 9.8

Decrease of labour costs of 5 percent for teaching staff and 41 percent of non teaching staff. Decrease in labour costs is realized because of more efficient use of labour, not because of change in wages for teaching and non teaching staff.

Financial analysis

Total investment costs: EUR 26 M (based on detailed example in ex-ante CBA)

Total private investment costs: 0

Total public investment costs: : EUR 26 M

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR):-

Socio-economic analysis

Average annual social benefits by type

EUR 4.4 M

Lower costs because of merging six universities to a multi faculty university and better management and control of teaching and non teaching staff by reform programme. This results in less labour costs and a higher cost-effectiveness and capacity increase. Impact of reform programme on quality of education is not calculated. Benefits calculated by decrease in labour costs.

Average annual environmental benefits by type: -

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): EUR 23.92 M, based on a 5% social discount rate

B/C ratio of 1.81 based on a 5% social discount rate

Economic rate of return (ERR): 12.93 %

Labour market institutions

Project information

Project name: Employment and Social Protection Project

Country and region: Romania, poor Eastern Europe country, national programme

Short description of the project: After the Communist era the Romanian economy is transforming to a market economy but lead to unemployment. This project aims to strengthen the capacity of labour offices to administrate unemployed and active adjustment services (job placement, employment counselling, training etc.). Other project objectives are the development of a flexible adult training system and the implementation of a social insurance and assistance programme to reduce poverty.

ECP programming period: -

Period of implementation: 1996-2001 (5 years)

Period of exploitation: 5 years

General CBA information:

Number of years for CBA analysis: 15 years

Social discount rate: 5%

Shadow price of labour: 920 EUR/y (shadow price of low skilled labour calculated by model)

Demand analysis

Because of data availability, only part of total project evaluated (D1. Labour Redeployment Programme)

Total participants: 92,223 participants

Total placements: 17,679 (19%) participants placed

Total participant who had training: 6,264

Change in prices for present level of demand (by type, due to investment):

Short run: employment: +10.8% (Rodriguez-Planas, N. and J. Benus (2006))

Short run: earnings: +28% (Rodriguez-Planas, N. and J. Benus (2006))

Long run: earnings: +3.5% (Mincerian earning coefficient of 7%, 6 months training)

Financial analysis

Total investment costs: EUR 9.8 M (Only part D1 of project is evaluated)

Total private investment costs: 0

Total public investment costs: : EUR 9.8 M

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR):-

Socio-economic analysis

Average annual social benefits by type

Short run EUR 9.3 M, long run EUR 0.2 M.

The following additional assumptions were made to evaluate part D1:

all investments in first year (no breakdown given of participants and costs over years)

Net impact of programme on employability only in the short run (first year)

All participants have a net impact on earnings in the short run (first year), in the long run (15 years) only benefits for participants who followed training and retraining programme

Non market benefits (less crime, less poverty, higher social participation etc) not calculated

Long term earnings equal over time by assumption that GDP growth rate equals human capital depreciation rate.

Average annual environmental benefits by type: -

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): EUR 1.25 M, based on a 5% social discount rate

Economic rate of return (ERR): 10.93 percent

Benefit/Cost ratio (BCR): 1.13

Project information

Project name: Aula Mentor Project, adult training project

Country and region: Spain, Mediterranean country, national programme for rural communities

Short description of the project: The Aula Mentor Project is an open internet-based adult training programme for individuals that don't have access to education, for example prisoners and inhabitants of small town (population less than 5,000). The objective is to provide courses to upgrade employability and professional skills of individuals. The programme is national organised and internet-based but all students will have a local mentor to assist them.

ECP programming period: -

Period of implementation: 1992- 2007(17 years)

Period of exploitation: 1 year

General CBA information:

Number of years for CBA analysis: 20 years

Social discount rate: 5%

Shadow price of labour: 9605 EUR/y (shadow price of medium skilled labour calculated by model)

Demand analysis

Evaluation based on 1 year exploitation of the Aula Mentor Project

Total enrolments in 2007: 19,200 participants

Pass rate 45 percent, drop out rate 52 percent and 3 percent did not do final exam.

Duration of the training: 4 months on average

Mincerian coefficient: 7.2 percent (Psacharapoulos and Patrinos, 2002)

Financial analysis

Total investment costs: EUR 10.3 M (Only part D1 of project is evaluated)

Total private investment costs: EUR 1.8 M

(student fee is 24 euro per month)

Total public investment costs: : EUR 8.5 M

Public investments consist of teaching materials and software (0.6 M), accommodation (0.9 M), and labour costs (6.9M). Labour costs are divided by 0.3 M for coordination team and tutors 6.6 M (estimated based on 444 sites in Spain).

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR):-

Socio-economic analysis

Average annual social benefits by type: EUR 1.5 M

Benefits are estimated based on the Mincerian approach, the following additional assumptions were made:

All graduates (45% pass rate) increase number of years of schooling by 0.333 (4 months)

Mincerian earning rate of 7,2 %, shadow price of medium skilled labour is EUR 9605.

Non market benefits (less crime, less poverty, higher social participation etc) not calculated

Long term earnings equal over time by assumption that GDP growth rate equals human capital depreciation rate.

Average annual environmental benefits by type: -

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): EUR 7.39 M, based on a 5% social discount rate

B/C Ratio is 1.75 based on a 5% social discount rate

Economic rate of return (ERR): 13.11 %

Project information

Project name: EU Phare youth employment project

Country and region: Estonia, rich Eastern European country

Short description of the project: The objectives of the project are to enhance employability of Estonian youth in the labour market and to improve the capacity of public employment services in providing tailor-made services to youth unemployed persons. Activities in the project mainly consisted of providing adjustment training and professional training to young unemployed persons in the age of 16-24 year. Also unemployed were assisted in searching for jobs. The project was partly funded by EU Phare and partly by the national government.

ECP programming period: -

Period of implementation: 2004

Period of exploitation: 2004 year

General CBA information:

Number of years for CBA analysis: 20 years

Social discount rate: 5%

Shadow price of labour: 1340 EUR/y (shadow price of low skilled labour calculated by model)

Demand analysis

Total participants in 2004: 569 participants

53 percent of participants found a job at the end of the programme, 17 percent started or continued education.

Mincerian coefficient for Estonia in 1994: 5.4 percent (Psacharapoulos and Patrinos, 2002)

Financial analysis

Total investment costs: EUR 1.1 M

Total private investment costs: -

Total public investment costs: : EUR 1.1 M

Investments are estimated based on labour costs for the activities in the project (costs are not given in the evaluation of the project). It is assumed that 84 full time equivalents do direct work for the participants and 84 full time equivalents do indirect work. Wages are assumed to be equal to the shadow price of high skilled labour in Estonia for direct work. For indirect work wages are assumed to be equal to the shadow price of medium skilled labour.

Average annual revenues/benefits: -

Discounted flow of revenue/benefits: -

Net present value (NPV): -

Internal Rate of Return (IRR):-

Socio-economic analysis

Average annual social benefits by type: EUR 61700

Benefits are estimated in three steps:

250 participants got employed during the programme (internships and normal employment)

302 participants got employed after the project. It is assumed that the employability effect only takes place in the first two years, the long term employability effect is set to zero. In the long run unemployed will seek and find jobs otherwise as well.

97 participants started or continued schooling due to the project. It is assumed that on average the additional schooling takes two years and after that participants receive more earnings based on the Mincerian approach.

Mincerian earning rate of 5.4 %, shadow price of low skilled labour is EUR 1340.

Non market benefits (less crime, less poverty, higher social participation etc) not calculated

Long term earnings equal over time by assumption that GDP growth rate equals human capital depreciation rate.

Average annual environmental benefits by type: -

Discounted social benefits by type

Discounted environmental benefits by type

Economic net present value (ENPV): EUR 14.49 mio, based on a 5% social discount rate

B/C Ratio is 1.02 based on a 5% social discount rate

Economic rate of return (ERR): 5.65 percent