Macroeconomic modelling of sustainable development and the links between the economy and the environment

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Final Report

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Preface

This report summarizes the main outcomes of the project “Macroeconomic Modelling of Sustainable Development and the Links between the Economy and the Environment”. Much more details can be found in the subtask reports. A reference to these detailed reports is given at the beginning of each chapter or subchapter.

A team consisting of Cambridge Econometrics (CE), the Institute of Economic Structures Research (GWS), the Sustainable Europe Research Institute (SERI) and the Wuppertal Institute for Climate, Environment and Energy (WI) collaborated to give answers to the research questions of the MACMOD project.

As the coordinator of the project I would like to thank the members of the team

Anthony Barker, Jennifer Barton, Katy Long, Hector Pollitt (Cambridge Econometrics),

Martin Distelkamp, Bernd Meyer, Mark Meyer, Helena Walter (GWS),

Stefan Giljum, Robert Kalcik, Barbara Lugschitz, Elke Pirgmaier, Christine Polzin (SERI)

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for an efficient and always friendly cooperation.

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1 INTRODUCTION

Europe 2020 is the EU's growth strategy for the coming decade, pushing the EU to become a smart, sustainable and inclusive economy. Under the Europe 2020 strategy the flagship initiative for a resource-efficient Europe points the way towards sustainable growth and supports a shift towards a resource-efficient, low-carbon economy.

The European Commission adopted a "Roadmap for a resource-efficient Europe"[1] which provides a framework in which future actions can be designed and implemented coherently. It sets out a vision for the structural and technological change needed up to 2050, with milestones to be reached by 2020.

The Roadmap proposes ways to increase resource productivity and to decouple economic growth from resource use and its environmental impacts. It explains how policies interrelate with and build on each other. Areas where policy action can make a real difference are a particular focus, and specific bottlenecks like inconsistencies in policy and market failures are tackled to ensure that policies are all going in the same direction.

The purpose of this MACMOD[2] project by Cambridge Econometrics, GWS, SERI and the Wuppertal Institute is to strengthen the economic underpinning for resource policy. Essentially to analyse, how important resources are to our economy, how we will use resources in the future under a business as usual scenario, what are the economic and environmental potentials of improved resource use, how we could achieve that, and what this would mean for our economy, our competitiveness, jobs and our environment. This report presents an overview of the results which provide strong support in favour of a resource policy.

1.1 THEORETICAL BACKGROUND

Which questions of sustainable development can be answered by macroeconomic modelling? Sustainable development is - in a very abstract definition - given, if future generations will be able to satisfy their needs. One part of these needs is supplied by the biosphere of the planet. Daly (1992) differentiates three kinds of services, which the biosphere provides to the human population on earth: source functions (energy and material), sink functions (land, water and air for the adaptation of waste) and eco system services (ozone shielding, climate stability and others). The economic system is growing in a way, which disrupts the natural process. The use of energy and space and the growing flows of material reduce the ability of the biosphere to provide all three services (Ekins and Speck 2011).

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[1] European Commission (2011)

[2] MACMOD: Macroeconomic modelling of sustainable development and the links between the economy and the environment. Study financed by the European Commission, DG ENV.

The modelling of the whole process – the interaction between the biosphere and the human sphere – can of course not be the object of macroeconomic modelling, because the biosphere has its own bio physical logic and different scales. The applied macroeconomic modelling approach has its limits. Of course it shows in detail how pressure variables like resource inputs from nature and emissions back to nature are depending from economic activity, but we are not able to quantify the impact on nature and to calculate how in a feedback loop the damage of the eco system services affects the economy. Those aspects had to be covered in accompanying qualitative analyses. The problem has to be solved by full integration of an economic model with a bio-physical model, instead of trying to add a bio-physical module to an economic system or an economic system to an existing bio-physical model. What we need is an integration of an economic model like E3ME or GINFORS with a bio-physical model which guarantees a well-balanced representation of both nature and economy. But this is a challenge for the future and has been far off the scope of the MACMOD project. Nevertheless, future research should be aware that the complex questions concerning biotic material inputs (biomass) and their interrelationships to population growth, water availability and energy supply can only be analysed adequately with such expanded modelling equipments.

From that point it should be clear that macroeconomic modelling of sustainable development is necessarily a partial analysis in the sense that the impact on the state of nature and the feedback to the economy cannot be the object of modelling. Positively spoken macroeconomic modelling of sustainable development describes economic development as the driver of pressures on the environment, such as emissions resulting from energy use and the extraction of materials.

Energy use has been and is still a huge field of macroeconomic modelling. Material flows are a prominent field of industrial ecology using input output models. A big literature has grown here so that a handbook on this topic is now available (Suh 2009). But macroeconomic modelling of the flow of materials which means the integration of material flows in a complete macroeconomic framework has just begun a few years ago. In a study financed by the Aachen Foundation “Kathy Beys” GWS did some policy simulations for total material requirement, based on data of the Wuppertal- Institute for Germany, with the economic environmental model PANTA RHEI (Distelkamp et al. 2005, Meyer et al. 2007). In the MOSUS project (5th EU framework program) global material extraction data provided by SERI was the data base for the simulation of European environmental policies, including material policy, in a global modelling framework provided by the model GINFORS from GWS (Giljum et al. 2008, Lutz et al. 2010). In the MaRess project, financed by the German Ministry of the Environment, GWS simulated with the model PANTA RHEI for Germany a policy mix, which showed that absolute decoupling between economic growth and total material requirement is possible (Distelkamp et al. 2010). In the framework of the PETRE project (Ekins and Speck 2011) the impact of an environmental tax reform on economic development and material and energy consumption in Europe has been analysed. CE simulated with the model E3ME direct material consumption in Europe and GWS with GINFORS global material extraction (Barker et al. 2011).

On the European scale only direct material inputs (DMI, i.e., domestically extracted resources plus those materials that are imported or directly part of imported goods) have been modelled until now. The reasons are restrictions in data availability as EUROSTAT’s MFA data publications only focus on DMI. However, resource efficiency analyses based on this data may provide biased conclusions as far as the countries under consideration reduce their resource inputs by substituting domestic production of resource intensive products via imports of these products. In this case DMI will indicate a rise of resource efficiency for the observed countries, because the consumption of resources now takes place abroad, but the global resource efficiency has not changed. Instead, if foreign resource efficiency was lower than in the countries under consideration, global resource efficiency might actually have been lowered. To avoid this problem it is useful to take the indicator TMR (total material requirement), which adds to the direct materials of imported products those hidden flows of materials that are induced abroad. Further domestic extractions cause excavation damages of nature that also have to be mentioned. It is one important objective of the project to calculate this TMR data for the different EU Member States and to use it for modelling.

1.2 OVERVIEW OF THE STUDY

The study starts with an analysis of the **risks that are associated with future resource use in European countries**, summarized in **chapter 2**.[1] The main outcome is a matrix of risks which distinguishes four headline categories of resource use related risks for eight different resource categories. Main findings might be summarized as follows:

- **metals and minerals** - the high market concentration is associated with high risks of supply restrictions and power of a few global players on the world market prices. In addition, import dependency is high for a number of metals and minerals and there are limited options to substitute or recycle, although potentials are high to increase the share of secondary materials.
- **fossil fuels** - the main risks arise due to limited geological availability ("peak oil") and high import dependencies particularly regarding oil and gas. Climate change poses a heavy environmental risk associated with this material category.
- **biotic resources** – agriculture, wood and fish – share equal risks with regard to threats of limited ecological availability, such as limited availability of water and fertile land for agricultural production and limited fish stocks as well as environmental impacts, such as biodiversity loss and climate change impacts.

In **chapter 3 total material requirement (TMR) data** is presented **for France, Germany and Italy for the years 1995, 2000 and 2005**[2]. For the further modelling exercises, this data is allocated to economic sectors and product groups. Material use is highly concentrated on specific sectors and imported product groups. It can further be shown that in Europe domestic extraction of resources is more and more substituted by

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[1] Pirgmaier et al. 2011 develop this in detail.

[2] Acosta and Schütz 2011a present the details.

imports, and that the hidden flows in imports play a rising role, with the result that environmental problems are more and more occurring abroad (Acosta and Schütz 2011b).

The chapter goes on to estimate **TMR time series data (1995-2006)** and material intensities for 10 kinds of materials for all European countries (Distelkamp 2011), an analysis of the trends of the material intensities (Giljum and Lugschitz 2011), and then summarize how this data has been used to build TMR modules for the models E3ME (Cambridge Econometrics 2011a) and GINFORS (Distelkamp 2011).

In **chapter 4,** on **"Market failures and their correction by an information program**" a theoretical and empirical study on market failures is summarized (Bleischwitz and Ritsche 2011). The report analyses information deficits, adaptation and coordination deficits both from a theoretical and empirical perspective. The analysis reveals the enormous importance of the different types of market failures and gives policy recommendations for avoiding this obstacle of resource efficiency. **Then, the results of a simulation study** with the model GINFORS are presented, in which the potential of a European information program to correct these market failures is discussed (Distelkamp et al. 2011a). The exercise is based on data from leading consulting firms (Fischer et al. 2004) about the costs and direct effects of information programs on material efficiency and follows a simulation study that Meyer et al. (2007) conducted for Germany. The results show a win-win situation for nearly all European countries: GDP rises and, in spite of the strong rebound effect, material inputs in physical terms fall absolutely.

Readers should be aware that all chapter 4 simulation results rest on the assumption that a variation of selected inputs will not be accompanied by direct reactions of the remaining inputs. This independency assumption facilitates the implementation of our simulation exercise. However, one might doubt whether this simulation setup did not suffer from over-simplification in this regard. We therefore decided to conduct further detailed econometric analyses concerning the question: "What happens to the remaining inputs if a selected material relevant input was independently reduced?" This **econometric study** was based on time series of Member States' input coefficients and focussed on those input coefficients that are supposed to represent the most important ones with regards to material use. Results of these analyses are summarized in **chapter 5** [1].

Chapter 6 develops **abatement cost curves**. Cost curves for the abatement of CO2-emissions play an important role in the discussion of alternative approaches in energy policy such as the cost curve produced by the consultancy McKinsey (Enkvist et al. 2007). The fact that material inputs are to a very large extent determined by only 30 input coefficients allows for a **top-down construction of an equivalent abatement cost curve**: In 30 simulations with the models E3ME and GINFORS each of the 30 most important input coefficients is reduced separately by 1%. Since the input coefficients have been endogenized, the models are able to calculate all cost, price and income reactions. Each simulation gives, with the change of GDP and the change of total material requirement,

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[1] A more detailed analysis is given by Cambridge Econometrics 2011a, Meyer 2011, Meyer and Meyer 2011.

one data point of the marginal abatement cost curve. The graph of the curve is obtained by ranking the TMR reductions with their costs, starting with the lowest costs.

In **chapter 7 "Policy simulations"** the choice of the policy scenarios is discussed, and then the results of several simulation runs are described and policy recommendations are given[1] .

Our findings indicate **potential resource efficiency gains supporting growth and jobs for a number of materials**, but the focus of this paper is on metals which - as a strategic input to many production processes - seems to offer particularly large opportunities (UNEP and CSIRO (2011)). Furthermore, metals also represent a resource where future supply might not be able to meet worldwide demand which will be boosted by rapid economic growth in Asia (Halada et al. (2009)).

Positively, in line with the results of the MaRess[2] project for Germany, we find that there is a **high potential to improve resource efficiency without economic losses in Europe** (Meyer et al. 2011, Distelkamp et al. 2010). Assuming a sector specific policy mix (international agreement on recycling for metals; taxation of the use of metals in investment goods industries; information and consulting program concerning material inputs in sectors with high concentration of small and medium sized firms) for Europe our model simulations show that if an active emission oriented climate policy is complemented by a material input oriented resource policy – as Ekins et al. (2011a) demand - then **absolute decoupling of economic growth from resource requirements is possible**.

If the assumptions about the increase in recycling ratios, about the costs and success of the information program and about the design of the taxation are right, both models indicate that within a period of 20 years:

- A reduction of resource use by 17% to 25% (compared to the baseline) could be achieved.
- The expected effects of this policy mix on real GDP are positive (+2% to +3.3%).
- Real labour income would be increased, and so up to 2.6 million new jobs could be created.

2 RISKS ASSOCIATED WITH RESOURCE USE IN EUROPEAN COUNTRIES

This study[3] analyses different risks associated with future resource use in Europe. The key outcome is a matrix of risks (see Table 2-1) for important resource categories, with information on the nature of the risks, timescales, examples and quantifications of risks as well as their economic, environmental and social impacts.

The risk analysis covers the following eight resource categories:

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[1] This chapter is based on Cambridge Econometrics 2011c, Distelkamp et al. 2011c.

[2] MaRess: Materialeffizienz und Ressourcenschonung. See: ressourcen. Wupperimnst.org/en/project/index.html

[3] This chapter is based on Pirgmaier et al. 2011.

1) Metals – Iron and Steel
2) Metals – Other Metals
3) Minerals – Construction Minerals
4) Minerals – Industrial Minerals
5) Fossil Fuels
6) Biomass – Agriculture
7) Biomass – Wood
8) Biomass – Fish

These resource categories give one dimension of the risk matrix. In contrast to most other studies on resource use risks, we describe risks for these broad resource categories rather than at more disaggregated levels, e.g. at the level of single metals or minerals. We provide examples for specific resources but tried to generalise risks for a whole category in order to give a broad overview of potential future risks related to resource use from the literature. This approach was also selected in order to provide information at a level of aggregation which the modelling partners could integrate in their scenario simulation models.

		Iron & steel	**Other metals**	**Construction minerals**	**Industrial minerals**
Availability	Geological availability	Iron production is energy intensive, but usable deposits of iron ore are geographically widespread	Rare earths: widespread resources in all continents	In some EU countries limited geological availability and topographical accessibility	Most industrial minerals are abundantly available in the earth crust, so generally low risk
	Ecological availability				
Technology	Extraction technologies				
	Substitution and recycling options	Increasing options to substitute iron and steel; increasing shares of scrap iron	Rare earths: limited recycling options	Potentials to recycle are high; shares in practice very different	Limited substitutability; unavailable for recycling, although indirect recovery (e.g. feldspar in glass)
Economic and policy issues	Economic availability			Restrictions due to competition for land	
	Power concentration	3 biggest iron ore producers control 75-80% of global supplies	High market concentration for some critical metals (e.g. antimony, gallium, germanium, indium, rare earths, tungsten largely from China)		High supply concentration for certain minerals (e.g. graphite); Barriers to trade
	Import dependency	High but not critical EU dependency on imported iron ore	Europe is 100% import dependent for many rare metals (e.g. rare earths)		High import dependency related to some IndM (e.g. phosphorous)
	Resource prices	Still among the cheapest metals, but expected future price increases may have economic impacts	Metals industry depends on several energy sources, most importantly electricity	Increase in the long run if spatial planning policies are not implemented	Global demand trends lead to price rise for certain IndM
	Economic vulnerability	Very high economic importance, as almost all industrial sectors depend on iron; EU is second largest manufacturer of iron and steel in the world	High importance of rare metals for many low-carbon technologies; Dependency of modern technology on aluminium, lead, copper	Sensitive to transport costs, have to be sourced locally	High importance in a wide range of industries; many IndM cannot be substituted
Environment	Environmental impacts	Globally, primary iron & steel production have the largest negative env. impacts of all metals (sector with very high energy intensity)	Mining of critical metals often causes considerable environmental burden, but their use in low-carbon may also bring environmental benefits	Landscape and habitat disruption. Emissions related to extraction, transport, processing and deposit	Related to extraction, transport, processing and deposit
	Risks of natural catastrophes	Japan is the largest global supplier of iron and steel; 5 Japanese mills are located in Tsunami affected areas			

Table 2-1: Matrix of risks associated with future European resource use (continued on next page)

		Fossil fuels	Agriculture	Wood	Fish
Availability	Geological availability	Resources will be diminishing in the medium-term	Critical availability of phosphorous		
	Ecological availability		Critical availability of land and water	European forests are generally well managed; continuous deforestation outside the EU due to land use change	Overfishing leads to collapsing fish stocks in the EU (and globally)
Technology	Extraction technologies	Become more complex and more expensive			
	Substitution and recycling options	High dependence on FF in energy supply. After combustion not available for recycling			Limited substitution in aquaculture production of fish
Economic and policy issues	Economic availability				
	Power concentration	Supply is highly concentrated	Future economically viable phosphorus reserves are concentrated in China and Morocco		
	Import dependency	High dependency on imports (50%) will increase	High import dependency on phosphorus and crops for feed		Rising import dependency
	Resource prices	Long-term price rise; price volatility and shocks	Rising food prices	Higher future prices due to increasing use of timber for energy and construction and growing global demand	
	Economic vulnerability	Dependence on ff in energy supply, transport and industrial processing; increasing demand			Negative impacts on fishery industries; fleets become increasingly economically unviable; employment is endangered
Environment	Environmental impacts	Fossile based emissions induce global warming	Climate impacts; soil degradation; water scarcity; biodiversity loss, etc.	Loss of forests due to conversion in agricultural land; climate change impacts	Biodiversity loss, destruction of vulnerable habitats, decreasing stability and water quality
	Risks of natural catastrophes		Reduced yields/harvests due to environmental impacts (climate change!)	Increasing intensity and frequency of extreme weather events due to climate change	

Table 2-1: Matrix of risks associated with future European resource use (continued)

A structured analysis and description of risks requires a solid and comprehensive framework. Building on existing studies we developed a framework of risks, clustered in the following four major risk categories:

- **Availability**: geological and ecological availability
- **Technology-related risks**: extraction technologies, substitution and recycling options
- **Economic and policy related risks**: economic availability, power concentration, import dependency, development of resource prices, economic vulnerability
- **Environment-related risks**: environmental impacts, risk of environmental catastrophes

These categories constitute the second dimension of the risk matrix. A comprehensive overview of the risks associated with each of the eight resource categories is given by Table 2-1.

The analysis reveals that, with regard to the categories of **metals and minerals**, the main risks are found in similar categories. In particular, a **high market concentration** is associated with high risks of supply restrictions and power of a few global players on the world market prices. In addition, **import dependency** is high for a number of materials in those categories. The second main risk regarding those materials is **limited options to substitute or recycle**, although potentials are high to increase the share of secondary materials. Taken together, this implies a risk of supply shocks.

Regarding **fossil fuels**, the main risks arise in the areas of **geological availability** ("peak oil") and **high import dependencies** of Europe particularly regarding oil and gas. Climate change poses a heavy **environmental risk** associated to this material category.

The three material categories of **biotic resources, agriculture, wood and fish** share equal risks with regard to threats of **limited ecological availability**, such as limited availability of water and fertile land for agricultural production and limited fish stocks as well as environmental impacts, such as biodiversity loss and climate change impacts.

Risks are linked. For example, where ecological availability is a problem, this can translate into economic risks as stocks are depleted or ecosystem services are disrupted.

3 TOTAL MATERIAL REQUIREMENT (TMR) DATA AND ITS INTEGRATION INTO THE MODELS

Before we can report about the potential to decouple economic growth from resource use and its environmental impacts, we have to clarify the definition of "resource use" used in this study.

The "Roadmap for a resource-efficient Europe" uses the ratio of GDP to **Domestic Material Consumption** (DMC) as a "provisional lead indicator". This should be complemented by indicators that take into account the global aspects of EU consumption" (European Commission 2011, p. 21).

This study uses the concept of **Total Material Requirement** (TMR) for a more comprehensive view on resource use. The TMR accounts not only for the direct material inputs (domestic extraction used [deu]) and imports [imp]) of an economy, but also for the hidden flows (unused domestic extraction [ude] and hidden flows associated to the imports [hf-imp]).

Unfortunately the decision for TMR implied as a first step the need for work on the historic data, as statistical information for all EU Member States does not exist. The calculation of TMR data for all European countries and as a time series in the same detailed way as for France, Germany and Italy for the years 1995, 2000 and 2005 (see Chapter 3.1) was beyond the capacity of this study. We are aware, that the way of handling this data problem (see Chapter 3.2) can only be seen as a second-best solution. By estimating the hidden flow parts of TMR on a detailed material level we think that we achieved a good estimate of the real values.

The whole modelling exercise within the project was based on Member States. This of course also holds for the modelling of resource use. One main outcome are datasets of TMR and DMI (historical and projection results) for all 27 EU countries. Due to the definition of these indicators according to Eurostat and OECD conventions it is not possible to add these Member State results to determine the EU27 values. Material inputs are also part of imported products. Because of intra European import flows the sum of the imports of the Member States is higher than the imports of the region EU27. Therefore material inputs for the sum of Member States are higher than that of the region EU27.

3.1 TMR DATA FOR FRANCE, GERMANY AND ITALY

This subtask studied the extent to which the production and consumption of various product groups contribute to the total resource use of three selected countries (Germany, France and Italy). Historical developments of resource use between 1995 and 2005 have been assessed and key product groups and key economic activities have been identified. Based on the framework of Environmentally Extended Input-Output Analysis (EE-IOA) this mapping allows the identification of the most relevant drivers of current levels of resource use with regards to industries and product groups. This is essential information for scenario analysis and modelling, as well as for EU policies.

The initial TMR datasets were prepared for the years 1995, 2000, 2005 in compliance with the following classification[1]:

metals
- iron/steel
- non-ferrous metals
- other

minerals
- construction (aggregates)
- industrial
- other

biomass
- wood
- agricultural
- other

fossil fuels

As accounting components, used domestic extraction, unused domestic extraction, imports and rucksacks were calculated. Further erosion and GLU_A (global agricultural land use) was part of the delivery.

All data has been adapted to fit to UN COMTRADE and EUROSTAT data. Furthermore, they have been allocated to the 59 sectors of EUROSTAT input output tables (task 1.2 of the project).

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[1] See for details Acosta and Schütz 2011a.

The mapping of resource uses is divided into two parts. First, primary and intermediate resource use caused by 59 domestic economic activities in Germany, France and Italy have been assessed separately. Furthermore, resource use associated to total final consumption of 59 product groups (produced domestically and imported) in these three countries has been focused.

In the second part (Acosta and Schütz 2011b), a deeper analysis of the direct and indirect resource use associated to the production of four selected economic activities and, respectively, to the consumption of four selected product groups has been carried out. In this vein, the focus has been set on direct and indirect resource use induced by the various inputs required for the production of each of these product groups. In other words, the amount of resources that is progressively accumulated through the whole production chain of each of these four products groups was disaggregated and examined with more detail. This approach has been applied to the four selected product groups in each of the three countries. It can be seen in line with the Polluter-Pays-Principle and as a prerequisite for strategies addressing relevant sectors and related clusters of economic interaction.

Just a few sectors and product groups contribute significantly to resource use of the economies. These are:

	France		**Germany**		**Italy**	
Rank	Sector / product group	Contribution to TMR	Sector / product group	Contribution to TMR	Sector / product group	Contribution to TMR
1	Other mining and quarrying products	17.8%	Coal and lignite; peat	32.0%	Other mining and quarrying products	17.8%
2	Products of agriculture, hunting and related services	15.4%	Other mining and quarrying products	12.1%	Basic metals	14.0%
3	Construction work	12.1%	Basic metals	9.1%	Products of agriculture, hunting and related services	8.4%
4	Basic metals	8.6%	Products of agriculture, hunting and related services	6.6%	Electrical energy, gas, steam and hot water	7.3%
5	Coke, refined petroleum products and nuclear fuels	4.9%	Coke, refined petroleum products and nuclear fuels	3.4%	Fabricated metal products, except machinery and equipment	7.2%

Table 3-1: Main contribution to TMR by sector / product group in France, Germany and Italy in 2005

Though their overall volume of demand is almost constant over the years observed, there are shifts in the significance of several sectors and product groups. The share of hidden flows per imported units has increased considerably, especially for products from agriculture and biomass, thus indicating a burden shifting from the EU abroad.

3.2 TMR DATA FOR ALL EU27 MEMBER STATES

3.2.1 THE ESTIMATION OF TIME SERIES DATA FOR ALL EU27 MEMBER STATES

GWS estimated TMR data for all EU27 Member States.[1] At time of examination the EUROSTAT database offered material flow data (MFA-data) on direct material inputs (domestic extraction used and imports) for the period 2000 to 2007. This data shows that in the majority of EU-27 countries the direct material input (DMI) has increased over the period covered. The only exceptions are Germany, Italy and the UK. A look at per capita data for 2007, the most recent year with official data available at time of examination, indicates quite big differences between the Member States. The highest value (Ireland) exceeds the lowest one (Malta) by a factor of nearly 10.

rank	country	DMI per capita in tons (2007)	rank	country	DMI per capita in tons (2007)	rank	country	DMI per capita in tons (2007)
1	Ireland	56.61	10	Cyprus	30.63	19	Lithuania	19.73
2	Luxembourg	50.51	11	Slovenia	29.93	20	Slovakia	19.27
3	Finland	47.01	12	Latvia	27.24	21	Poland	18.66
4	Estonia	37.06	13	Czech Rep.	24.57	22	Greece	18.55
5	Denmark	36.94	14	Spain	23.56	23	France	17.26
6	Belgium	36.43	15	Portugal	23.41	24	Italy	16.02
7	Netherlands	35.01	16	Romania	21.02	25	Hungary	15.91
8	Sweden	34.92	17	Bulgaria	20.77	26	United Kingdom	15.05
9	Austria	31.94	18	Germany	20.75	27	Malta	6.00

Data sources: Eurostat

Table 3-2: Differences among Member States regarding DMI per capita

The first task within the historic data calculations was to allocate the MFA-data for more than 70 materials to the material categories of the WI dataset. See Table 3-3 for a condensed overview which associates EUROSTAT's MFA-categories (MF1 – MF6) with the respective TMR categories.[2]

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[1] This chapter is based on Distelkamp 2011.

[2] For example the MFA-data accounts for non-metallic minerals like "chalk and dolomite", "slate" and "chemical and fertilizer minerals" etc. whilst the WI dataset (and the TMR module) differs between "construction minerals" and "industrial minerals.

	Domestic extraction used	Imports
Biomass (MF1)	agriculture	agriculture
	wood	wood
	other	other products mainly from biomass
Metal ores (MF2)	iron	iron and products mainly from iron/steel
	non-ferrous metals	non-ferrous metals and products mainly from non-ferrous metals
	others	other metals and products mainly from metals
Non-metallic minerals (MF3)	construction minerals	construction minerals
	industrial minerals	industrial minerals
	others	other products mainly non-metallic minerals products
MF4	fossil energy materials/carriers	fossil energy materials/carriers
MF5 + MF6		others and waste

Table 3-3: Material categories for domestic extraction used and imports in the TMR module of GINFORS

Unused domestic extraction was estimated by the relation of material flows to their appropriate direct material flow as given within the TMR data calculated by WI for France, Germany and Italy. As illustrated by Table 3-4 these “rucksack-factors” did not exhibit distinct time trends in any of the considered material flow categories.

Material flow category		Material intensity (rucksack-factor) in kg per kg								
Unused domestic extraction	Domestic extraction used	France			Germany			Italy		
		95	00	05	95	00	05	95	00	05
Biomass: Agriculture	Biomass: Agriculture	0.20	0.20	0.21	0.13	0.14	0.14	0.13	0.14	0.14
Biomass: Erosion	Biomass: Agriculture	0.70	0.62	0.68	0.62	0.55	0.57	0.50	0.52	0.47
Biomass: Wood	Biomass: Wood	0.45	0.45	0.45	0.45	0.45	0.45	0.15	0.15	0.15
Biomass: Other	Biomass: Other				0.33	0.33	0.33	0.16	0.13	0.17
Metal ores: Iron	Metal ores: Iron	0.59	0.59		0.59	0.59	0.59			
Metal ores: non-ferrous metals	Metal ores: non-ferrous metals	2.84	3.62	4.45				0.11	2.10	0.11
Non-met. min.: Construction minerals	Non-met. min.: Construction minerals	0.15	0.15	0.15	0.16	0.16	0.16	0.04	0.04	0.03
Non-met. min.: Industrial minerals	Non-met. min.: Industrial minerals	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.11
Fossil energy materials/carriers	Fossil energy materials/carriers	1.75	1.62	0.21	7.11	7.38	7.78	0.09	0.04	0.04

Data sources: Eurostat MFA data, Wuppertal Institute TMR data; own calculations

Table 3-4: Domestic rucksack-factors

Furthermore, for the majority of material flow categories the levels do not differ much between the three countries. This does not hold for some data for Italy (Biomass: wood / Metal ores: non-ferrous metals / Non-metallic minerals: construction minerals) and for the material category “fossil energy materials/carriers”. As the unused domestic extraction for those categories with differences in the level of the rucksack-factor in Italy is not of high relevance for the TMR, we tried not to examine the reasons for these differences.

But this work has been done for the unused domestic extraction of fossil energy materials/carriers. In a regression analysis it could be shown that the share of coal in the three countries and the three years could explain the variance in the factors for unused extractions. Knowing the share of coal in fossil fuels for all EU-27 countries, it was possible to calculate with the parameters of the regression the factors of unused extraction for fossil fuels.

Overall, our rucksack-factor estimates thus result from the following calculations and assumptions:

- for the rucksack factor of fossil energy materials/carriers:
    - for all countries and all years by using the parameters of the regression
- for the rucksack-factors of all other material categories:
    - in the years 2001 to 2004 for France, Germany and Italy interpolation of the rucksack-factors on the basis of the WI data
    - for all 24 other countries the rucksack-factors are the average of the three countries observed by WI
    - in the years 2006 onwards rucksack-factors for all countries and material categories are assumed to be constant

A special case within the unused domestic extraction is the material flow category “excavation and dredging”. This is not linked to a direct material flow but to an economic activity, namely that of the construction sector. To calculate this TMR-category for all EU-27 countries we first calculate the material intensities, defined as excavation and dredging (in kg) per output at basic prices in constant prices of the construction sector (in €), for France, Germany and Italy in the years 1995, 2000 and 2005. For those countries with an I-O-module in GINFORS[1] we assume that the material intensities equate to the average of these three countries. For all other EU-27 countries[2] we use a different definition of material intensity: excavation and dredging (in kg) per GDP in constant prices (in €). We assume that the material intensities for these countries equate to the average of the EU countries with I-O-modules.

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[1] Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, United Kingdom.

[2] Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Malta, Romania, Slovenia.

The results show that the unused domestic extraction has increased in 22 countries. Only in five countries (Germany, Poland, Czech Republic, Italy and Hungary) do we observe a fall. The other very interesting result is that there are very big differences among the Member States with regard to the per capita values which range from less than 2 tons (Malta) up to more than 100 tons (Estonia). What are the reasons for these differences? A high per capita value is the result of one or more of the following circumstances:

- a high per capita value of domestic extraction used,
- a high relevance of materials with a relative high rucksack-factor (metal ores; biomass agriculture) within the domestic extraction used,
- a high share of coal within the extraction of fossil energy materials/carriers.

The next task on the way to building a complete TMR time series data for all EU-27 countries is the **estimation of hidden flows associated to the imports**. Again we examined the relation between these material flows and the appropriate direct material flow (imports) on base of the TMR data for France, Germany and Italy. These "rucksack-factors" are given in Table 3-5. As for the domestic side there is in none of the material flow categories a clear time trend of rucksack-factors observable. Also the levels do not differ much between the three countries. Due to these observations the rucksack-factors are the result of the following calculations and assumptions:

- in the years 2001 to 2004 for France, Germany and Italy interpolation of the rucksack-factors
- for all 24 other countries the rucksack-factors are the average of the three countries observed by WI
- in the years 2006 onwards rucksack-factors for all countries and material categories are assumed to be constant

The results show that the hidden flows associated to the imports have increased in all 27 countries. Again there are quite big differences among the Member States with regard to the per capita values observable. The range spans from 10 tons (Romania) up to nearly 150 tons (Luxembourg). What are the reasons for these differences? A high per capita value is the result of one or more of the following circumstances:

- a high per capita value of imports,
- high relevance of materials with a relative high rucksack-factor (metal ores; other products mainly from biomass; others and waste) within the imports.

Last but not least we can add all material flow categories to the TMR. These results can be inferred from Table 3-6. The results show that **TMR has increased in all Member States except Italy**. It can also be observed that big differences in the per capita values do not only count for the subcategories but also with reference to the overall TMR. In addition Figure 3-1 illustrates the differences with respect to the composition of TMR between the Member States.

Material flow category	Material intensity (rucksack-factor) in kg per kg								
	France			Germany			Italy		
	95	00	05	95	00	05	95	00	05
Biomass: agriculture	4.56	4.42	2.75		6.99	6.63	8.94	8.09	6.45
Biomass: wood	0.20	0.19	0.17		0.19	0.21	0.36	0.32	0.28
Biomass: other product mainly from biomass	8.87	8.97	8.33		8.77	9.08	8.65	9.38	10.50
Metal ores: iron and products mainly from iron/steel	3.97	5.47	5.17		4.45	4.80	4.93	5.47	5.99
Metal ores: non-ferrous metals and products mainly from non-ferrous metals	50.02	45.16	44.68		53.54	50.54	58.15	78.76	65.37
Metal ores: other metals and products mainly from metals	7.61	7.86	9.04		7.31	7.13	20.14	10.83	9.39
Non-metallic minerals: construction minerals	0.60	0.59	0.59		0.60	0.64	0.86	0.80	0.73
Non-metallic minerals: industrial minerals	1.06	0.87	0.50		0.47	0.50	0.63	0.88	0.74
Non-metallic minerals: other products mainly non-metallic minerals products	0.68	0.79	0.94		1.43	1.42	1.65	0.99	1.42
Fossil energy materials/carriers	0.58	0.63	0.82		0.96	1.14	0.99	0.95	1.09
Others and waste	9.34	10.80	10.84		6.73	6.74	8.70	10.98	9.05

Data sources: Eurostat MFA data, Wuppertal Institute TMR data; own calculations

Table 3-5: Import rucksack-factors

	2000	2001	2002	2003	2004	2005	2006	2007	per capita in tons (2007)
Germany	5 864	5 753	5 805	5 837	6 049	6 017	6 164	6 386	77.58
France	2 871	2 763	2 756	2 676	2 881	2 858	2 915	2 991	46.99
Poland	2 726	2 679	2 616	2 702	2 830	2 785	2 837	2 901	76.10
Spain	2 180	2 246	2 403	2 468	2 568	2 670	2 735	2 694	60.57
Italy	2 734	2 660	2 595	2 526	2 678	2 686	2 793	2 675	45.24
UK	2 293	2 362	2 313	2 332	2 451	2 381	2 415	2 442	40.17
Netherlands	1 480	1 518	1 485	1 485	1 564	1 586	1 672	1 820	111.26
Belgium	1 375	1 350	1 411	1 450	1 536	1 547	1 461	1 493	141.05
Czech Rep.	1 055	1 056	1 026	1 056	1 147	1 114	1 156	1 174	114.11
Greece	972	1 027	1 046	1 075	1 085	1 064	1 048	1 096	98.06
Romania	545	617	599	683	752	783	831	876	40.61
Sweden	547	538	552	570	612	636	639	685	75.13
Austria	509	534	545	561	612	627	659	684	82.60
Ireland	499	524	542	567	581	598	615	656	152.16
Finland	514	539	562	572	513	562	631	605	114.62
Portugal	451	466	460	434	465	473	513	529	49.90
Bulgaria	399	409	406	451	471	461	494	524	68.28
Denmark	405	412	387	411	422	442	471	481	88.22
Hungary	340	368	367	381	408	430	403	388	38.59
Slovakia	192	210	215	223	260	267	289	315	58.35
Slovenia	162	174	182	196	208	206	230	250	124.52
Estonia	146	147	163	192	188	191	200	224	166.96
Lithuania	77	79	96	118	124	134	140	149	44.00
Latvia	75	74	81	84	89	99	103	110	48.31
Luxemburg	91	86	85	86	92	87	100	97	203.72
Cyprus	33	34	36	35	39	42	41	44	57.01
Malta	8	6	7	7	9	10	11	11	26.17

Data sources: own calculations

Table 3-6: Time series of TMR in millions of tons for EU-27 countries

Distelkamp (2011) appraises the TMR data in deep detail. **In the majority of the countries the imports and their "rucksacks" represent more than 50% of TMR**. In Malta and Luxembourg domestic activities contribute less than 10% to TMR. On the other hand there are three countries (Poland, Greece, Estonia), where domestic activities contribute to about 80% to TMR.

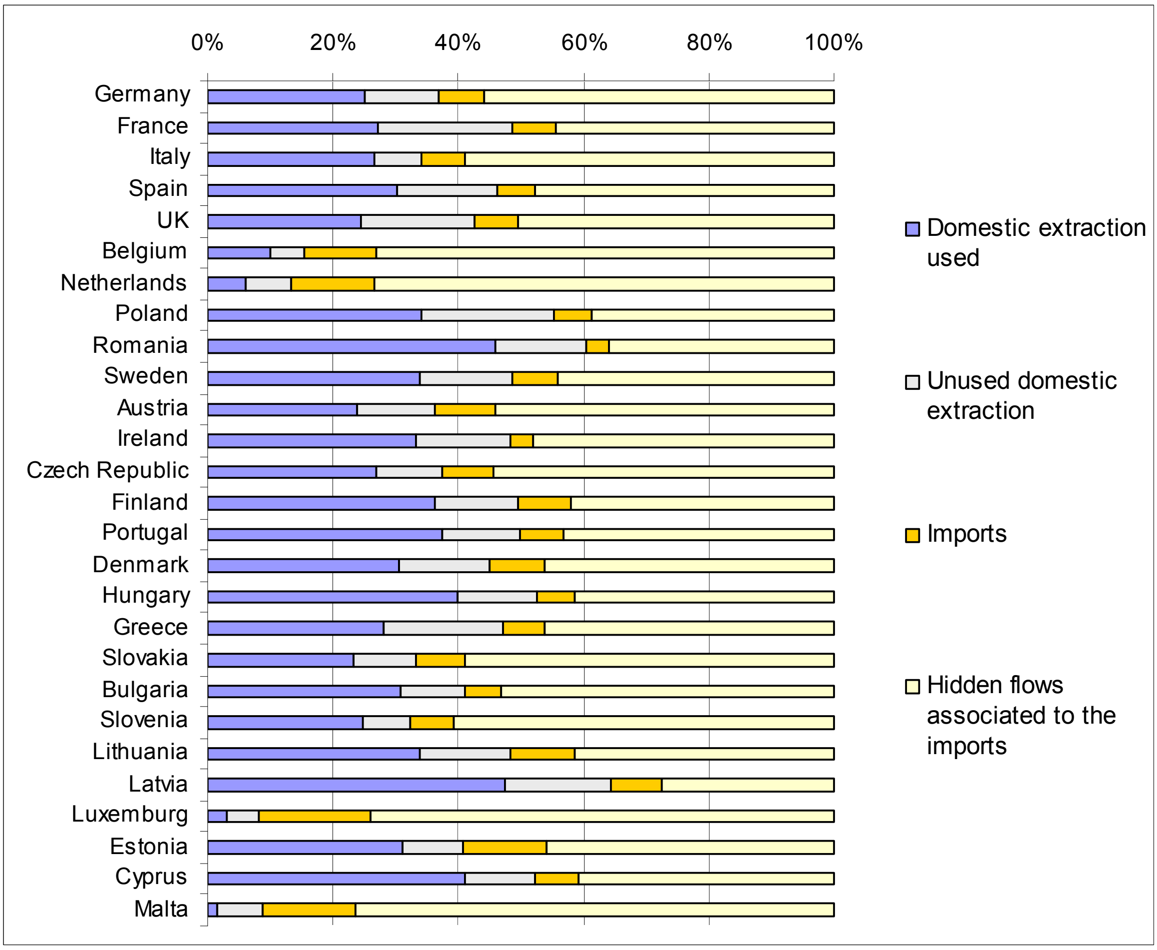

Figure 3-1: Composition of TMR in the EU27-countries in the year 2005

Please note that whereas we report only results with regards to the four main TMR-categories (domestic extraction used, unused domestic extraction, imports, hidden flows associated to the imports), our calculations actually distinguished the material flows for 40 different material categories per Member State.[1]

Another finding of these calculations is that there are a few material flows that rank among the most important ones in many of the Member States. This applies to the domestic extraction used of construction minerals and to the hidden flows associated to the imports of non-ferrous metals and products mainly from non-ferrous metals.

The following figure presents the values for Total Material Productivity (GDP per TMR) in 2007 and the change in these observations between 2000 and 2007.

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[1] Detailed TMR data for all Member States as calculated for the year 2005 are given in appendix A of this report.

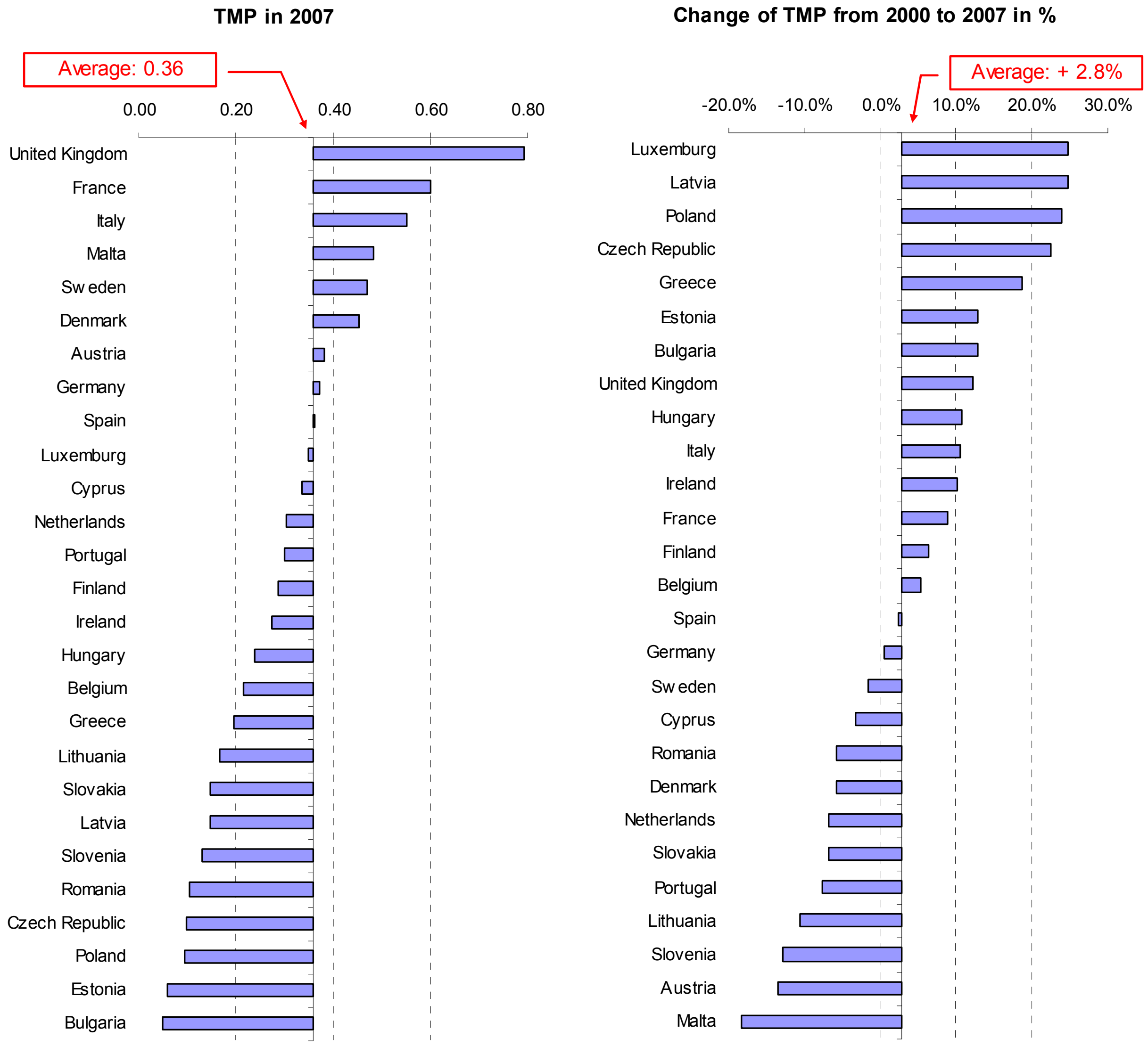

Figure 3-2: Level and development of Total material productivity (TMP) for the EU27-countries

Summing up it has to be emphasized that the estimation of TMR data for 24 Member States on base of observations for only three countries as well as the estimation procedure along the time axis as described can only be seen as a second best solution.[1] Hence the certainty of the presented TMR values is restricted. But to be clear: The uncertainty applies only to the indirect parts of TMR (unused domestic extraction, hidden flows associated to the imports) as the direct parts (domestic extraction used, imports) are derived from official MFA-data.

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[1] A first best solution would have been the calculation of TMR data for all EU27 Member States and all years in the same manner as for France, Germany and Italy which was beyond the reach of this project.

By estimating the indirect parts of TMR in a way as detailed – with regard to material categories – as affordable we tried to minimize the remaining uncertainties. These uncertainties are the higher

- the less homogenous the material category in question is and
- the higher the differences among the three countries for the rucksack-factors (see Table 3-4 and 3-5) of the material category in question are.

For example the material category "biomass: wood" is relative homogenous and the rucksack-factors in the three countries do not differ substantially.[1] Therefore the estimated values for "unused domestic extraction; biomass: wood" and "hidden flows associated to the imports; biomass: wood" for all other countries should be a very good guess for the "real" values.

The opposite holds for example for the material category "Metal ores: other metals and products mainly from metals" which is a lot more diverse and we observed higher differences of rucksack-factors between France, Germany and Italy. Hence with regard to this material category – and others with similar attributes – the estimated indirect flows are more uncertain.

3.2.2 CALCULATION OF MATERIAL INTENSITIES FOR DIRECT MATERIAL FLOWS

Besides the estimation of time series data for TMR of all EU-27 countries the second function of the historic part of the TMR module was to calculate material intensities for direct material flows (domestic extraction used, imports). This has been done, because material intensities measuring the input of materials in physical terms in relation to their economic drivers in monetary terms and constant prices are the link between the monetary world and the physical world.

On the domestic side the material intensities of all countries are defined as the relation between the material flow $mfdeu_m$ and the gross output in constant prices of the extracting sector $prodr_i$. Data sources for this work are on the one hand the MFA data of Eurostat. The gross output at basic prices in current prices is also taken from the Eurostat database. Unfortunately Eurostat does not offer information about price indices of gross output. This historical data was taken from the EU-KLEMS database.

$_{ca}\mathrm{mideu}_m = {}_{ca}\mathrm{mfdeu}_m / {}_{ca}\mathrm{prodr}_i$

To use the results of the analysis of historic time trends in material intensities in the projection part of GINFORS in an appropriate way, already the definitions have to bear in mind the classification of industrial sectors in the economic modelling part.

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[1] With the exemption of the domestic rucksack-factors in Italy that are substantially lower than in France and Germany.

$_{ca}$mideu$_m$ of material …	is defined as material flow domestic extraction used $_{ca}$mideu$_m$ divided by output of sector …
Biomass: Agriculture	Agriculture, hunting, forestry and fishing
Biomass: Wood	
Biomass: Other	
Metal ores: Iron	Mining and quarrying (non-energy)
Metal ores: Non-ferrous metals	
Non-metallic minerals: Construction minerals	
Non-metallic minerals: Industrial minerals	
Fossil energy materials/carriers	Mining and quarrying (energy)

Table 3-7: Definition of material intensities domestic extraction used

Imported materials *imp* are also given in deep disaggregation as time series in the EUROSTAT data, but here the driving economic variable is not clearly known as it is the case in domestic extraction. Here we use the information of the Wuppertal data. The tables for the three countries give for the different imported materials the CPA codes of the imported products to which they are related. The imports in current prices are given in deep sectoral disaggregation as time series in the STAN dataset of OECD. The calculation of time series in constant prices was possible by using the GINFORS import price indices. They are calculated for the different import goods of all countries from the bilateral trade model from the prices of the exporting countries in a consistent way and afterwards aggregated to groups of imported goods g according to the Wuppertal data. Based on the import vectors in constant prices *imr* for all countries, the intensities for imported materials could be calculated as (see Table 3-8 for further details)

$_{ca}\mathrm{miimp}_m = {}_{ca}\mathrm{mfimp}_m / {}_{ca}\mathrm{imr}_g$

3.3 TRENDS IN MATERIAL INTENSITIES

An objective was to deliver estimations for the future development of material intensities across the EU based on the analysis of trends in the past.[1] The outcome is a bottom-up data set on annual changes of material intensities of both used domestic extraction and imports in European countries by material categories. But what do these material intensities reflect? To make this clear we look at two examples:

1. The material intensity “biomass: wood” for domestic production is the ratio of “domestic extraction used: biomass wood” in physical terms (tons) in relation to the domestic production of the sector “agriculture, hunting, forestry and fishing” in monetary terms in constant prices. If the denominator would only incorporate the forestry sector we would expect an almost constant relation between the material

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[1] Empirical restrictions hindered us from calculating time trends of material intensities in detailed disaggregation for each Member State. Therefore, our corresponding tables of results do not cover whole sets of EU27 national estimates.

flow and the production value in constant prices. But this is not the case. For this example it becomes clear that a change in material intensity on first hand reflects changes in the sectoral composition within the "agriculture, hunting, forestry and fishing" sector.

2. The material intensity "metal ores: other products mainly from metals" for imports is the ratio of the respective import material flow (imports, MF32) in relation to the sum of imports for 7 categories of goods (see Table 3-8). In this case not only the numerator covers different metal ores (with different prices per ton) but also the denominator covers many different products. A change in material intensity for this example can be founded in change in the product mix (denominator) or in a change in the material mix (numerator).

Estimated trends are then implemented into the GINFORS model, in order to reflect past developments in material intensities in the various baseline scenarios until the year 2030. Accordingly, eventual estimation errors will not impact any interpretation of our policy simulations as long as the results are measured as relative deviations from the baseline.

The material intensity factors developed in this task only include direct material flows (used extraction plus direct imports) and were calculated based on data from EUROSTAT. Time series for unused domestic extraction and hidden flows of imports were not available. Therefore, the scenarios modelled with GINFORS will assume constant factors for calculating total domestic extraction (constant factor for unused domestic extraction per used extraction) and for calculating total imports (constant factor for hidden flows per direct import).

3.3.1 METHODOLOGY

We investigated trends for used domestic extraction and imports separately. Regarding used material extraction, different resources in physical units (tonnes) were correlated with the development of monetary output (total output in constant EURO) of the sectors extracting those resources. This was carried out for each EU country. Using the historic developments in resource efficiency, country-specific decoupling coefficients for each resource category were determined. A similar approach was applied regarding imports, where direct imports (in tonnes) were investigated in relation to the value of imports (in constant EURO).

Domestic extraction used

Two main components were necessary to calculate material intensity trends for domestic extraction used: sectoral output in constant prices (in EURO) and used domestic extraction (in tonnes).

Output at basic, constant prices in million EURO was calculated by division of the output in current prices (data source: EUROSTAT) by the price indices, calibrated for the year 2000 taken from the EU KLEMS data base. Material intensity was then calculated by dividing the domestic extraction used in thousands of tonnes (data source: EUROSTAT MFA data) by the output at constant prices in million EURO.

Imports

The material intensities of imports were calculated by dividing the material flows of total imports in thousand tonnes (data source: EUROSTAT MFA data) through the imports of goods at constant prices in local currency. The imports of goods at constant prices in local currency were calculated by division of the imports at currrent prices (Data source: OECD - STAN-Database) by an import price index calculated by the GINFORS model (via weighted export prices from the bilateral trade matrices).

$_{ca}$miimp$_m$ of material …	is defined as material flow imports $_{ca}$miimp$_m$ divided by imports of …
Biomass: Agriculture	Agriculture, hunting, forestry and fishing
Biomass: Wood	
Biomass: Other products mainly from biomass	Food products, beverages and tobacco Wood and products of wood and cork Pulp, paper, paper products, printing and publishing
Metal ores: Iron + products mainly from iron/steel	Mining and quarrying (non-energy) Iron & Steel
Metal ores: Non-ferrous metals + products mainly from non-ferreous metals	Mining and quarrying (non-energy) Non-ferrous metals
Metal ores: Other metals and products mainly from metals	Fabricated metal products, except machinery & equipment Machinery & equipment, nec Office, accounting & computing machinery Motor vehicles, trailers & semi-trailers Building & repairing of ships & boats Aircraft & spacecraft Railroad equipment & transport equip nec.
Non-metallic minerals: Construction minerals	Mining and quarrying (non-energy)
Non metallic minerals: Industrial minerals	
Non metallic minerals: Other products mainly non-metallic mineral products	Other non-metallic mineral products
Fossil Energy Materials/Carriers	Mining and quarrying (energy) Coke, refined petroleum products and nuclear fuel
Others	Textiles, textile products, leather and footwear Pulp, paper, paper products, printing and publishing Chemicals excluding pharmaceuticals Pharmaceuticals Rubber & plastics products Electrical machinery & apparatus, nec Radio, television & communication equipment Medical, precision & optical instruments Manufacturing nec; recycling (include Furniture)

Table 3-8: Definition of material intensities imports

3.3.2 ANALYSING TIME SERIES AND SETTING CORRIDORS FOR MATERIAL INTENSITY CHANGES

To accommodate the circumstances that the material intensities will not stay constant over the coming years we had a closer look at the time series of the material intensities of domestic extraction used and imports. If the time series had an outlier we corrected the years under consideration to a shorter period of time.

The empirical analysis revealed that in the past 5 to 15 years, material intensity changes were in many cases very high, sometimes up to an average annual change of +/- 10%. As a result of eco innovation we expect reductions of material intensities. But positive changes of material intensities might happen, if the product mix of a sector changes or the material quality of a given product demands more physical input. In order to produce realistic results in the modelled scenarios and to avoid that material intensities approach zero in the year 2030, we decided to implement a corridor of a minimum of -2% p.a. Similarly, avoiding the growth of material intensities to very high numbers, we introduced a threshold of a maximum growth of 2% p.a., in case the past analysis revealed an increase in material intensity. As illustrated in the following subsection, adjustments had to be applied in a large number of cases. This implies that the general trend for increasing or decreasing material intensities observed in the past is represented in the future scenarios, but that the development curve is smoothed towards lower (positive or negative) growth rates.

3.3.3 RESULTS

Domestic extraction used

This subsection provides a short review with regards to categorized material intensity tendencies in domestic extraction used. Detailed data tables can be inferred from Giljum and Lugschitz (2011, Annex 1). Table 3-9 summarizes the final results of their analysis, i.e. annual changes in material intensity recommended for the simulation baseline.

Biomass: Agriculture

The analysis of the material intensity of “Biomass: Agriculture” showed an overall tendency of declining material intensities. Twelve countries had numbers within the corridor, the others had to be corrected.

Biomass: Wood

For the category “Biomass: Wood” the analysis showed a tendency of rising material intensities. For one of the new EU countries the time series was corrected to 1998-2007. Eleven countries had numbers within the corridor.

Biomass: Other

The category “Biomass: Other” provided data for only three countries. All of them showed a tendency of declining material intensities with numbers outside the corridor; therefore, all of them were corrected.

Metal ores: Iron

Data for only four countries was available for the category “Metal ores: Iron”. Two of them showed a declining tendency of material intensity. Overall two countries had numbers within the corridor, the other two values were adjusted.

	Biomass			Metal ores		Non-metallic minerals		Fossil energy materials/ carriers
	agriculture	wood	other	iron	non-ferrous metals	construction minerals	industrial minerals	
Austria	0.4%	2.0%	0.0%	-2.0%	-1.1%	-2.0%	1.5%	-2.0%
Belgium	0.4%	2.0%	0.0%	0.0%	0.0%	-2.0%	0.0%	0.0%
Denmark	-2.0%	1.6%	-2.0%	0.0%	0.0%	0.0%	0.0%	1.9%
Finland	-0.7%	0.3%	0.0%	0.0%	0.5%	2.0%	1.0%	1.9%
France	0.0%	-0.1%	0.0%	0.0%	0.0%	0.3%	-2.0%	-2.0%
Germany	-0.6%	2.0%	0.0%	-0.6%	0.0%	-2.0%	2.0%	2.0%
Greece	2.0%	-2.0%	0.0%	0.1%	0.7%	2.0%	-2.0%	-2.0%
Ireland	-1.9%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Italy	-2.0%	-2.0%	0.0%	0.0%	-2.0%	-0.4%	-1.4%	-1.9%
Luxembourg	1.7%	2.0%	0.0%	0.0%	0.0%	-1.6%	0.0%	0.0%
Netherlands	-0.2%	-0.1%	0.0%	0.0%	0.0%	-2.0%	2.0%	0.1%
Portugal	-1.1%	0.1%	0.0%	0.0%	-2.0%	2.0%	2.0%	0.0%
Spain	-1.6%	1.0%	0.0%	0.0%	-2.0%	0.0%	-2.0%	-2.0%
Sweden	-2.0%	0.6%	-2.0%	1.9%	2.0%	0.0%	2.0%	2.0%
United Kingdom	-2.0%	-0.8%	0.0%	0.0%	0.0%	-0.7%	-2.0%	-0.4%
Czech Republic	-2.0%	1.2%	0.0%	0.0%	-2.0%	-2.0%	-2.0%	-0.3%
Estonia	-2.0%	0.3%	-2.0%	0.0%	0.0%	2.0%	-2.0%	0.8%
Hungary	1.7%	1.0%	0.0%	0.0%	-2.0%	-0.3%	-2.0%	-2.0%
Slovakia	-2.0%	-2.0%	0.0%	0.0%	0.0%	0.3%	2.0%	-1.1%
Slovenia	2.0%	2.0%	0.0%	0.0%	0.0%	-1.7%	-0.6%	2.0%
Weighted average	-0.9%	0.4%	-0.7%	1.4%	0.3%	-0.6%	0.0%	0.1%

Source: own calculations based on EUROSTAT data

Table 3-9: Recommended annual material intensities for used domestic extraction

Metal ores: Non-ferrous metals

The analysis of “Metal ores: non-ferrous metals” showed a tendency of declining material intensities in the EU. For three countries the years used for the time series were corrected. Only one country had a number within the corridor, all others had to be corrected.

Non metallic minerals: Construction minerals

A very mixed picture was observed for “Non metallic minerals: Construction minerals”. For five countries the length of the time series was corrected. After that there was a slight tendency for declining material intensities. Overall four countries had original numbers within the corridor.

Non metallic minerals: Industrial minerals

Also the category “Non metallic minerals: Industrial minerals” showed a very diverse picture. For two countries the years used for the time series had to be corrected. After that about half of the countries showed a tendency of declining material intensities. Three countries of the EU15 had numbers within the corridor, all others were corrected.

Fossil Energy Materials

A slight tendency of decreasing material intensities emerged for the category “Fossil Energy Materials”. For two countries the length of the time series was corrected. Eight countries had numbers within the corridor.

Imports

This subsection provides a short description of the material intensity trends for individual import categories (see Table 3-10). Detailed data tables are again given by Giljum and Lugschitz (2011, Annex 2).

	Biomass			Metal ores			Non metallic minerals			Fossil Energy Materials/ Carriers	Others and Waste
	Agriculture	Wood	Other products mainly from biomass	Iron & Products mainly from iron/steel	Non-ferrous metals & products mainly from non-ferreous metals	Other metals and products mainly from metals	Construction minerals	Industrial minerals	Other products mainly non-metallic mineral products		
Austria	-1.3%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-0.1%	-2.0%	-2.0%
Belgium	-2.0%	-2.0%	-2.0%	-1.5%	2.0%	-2.0%	2.0%	-2.0%	-2.0%	-2.0%	-2.0%
Denmark	-2.0%	-1.6%	-2.0%	-2.0%	1.0%	-2.0%	2.0%	2.0%	-2.0%	2.0%	-2.0%
Finland	-2.0%	1.5%	-2.0%	-2.0%	-2.0%	-2.0%	-1.2%	-2.0%	-2.0%	1.4%	-2.0%
France	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	2.0%	-0.7%	-2.0%	-1.1%	-2.0%
Germany	-1.6%	1.5%	-1.1%	-2.0%	-0.9%	-1.3%	-2.0%	-2.0%	-2.0%	0.6%	-2.0%
Ireland	-2.0%	-0.4%	-2.0%	-2.0%	-2.0%	-0.8%	2.0%	-2.0%	-0.6%	-2.0%	1.1%
Italy	0.2%	-0.1%	-2.0%	-2.0%	0.3%	-2.0%	2.0%	2.0%	-2.0%	2.0%	-2.0%
Luxembourg	-2.0%	-1.0%	-2.0%	-2.0%	-0.1%	0.4%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%
Netherlands	-2.0%	-0.3%	-2.0%	-2.0%	-2.0%	1.5%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%
Portugal	0.1%	-2.0%	-1.4%	-2.0%	-2.0%	-2.0%	2.0%	2.0%	-2.0%	-0.8%	-2.0%
Spain	-0.2%	-2.0%	-2.0%	-2.0%	-1.5%	-2.0%	2.0%	-2.0%	-2.0%	0.7%	-2.0%
Sweden	-2.0%	-2.0%	-1.7%	-2.0%	-2.0%	0.0%	-1.6%	-2.0%	-1.8%	-1.9%	0.2%
United Kingdom	-2.0%	-2.0%	-2.0%	-0.6%	-0.1%	-1.5%	2.0%	2.0%	-2.0%	-0.2%	-2.0%
Czech Republic	-1.8%	-2.0%	-2.0%	-2.0%	-0.4%	-2.0%	2.0%	1.3%	-2.0%	-1.2%	-2.0%
Hungary	-2.0%	-2.0%	-2.0%	-2.0%	2.0%	-2.0%	2.0%	2.0%	-2.0%	-2.0%	-2.0%
Slovakia	-2.0%	2.0%	-2.0%	-2.0%	-2.0%	2.0%	2.0%	-2.0%	-2.0%	-2.0%	-2.0%
Weighted average	-1.4%	-0.8%	-1.8%	-1.8%	-0.8%	-1.4%	0.2%	-0.9%	-1.9%	-0.2%	-1.9%

Source: own calculations based on EUROSTAT data

Table 3-10: Recommended annual changes in material intensity for imports

Biomass: Agriculture

A mixed picture was observed for the material intensities of “Biomass: Agriculture”. Nine out of the 17 investigated countries had increasing material intensities. All time series were corrected to 2000-2006 due to high increases in material intensity between 2006 and 2007. After this correction almost all countries of the EU15 showed a long-term decreasing tendency of material intensities, nine had numbers outside the corridor and were corrected to the corridor minimum. All of the investigated new EU countries showed a decreasing tendency of material intensities after the correction, two of them with original numbers outside the corridor.

Biomass: Wood

The analysis of material intensity "Biomass: Wood" showed a general tendency of declining material intensities. Seven of the EU15 countries had numbers within the corridor. For seven countries the numbers were outside the corridor and had to be corrected. Of the three investigated new EU countries all numbers were outside the corridor and had to be corrected.

Biomass: Other products mainly from biomass

Declining material intensities for all countries were observable for the category "Biomass: Other products mainly from biomass". Three countries had original numbers within the corridor, all others were corrected.

Metal ores: Iron + Products mainly from iron/steel

The analysis of material intensity "Metal ores: Iron + products mainly from iron/steel" revealed declining material intensities for all countries. Two countries had numbers within the corridor, all the others were corrected.

Metal ores: Non-ferrous metals + products mainly from non-ferrous metals

A general tendency of declining material intensities was observed for the category of "Metal ores: Non-ferrous metals + products mainly from non-ferrous metals". Almost half of the EU15 countries had numbers within the corridor. Out of the three investigated new EU countries only one number was within the corridor. All other countries' intensities were corrected to be within the corridor.

Metal ores: Other metals and products mainly from metals

The analysis of "Metal ores: Other metals and products mainly from metals" showed a general tendency of declining material intensities. Six countries of the EU15 had numbers within the corridor, all three of the investigated new EU countries had numbers outside the corridor and were corrected.

Non metallic minerals: Construction minerals

A mixed picture of increasing and decreasing tendency of material intensities occurred in the analysis of the category of "Non metallic minerals: Construction minerals" for the EU15 countries. Only three countries had numbers within the corridor. All of the three investigated new EU countries showed increasing tendency of material intensities with numbers outside the corridor.

Non metallic minerals: Industrial minerals

The analysis of "Non metallic minerals: Industrial minerals" for the EU15 countries revealed a general tendency of declining material intensities for this import group. Except one, all countries had numbers outside the corridor. Out of the three investigated countries of the new EU two had increasing material intensities, one of them with a number within the corridor.

Non metallic minerals: Other products mainly non-metallic mineral products

All analysed countries had declining material intensities in the category of "Non metallic minerals: Other products mainly non-metallic mineral". Only three of them had numbers within the corridor, all others were adjusted.

Fossil Energy Materials/Carriers

An overall tendency of declining material intensities could be observed in the analysis of “Fossil energy material/carriers”. Nine of the 17 investigated countries had numbers outside the corridor and were adjusted.

Others and Waste

The analysis of “Other and waste” showed a general tendency of declining material intensities. Two of the 17 investigated countries had numbers within the corridor.

Overall the analysis of material intensity trends over the past 5 to 15 years revealed that the trends for different categories and countries were very heterogeneous. For many resource categories, material intensities were increasing for some EU countries and decreasing for others. This can be explained by the fact that the investigated material categories were defined quite broadly and that different countries can face different developments within each material group. For example, the extraction in the category of agriculture comprises a huge number of different products, from low-price cereals and fodder crops to high-price vegetables or fruits.

In addition the available time series were relatively short and in many cases needed to be adjusted in order to eliminate outliers, with implications for the recommended de-coupling factor. However, working with the data available and introducing a corridor for the annual change of material intensity still leads to more realistic results than using constant factors of material intensities from the last available year (2007) for the scenario simulations until 2030.

3.4 THE MATERIAL MODULES OF THE MODELS

3.4.1 THE MATERIAL MODULE OF GINFORS

At the beginning of the project the material module of GINFORS considered domestic extraction only (Lutz et al. 2010, Barker et al. 2011). Thus, indirect flows associated with material inputs of a region could only be identified in relation to a reference. In the context of the MACMOD project this is a problem since the level of direct and indirect material inputs in Europe is in the focus of the project. Therefore it was decided to replace the existing material module by a system that is based on the TMR data for Europe produced in the project.

This new module applies a straightforward modelling approach (Distelkamp 2011): The material intensities are taken as variables that are historically explained and forecasted by trends. Multiplication of these trends with its economic drivers gives the material input in tonnes.

Domestic extraction is driven by gross production of the extracting economic sector in constant prices. This figure is derived via the input output connections with the economic activity of all other sectors in the economy. So every change in final demand and in the structure of production (represented by the input coefficients) and in import substitution finds automatically its appropriate impact on material extraction.

Imports of materials are driven by their equivalent product group in monetary terms at constant prices. These imports are related to final demand and via shares to intermediate and final demand, so that also here every change in economic activity and especially in international competition gives an impact on imported materials.

3.4.2 THE MATERIAL MODULE OF E3ME

In the case of E3ME a different situation is given. E3ME has already a material module for the calculation of DMI, which includes domestic extractions and imports of materials and those that are directly part of imported goods (Cambridge Econometrics 2011a). The database for this material module is the MFA data from EUROSTAT. Two reasons speak for an extension of the system and not for a substitution by a new one: First the equations for material inputs can easily be extended by factors for unused extraction and hidden flows from abroad to achieve TMR. Secondly the material module is linked with the energy module of E3ME, which means that a replacement of the existing system would have severe consequences for the whole model.

E3ME covers the following materials:

Food, feed, wood, construction minerals, industrial minerals, iron ores, non-ferrous ores and unallocated. Water is considered separately.

SECTORAL LINKS		
Material	Domestic Extraction Sector	Imports Sector
1 Food	01 Agriculture	05 Food
2 Feed	01 Agriculture	01 Agriculture
3 Wood	01 Forestry (part of agriculture)	01 Forestry (part of agriculture)
4 Construction Minerals	04 Other Mining	04 Other Mining
	13 Non-Metallic Minerals	13 Non-Metallic Minerals
5 Industrial Minerals	04 Other Mining	04 Other Mining
	11 Chemicals (exc pharm)	11 Chemicals (exc pharm)
	13 Non-Metallic Minerals	13 Non-Metallic Minerals
6 Iron Ores	04 Other Mining	14 Basic Metals
7 Non-Ferrous Ores	04 Other Mining	14 Basic Metals
8 Water	24 Water Supply	-

Note(s) : E3ME's "Agriculture etc" sector is split into agriculture, forestry and fishing, pending revision for NACE revision 2 data.

Table 3-11: Sectoral links in the material module of E3ME

As a sectoral model, where aggregate results reflect the sum of activities within the sectors, the sectoral linkages play a key role within the overall modelling framework of E3ME. A lot of effort was therefore put into setting up these linkages. Even so, there are cases where it was necessary to make arbitrary assumptions.

The two key links are on the demand side, linking material user groups to industry sectors (plus households) and on the supply side, linking materials to their production industries.

As E3ME uses input-output tables that combine domestic production and imports (subsequently counting imports as a negative demand) the closest MFA indicator is Direct Material Input (DMI). The series for DMI therefore provide the totals that are allocated to sectors, described above. It should be noted that there is an inconsistency in the fuel links as the fuel consumption data are consumption based and do not include exports. This is not a major issue in most European countries, but does have an impact in Norway, due to oil exports.

The links on the demand side are relatively straightforward, as the Material User classification was designed to take this into account. The supply-side links are more problematic, however, as these must link two large data sets based on different definitions and units.

Table 3-11 gives just a summary of the sectoral links. This is the most complex part of the modelling and the underlying theory, the split between domestically extracted and imported materials and the necessary assumptions is explained in detail below.

E3ME already includes links between the fuels and the fuel sectors so the additional link required is between the main fuel classification and the fuels as defined in the materials data set (solid, liquid and gas). This is fairly trivial and assumes a constant ratio between weight and energy content. The category "Products mainly from fossils" is added to solid fuels.

The materials submodel consists of eight sets of equations (including water), estimating demand for each of the material groups. Separate model routines include the fuel converters and feedback links to the main economic model.

Following the existing framework of E3ME's fuel demand equations, material demand (defined as DMI) is modelled as a function of economic activity, material prices and two measures of innovation (investment and R&D spending). An additional variable to take into account the differences in definition between domestically extracted and imported materials has also been added.

For each material an equation was estimated for the 14 user groups (excluding unallocated) in each country, meaning that a total of up to 2,842 new equations were estimated. However, in reality a large proportion of these equations are not used as not all the material user groups demand all the materials. For example, construction is the only user group to demand construction minerals.

Equation parameters are estimated empirically on the basis of historical annual time series, mainly covering the period 1970-2007 (when materials data were available). Key price elasticities were imposed following a more in-depth analysis of results (see Section 5.3), but otherwise the only restrictions on the parameter coefficients were on the direction of the responses. These were a positive sign on the economic activity indicator, a negative sign on the price variable, and negative signs on the innovation measures as processes become more efficient. The imports ratio is fixed to take into account the relatively higher weight of domestically extracted materials.

Even without the additional materials submodel, E3ME includes measures of material demands, in economic terms. These are applied through input-output (IO) relationships which, for each economic sector, determine the necessary inputs from all other sectors to produce one unit of output. When the inputs come from sectors that provide raw materials, this gives a measure of the material requirements and, when multiplied by total output, overall material demands.

Input-output tables are exogenous in the modelling meaning that, relative to overall output levels, material demands are fixed. This means, for example, that if the prices of minerals doubled, the construction industry would still demand the same amount of cement (relative to output) rather than use cement more efficiently.

Including the materials equation sets allows this assumption to be relaxed, effectively making these input-output relationships endogenous in the modelling. This has previously been implemented in the energy sectors but it should be noted that this represents a highly ambitious aspect to the modelling, moving away from the traditional fixed Leontief input-output structure. For a detailed discussion of some problems see Cambridge Econometrics (2011b, pp. 8).

The basic assumption behind changing the IO coefficients is that, for a given level of output and price, there is a one-to-one relationship between physical material demands and economic transactions. For example, a 10% increase in the construction industry's demand for construction minerals will cause the IO coefficients from the other mining and non-metallic mineral products sector to construction to increase by 10%.

The validity of this assumption and the suitability of applying economic (monetary) IO tables to modelling physical demands is discussed in depth in Weisz and Duchin (2006). However, in the case of E3ME and forging the links between economic and physical demands, there is no obvious alternative approach, and it seems reasonably accurate and realistic an approach for the purposes of the modelling.

3.4.3 A COMPARISON OF THE MATERIAL MODELLING APPROACHES OF E3ME AND GINFORS

Both models explain TMR in detailed sectoral disaggregation for different kinds of materials. But the way how they do this is quite different. E3ME follows a modelling strategy that bas been chosen already for energy modelling in E3ME and GINFORS (Barker et al. 2010, Lutz and Meyer 2009). The EUROSTAT DMI data that is the basis (extended with "rucksack" factors) is available as time series information for all European countries. With the sectoral allocation of the data it is possible to estimate typical input functions with the economic activity of the driving economic unit (domestic production or imports) and the relative price of the material as the central variables. In this way the necessary flexibility of structures for policy analysis is achieved. Since the input output relations also give material inputs – not in physical but in the closely related monetary values at constant prices – there is an inconsistency. This is corrected adjusting the material input coefficients of the I/O matrix to the movement of the material demand functions, which is done not without allocation problems (Cambridge Econometrics 2011b, pp. 8). In this way those parts of the input output matrices can be endogenized that are essential for environmental analyses. This was a big advantage as long as input output tables have been available only for single years.

The GINFORS modelling approach of material inputs gets its flexibility from variable input output structures, which can be derived from Member States' time series of use tables. As will be shown later, the input output coefficients are directly econometrically estimated and get from there the needed flexibility of structures, which are transferred to production and import figures that are the drivers of physical material inputs.

4 MARKET FAILURES AND THEIR CORRECTION BY AN INFORMATION PROGRAM

4.1 MARKET FAILURES

Bleischwitz and Ritsche (2011) reveal that a number of market failures are relevant for the performance of the EU towards achieving the 2020 strategy and its resource efficiency flagship project.

Negative externalities matter in regards to environmental impacts and problem shifting from the EU abroad that can be associated with the use of natural resources. There is evidence that the EU increasingly shifts such environmental burden abroad.

Collective goods matter in regards to raw materials security, competition for natural resources and international trade distortions, conflicts over access (usually in Developing Countries). Evidence is robust that these issues have become more severe over the last ten years when raw material prices have started to soar (the financial crisis has marked a temporary break).

The “classical” market failures call for international mechanisms and policy approaches, where the EU should agree with main mining countries and other relevant countries on appropriate steps. In other words: this is a task where the international dimension is especially relevant.

It needs to be emphasized that the current pitfalls of these failures also hinge on domestic approaches. The impacts on European business are manifold: price distortions and volatility, uncertainty in the supply chains of minerals, dumping practices that put eco-innovation at risk, reputational risks for companies being unaware of illegal practices abroad. Thus, pursuing international action should be seen as a European interest that can be aligned with interests of others and global concerns.

A strong conclusion is that policies matter. Despite the argument that increasing commodity prices will deliver resource savings, both theoretical and empirical evidence suggests that this incentive alone is unlikely to be translated into continuous and far-reaching resource efficiency performance improvements. It is even less likely to stimulate product innovation and system innovation that help to reduce the use of primary materials in the EU.

Overall, the enormous importance of externalities, information deficits, adaptation and coordination deficits are highlighted, both from a theoretical and an empirical perspective:

- Positive externalities associated with eco-innovation that pose barriers to entrepreneurs and product innovation,
- Wide-spread information deficits as regards to potentials for saving material purchasing costs within companies and across industries,
- More fundamental information deficits concerning uncertainties about future demand for new eco-innovations, including in critical areas such as construction,

- Adaptation and coordination deficits with regard to existing market power, path dependencies and difficulties to finance mass market development of radical innovations.

These deficits culminate in a lack of orientation about general pathways and directions for natural resources, e.g. any complement to the commitment of reducing CO_2 emissions by 80 – 95 % by the year 2050, synergies and trade offs between resource efficiency and climate policy.

Given stronger barriers against product innovation and system innovation, more stringent measures may be needed in areas such as material intensity standards, supply chain management, financing and mass market development. Certainly, a coalition with business that facilitates improving their resource efficiency performance should be a top priority. For example:

- Infrastructure redesign requires specific attention in regards to public planning, urban mining, re-use of construction waste etc.
- Formulating targets would provide orientation for market actors.
- A strong role for prices as determinants for innovations –this will at least partly come from markets. However, economic incentives will also be needed to stabilize expectations and to bridge the coordination gaps between diverse actors. They may also play a macro-economic role for example through a shift from labour-based taxation regimes to resource-based ones, and as provider of revenues that finance investments and help to lower public deficits. More detailed analysis will be needed to design such appropriate incentives.

4.2 THE IMPACT OF AN INFORMATION AND CONSULTING PROGRAM

Background

The existence of market failures is the supposition for the success of consulting firms. In the case of material efficiency a broad literature describes this success, which means for manufacturing as the customers of the consultants a win- win situation with falling costs and rising material efficiency: ADL, Wuppertal-Institut, ISI Fraunhofer- Institut (2005), Fischer et al. (2004) and Kristof et al. (2008) estimate the potential for material savings to range between 10% and 20%. Similar results have been reported by Oakdene Hollins (2011). Fischer et al. (2004) estimate that a 20% reduction of material cost is possible through an information and consulting program for firms costing the savings of one year.

So after one year firms have a permanent surplus and there is a reduction of material use which diminishes the pressure on nature – a typical win-win result. The German official material efficiency agency demea (2010) reports that small and medium sized firms joining their information and consulting program could, on average, raise their profits by 2.4% of their respective sales.

Based on these experiences Meyer et al. (2007) and Distelkamp et al. (2010) have presented model simulations for Germany with the model PANTA RHEI in which all input coefficients for materials (Distelkamp et al. 2010) or for materials and energy (Meyer et al.

2007) have been reduced in manufacturing by the same amount at the costs described by Fischer et al. (2004). In the MOSUS project this has been done with the model GINFORS in the European context (Giljum et al. 2008). But here the modelling of material was restricted to domestic extraction. The results showed a huge potential for the reduction of resource consumption combined with a strong rebound effect from cost reductions that create economic growth.

Scenario Modelled

GINFORS is used to model a scenario based on the background information set out above (Distelkamp et al. 2011a) assuming that such an information and consulting program would be installed for material and energy inputs in 18 European countries. These 18 countries cover 95 % of GDP of EU27. Insofar the simulation results for an information and consulting program in all 27 European countries will not be much different from the results presented here. It is assumed that:

- all manufacturing firms in the 18 European countries achieve an improvement of their material and energy costs of 20 %.
- In the case of materials necessary expenditures for consulting services for the implementation of the achieved efficiency improvements should equal the savings generated within a one year horizon.
- In the case of energy the costs are equivalent to the savings of six years.
- Each year 5% of firms are reached by this information program. Thus, it needs from 2011 till 2030 about 20 years to see the full effect in the economy.

The simulation has to be interpreted as a modelling experiment, which follows the information of the consultants about the direct impact on the structure of production as far as possible. Insofar a model version has been used in which the input coefficients have been changed only by the scenario assumptions.

The improvement of material efficiency has a clear direct effect: the consumption of material will be reduced. The economic situation is more complicated: On the one side sales of the firms that produce materials will sink, on the other side the production costs of firms that use materials as inputs will fall.

Cost reductions have a lot of indirect effects: not assuming perfect markets, prices will fall less than costs which induces additional value added in those branches which dematerialise their production. Thus, in case of these firms productivity rises which will have a positive impact on wages. However, on the other side a coincidental negative impact applies on wages as prices tend to be lower in the alternative scenario than in the baseline scenario.

Lower prices induce higher demand via rising exports, falling imports, and rising domestic consumption because of rising real income. Furthermore, domestic demand is positively affected by the push on value added of those firms who are dematerialising their production. Those firms will expand their material demand which represents the rebound effect.

We start with a closer look at Germany in Table 4-1. For the understanding of the macroeconomic effects it is central to start from the rise of value added (+7.3% in constant prices) compared to the baseline in the year 2030. All figures in the following argumentation have this reference. Since on the one side value added is not distributed completely to the households and since consumer prices fall less than producer prices, disposable income in constant prices of private households rises by 6.3% which raises private consumption in constant prices by 6.1%. Tax income of the government in constant prices rises by 5.4%, but public consumption will expand in constant prices only by 1.1 % because the public services (internal security, external security, jurisdiction, administration, education) are less income elastic than private consumption. Consequently the government realises savings that reduce public debt. Real gross fixed capital formation rises by 5.5%.

Value added in constant prices	+ 7.3
Disposable income of private households in constant prices	+ 6.3
Tax revenue in constant prices	+ 5.4
Consumption of private households in constant prices	+ 6.1
Public consumption in constant prices	+ 1.1
Gross fixed capital formation in constant prices	+ 5.5
Exports in constant prices	+ 5.4
Imports in constant prices	- 1.7
GDP in constant prices	+ 8.6
Gross production in constant prices	+ 1.2
Total material requirement	- 10.1

Table 4-1: The impact of improved material efficiency on selected macro indicators in Germany. Deviations from the baseline in the year 2030 in percent.

The other components of GDP (see table 4-1) are affected in a different way. Exports rise by 5.4% due to the falling prices in manufactured goods. Imports fall less (-1.7%) because of two effects: On the one side we observe improved competitiveness on international markets for manufactured goods and falling imports of resources like metals, non metallic minerals, and biomass; on the other side rising real GDP induces more imports. The impact on imports in the stand alone simulation for Germany (Distelkamp et al. 2010) is much higher (-10.7%), because now (in the EU simulation) the German competitors in the EU are also able to reduce their prices.

Gross production in constant prices will be 1.2% higher than in the baseline scenario because the positive effects in export intensive and consumer oriented branches over-compensate the negative effects coming from the material producing branches.

Resource efficiency rises by 18.7%, which is much stronger than the rise in GDP (8.6% in constant prices). This allows a reduction of total material requirement by -10.1%. So the information and consulting program produces indirectly a strong rebound effect, which pushes GDP, but the direct material efficiency gain is even much stronger.

Overall these results appear similar to a previous German simulation exercise based on the national model PANTA RHEI (Meyer et al. 2011). However, given that the German economy is characterized by a rather large manufacturing sector, one might have expected smaller effects for other European countries. Surprisingly, our simulation study indicates the second smallest positive effect on GDP and a rather strong negative impact on total material requirement for Germany (Table 4-2). Thus, our results imply rather weak rebound effects in case of the German economy in comparison to other European countries.

	TMR	Real compensation of employees	Real GDP	Priceindex of GDP	Real exports	Real imports
Austria	-9.1	12.9	10.6	-18.0	10.1	-2.4
Belgium	-4.0	23.0	20.3	-27.3	17.1	0.7
Luxembourg	-7.7	28.3	28.5	-28.1	19.1	6.3
Denmark	-9.2	8.5	10.4	-15.8	12.0	-1.4
Finland	-10.9	16.4	15.6	-19.0	15.9	-5.4
France	-5.0	16.5	13.4	-20.4	20.4	-3.7
Germany	-10.1	9.4	8.6	-12.5	5.5	-1.7
Greece	-11.0	9.9	13.5	-21.6	13.9	-2.0
Ireland	-12.0	19.0	15.9	-26.8	11.0	-3.7
Italy	-15.9	12.4	10.0	-23.6	23.2	-6.6
Netherlands	-7.3	17.0	18.9	-27.4	16.3	-5.2
Portugal	-5.3	15.8	15.2	-24.1	16.9	-6.1
Spain	-10.5	15.3	20.2	-28.7	24.2	-4.7
Sweden	-8.7	6.0	5.1	-15.8	8.3	1.9
United Kingdom	-6.1	10.5	11.8	-15.4	10.6	1.2
Czech Republic	-7.9	37.6	35.7	-38. 5	22.3	-4.0
Hungary	-3.8	41.7	43.0	-44.0	32.2	-3.6
Slovakia	1.8	47.8	40.3	-42.0	29.1	8.4

Table 4-2: The effects of an improved material efficiency on TMR in tons, and macroeconomic variables in monetary terms and constant prices in 18 European countries. Deviations from the baseline in the year 2030 in percent.

This incidence indicates that total size of the manufacturing sector is not solely responsible for the simulation results. The size of the rebound effect in the simulation is depending from the share that materials and energy have in the cost structure of the different manufacturing sectors. This share depends from three determinants: The first is the position of the sector in the structure of production of manufacturing. Are finished products made like cars and machinery or is it steal, metallic products, ceramics etc.? Finished products have much higher shares of services, labour and capital. The second point is which qualities of the product in question are given. Is it a high-tech product or standard product? This point counts for all stages of production. It is not only relevant for cars and machinery, it is also important for steal making and ceramics. The third point is the importance of the market failure itself. There may be a variety in the different European countries. It can be assumed that in the former transition economies these market failures are bigger than in other economies. If we agree that the German economy is producing to a large extent finished manufacturing goods like machinery and cars with a high technological standard, the result is no longer surprising.

A further conclusion of the simulation is that an information and consulting program for the improvement of resource efficiency is helpful to reduce resource consumption in

Europe, and it will also improve economic efficiency especially in countries with lower income and insofar will contribute to a more harmonized economic development in Europe.

USA	- 2.6
Canada	- 2.3
Japan	- 1.6
China	- 1.3
Russia	- 1.1
India	- 1.1
Australia	- 1.6
South Africa	- 3.6

Table 4-3: The impact of an improved material efficiency in Europe on real GDP of selected trade partners. Deviations from the baseline in 2030 in percent.

A regards the rest of the world (ROW), a rise in European competiveness tends to reduce ROW-exports and to increase ROW-imports. Thus, we have to expect negative impacts on overall economic performance in these countries. In this regard, Table 4-3 exemplarily provides real GDP simulation results for some selected countries.

One might criticize the assumptions about market failures and the possibility of their correction. Is a permanent reduction of 20% of material inputs possible with only temporary additional costs for services – as consulting firms assert – or is it only an 8 to 10% reduction of material costs – as the governmental institution demea argues? A first comment is that even half of the impact remains a huge result. The central question though is whether there are market failures or not that can be corrected by instruments of information which in any case defines a cheap policy. The literature answers this question with a very clear “Yes” (Bleischwitz and Ritsch 2011).

5 THE ENDOGENIZATION OF INPUT COEFFICIENTS – CHECKING IF THE DATA SUGGESTS WIN-WINS ARE POSSIBLE

The analysis of the impact of an information and consulting program in section 4 can be interpreted as a modelling experiment, in which the insights of consulting firms about success and costs of improvements of material efficiency have been assumed for all material and energy inputs in the whole manufacturing sector. For that exercise the assumption of only scenario driven exogenous input coefficients was appropriate. But for a general policy debate we can not assume that the coefficients are exogenous. The task is to endogenize the input coefficients. This is done, essentially, to see if the data in the model supports the bottom-up conclusion (from section 4) that material efficiency can be improved whilst also improving profitability.

Background

According to neoclassical theory input coefficients are the result of the optimization of factor demand under substitutional production functions. The reduction of one coefficient will induce the rise of at least one other and must produce costs because the optimality is disturbed. But in reality this is not the whole story; relative prices play of course a role in real factor allocation, but there are also other influences: As was already discussed in section 4 we should bear in mind that market failures might hamper optimal conditions to take effect. Historically material consumption will not have attracted the main attention of management boards and controlling systems as material prices exhibited cyclical movements rather than sustained upswings. The latter is a new experience of the last years. So, poor information might induce notable market failures which avoid an efficient use of resources.

Further there may exist limitational relations between product design and specific inputs, because especially material inputs are a physical part of the product (Georgescu-Roegen 1990). So we cannot argue that even in the absence of waste a reduction of a specific material input necessarily induces more input from another factor of production in the sense of a movement on the isoquant, because with the change of material inputs we are facing a different product. A change in the product mix of the sector may allow a reduction of the input coefficient in question without a change of other inputs.

From that theoretical point of view we have to be open for independency, negative and positive correlations (i.e. substituting and complementary goods) between input coefficients. But market failures as well as the degrees of freedom in product design and product mix provide strong arguments in favour of the occurrence of win-win situations.

However, the MACMOD project was not intended as an exhaustive empirical analysis of the interdependences between thousands of coefficients per Member State. Thus, our modelling approach relied on previous empirical findings indicating that only a relative small amount of input coefficients seems to trigger economy-wide material consumption patterns.[1]

Apart from distinct price elasticity estimates, all regression analyses were thus closely related to the seminal approach of Distelkamp et al. (2005) who identified a set of 30 material important input coefficients. However, their study was rooted on the European CPA/NACE classification. Thus, their initial list of 30 important input coefficients also had to be rearranged to a STAN compatible regressor set. Due to the explicit distinction of the STAN classification between “Mining and quarrying (energy)” and “Mining and quarrying (non-energy)” our final regressor set under investigation therefore comprised 37 material relevant input coefficients (see appendix B for details).

With regards to related model enhancement works we had to decide whether to model identical input-interrelationships across countries or to model individual interrelationships per Member State. Whereas an integration of identical input-interrelationships across

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[1] See appendix B for further information.

countries would have diminished our related model enhancement works significantly, this approach might have resulted in biased simulation results at the Member State level. In this regard we had to settle the question whether the observed differences in national input-interrelationships appeared statistically negligible or not.

Econometric methodology offers the panel estimation technique as a powerful tool for exposing this issue. Basically, panel estimates can be understood as representing identical correlation patterns across individual units of analysis (i.e., Member States in our case). Moreover, they enable researchers to tackle the task of uncovering the significance of individual departures from these "averaged" correlation patterns by means of statistical testing procedures. Our empirical work thus initiated from a multi country panel analysis as illustrated within subsection 5.1. These preliminary analyses indicated that the simulation models should incorporate country specific instead of cross-country "averaged" estimates of input interrelationships.

Yet, econometric theory also offers a wide range of methods for the required time series analyses on Member State levels. Being interested in deriving significant qualitative findings we thus decided to account for this methodological plentifulness as far as possible. See sections 5.2 and 5.3 for brief representations of applied algorithms for the derivation of country-specific elasticity estimates. Overall, the common findings of these individual approaches should be understood as a special feature of our study (common qualitative findings emerging from individual methodological frameworks appear more reliable than a single result derived within a single framework).

5.1 A MULTI COUNTRY PANEL ANALYSIS

The paper by Meyer and Meyer (2011) reports the empirical findings of comprehensive multi-national European regression analyses: Elasticity-estimates between material important coefficients and the remaining other input coefficients of a given sector have been derived by means of panel econometric methods. As will be shown, these thorough regression analyses cannot rule out the possibility of win-win situations where a reduction of material inputs comes along with a reduction of costs.

5.1.1 DATA

Input-output tables for European countries are not available as time series with a length that would allow econometric analyses. But all European countries offer make and use tables that show the outputs (make tables) and the inputs (use tables) of product groups in institutionally defined economic sectors for the period 1995 to 2007. For our purpose the use tables provide relevant information for the inputs of 60 intermediate factors and labour as well as gross production of the sector in current prices. In the ideal case one could observe 13 annual observations per variable. However, not every country provides complete datasets. We therefore decided to restrict our preliminary panel analyses to a 17 country-sample. Given that the selected Member States did not represent homogenous economies we decided to categorise their individual country data in accordance with their respective national manufacturing-output shares. Thus, our statistical analyses have been applied to the following panel data sets:

- Panel I: Czech Republic, Finland, Germany, Hungary, Ireland, Estonia, Slovakia, Sweden.
- Panel II: Austria, Belgium, Denmark, France, Greece, Luxembourg, Netherlands, Portugal, United Kingdom.

The relevant data pre-processing transformations with regards to the use tables can be summarised as follows: In a first step nominal input coefficients have been calculated directly from the use tables. This has been done for all intermediate inputs and the labour input. In a second step input coefficients in constant prices have been calculated by dividing nominal inputs and output by their respective price indices. In order to satisfy reliable statistical inference cases of very low real input coefficients, i.e. coefficients not exceeding a threshold value of 0.0001, were omitted from our database. Finally, indices of the compensation for employees per employee data have been calculated in order to denominate the corresponding labour inputs.

Prices for intermediate inputs have been taken from the OECD STAN data set, which rests on a sector classification comparable to those of the use tables. Problems occurred only in the following situations: In two cases the sector/product group of the use tables are an aggregate of two or three STAN sectors. In these cases an average price has been calculated. In five other cases the sectors of the STAN data set do effectively represent an aggregate of two or three individual sectors of the use tables. In those cases the aggregate price had to be allocated to each of the corresponding use sectors.

In accordance with the relevant discussion on the inception meeting (see the inception report) our capital data has been taken from the KLEMS data set. Capital input coefficients in constant prices have been calculated by dividing volume inputs of capital by gross production indices in constant prices. However, we have to report that individual sector allocations happen to appear far from obvious as the underlying classifications differ to a significant extent between the KLEMS and the input-output data set.

5.1.2 METHODOLOGY

For any individual panel estimation the task of selecting an appropriate statistical representation initiated from a fixed effects regression setup as follows:

With regards to the Eurostat use-tables classification a selected material relevant input coefficient might be identified by its row-index r^* together with its corresponding column-index c (both ranging from 1 to 59).[1] Given a historical time series of material relevant input coefficient observations io^{r^*c} we have been interested in estimating bivariate correlations between io^{r^*c} and each of the remaining input-coefficient series (including capital as well as labor inputs) of industry c. The nucleus of our regression setup might therefore be illustrated as

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[1] Occasionally available information with regards to financial intermediation services indirectly measured (FISIM, column 60 of the Eurostat use-tables) have been omitted from our analyses.

(1) $$io^{rc}_{i,t} = \alpha_0 + x'_{i,t}\beta + u_{i,t}, \qquad r = 1 \ldots 61, \qquad r \neq r^*,$$

with $io^{rc}_{i,t}$ denoting the natural logarithm of an arbitrary input coefficient (including capital as well as labor inputs) at date t in country i, vector $x'_{i,t}$ merging the natural logarithm of the selected material relevant input coefficient with the natural logarithm of the relative price of $io^{rc}_{i,t}$

(2) $$x'_{i,t} = \left(io^{r^*c}_{i,t}, p^{rc}_{i,t}\right),$$

and $u_{i,t}$ denoting an error term.

Note that equation (1) imposes the restriction of equal elasticities (i.e., equal β's) across all sample countries in absence of any further (country specific) effects. It seems reasonable to ask whether this supposition might be falsified by empirical evidence. Thus, our specification algorithm was indeed arranged as a general to specific procedure. Our most general specifications incorporated country as well as time specific fixed effects

(3) $$io^{rc}_{i,t} = \alpha_0 + \delta_i + \gamma_t + x'_{i,t}\beta + u_{i,t},$$

with scalar δ_i combining the country specific effects of country i (i.e., the individual departure of country i from the conditioning intercept α_0),[1] and scalar γ_t accounting for remaining time specific effects not captured by the vector of regressors x'_{it}. Our first specification test considered the joint significance of all io^{r^*c} and p^{rc} observations in the results of a pooled least squares estimation of equation (3) by means of a conventional F-test. Only if both variables happened to appear jointly significant at a 10% we continued our specification search with a similar F-test for the joint significance of all γ_t parameters. If this exclusion test indicated significant time effects at the 10% level we decided to continue our analysis within the fixed effect framework of equation (3).

Otherwise, we applied a further exclusion test for the joint significance of the individual country effects in the results of a pooled least squares estimation of equation (4).

(4) $$io^{rc}_{i,t} = \alpha_0 + \delta_i + x'_{i,t}\beta + u_{i,t}$$

If this exclusion test indicated significant country effects at the 10% level we decided to estimate a fixed effect panel model in accordance with equation (3). Otherwise, we decided to apply the restricted framework of equation (4).

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[1] Given a panel of n individual country sets, only n–1 δ_i parameters can be identified by this estimation approach. Thus, parameter α_0 has to absorb the individual effects of the omitted n-th country. Nevertheless, we decided to encode any of our tested model specifications in accordance to the notation of equation (3) as the inclusion of an overall intercept α_0 facilitates a straightforward application of standard F-Tests.

The specification tests considered so far relied on straightforward applications of conventional F-tests in a fixed effects regression setup. Random effects estimators represent the natural alternative to the fixed effects approach. Yet, given that random effects estimators suffer from inconsistency in presence of correlations between regressors $x'_{i,t}$ and country specific effects, we preferred to base our preliminary analyses on the just mentioned fixed effects framework. Nevertheless, whenever applicable, the selected specification we checked the discrepancies between a fixed effects and a random effects estimation by means of a Hausman test (see Hausman 1978 for details). If these discrepancies did not seem to be significant at the 10% level we re-estimated the selected specification with random effects methods as these are known to yield efficient estimates as far as $x'_{i,t}$ does not correlate with individual country specific effects. Finally, we tested for the individual significance of the $io^{r^{*}c}$ and p^{rc} variables. If the material relevant coefficient did not appear significant we omitted to report any estimation results. If the relative price was insignificant, we re-estimated the chosen specification with the price variable excluded.

The model selection and estimation algorithm has been implemented within the statistical programming environment R. Inference was always based on heteroskedasticity robust standard errors according to MacKinnon and White (1985) and Driscoll and Kraay (1998) with the lag of the selected resource relevant input coefficient being incorporated as instrumental variable. On the model selection stage the least squares testing procedures were based on repeated applications of the “dynlm”-library. Finally reported results are based on the estimators of the “plm”-library.

5.1.3 RESULTS

We decided to judge our widespread indications of input correlations on the basis of theoretical plausible supply chain considerations. Due to space constraints we omit a detailed replication of the corresponding explanatory notes (see Meyer and Meyer (2011) in this regard). Instead, this subsection summarizes some descriptive statistics of the overall findings.

For a given panel data set the task of examining bivariate correlations for each of the 30 material relevant input coefficients with the remaining 58 intermediate input coefficients as well as with the capital and labour input coefficients of the concerned sector results in a maximum of 1800 analyses. However, as some of the analysed time series did not provide sufficient observations for our regression analyses (missing or confidential information) the actual number of performed analyses was slightly lower.

As regards the link between material relevant input coefficients and capital utilisation we have to state that hardly any of our regressions ended up with significant estimates. In light of the substantial amount of significant labour input elasticity estimates this might appear astonishing. However, given that investment decisions usually evolve over longer time horizons it might well be the case that it is simply impossible to observe relevant capital coefficient variations within our sample period. Furthermore, we have to note that our measures of capital utilisation could not be directly derived from the harmonised Eurostat dataset (as was the case with the labour input coefficients). Thus, eventually, these estimates might also have suffered from fundamental data problems. All things considered we thus decided to omit a presentation of the set of results with regards to capital utilisation. Nevertheless, our inconclusive findings are of course also available on request.

For the intermediate coefficients the following results have been achieved:

	number of regressions	number of significant β_1		number of significant $\beta_1 > 0$		number of significant β_2	
		total	as percentage of number of regressions	absolute	as percentage of number of significant $\beta 1$	absolute	as percentage of number of regressions
Group 1	453	273	60,26%	112	41,03%	400	88,30%
Group 2	271	175	64,58%	71	40,57%	231	85,24%

Table 5-1: Overview on results for intermediate coefficients

Some elementary summary statistics can be inferred from Table 5-1: Effectively 453 regressions passed the model specification algorithm in panel 1 (271 in panel 2). The difference in both panels fits with the expectation, because panel 2 consists of the countries with less manufacturing. At the 10% level about 88% of the regressions in panel 1 provide significant price elasticities and about 60 % provide significant cross elasticities with the important input coefficients. Finally, about 41 % of these significant cross elasticities happened to be positive. The results for panel 2 are quite close to this.

Information with regards to the frequency distribution of the elasticities is given in the histograms of Figure 5-1 (panel 1) and Figure 5-2 (panel 2). In both cases we approximately face Gaussian normal distributions with a slightly negative mean close to zero. Negative cross elasticities – representing situations where a reduction of an important coefficient will raise other input coefficients – do represent the larger fraction of our significant estimates.

However, detailed analyses indicated that this effect might especially arise in case of the main diagonals and must therefore be interpreted with care. Main diagonal elements are inputs of the same kind as the product. In many cases this indicates imports of the good in question. If now such a main diagonal input coefficient has a negative elasticity with one of the important material inputs, this can not be interpreted as factor substitution. A reduction of the material input means a rise of imports with the implication of less domestic production. So in this case we are measuring import substitution of the product and not factor substitution.

The dominance of positive or zero cross- elasticities for important off- diagonal coefficients indicates a noticeable potential for win-win situations in cases of rising resource productivity. This is in line with the central message of the MaRess project that rising resource productivity reduces the costs of firms (Hennicke et al. 2011).

However, the overall findings apparently illustrated significant differences in results between both panels. This suggests that country specific estimates should be incorporated into the models. The following subsections summarize the corresponding model enhancement works.

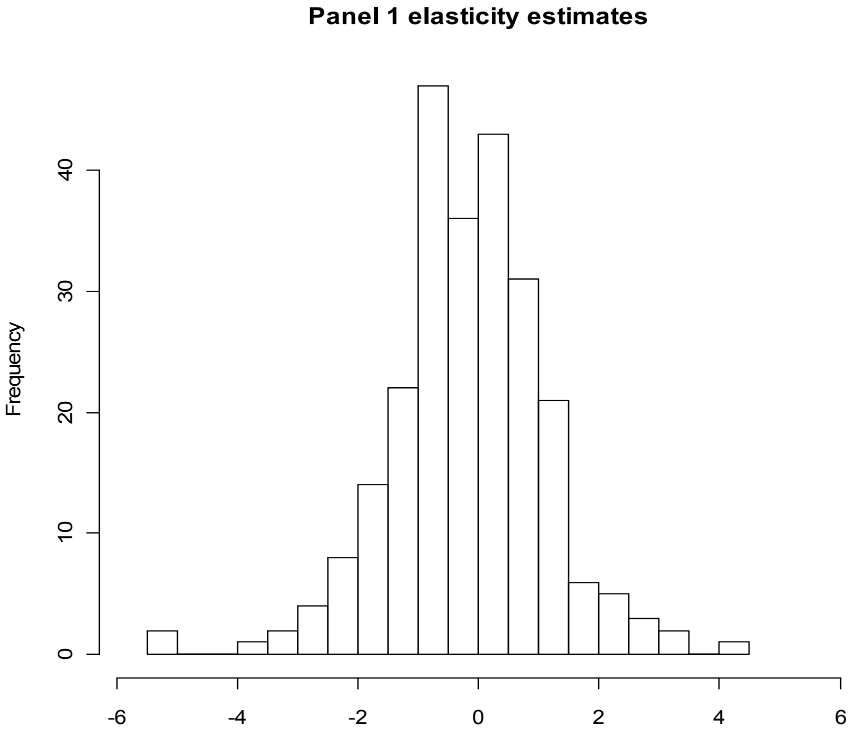

Figure 5-1: Histogram of panel 1 price elasticity estimates

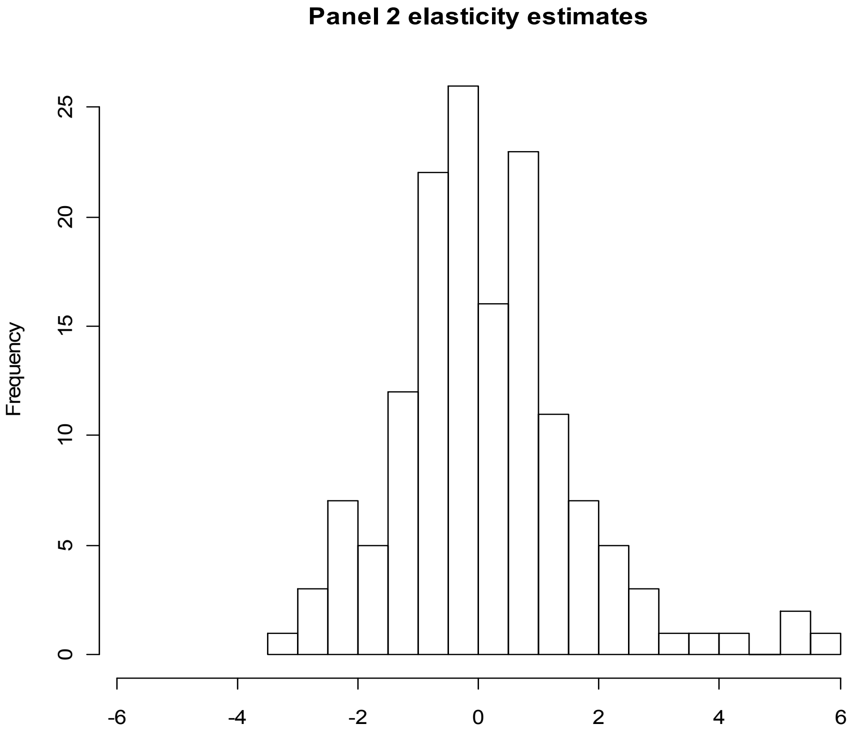

Figure 5-2: Histogram of panel 2 price elasticity estimates

5.2 TIME SERIES ESTIMATIONS FOR GINFORS

5.2.1 DATABASE

The GINFORS model maps international trade flows in accordance with the OECD Structural Analysis Database (STAN). Thus, all sectoral regression results presented within this subsection rest on time series of Eurostat Use-Table input coefficients, deflated by appropriate price indices and transformed to a STAN compatible 48 by 48 pattern.[1]

Statistical analyses of the use tables for each of the EU27 Member States is not possible. For smaller economies like Cyprus the corresponding Use-Tables completely lack their publication whereas some new member States (like, e.g., Bulgaria) are subject to individual derogations with regards to general disclosure obligations. Furthermore, even well established Member States like the United Kingdom do not provide Use-Tables for the most recent reporting periods.

This irregular data availability impedes exhaustive EU27 analyses on a self-contained Member State level. Therefore we had to decide on the inclusion of national datasets on an individual basis. Taking the economic weights of the individual Member States and the timeliness of their respective data sets as well as our fundamental needs for sufficient degrees of freedom into account we finally decided to consider the following economies within our study: Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Spain, Sweden, Slovak Republic.

5.2.2 MODEL SPECIFICATION ALGORITHM

The longest time series in the data set have 13 observations. Given that this limited amount of information comes along with sparse degrees of freedom for any statistical analysis we decided to base all regressions on undifferenced time series. Thus we implicitly assume the existence of cointegration relationships between the analysed series.[2]

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[1] See the GWS report on subtask 4.3 for further information with regards to general data availability and the applied data pre-processing steps.

[2] From a plain statistical viewpoint this approach can be exposed to a „spurious regression" critique. However, this critique is apparently attenuated by the fact that all reported regression results have been implemented into the interdependent GINFORS model: Given that the enlarged GINFORS model provides numerically stable iterative simulation results we do not perceive any serious signals pointing to the existence of spurious regression estimates. (See also the GWS report on subtask 4.2 for further methodological annotations in this regard)

Accordingly, we also decided to report only the results for ordinary least squares estimates.[1]

The applied model selection and estimation algorithms were implemented within the statistical programming environment R.

INTER-INDUSTRY SUPPLY FLOWS

Letting $\mathrm{io}_{\mathrm{i}}^{\mathrm{rc}}$ denote an arbitrary time series of (logged) real input coefficient observations for a given country i (with country index i ranging from 1 to 17), p_i^r, p_i^c denoting the corresponding output price indices of industries r and c and u_{i} denoting the regression error term we have generally been estimating 2256 (i.e., 47 times 48) relative price elasticities for any country (adding up to a total of 38352 regression analyses) according to the following equation:[2]

$$\text{(1)} \qquad \mathrm{io}_{\mathrm{i,t}}^{\mathrm{rc}} = \beta_0 + \beta_1 \frac{p_{i,t}^r}{p_{i,t}^c} + \mathrm{u}_{\mathrm{i,t}}, \qquad \mathrm{r,c} = 1...48, \qquad \mathrm{r} \neq \mathrm{c}.$$

Furthermore, as far as any of our 37 material relevant input coefficients also fell into the given column under consideration, i.e., for any material relevant (logged) real input coefficient $\mathrm{io}_i^{\mathrm{r^*c}}$ with $\mathrm{r} \neq \mathrm{r}^*$ we also estimated an additional specification as illustrated by equation (2):

$$\text{(2)} \qquad \mathrm{io}_{\mathrm{i,t}}^{\mathrm{rc}} = \beta_0 + \beta_1 \frac{p_{i,t}^r}{p_{i,t}^c} + \beta_2 \mathrm{io}_{\mathrm{i,t}}^{\mathrm{r^*c}} + \mathrm{u}_{\mathrm{i,t}}.$$

Finally, in cases when more than one material relevant input coefficients could be assigned to the selected column, i.e., when we were facing a set of individual material relevant input coefficients so that $\mathrm{io}_{\mathrm{i}}^{\mathrm{r^*c}} = \left(\mathrm{io}_{\mathrm{i}}^{\mathrm{r_1^*}c},...,\mathrm{io}_{\mathrm{i}}^{\mathrm{r_4^*}c}\right)'$ each of them was tested individually in a two regressor setup according to equation (2) and all of them were tested for their joint significance in the following regression setup:[3]

$$\text{(3)} \qquad \mathrm{io}_{\mathrm{i,t}}^{\mathrm{rc}} = \beta_0 + \beta_1 \frac{p_{i,t}^r}{p_{i,t}^c} + \beta_2 \mathrm{io}_{\mathrm{i,t}}^{\mathrm{r_1^*c}} + \beta_3 \mathrm{io}_{\mathrm{i,t}}^{\mathrm{r_2^*c}} + \beta_4 \mathrm{io}_{\mathrm{i,t}}^{\mathrm{r_3^*c}} + \beta_5 \mathrm{io}_{\mathrm{i,t}}^{\mathrm{r_4^*c}} + \mathrm{u}_{\mathrm{i,t}}.$$

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[1] Preliminary analyses also incorporated lagged values of the regressors as instrumental variables. However, as the overall qualitative findings did not appear sensitive to this kind of specification we retained the traditional OLS approach.

[2] Single zero entries of individual tables did in fact slightly lower the amount of our analyses. However, as this section is only intended to document our general study framework we omit a detailed representation of the individual country-specific datasets. Furthermore, in order to account for long rung shifts in preferences, a re-specification of equation (1) incorporating an additional hyperbolic time trend has also always been estimated.

[3] Overall, the maximum number of possible relevant input coefficients never exceeded four in any industry.

For any specification under consideration the following statistical exclusion criteria applied: Regression results were generally only considered if their corresponding degrees of freedom reached a minimum threshold of four. F-tests of the joint significance of all regressors except the intercept were performed at a marginal significance level of .15. Furthermore, regressors with individual t-statistics less than 1.55 also had to pass a joint significance test at this .15 level. If they failed they were excluded from the initial regressor list and this restricted specification was re-estimated.

This resulting static specification was then tested against the results of a dynamic re-specification with additional lags of the regressors added to the list of covariates. If both modelling approaches successfully passed this battery of diagnostic tests the final choice between the static and the dynamic version was guided by the respective $\overline{R}^2$ values. However, if both of them did not exceed a threshold $\overline{R}^2$ value of .62 the individual specification under consideration was rejected.

Apart from statistical significance checks we did of course also apply parameter restrictions in our search for appropriate inter-sectoral reaction functions. Besides stability restrictions with regards to intercept and trend estimates these parameter restrictions primarily focused on theoretically meaningful restrictions: All price elasticity estimates had to range between -1.7 and 0 and the elasticities with regards to the material relevant input coefficients were restricted to range between -3 and 3.

If more than one specification passed all statistical and theoretical restrictions we incorporate those estimates which yielded the highest $\overline{R}^2$ values on an identical sample into the GINFORS model.

LABOUR INPUTS

In case of labour inputs, national reaction functions were already available within the GINFORS model framework. However, the respective equations usually rely on sectoral wage and production developments only and had thus not been tested for an additional inclusion of any input coefficients until now. Consequently, the related model enhancement works demanded for extensive checks of supplemental correlations between labour input figures and the corresponding set of real input coefficient observations. Due to space constraints we omit an elaborated discussion of the underlying GINFORS employment reaction functions but continue with an overview on our tests for the additional significance of the material relevant input coefficients.

As theoretical limits cannot be straightforwardly derived, we did not apply any parameter restriction tests with regards to the resulting labour input coefficient elasticity estimates. Therefore, the reported findings concerning sectoral employment rely only on the following statistical specification algorithm:

Each sectoral employment function under consideration was thus re-estimated with all material relevant input coefficients of the concerned industry additionally included on the regressor list. Then, akin to the aforementioned procedure, a general to specific specification search was carried out which checked for the joint significance of all regressors on a .15 level. If this test failed, individual regressors with t-statistics less than 1.51 were excluded from the regressor list. Specifications which did not exceed a threshold $\overline{R}^2$ value of .65 were generally rejected and static specifications were again tested against dynamic re-specifications with additional lags of the regressors added to the list of covariates. The final choice between competing specifications was again guided by the respective $\overline{R}^2$ values.

5.2.3 RESULTS

In this report only a short overview can be given. For a detailed analysis of results look at Meyer, M (2011).

INTER-INDUSTRY FLOWS

PRICE ELASTICITY ESTIMATES

Whereas 6665 input coefficient reaction functions have been significantly estimated the empirical evidence clearly varies between individual Member States: Most of the endogenised input coefficients can be allocated to the Netherlands (674 reaction functions), Italy (666 reaction functions), Sweden (663 reaction functions), Hungary (607 reaction functions), Germany (583 reaction functions) and France (575 reaction functions). On the other hand, there are only 159 significant estimates for the Czech economy and even less in the cases of Greece (100), Ireland (65) and Austria (63).

Nevertheless, the respective modelling works with regards to price elasticities seem to reflect widespread empirical evidence. Generally, more than one out of two input coefficient reaction functions (52.35%) does include a price elasticity estimate. The corresponding numerical values are widely distributed among the theoretical acceptance region [-1.7, 0] and are characterized by a median close to -1. Most price elasticity estimates have been found for Hungary (452), Sweden (425) and the Netherlands (400). At the same time, only infrequent information can be provided for the Czech Republic (20 price elasticity estimates), Greece (22 price elasticity estimates), Austria (25 price elasticity estimates), Luxembourg (39 price elasticity estimates), Ireland (43 price elasticity estimates) and Finland (63 price elasticity estimates).

DIRECT INPUT ELASTICITY ESTIMATES

The total of significant cross elasticity estimates is 1915. The numbers of significant estimates and the estimated numerical values tend to differ between countries. This feature reflects the degree of heterogeneity between the individual Member States' economies and should therefore not come up as a surprise. At a first glance, all national estimates seem to be roughly symmetrically distributed on the [-3, 3] interval. The national medians tend to emerge slightly positive. This means that we found slightly more complementarities than substitutions between the coefficients in the different countries. Nevertheless, a mean zero distribution seems to fit well to the overall picture.

LABOUR INPUTS

In case of labour inputs only rare indication of direct input coefficient elasticities have been found.

5.3 TIME SERIES ESTIMATIONS FOR E3ME

In this chapter the approach of Cambridge (2011a,b) is reported.

5.3.1 DATABASE

For estimating price elasticities the EUROSTAT national accounts database was used, combined with the EUROSTAT material flows data. The coverage in these data sets is generally good, with gaps being filled out using custom software algorithms.

The same data base has been used to estimate the input-substitution coefficients as in the GINFORS case with one difference: It was not necessary to transfer the data into the STAN classification, because E3ME uses EUROSTAT input output tables.

In some cases there were missing data either for the IO coefficients or for capital stock. When IO coefficients were missing for a particular year, these were filled using an interpolation method, using the data that were available in years either side. However, if the data were missing at the beginning or end of the time series, a shorter time series was used for that particular estimation (i.e. there was no extrapolation). If there were less than six data points the estimation was not carried out.

It is also noted that not all the independent variables were used in all the estimations. In addition to the special cases outlined earlier in this chapter there were some further restrictions made by the available data. For capital stock data, entire time series of data were missing for the following countries: Belgium, Estonia, France, Greece, Hungary, Ireland, Luxembourg and Slovakia. In these cases capital stock was not used as an explanatory variable in the equation.

5.3.2 METHODOLOGY

ESTIMATION OF PRICE ELASTICITIES

The objective of this exercise was to obtain long-term estimates of price elasticities for each material type. As was found in previous analysis, attempts to estimate elasticities at the national/sectoral level did not produce robust results, so estimates were made at the EU level. A weighted average of the price of each material type for the EU27 plus Norway and Switzerland was calculated. The weights were based on each region's share in total material use for a given material. The price values were then logged, such that the price coefficient estimated in the regression below can be interpreted as the price elasticity for the respective material type.

In order to obtain price elasticity estimates, the following OLS regression was run for each material type:

$$logQ_{it} = \beta_{0i} + \beta_{1i} logP_{it} + \beta_{2i} GDP_t$$

Where:

Q_it = sum of use of material i across EU29 regions in time period t.

P_it = EU29 average price of material i in time period t.

⟦GDP⟧_t = sum of GDP across EU29 regions in time period t.

The price and GDP variables were instrumented using their one period lags.

ESTIMATION OF INPUT SUBSTITUTES

The relationship between the resource-important coefficients and other inputs to the purchasing industry can be shown by estimating the substitution elasticities between them. If after estimation the relative parameter coefficient has a positive sign, this means that the inputs are complements, as if use of one goes up, so too does use of the other input. On the other hand, if the parameter coefficient has a negative sign then this suggests the inputs are substitutes, as if the use of one input increases, the other will decrease.

EQUATION SPECIFICATION

Cross-substitution elasticities of input coefficients for the relevant technologies were estimated. A time-series econometric method was used to estimate the equation, which had the following specification:

$$\frac{IO_{ajt}}{P_{at}} = \alpha + \beta_1 \frac{IO_{bjt}}{P_{bt}} + \beta_2 \frac{P_{at}}{P_{jt}} + \beta_3 k_{jt} + \beta_4 l_{jt} + \varepsilon_t$$

Where:

IO_{aj} = input-output coefficient for input a to industry j, time t

IO_{bjt} = input-output coefficient for alternative input b to industry j, time t

P_{at} = prices in industry a (supplying input a), time t

P_b = prices in industry b (supplying input b), time t

P_{jt} = prices in purchasing industry j, time t

k_{jt} = capital stock per unit of output in purchasing industry j, time t

l_{jt} = labour costs per unit of output in purchasing industry j, time t

All the estimations are also carried out at the national level for 18 countries, due to limited availability of comprehensive material intensity figures.

Logs of the variables were taken in order for the results to be interpreted as elasticities. Taking logs also has the added advantage of reducing the chances of heteroskedasticity, whereby the variance of the error term is not constant across observations.

Lags of the explanatory variables were used as instruments, to control for potential endogeneity problems (i.e. that quantity might determine price rather than vice versa; as by definition we are looking at the largest consuming sectors this is a possibility).

In total, a maximum of around 30,000 OLS estimations were carried out, since an estimation was conducted for each of the 30 important coefficients, for each of the 17 countries selected, and for each of the 59 input coefficients that make up the use tables (30x17x59=30,090).In practice, however, some of the equations were omitted because:

there were not enough data points

the potential substitute was never used (input-output coefficient always zero)

the dependent variable was missing or constant

STATIONARITY

The results from the analysis suggested that there were many cases of non-stationarity in the results. The estimations were therefore carried out for both levels and first differences. The results given in this document are for differenced equations.

5.3.3 RESULTS

PRICE ELASTICITIES

After testing various alternative specifications, a set of long-run price elasticities was obtained. The result for feed is not considered robust (economic data cannot adequately track this category as the supplier and purchaser are both part of agriculture) so is not used.

Table 5-2 presents the results alongside the previous estimates that were derived in Cambridge Econometrics (2008). The differences are mainly due to:

- Three additional years of data
- Expansion of data to include EU27 rather than EU12
- Revisions to historical data

In most cases results are quite similar to previously. In particular the estimated elasticity for construction minerals, the largest category by weight, is almost identical to previously. The largest difference (excluding feed) is for wood, while the magnitude of the elasticities for ores (previously a single category) has also increased.

Material	2011 Estimate	2008 Estimate
Food	-0.26	-0.42
Feed	-0.96	0.17
Wood	-0.70	-0.18
Construction Minerals	-0.80	-0.81
Industrial Minerals	-0.25	-0.10*
Iron Ores	-0.60	-0.31**
Non-Ferrous Ores	-0.91	-0.31**

Note(s): * Non-significant result at 5% level.
** Previous classification grouped all ores.

Table 5-2: Estimated Long-Run Price Elasticities

SUBSTITUTES AND COMPLEMENTARY INPUTS

In order to pick out the most important results, a process of elimination was necessary. First, only results that were significant at the 5% level were kept. This produced close to 450 results from the 30,000 equations estimated. From these, the raw data that went into each equation were inspected for anomalies or structural breaks that may affect the validity of the results; due to the nature of the data involved (particularly some of the smaller coefficients in the Supply and Use Tables), this was quite common in the analysis.

Around 60 results were kept after this stage of elimination, which were further reduced when it became apparent that missing data were leading to some results with zero degrees of freedom. These results are reported in the following section, and are separated based on whether one or more significant inputs were found for an industry within a particular country, and are then further separated by substitutes and complements.

No prior assumptions were made about the outcomes; these results are derived entirely using the statistical methodology described in previous sections. Given the large number of equations involved in the estimation process and the short length of the data sets, it is not surprising that there are some results that do not make intuitive sense.

ANALYSIS OF POSSIBLE SUBSTITUTES

A total of seven significant alternatives were found. There is a small number of results that are immediately quite plausible:

The basic metals sector replacing metals inputs with secondary raw materials (Denmark)

The chemicals sector replacing chemicals inputs with rubber and plastics (Luxembourg)

Non-metallic minerals using more wood inputs (i.e. biomass) instead of non-metallic minerals (Belgium)

In addition, there may be substitutes in:

Fabricated metal products using inputs of ‘other manufactured goods’ rather than metal products (Germany)

In the other sectors it needs to be determined whether there is a real-life relationship that is not immediately obvious or whether the results are due to statistical anomalies. However, in all cases it is noted that the coefficients are small and often less than one. In most cases the sector that provides the substitute is also not particularly material intensive.

In summary, the results do not show large rates of substitution from one material input to another.

ANALYSIS OF COMPLEMENTARY FACTORS

A total of four coefficients were found to have significant complementary goods. These results provide some relationships that are quite easy to interpret. For example:

The metal products sector buys more chemicals when it buys more metal products (Sweden)

The financial services sector buys more insurance when it buys financial services (Austria)

The second of these is less interesting from the perspective of material consumption.

Again, the coefficients are generally quite small and in most cases less than one. The conclusion to take from this is that there may be some beneficial complementary effects but they are probably not very large.

5.4 CONCLUSIONS

CE and GWS presented rather different results of their econometric estimations of cross elasticities between the material relevant input coefficients and the other coefficients. GWS found 1915, CE only 11 significant estimations. How can this be explained and what does it mean for the project as a whole?

First it has to be mentioned that CE filled data gaps for missing years by interpolation, which has not been done by GWS. The most important difference between both approaches is given with the methodology. CE estimated with the first difference of the variables to avoid stationarity problems, whereas GWS defined the variables in levels.

As a matter of fact, we are confronted with rather short time series. This incidence essentially hampers the significance of plain statistical approaches. Thus, the straightforward statistical approach of CE which heavily accentuates dynamic time series properties might indeed suffer from insufficient degrees of freedom and unconsidered long-run relationships. The estimation in levels might however suffer from spurious regression diagnostics. Therefore their empirical findings call for a sound theoretical interpretation of results as has been done for the results of the multicountry panel analysis by GWS (Meyer and Meyer 2011, task 4.2 of the project) with an interpretation of each equation following the supply chain of the structure of production.

But nevertheless, both studies support one common conclusion: Empirical evidence does not hint at the dominance of substitution effects. Thus, (at least in most cases) reductions of material relevant input coefficients do not seem to induce increases in other coefficients. This is a very import result which hints at the potential of win- win situations with reductions of material inputs in physical terms being accompanied by decreasing business costs.

CE rarely reports significant relations. Thus, **the reduction of a material important coefficient seems to induce declining costs and lower material consumption in almost any case**. However, the GWS approach provides widespread indications of interrelated supply-chain clusters with more or less evenly spread negative and positive correlations. Overall one might therefore also expect that the reduction of a selected material relevant coefficient will, at least in many cases, not raise total costs.

6 THE CALCULATION AF ABATEMENT COST CURVES FOR MATERIAL REQUIREMENT

Cost curves for the abatement of CO2-emissions play an important role in the discussion of alternative approaches in energy policy. These cost curves are based on bottom-up information, i.e. on detailed technical descriptions of different technologies that allow direct calculations of their respective installation costs. A very popular example is the cost curve produced by the consultancy McKinsey (Enkvist et al. 2007). More recently, McKinsey have also produced some of the first abatement costs curves for resources (McKinsey Global Institute 2011).

6.1 THE IDEA: HOW TO CLACULATE TOP DOWN ABATEMENT COST CURVES FOR MATERIAL INPUTS

In the case of materials, there is no bottom up description of technologies that would allow for abatement cost curves to be built in the same way as happens for CO2. Therefore, an alternative top down approach is taken based on the already mentioned fact that material inputs are to a very large extent determined by only 30 input coefficients.

In 30 simulations with the models E3ME and GINFORS each of the 30 most important input coefficients is reduced separately by 1%. Since the input coefficients have been endogenized (see chapter 5), the models are able to calculate all cost, price and income reactions. Each simulation gives one data point of the marginal abatement cost curve in the form of the resulting change of GDP and of total material requirement. For every single coefficient change we calculate the average percentage change of GDP in constant prices and the average percentage change of TMR over the set of countries represented in E3ME and GINFORS by input output models. The graph of the curve in Figure 6-1 and in Figure 6-2 is obtained by ranking the TMR reductions, starting with the lowest costs.

We choose a conservative scenario, in which the firm that introduces the efficiency gain has additional costs, which equal the material savings: It is assumed that the reduction of the input coefficient is caused by a tax. If the tax revenue is recycled (ie the additional tax burden leads to taxes being recycled), the simulations with both models come to the result that the aggregated cost curve has negative values for most of its data points, in other words that there is a win- win situation. If we would have assumed that the reduction of the input coefficient is caused by an information and consulting program, we would get an even stronger win-win result.

This chapter summarizes the papers Cambridge (2011a) and Distelkamp et al. (2011b).

6.2 METHODOLOGY

In the simulation the 30 (37 due to different disaggregation schemes in the models) material relevant input coefficients are reduced by 1% exogenously in separate 30 (37) single simulation runs. Further a tax is laid on the sector that just keeps the costs constant. The consequence is no price reaction of the sector and also no endogenous reaction of input coefficients. If the price would change, there would be additionally to the exogenous change of the input coefficient of 1% endogenously driven changes and the comparison of results would be problematic.

Implicitly the simulation can be interpreted as if the input coefficient reacts with an elasticity of minus one on the tax, which is not far off the averages that came out of the regression analysis (see chapter 5). The tax revenue is used to reduce income taxes.

6.3 EFFECTS

The reduction of the material relevant input coefficient reduces directly and indirectly demand and employment in the delivering sectors and domestic extractions and imports of materials. The effect on value added will be negative and depends on the import shares of material inputs. On the other side the tax revenue is used for reduction of income taxes, which raises final demand. Thus, a lot of indirect economy-wide price, demand and income effects will be generated.

Short run effects are defined as the reactions on GDP and TMR in the first year. However, we should be aware that both models rely heavily on dynamic reaction functions. Therefore, not all price and income effects will make an impact within the first period. Accordingly, results in the fifth year after the initial disturbance are also examined.

6.4 RESULTS

Figure 6-1 gives the short run abatement cost curve of E3ME and GINFORS, Figure 6-2 the medium run curves.

A comparison of the short run curves shows that both models estimate for a broad range of input coefficients negative costs, which means a surplus in terms of GDP. In other words: a win-win result with rising GDP at the same time as reductions of TMR. In the case of E3ME this is given for nearly all 30 of the coefficients.

The cumulative reductions of TMR are in the case of GINFORS much greater than for E3ME. The reason is that GINFORS has much more complementarities between the material relevant coefficients and the other coefficients than E3ME. In GINFORS, for example, the reduction of metal inputs in the industry “motor vehicles” reduces the input of electricity in this sector. This means that there are two channels through which demand reduction and the further reduction of material inputs takes place: The production of “basic metals” and “electricity” are reduced simultaneously. Without this complementarity relation in the sector “motor vehicles” the channel would be only via production of “basic metals”. So the reduction of the coefficient in the simulation induces further reductions of others in GINFORS, but not in E3ME.

The E3ME-effects on GDP tend to exceed the corresponding GINFORS estimates. This result is consistent with the different reactions of the two models to reductions of TMR, and the reason is the same one already mentioned: As GINFORS mirrors a significant set of complementaries, it tends to indicate stronger overall reductions in total material requirements which implies that more firms are negatively influenced by demand reductions, which reduces the positive GDP effects.

The order that the coefficients appear in is interesting. There are two clear trends for both models:

1. Longer production chains tend to incur higher costs, and higher import shares mean lower costs. The modelled IO coefficients that are directly related to extraction sectors (eg coal, other mining) have lower costs, while the ones associated with more complex goods have higher costs. There is a higher cost for biomass than for minerals. The reason is that most minerals are imported to Europe, while a large share of biomass is produced domestically.
2. There are many important metal input coefficients, which belong to the win-win range of the abatement cost curve: The inputs of “basic metals” in “machinery and equipment”, in “motor vehicles” and in “fabricated metal products” further the inputs of “mining and quarrying” in “basic metals” are important examples. In this context it has to be mentioned that the share of metals in TMR of all Member States in the average is higher than the share of metals in the TMR of the region EU27. The reason is that the intra European imports that are mentioned in member state TMR but not in EU27 TMR have high contents of metals.

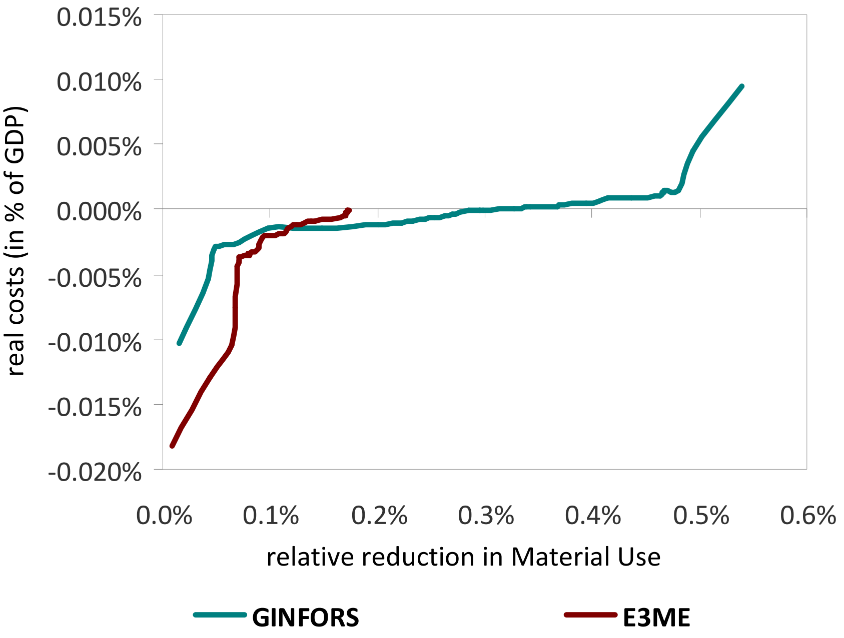

Figure 6-1: Short run abatement cost curves

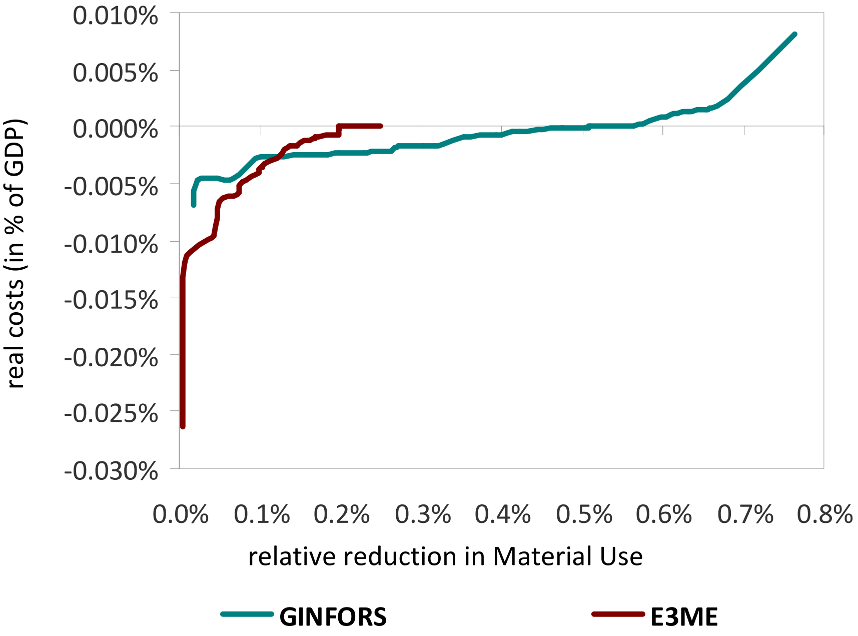

Figure 6-2: Medium run abatement cost curve

It is interesting that compared with the short run curve the overall win-win situation of the medium run curve is now slightly improved. Many behavioural equations in the models are dynamic in the sense that in the short run only a fraction of the total reaction happens. This concerns the already mentioned complementarities that take time to evolve. Furthermore, if delivering industries lose demand and so produce at higher unit costs (less economies of scale) they will further raise their price, which will further reduce demand in this industry. Also the adaptation of employment to lower production levels often needs time, which means that the consequences for labour income and consumption demand will be fully there in later periods. On the other side the efficiency gains in the material receiving industries create surplus in disposable income, which pushes in a dynamic process consumption and the circular flow of income. All these reactions take time and it seems that the positive results are lagged more.

Until now we have looked only at the impacts of marginal changes of input coefficients not at the result of concrete policy measures, which always have a more complex impact structure. The implication is that we should interpret the results carefully (Ekins et al. 2011b). Long run implications can be derived from our policy simulations till 2030, which we discuss in the following chapter.

7 POLICY SIMULATIONS

Our findings indicate potential resource efficiency gains supporting growth and jobs for a number of materials, but the following discussion concentrates on metals which - as a strategic input to many production processes - seem to offer particularly large opportunities (UNEP and CSIRO (2011)). Furthermore, metals also represent a resource where future supply might not be able to meet worldwide demand which will be boosted by rapid economic growth in Asia (Halada et al. (2009)). McKinsey forecasts a rise of global steel demand of 80% till 2030 (McKinsey Global Institute 2011). A further problem is given by the high concentration on the supply side: In the case of iron ore only three firms control 80% of global supply (Pirgmaier et al. 2011). On the other side, metal extraction causes environmental damages of the worst kind during its transport and processing and the use of stocks made of it – like cars - induces high energy consumption.

Positively, in line with the results of the MaRess[1] project for Germany, we find that there is a high potential to improve resource efficiency without economic losses in Europe (Meyer et al. 2011, Distelkamp et al. 2010). Assuming a sector specific policy mix for Europe our model simulations show that if an active emission oriented climate policy is complemented by a material input oriented resource policy – as Ekins et al. (2011a) demand - then absolute decoupling of economic growth from resource requirements is possible.

It should be noted that the following focus on metals does not imply that other resources are not important. The model scenarios suggest that there are win-win gains across a wide range of resources. However, for the policy scenarios, a focus on metals allowed much easier to understand policy stories alongside transparent model results. The focus of attention was also on the potential for win-wins, rather than the specific policies to deliver those benefits, which were not the focus of this study.[2] The results presented here are based

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[1] MaRess Materialeffizienz und Ressourcenschonung,

see ressourcen.wupperinst.org/en/project/index.html for further information.

[2] For example, in the context of metals, the substitutability between metals and other competing materials and the possible impacts in terms of distortion of competition are not fully taken into account.

on two reports provided by CE (Cambridge Econometrics 2011c) and GWS (Distelkamp et al. 2011c), the scenarios are discussed in Meyer (2011a).

7.1 THE POLICY SCENARIOS

7.1.1 ECONOMIC INSTRUMENTS

OPTIONS FOR ECONOMIC INSTRUMENTS

Before choosing the instruments it is necessary to make some assumptions about the international framework in which such a policy has to be seen. It has been argued that the recent developments in climate policy show that global agreements on economic instruments can be hindered because countries want to protect their self-interest (Keohane and Victor 2010). Furthermore border tax adjustments can be weakened if affected groups manage to avoid them. We therefore try to define a policy mix, which does not need border tax adjustments.

Tradable permits are not an adequate instrument in the context of material efficiency, since for most materials the suppliers are outside Europe and demand comes from a large number of small users. For taxes a number of different specifications are possible.

The "classical" resource tax is related to domestic extractions and imports of materials in physical terms. A central question is whether not only imported materials, but also materials that are embodied in imported intermediate and finished goods should be taxed. Our first scenario models a "classical" resource tax on metal ores without a border tax adjustment. The tax has to be paid by the users of the metals – the basic metal industry. The results are not encouraging: The price of domestically produced metals rises and these are partly substituted by imports. So the effect on metal ores inputs is rather low, and on the other side the effect on real GDP and real labour income is slightly negative (Distelkamp et al. 2011c, pp. 10).

A variant of the classical resource tax has been simulated already in the MOSUS project with the model GINFORS (Giljum et al. 2008) and in the PETRE project with the models E3ME and GINFORS (Barker et al. 2011, pp. 204). Here the prices of materials were raised by certain percentage points for European countries. Yet, the material models differed from the MACMOD approach: Within the PETRE project, E3ME calculated DMC for European countries whereas GINFORS calculated domestic extraction for all extracting countries (Barker et al 2011, pp. 188).

In a fuller assessment, the possible impact on the concerned sectors and their competitive position both on domestic and international market would also need to be examined further. In the EU, recycling rates for metals are high in comparison to other materials and the supply of scrap of required quality is limited. From this perspective, taxation applied to metal input might have only very limited effects on the recycling rate of metals. Finally, the distributional effects that a tax applied to a specific group of industries is likely to have would need to be studied in detail.

An alternative to the resource tax that raises the price of resources is a taxation of intermediate inputs made of materials. This tax has to be paid by the firm, which uses these inputs. The big advantage is that without any border adjustment domestically produced and imported inputs can be taxed. Meyer (2010) proposed a tax that charges the nominal inputs of materials on all stages of production: All firms pay a tax on sales as they do now. But instead of subtracting the tax lying on intermediate inputs they now subtract taxes lying on value added and service inputs. Of course this cannot be done on a monthly basis, as is the case today; this is only possible on a yearly basis. The result is that materials are taxed and not value added, which would be in line with the principles of an environmental tax reform. Without any border tax adjustments not only direct material consumption, but also the consumption hidden in goods imports would be taxed. Since the nominal inputs may correlate with the indirect material consumption "rucksacks", the targeting of the instrument might be better than it seems to be at the first sight. The administrative changes are very small, but the change in the tax system would be a revolution. It is of course an interesting approach that should be on the research agenda, but it can be questioned whether it should be part of a policy relevant project.

To use the existing value added tax in taking different tax rates for material intensive and less intensive goods is a step in the right direction, but it is a small one, as the simulation results of the MaRess project have shown (Distelkamp et al. 2010): The small ranges of variation of the tax rate do not induce strong changes in consumer demand, and there is no incentive for the producer to change material intensity.

THE CHOSEN ECONOMIC INSTRUMENT

A better step in the right direction could be the taxation of the inputs of metals and metal products in later stages of production like the automobile industry and the machinery industry and other productions of consumer durables and investment goods, which have been identified as important resource consumers (Acosta Fernandez and Schütz 2011). The industries producing investment goods and consumer durables are the most important users of metals. The use of metals in these sectors is less determined by technological constraints. Here product design and product mix seem to represent the most important drivers with regards to metal inputs. To provide an example we refer to Bringezu and Bleischwitz (2009): Even in absence of any technological changes cars might be produced with less metal inputs. Furthermore, even if we assume a given product design, a change of the mix of existing car types influences metal consumption. Thus, we assume an increasing flexibility in the use of metal inputs for later stages of the metal supply chain.

It seems plausible that a tax on the input of metals in these industries will not endanger their international competitiveness even without any border tax adjustment. We assume a tax on the nominal input of metals with a rate rising from 1% in 2011 to 70% in 2030. The tax revenue is recycled by a reduction of income taxes.

However, we have to be aware that the induced cost dynamics are far from any historical observation: The reaction functions of the GINFORS model usually reflect historical observations of the 1995 to 2007 period. However, with regards to price developments in the investment industries we have to acknowledge that severe increases of metal input prices could only be observed for years 2006 and 2007. As our simulated taxation paths assume even higher increases of metal prices over a 20 year horizon this scenario apparently challenges the rationale for applications of estimated reaction functions for metal inputs in the investment industries. Taking the Lucas critique on econometric modelling seriously we therefore decided to model the investment goods industries with an assumed learning behaviour of agents. Thus, (negative) price elasticities of metal inputs in investment industries are assumed to rise in absolute terms from zero to 1 until 2030 in accordance with an S-shaped diffusion pattern. With E3ME two versions have been calculated. The first with zero elasticities and the second with an elasticity of -1 over the whole simulation period. We refer here to the second version.

The tax on metal inputs hits the following sectors, which we will call in the following „investment goods industry“:

- Machinery and equipment
- Office, accounting and computing machinery,
- Electrical machinery and apparatus,
- Radio, television and communication equipment,
- Medical, precision and optical instruments,
- Moter vehicles, trailers and semi trailers,
- Building and Repairing of ships,
- Aircraft and Spacecraft,
- Railroad equipment and transport equipment.

This scenario of a taxation of metal inputs in the investment goods industries will be part of the policy mix scenario.

7.1.2 INTERNATIONAL SECTORAL AGREEMENT ON RECYCLING OF METALS AND NON METALLIC MINERALS

Taxing the input of ores without a border adjustment raises domestic prices and induces the substitution of domestically produced metals by imports. We found out that this expected result is confirmed by simulations and the impact on metal requirement in physical terms is low.

The alternative is to push the substitution of metal ores by recycled material through a negotiated agreement[1]. Given the growing worldwide awareness of the scarcity of metals, it seems plausible that the metal producer countries facing the oligopoly of ores production could make an international negotiated sector agreement to strengthen their market power.[2] Furthermore international environmental policy is more and more favouring the sectoral

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[1] De Clerq (2002) mentions three positive factors for the success of such an instrument, which are all given for the “basic metals” industry: A homogenous product, a small number of players, and an industry that is dominated by some or has a powerful association.

[2] The chances for a global agreement are good, because two very important producers of basic metals have already installed general plans for the improvement of recycling: China introduced in 2008 the “Circular Economy Law”, and Japan started in 2008 the “Second Fundamental Plan for Establishing a Sound Material- Cycle Society” (UNEP and CSIRO 2011).

approach, because the number of players is small, which favours the chance for agreements: Sectors are highly concentrated of both companies and countries as steel, aluminum, copper and the other non-ferrous metals (Bodansky 2007).

Such an international negotiated agreement could contain measures to raise the availability of scrap (improvement of recycling technologies, product design, stakeholder cooperation, better use of old stocks of scrap, etc. (Gomez et al. 2007, Wilts et al. 2011). The agreement itself could also mean that the basic metal producing countries announce for the year 2030 the taxation of ores inputs in the production of basic metals, if the input coefficient in constant prices for ores exceeds in 2030 that of secondary materials. A threat with penalties will help to reach the targets (Price 2005). The European basic metals industries reduce their inputs of ores and raise the inputs of secondary materials. The necessary change of the input coefficient for ores is then distributed over time in an S shape. Further the material intensities of imported products fall because basic metals produced abroad and the metal products produced with them have also less content of ores. It is assumed that material intensities for metals of imported products are reduced till 2030 by 50%.

The target in our simulations is more or less arbitrary and justified only by actual recycling ratios. UNEP (2011) cites the estimates of different authors for the RC ratio (recycled content in the fabricated metal flow): iron between 28% and 52%, aluminium 34%-36%, copper 32%.

Which further adjustments in the input structure have to be mentioned? In the case of steel production recycling means a reduction of coke inputs (basic oxygen furnace (BOF) technology) and a proportionate rise of electricity inputs (electric arc furnace (EAF) technology). This assumption is conservative, since the energy costs of recycled inputs are lower than that of ores. Schleich et al. (2006) estimate the intensity of primary energy in the EAF technology (including the indirect inputs in electricity generation) to be half of the number in the BOF technology. Further we assume that the investment per output unit is the same as in the baseline, which means that additional investment in the EAF technology is compensated by less investment in the BOF technology.

The scenario further assumes a substitution of non metallic minerals by secondary products. Here it is also assumed that in 2030 secondary inputs in constant prices reach the share of primary material. The E3ME team assumed a general substitution of construction minerals, whereas the GINFORS team restricted it to the direct deliveries of the mining and quarrying sector to the construction sector, which means that construction minerals being part of glass and ceramics are not mentioned.

7.1.3 INFORMARTION AND CONSULTING

There is bottom up information about abatement costs based on empirical research and the expertise of consulting firms. ADL, Wuppertal-Institut, ISI Fraunhofer- Institut (2005), Fischer et al. (2004) and Kristof et al. (2008) estimate the potential for material savings to range between 10% and 20%. Fischer et al. (2004) estimate that a 20% reduction of material cost is possible by an information and consulting program for firms with the costs of the savings of one year. So after one year firms have a permanent surplus and there is a reduction of material use which diminishes the pressure on nature – a typical win-win result. Oakdene Hollins (2011) came to a similar result. The German official material efficiency agency demea (2010) reports that the small and medium sized firms joining their information and consulting program could on average raise their profits by 2.4 % of their respective sales.

Based on these experiences Meyer et al. (2007) and Distelkamp et al. (2010) have presented model simulations for Germany with the model PANTA RHEI in which all input coefficients for materials (Distelkamp et al. 2010) or for materials and energy (Meyer et al. 2007) have been reduced in manufacturing by the same amount as the costs described by Fischer et al. (2004). In the MOSUS project this has been done with the model GINFORS in the European context (Giljum et al. 2008). But here the modelling of material was restricted to domestic extraction. The results showed a huge potential for the reduction of resource consumption combined with a strong rebound effect from cost reductions that create economic growth. The assumption of a general reduction of all material inputs for all manufacturing sectors might overestimate the win-win potential. Insofar such a procedure can be interpreted as the calculation of a potential.

As already mentioned, our simulations in chapter 4 about the impact of an information and consulting program for the correction of market failures can be criticized in two respects. The first is that the simulations had been calculated with exogenous input coefficients. Induced changes of relative prices and direct interrelations between input coefficients did not influence these results. This alone could justify a further calculation of the scenario. Additionally it has to be mentioned that section 4 identified market failures as a problem of small and medium sized firms (SME). In task 4.1 this has not been mentioned, since all commodity producing sectors were assumed to benefit from the information program. This is corrected by concentrating the analysis on sectors, which are dominated by SME's; these are:

- food products,
- textiles, textile products, leather and footware,
- wood and products of wood and cork,
- pulp, paper, paper products, printing and publishing,
- chemicals
- pharmaceuticals
- rubber and plastics products,
- other non-metallic mineral products,
- fabricated metal products.

We will call them “other manufacturing”.

In the E3ME scenarios a shorter list of material user groups is used:

- agriculture,
- food,
- wood and paper
- chemicals.
- non-metallic mineral products

Whereas the sector definitions of both models are not identical, the difference is not as sharp as it seems to be at first sight: “chemicals” in the E3ME classification includes "pharmaceuticals" and "rubber and plastics" and "wood and paper" includes "pulp and paper". But of course there remains a quite substantial difference as "fabricated metal products" are missing.

We assume that all SMEs in the manufacturing sectors might overcome these market failures within a 20 years horizon. For the gains and the costs of this operation we follow Fischer et al. (2004): It is assumed that firms are able to reduce their expenditures for deliveries of intermediate products of materials permanently by 20%. On the other side they have additional costs for consulting only in the first year, which equal the savings of material inputs for one year. The reactions of physical material inputs are endogenous.

7.1.4 THE POLICY MIX SCENARIO

The policy mix scenario includes the taxation of metal inputs in investment goods industries, the international agreement on recycling of metals and the information and consulting program simultaneously. This means that there is interaction between the single scenarios so that the impact of the policy scenario is not just the sum of the effects of the individual policy scenarios.

The policy mix has a sectoral and an instrumental structure as the following table shows:

		sectors		
		basic metals, construction	investment goods industries	other manufacturing industries
instruments	recycling	**X**		
	taxation		**X**	
	information			**X**

Table 7-1: Structure of the policy mix

To get an idea about the influence of raw material prices two versions of the baseline were calculated. Scenario 1 is based on European Commission (2010a) (and referred to as the PRIMES 2009 reference scenario). In scenario 2 a baseline with weaker raw material price dynamics is assumed. This variation is governed by the oil price, which is modelled as leading raw material price: Under scenario 2 the oil price increases more slowly so that its 2030 value comes up 20% lower than in simulation 1.

7.2 RESULTS FOR THE BASELINE SCENARIOS

The base for the simulations is the PRIMES 2009 reference scenario, in which the energy related CO2 emissions in 2030 are 21% lower than in 1990 (Capros et al. 2010). The PRIMES reference scenario assumes that the EU ETS, energy efficiency programs outside the ETS and measures for a rise of renewable energies are the main instruments.

This means that the main economic developments in the European countries and the CO2 emissions described in the PRIMES reference scenario should be met by E3ME and GINFORS. In addition, the time paths of the exogenous variables and also some parameters of the models have to be changed to be consistent with the PRIMES scenario. The baseline also includes trends for material productivity (see chapter 3.3.2) identified by Giljum and Lugschitz (2011).

7.2.1 RESULTS FOR BASELINE 1 (SIMULATION 1)

The inputs to the PRIMES projections include a GDP growth of 2.2% in constant prices in the period 2010-2020 and of 1.8% for the period 2020-2030 for EU 27. Since the dynamics of GINFORS have not been far off the PRIMES paths, it was possible to meet more or less for every country the PRIMES developments calibrating GINFORS. E3ME was calibrated using its standard scaling factors (as described in the model manual, Cambridge Econometrics, 2010). However, it is noted that the baseline economic results are not of particular interest here other than as an input to the modelling.

The oil price in PRIMES is a real price in US Dollars of the base year 2008 with 88$ for 2020 and 106$ in 2030. E3ME and GINFORS need a nominal price for raw materials. The calculations with the endogenous price deflators gave a price that is nominally about 3% higher in 2030 than the PRIMES price. We further have a slightly different dynamic growth pattern from 2010 to 2030. The prices for the other raw materials have been calculated by historic correlations with the oil price. In relation to 2010 levels the nominal oil price will be in 2030 123% , the price for wheat 20%., the price for copper 58% and the price for iron ore 62% higher.

Of greater interest are of course those environmental pressures which are not the subject of the PRIMES report: The use of materials.

Figure 7-2 shows that the GINFORS baseline expects sustained differences in Total material productivity among Member States over the next 20 years. Also, the figure shows big differences among Member States with regard to the expected growth of TMR between the years 2010 and 2030. Only in three countries (Germany, Greece and Romania) the model predictions see an absolute decoupling of material use and economic growth in the long run. On the other side for 14 member states an average annual growth rate of TMR above 1% is expected.

But to get a better insight into the causes of these overall results we have to look at a few more details. As already mentioned the TMR results for the Member States in both models (E3ME and GINFORS) are derived by an explicit bottom-up approach with regard to the different categories and material flows within the overall TMR.

As Table 7-2 shows GINFORS anticipates an ongoing shift of environmental burden to other countries for the broad majority EU27 countries. This can be observed by an increase in the share of the foreign parts of TMR. In the case of Austria for example domestic extraction will reduce its share in TMR from 18.4% in 2010 to 16.9% in 2030. Also the direct material inputs in imports reduce its share from 14.6% in 2010 to 13.2% in 2030, whereas unused domestic extraction rises from 9.9% to 10.1% and especially the hidden flows associated to the imports raise its share in TMR from 57.1% in 2010 to 59.8% in 2030.

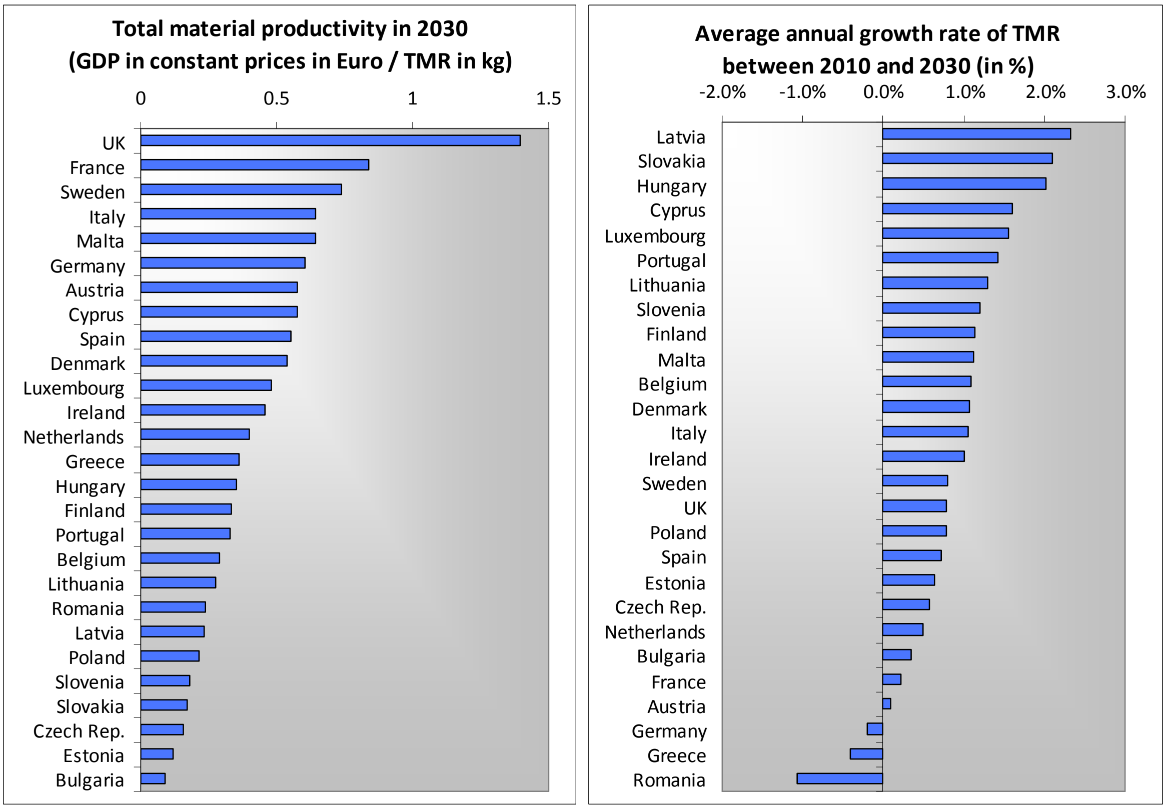

Figure 7-2: Differences in Total material productivity (2030) and in growth of TMR among the EU27-countries; GINFORS baseline results

Table 7-3 reports about the baseline results of GINFORS with regard to the different material flows (but without distinction between accounting components). As we can see for the majority of Member States the model predicts an increase in the relevance of material flows biomass, metal ores and industrial minerals and a decrease in the relevance of construction minerals and fossil energy materials/carriers.

Overall, the general pattern in the two sets of projections is quite similar but there are some notable differences. These are primarily explained by differences in modelling approaches and the assumptions that were used in each case. Another important point to note is that the short-term impact of the economic crisis and recession will have an influence on these results. The main differences between the GINFORS and the E3ME baseline are given in overview below:

The average growth of TMR over all Member States from 2010 to 2030 is in the GINFORS baseline 11%, while the E3ME baseline has a smaller increase, around 2.5%. Since GDP growth is much stronger, both models forecast a relative decoupling of economic growth and resource inputs.

Evolution of the main accounting components between 2010 and 2030 in the GINFORS baseline scenario; shares of national TMR in %

		Direct material input (DMI)		hidden flows	
		domestic extraction used	imports	unused domestic extraction	hidden flows associated to the imports
Austria	2010	18.4%	14.6%	9.9%	57.1%
	2030	16.9%	13.2%	10.1%	59.8%
Belgium	2010	5.6%	17.3%	4.5%	72.6%
	2030	2.4%	14.5%	3.8%	79.3%
Bulgaria	2010	14.1%	6.0%	52.6%	27.2%
	2030	8.1%	7.1%	41.5%	43.3%
Cyprus	2010	29.4%	14.7%	8.7%	47.2%
	2030	24.2%	17.0%	7.8%	50.9%
Czech Rep.	2010	17.1%	5.5%	50.2%	27.2%
	2030	14.2%	5.1%	54.6%	26.0%
Denmark	2010	27.5%	14.8%	10.6%	47.0%
	2030	21.7%	18.4%	8.6%	51.3%
Estonia	2010	15.5%	6.1%	62.1%	16.3%
	2030	12.8%	9.7%	56.3%	21.2%
Finland	2010	26.0%	11.4%	26.3%	36.3%
	2030	21.0%	13.2%	32.9%	33.0%
France	2010	26.2%	11.9%	19.2%	42.7%
	2030	26.4%	10.8%	18.0%	44.8%
Germany	2010	16.1%	9.8%	30.9%	43.2%
	2030	9.7%	11.8%	18.4%	60.2%
Greece	2010	14.1%	5.4%	58.2%	22.3%
	2030	15.4%	7.0%	45.6%	31.9%
Hungary	2010	22.0%	11.5%	15.6%	50.9%
	2030	24.2%	8.7%	17.6%	49.5%
Ireland	2010	29.4%	6.4%	15.7%	48.6%
	2030	21.3%	6.7%	14.1%	57.9%
Italy	2010	17.3%	14.9%	5.7%	62.0%
	2030	8.5%	15.9%	3.6%	72.0%
Latvia	2010	39.6%	12.1%	14.7%	33.6%
	2030	31.0%	12.2%	13.3%	43.6%
Lithuania	2010	26.3%	16.4%	12.2%	45.2%
	2030	19.6%	16.8%	11.5%	52.1%
Luxembourg	2010	2.7%	18.5%	4.1%	74.7%
	2030	1.7%	17.2%	4.5%	76.5%
Malta	2010	1.2%	22.1%	4.9%	71.7%
	2030	1.7%	24.2%	5.2%	69.0%
Netherlands	2010	6.1%	19.4%	4.9%	69.6%
	2030	4.5%	15.9%	4.1%	75.5%
Poland	2010	19.7%	5.1%	52.3%	23.0%
	2030	16.2%	6.6%	45.7%	31.5%
Portugal	2010	37.7%	10.6%	10.1%	41.6%
	2030	30.5%	11.1%	10.1%	48.3%
Romania	2010	43.6%	6.0%	24.6%	25.8%
	2030	30.6%	7.7%	22.7%	38.9%
Slovakia	2010	14.7%	13.3%	6.2%	65.8%
	2030	11.5%	12.3%	4.3%	72.0%
Slovenia	2010	20.8%	8.7%	20.3%	50.3%
	2030	15.8%	10.7%	18.4%	55.1%
Spain	2010	25.0%	10.8%	18.6%	45.6%
	2030	20.6%	11.3%	15.0%	53.2%
Sweden	2010	28.3%	11.6%	12.6%	47.5%
	2030	25.1%	9.6%	11.8%	53.5%
UK	2010	21.9%	14.0%	11.6%	52.5%
	2030	12.2%	15.3%	10.4%	62.1%

Table 7-2: Evolution of the main accounting components of TMR among EU27-coutries; GINFORS baseline results

The greatest differences are given for metals and non metallic minerals. The E3ME baseline includes a rise in the use of non-metallic minerals in the average of all Member States of +13% and a small fall in the use of metals of -2%, although this is due to short-term reductions in the recession, the longer-term trend is also positive. The average growth of TMR over all Member States is in the GINFORS baseline for non metallic minerals slightly negative (-6%) and for metals a rise of +36% is predicted.

Evolution of the material flows between 2010 and 2030 in the GINFORS baseline scenario; shares of national TMR in %

		Biomass				Metal ores			Non-metallic minerals				Fossil energy materials/carriers	Others
		Agriculture	Wood	Erosion	Other	Iron	non-ferrous metals	Other metals and products mainly from metals	Construction minerals	Industrial minerals	Excavation and dredging	Other prod. mainly non-metallic min.		
Austria	2010	9.8%	5.6%	2.7%	11.4%	17.7%	11.4%	2.2%	10.7%	2.6%	4.1%	1.7%	10.7%	9.3%
	2030	11.0%	7.1%	2.7%	14.0%	18.1%	12.0%	2.3%	7.1%	3.0%	4.4%	2.2%	6.6%	9.5%
Belgium	2010	12.0%	0.6%	1.3%	16.7%	13.6%	17.3%	4.3%	7.2%	0.5%	2.5%	0.8%	14.5%	8.7%
	2030	11.2%	0.6%	1.0%	18.9%	11.8%	28.6%	3.7%	5.8%	0.3%	2.4%	0.6%	7.5%	7.6%
Bulgaria	2010	3.7%	1.1%	1.1%	2.4%	4.4%	11.9%	2.7%	7.0%	0.3%	0.5%	0.4%	62.3%	2.2%
	2030	3.4%	1.8%	0.8%	4.1%	5.0%	25.1%	3.3%	2.6%	0.6%	0.6%	0.4%	49.7%	2.7%
Cyprus	2010	14.9%	0.4%	1.9%	10.7%	7.3%	2.8%	4.3%	29.7%	0.3%	3.3%	1.1%	16.5%	6.8%
	2030	17.5%	0.7%	1.4%	10.5%	6.7%	3.2%	4.1%	25.4%	0.2%	3.6%	0.8%	19.8%	6.2%
Czech Rep.	2010	3.9%	1.7%	1.2%	4.6%	7.3%	5.6%	4.0%	10.0%	0.5%	2.0%	0.5%	54.1%	4.4%
	2030	3.9%	2.5%	1.0%	4.7%	7.1%	4.9%	4.0%	6.7%	0.6%	2.4%	0.4%	57.6%	4.3%
Denmark	2010	17.5%	1.5%	3.2%	9.5%	5.3%	5.2%	5.6%	20.7%	0.7%	4.2%	0.9%	19.3%	6.4%
	2030	17.4%	1.9%	2.2%	9.8%	3.8%	7.5%	5.0%	20.0%	1.3%	3.8%	0.7%	21.0%	5.5%
Estonia	2010	2.8%	4.3%	0.6%	3.9%	2.4%	1.1%	2.2%	7.6%	0.3%	0.6%	0.7%	69.9%	3.6%
	2030	3.4%	8.7%	0.6%	5.9%	2.4%	1.7%	2.2%	4.7%	0.5%	0.8%	0.8%	63.5%	4.9%
Finland	2010	2.4%	10.5%	0.6%	3.8%	6.3%	14.2%	3.1%	18.4%	1.9%	3.0%	0.4%	29.8%	5.5%
	2030	2.0%	12.6%	0.4%	4.2%	5.0%	11.8%	2.7%	13.0%	1.6%	2.2%	0.3%	39.0%	5.0%
France	2010	13.4%	1.6%	5.7%	8.4%	8.4%	10.2%	5.3%	20.0%	0.8%	8.8%	1.0%	10.7%	5.7%
	2030	14.1%	1.6%	5.7%	9.6%	8.7%	12.3%	5.4%	21.8%	0.8%	7.6%	0.7%	6.2%	5.4%
Germany	2010	8.4%	1.2%	2.0%	8.8%	7.8%	13.0%	3.8%	10.2%	0.8%	2.0%	0.3%	38.4%	3.2%
	2030	9.4%	1.7%	1.8%	13.7%	9.1%	21.6%	5.1%	5.1%	0.9%	1.9%	0.2%	26.1%	3.4%
Greece	2010	6.6%	0.3%	1.8%	4.5%	2.8%	6.8%	2.7%	5.2%	0.3%	1.5%	0.2%	64.0%	3.3%
	2030	9.7%	0.3%	2.9%	7.2%	3.7%	8.6%	6.9%	7.3%	0.8%	2.1%	0.2%	46.3%	4.2%
Hungary	2010	10.1%	2.0%	3.6%	9.3%	8.2%	13.8%	8.7%	13.0%	1.0%	1.2%	1.2%	21.9%	6.0%
	2030	21.1%	3.3%	7.7%	6.7%	4.8%	21.3%	7.0%	8.6%	1.5%	1.0%	0.8%	11.4%	4.6%
Ireland	2010	10.3%	0.6%	3.3%	5.5%	1.1%	33.8%	3.2%	10.5%	15.0%	3.3%	0.9%	10.5%	1.8%
	2030	8.1%	0.7%	2.1%	6.9%	1.4%	39.4%	4.4%	9.1%	11.3%	5.0%	1.1%	7.1%	3.4%
Italy	2010	11.4%	0.9%	2.2%	10.6%	12.8%	19.8%	2.8%	13.3%	0.6%	2.5%	0.8%	18.6%	3.9%
	2030	10.8%	1.1%	1.1%	11.6%	9.9%	30.1%	2.5%	8.8%	0.9%	2.1%	0.6%	17.3%	3.2%
Latvia	2010	9.5%	34.5%	2.8%	7.5%	8.1%	1.2%	2.9%	14.5%	0.5%	1.4%	2.4%	7.3%	7.5%
	2030	10.9%	35.2%	2.3%	14.8%	7.5%	2.2%	2.6%	4.7%	1.8%	1.4%	1.8%	4.5%	10.3%
Lithuania	2010	16.6%	6.1%	5.6%	12.6%	4.5%	1.0%	8.7%	16.1%	2.3%	1.6%	2.0%	15.8%	7.0%
	2030	22.1%	7.2%	5.6%	17.5%	4.0%	2.1%	7.6%	10.7%	2.1%	1.7%	1.6%	10.3%	7.4%
Luxembourg	2010	3.5%	2.4%	0.8%	8.0%	35.3%	16.6%	6.6%	6.5%	2.1%	2.9%	2.9%	5.5%	7.1%
	2030	3.2%	2.7%	0.7%	6.5%	30.2%	23.4%	10.2%	6.6%	2.5%	3.5%	1.9%	2.6%	5.9%
Malta	2010	19.1%	0.3%	0.7%	22.9%	3.8%	2.0%	7.7%	1.6%	0.1%	4.0%	7.7%	20.2%	9.8%
	2030	19.6%	0.4%	0.9%	20.2%	3.5%	3.1%	6.6%	5.2%	0.3%	4.0%	5.6%	22.6%	8.0%
Netherlands	2010	14.2%	0.5%	1.3%	18.5%	8.8%	11.6%	7.0%	4.2%	0.6%	3.1%	2.5%	21.1%	6.7%
	2030	10.8%	0.5%	1.1%	25.9%	7.9%	12.2%	13.9%	2.7%	0.4%	2.6%	2.2%	13.3%	6.6%
Poland	2010	7.0%	1.3%	2.7%	5.8%	8.2%	5.9%	2.7%	9.5%	0.6%	1.5%	0.4%	52.1%	2.1%
	2030	4.1%	1.7%	1.4%	13.6%	7.8%	7.1%	2.6%	9.7%	1.0%	1.4%	0.3%	47.5%	1.8%
Portugal	2010	12.3%	3.4%	1.5%	12.6%	5.8%	4.7%	2.4%	36.3%	0.9%	3.5%	0.9%	9.7%	5.9%
	2030	18.3%	4.4%	1.5%	15.3%	6.3%	4.9%	2.7%	28.7%	2.0%	4.2%	0.7%	5.5%	5.5%
Romania	2010	8.8%	1.9%	2.9%	3.4%	7.5%	5.5%	3.7%	35.3%	0.3%	1.0%	0.5%	25.9%	3.2%
	2030	11.3%	2.0%	2.8%	7.6%	9.2%	7.8%	5.6%	22.1%	0.3%	1.5%	0.6%	24.5%	4.8%
Slovakia	2010	6.2%	3.9%	1.8%	6.3%	16.4%	13.1%	20.7%	10.3%	0.3%	2.0%	0.7%	11.3%	7.0%
	2030	4.9%	3.3%	1.1%	5.2%	11.8%	9.6%	41.0%	9.8%	0.2%	1.4%	0.5%	5.6%	5.6%
Slovenia	2010	5.2%	1.7%	1.3%	13.3%	4.8%	20.5%	4.3%	19.9%	0.6%	1.1%	1.4%	21.5%	4.5%
	2030	4.1%	3.0%	0.7%	25.3%	3.9%	15.3%	5.1%	17.2%	0.9%	1.1%	1.2%	18.5%	3.6%
Spain	2010	11.2%	1.0%	2.4%	7.2%	6.8%	15.5%	3.2%	21.8%	0.8%	7.7%	1.2%	17.8%	3.5%
	2030	14.9%	1.2%	1.8%	6.7%	7.0%	19.4%	3.6%	19.0%	0.5%	8.5%	1.3%	12.5%	3.6%
Sweden	2010	5.4%	11.0%	1.5%	10.3%	10.9%	12.5%	6.9%	17.6%	0.5%	3.4%	0.5%	10.8%	8.6%
	2030	4.1%	10.4%	0.8%	12.1%	13.4%	12.7%	10.0%	14.9%	0.5%	3.6%	0.4%	4.5%	12.6%
UK	2010	12.1%	1.3%	3.0%	12.6%	8.2%	7.5%	7.4%	11.5%	0.5%	5.9%	0.4%	22.4%	7.3%
	2030	11.1%	1.2%	2.0%	15.8%	10.7%	11.2%	8.1%	5.7%	0.7%	6.9%	0.3%	19.6%	6.8%

Table 7-3: Evolution of material flows of TMR among EU27-coutries; GINFORS baseline results

A description of the material modules of both models is given in section 3. There are four main disparities in the structures of the material modules:

First in each material category GINFORS distinguishes the group “others” (see Table 3-3), whereas in E3ME this category does not exist and insofar is included in the mentioned categories (see Table 3-11). This is important for imports, because the economic drivers for “others” are in GINFORS different from the drivers of the other subcategories of that material. The example of imported “other metals and products mainly from metals”. Here the economic drivers are imports of semi finished and finished imported investment goods. These product groups are not mentioned as drivers of material inputs in E3ME, which may contribute to the less dynamic development of metals in comparison with GINFORS. This discrepancy in modelling is given for all materials.

A second disparity concerns the fact that the material imports of “iron ores” and “non ferrous metals” are driven in E3ME by the imports of “basic metals” (see Table 3-11), whereas in GINFORS the material imports of “iron ores” is driven by the economic imports of “iron and steel” and the material imports of “ores of non ferrous metals” by the economic imports of “nonferrous metals”. This differentiation is in E3ME not possible, because the EU input output tables only have the aggregate “basic metals”, whereas the OECD tables used in GINFORS have the detailed information. This point is very important for the result of the forecast, since the economic imports of “non ferrous metals” are much more dynamic than those of “iron and steel”, and further the material group “ores of nonferrous metals” has much higher hidden flows than “iron ores”.

A third difference in the material modules concerns the method how prices enter the calculations of material demand. In E3ME prices of materials are explicitly part of the estimated material demand functions. The model GINFORS transforms the international raw material prices into the vector of import prices. From there the price information gets into the input- output system and influences together with domestic prices the input coefficients. A change of the input coefficients has then an impact on imports and domestic production, which change material demand. This is the reason why in the case of GINFORS simulation results can only be presented for countries with time series information of their input coefficients.

A fourth difference between the material modules is the forecast of material intensity. In the case of E3ME the econometric estimation of every material demand function implicitly contains an estimate of the material intensity. In the case of GINFORS the historic material intensities have been analysed in section 3 of this report (see Table 3-9). This information is used to calibrate the parameter in E3ME linking material consumption in physical terms with the economic driver (Cambridge Econometrics 2011c, p. 22). There may be a consistency problem concerning the estimates for the other explanatory variables in the material demand equations.

These disparities in the methodology explain the differences in results, and illustrate to some extent the degree of uncertainty inherent in the results, and that is unavoidable in any modelling scenario.

7.2.2 RESULTS FOR BASELINE 2: THE EFFECTS OF LOWER RAW MATERIAL PRICES (SIMULATION 2)

What would be the impact of the policy mix, if the oil price would be 20% lower in 2030? With regards to historical raw material price correlations one might assume that this lower price scenario would be accompanied by a reduction of -17% in the price of iron ores, -13% in copper prices and -5% in wheat prices. For E3ME a detailed description of results is not given in Cambridge Econometrics (2011c), so only GINFORS results can be inferred.

Canada	+ 1.2%	China	- 0.3%
EU27	+ 1.5%	Southafrica	- 2.7%
USA	+ 3.1%	Russia	- 4.2%
Japan	+ 3.2%	OPEC	- 7.0%
Korea	+ 3.6%		

Table 7-4: The impact of lower raw material prices on real GDP of selected countries. Deviations of simulation 2 from the baseline (simulation 1) in %. Results from GINFORS.

Lower raw material prices influence the world economy in separate ways. Table 7-4 shows that typical exporters of raw materials like South Africa, the OPEC countries and Russia, would have strong losses in their real GDP, whereas major importers of raw materials like Japan, the USA and Korea, increase their GDP by more than 3%. But the story is much more complex: the effects on GDP depend additionally on the material intensity of production in the different countries and the regional structure of their trade with manufactured goods. The first point is self evident, the second means that for a country with high material imports and a high material intensity of production the total effect on GDP is strongly influenced by the answer to the question: does it deliver more to Russia and to the OPEC countries than to the USA and Japan? These indirect effects matter. They play a role interpreting the lower impact on GDP of EU27 compared with the impact on GDP of the USA.

What are the effects in detail for real GDP and TMR of the European countries? Table 7-5 gives an overview for the 17 European countries that are available with time series of input- output tables.

In all countries we observe a rise in GDP with a variety between +0.1% (Denmark) and +5.8% (Slovakia). The fall in raw material prices reduces nominal imports of raw materials and thus raises GDP. The rise in GDP increases also TMR in all countries. In most countries the rise in TMR is stronger than the rise in GDP, which means a fall in resource efficiency, which is in line with our expectations when there are falling resource prices.

But in Hungary, the Slovak Republic and Luxembourg this is not the case. The reason for these “abnormal” reactions is a structural effect: Product imports on later stages often have high hidden flows in their “rucksacks” and insofar have a high weight in TMR. The reaction of these imports on later stages depends from the relation of the domestic price on later stages and the import price on later stages. So for example the import ratio for investment goods in the Slovak Republic may fall because the domestic price for investment goods in the Slovak Republic falls stronger than the import price for investment goods. So it may happen that the imports of investment goods fall in spite of the rise in GDP. If these goods have a high weight in TMR a rise in GDP could even be consistent with a fall in TMR.

	real gdp	TMR
Austria	+ 1.2%	+ 1.8%
Czech Republic	+ 4.8%	+ 5,0%
Denmark	+ 0.1%	+ 1.9%
Finland	+ 2.5%	+ 5.6%
France	+ 1.3%	+ 1.6%
Germany	+ 0.5%	+ 3.8%
Greece	+ 2.4%	+ 4.2%
Hungary	+ 1.9%	+ 1.6%
Ireland	+ 2.3%	+ 3.4%
Italy	+ 1.0 %	+ 1.4%
Luxembourg	+ 3.0 %	+ 1.7%
Netherlands	+ 1.5%	+ 2,0%
Poland	+ 3.6%	+ 4.8%
Portugal	+ 2.4%	+ 0.7%
Slovakia	+ 5.8%	+ 2.4%
Spain	+ 3.3%	+ 4.6%
Sweden	+ 1.0 %	+ 3.4%
Weighted average	+ 1.7%	+ 3.4%

Table 7-5 The impact of lower raw material prices on real GDP and TMR of selected European countries. Deviations of simulation 2 from the baseline (simulation 1) in %. Results from GINFORS

This result shows that we have to be very careful in the interpretation of aggregated figures. What at first sight seems to be an abnormality can be identified as a structural effect. In all three countries metals are reacting very weakly compared with TMR.

7.3 IMPACTS IN THE POLICY SCENARIOS

The following section summarizes the results in relation to the simulation 1, which is based on the PRIMES reference scenario. In Cambridge Econometrics (2011c) and Distelkamp et al. (2011c) the results for all scenarios are discussed separately with detail at the sectoral level. We now concentrate on the macro impacts.

7.3.1 THE ECONOMIC RESULTS FOR MEMBER STATES

Table 7-6 gives an overview of the impact on GDP by Member State for the detailed scenarios and the integrated policy mix scenario. The policy mix scenario covers all policy instruments of the three single scenarios, but because of the existence of joint interaction effects the impacts are not just the sum of the single scenario impacts. GINFORS is represented with results only for those 17 European countries, which have time series information for input coefficients. This is necessary, because input coefficients of GINFORS are generally endogenized. Because the coverage of EU27 by these 17 countries is very high (in terms of gdp about 80%), the percentage change of these numbers can be taken as a proxy for EU27.

The taxation scenario assumes a tax on the inputs of metals in the investment goods industries. The related input coefficients have in E3ME a price elasticity of -1 from the beginning of the simulation period, whereas in GINFORS it is assumed that the price elasticity shifts S shaped from 0 in 2010 to -1 in 2030. For the rationale of this assumption see section 7.1.1. This means in the case of E3ME that the taxation has no direct costs in the investment goods industries, whereas in the case of GINFORS there are direct costs.

Impact on real GDP by member state

	Taxation		Recycling		Information programme		Policy mix	
	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS
Austria	3.9%	-1.0%	-2.8%	0.2%	1.2%	4.4%	1.8%	3.1%
Belgium	0.9%		-1.6%		4.5%		4.1%	
Bulgaria	0.7%		-0.1%		-0.9%		-1.0%	
Cyprus	-0.5%		0.4%		0.6%		0.3%	
Czech Rep.	3.1%	0.0%	-2.0%	4.0%	4.0%	7.1%	4.0%	7.9%
Denmark	0.7%	0.0%	1.7%	-0.1%	-0.9%	2.3%	1.3%	2.1%
Estonia	1.8%		0.4%		-0.5%		2.2%	
Finland	1.4%	0.2%	-0.5%	0.7%	0.1%	4.3%	1.2%	4.9%
France	2.0%	0.3%	-0.2%	-0.2%	1.7%	2.6%	3.4%	2.5%
Germany	1.4%	0.3%	-0.5%	0.0%	-0.2%	3.1%	0.4%	3.1%
Greece	0.0%	1.6%	-1.1%	1.6%	-0.3%	3.3%	-1.2%	6.1%
Hungary	1.7%	-0.3%	-2.8%	0.7%	1.0%	5.3%	-0.7%	5.4%
Ireland	1.0%	1.2%	-0.8%	0.6%	-1.2%	5.4%	-1.0%	5.7%
Italy	1.4%	-0.3%	0.3%	0.1%	0.0%	1.7%	1.5%	1.3%
Latvia	0.9%		0.3%		0.9%		1.7%	
Lithuania	2.8%		0.1%		1.6%		4.3%	
Luxembourg	-1.8%	6.0%	-4.9%	0.9%	-0.2%	5.4%	-5.6%	10.5%
Malta	2.3%		4.0%		0.8%		6.2%	
Netherlands	0.4%	2.5%	0.2%	-0.1%	0.7%	7.2%	2.5%	9.6%
Poland	2.9%	-0.5%	0.3%	0.0%	0.5%	2.9%	3.8%	2.1%
Portugal	1.7%	-0.3%	-2.7%	0.7%	-0.2%	2.4%	-1.4%	1.4%
Romania	1.5%		0.5%		0.2%		1.7%	
Slovakia	0.6%	-3.9%	2.1%	1.1%	-1.0%	5.4%	1.0%	3.3%
Slovenia	1.4%		-1.4%		0.1%		0.1%	
Spain	1.7%	-0.1%	-0.6%	0.1%	1.6%	4.4%	3.0%	4.2%
Sweden	2.6%	0.4%	0.0%	0.6%	1.0%	1.5%	4.5%	2.0%
UK	1.0%		0.5%		1.0%		2.3%	
EU27	1.5%		-0.2%		0.8%		2.0%	
EU17		0.2%		0.2%		3.3%		3.3%

Source(s): E3ME, Cambridge Econometrics; GINFORS, GWS

Table 7-6 Impact on GDP by Member States. Deviations from the baseline in the year 2030 in per cent.

Further effects of the scenario are a reduction of metal imports and a reduction of production and value added in the domestic basic metals industries. The reduction of imports has a positive impact on GDP, the reduction of production in basic metals a negative impact. The recycling of the tax via a reduction of income taxes gives a positive impact. For E3ME we expect a positive total impact, which is approved by the results. In the case of GINFORS we have rising costs and prices in the investment goods industries, which increase imports and reduce exports depressing GDP. So the impact on GDP is in the average lower for GINFORS than for E3ME. The variation in country results is influenced greatly by the structure of production and the extent to which the country is engaged in international trade (including trade between Member States).

In the recycling scenario the substitution of ores by secondary products, which are at least partly produced domestically, has a positive impact on GDP. The conservative assumption that the sum of real input coefficients for ores and for secondary metal inputs in the production of basic metals remains constant gives higher production costs for basic metals, if the prices for secondary metals rise stronger than that for ores. For energy inputs in basic metals a substitution of coal (coke) by electricity offers also the possibility of cost and price effects (positive or negative) for basic metals. This explains the variety in country results, but also differences between E3ME and GINFORS, which are in most countries very small.

The information and consulting scenarios are different for E3ME and GINFORS and insofar the results are not directly comparable without further reasoning. In the case of E3ME it has been assumed that the information program is applied in fewer manufacturing sectors than in GINFORS (see chapter 7.1.3.). But nevertheless this communication error gives some interesting insights.

The sectors addressed by the program will be able to reduce their material costs. Since the additional costs for consulting services equal the material savings of one year, the sectors under the program realize a reduction of unit costs and prices, which raises domestic and international demand. On the other side value added in those sectors that deliver the saved materials will fall. The strength of this effect depends on the relation between imported and domestically produced materials that are saved. The simulation results for GINFORS are strict positive. The results for E3ME are in the average also positive, but lower. This is consistent with the differences in the scenario assumptions. The results further show that for some countries E3ME generates negative impacts on GDP. This can be explained with lower price reductions on the one side, because a smaller number of industries take part in the program, and a selection of industries is under the program, whose deliverers of materials are to larger extent domestic producers.

Compared with the results of the MOSUS project (Giljum et al. 2008) the rebound effects found in the MACMOD project are much smaller. The reason is that in the MACMOD project we make, what we consider to be the more realistic assumption that the information program is concentrated on sectors that typically have small and medium sized firms, whereas in the MOSUS project it was assumed that the whole manufacturing sector was subject to the information program.

The impacts in the policy mix scenario are not equal to the sum of the individual policies due to joint interaction effects, but nevertheless can be easily explained by it.

Table 7-7 gives the results for employment. Of course these are not identical to the GDP effects, because labour intensities vary across sectors. Further the movement of the real wage rate is an additional factor that has to be mentioned. But a positive correlation between GDP effects and effects on employment is shown, and generally to be expected.

Impact on employment by member state

	Taxation		Recycling		Information programme		Policy mix	
	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS
Austria	1.0%	-0.7%	-0.2%	0.1%	-0.6%	1.3%	0.2%	0.4%
Belgium	-0.1%		0.2%		0.9%		0.6%	
Bulgaria	0.0%		-0.2%		-3.1%		-3.4%	
Cyprus	0.7%		-0.2%		-0.3%		0.1%	
Czech Rep.	0.2%	-0.6%	-0.1%	1.9%	-0.2%	2.8%	-0.2%	2.7%
Denmark	-0.3%	-0.1%	0.8%	-0.1%	-0.7%	0.1%	-0.3%	-0.2%
Estonia	0.1%		-0.4%		-1.8%		-2.0%	
Finland	-0.3%	0.0%	0.5%	0.5%	-1.6%	1.4%	-1.8%	1.7%
France	0.2%	0.2%	0.9%	0.0%	0.4%	0.5%	1.3%	0.6%
Germany	0.4%	0.5%	0.4%	0.1%	-0.4%	1.0%	0.3%	1.4%
Greece	0.0%	0.7%	-0.1%	0.8%	0.0%	1.8%	0.0%	3.0%
Hungary	-0.1%	-0.5%	-0.1%	0.6%	-0.6%	1.8%	-0.9%	1.8%
Ireland	0.1%	0.4%	0.1%	0.3%	0.0%	0.5%	0.2%	0.5%
Italy	-0.3%	-0.3%	1.8%	0.1%	-0.7%	0.5%	0.4%	0.1%
Latvia	0.3%		0.5%		-0.3%		0.6%	
Lithuania	0.7%		0.4%		-0.5%		0.5%	
Luxembourg	-0.3%	2.3%	2.7%	0.4%	-0.4%	1.4%	1.1%	3.2%
Malta	0.2%		0.7%		-0.2%		0.6%	
Netherlands	0.3%	1.0%	0.7%	0.0%	-0.2%	2.4%	0.6%	3.1%
Poland	0.4%	-0.3%	0.2%	0.0%	0.3%	1.1%	0.9%	0.6%
Portugal	0.4%	-0.1%	2.0%	0.2%	0.6%	0.8%	3.1%	0.4%
Romania	0.3%		0.6%		-0.7%		0.2%	
Slovakia	0.4%	-5.5%	0.7%	0.3%	0.2%	1.2%	0.5%	-2.9%
Slovenia	0.6%		-0.2%		-0.1%		0.1%	
Spain	0.4%	-0.1%	0.5%	0.0%	0.6%	1.8%	1.7%	1.6%
Sweden	0.6%	0.7%	0.3%	0.3%	-0.4%	0.7%	0.9%	1.5%
UK	0.2%		0.3%		0.0%		0.4%	
EU27	0.2%		0.6%		-0.2%		0.6%	
EU17		0.0%		0.1%		1.4%		1.3%

Source(s): E3ME, Cambridge Econometrics; GINFORS, GWS

Table 7-7 Impact on employment by Member States. Deviations from the baseline in the year 2030 in per cent.

7.3.2 THE SUMMARIZED RESULTS

In this section we discuss summarized results, which for E3ME means that aggregates for the EU27 are calculated, whereas in the case of GINFORS aggregates for the 17 countries with time series input output data are given.

summary economic impacts

	Taxation		Recycling		Information		Policy mix	
	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS
GDP	1.5%	0.2%	-0.2%	0.2%	0.8%	3.3%	2.0%	3.3%
Employment	0.2%	0.0%	0.6%	0.1%	-0.2%	1.4%	0.6%	1.3%
Household spending	1.1%	0.4%	0.3%	0.3%	1.3%	1.8%	2.9%	2.2%
Consumer prices	-0.4%	0.1%	-0.2%	-0.1%	-1.1%	-5.1%	-1.8%	-4.9%

Source(s): E3ME, Cambridge Econometrics; GINFORS, GWS

Table 7-8 Summary economic impacts. Deviations from the baseline in per cent.

Table 7-8 sets out the already known results for GDP and employment with further macroeconomic information on real household spending and consumer prices. We see that in nearly all the scenarios and for both models positive effects on GDP and employment are accompanied by positive effects on real household spending and (with one exception) with falling consumer prices. The exception concerns the GINFORS results for the taxation scenario, where we have already seen that different assumptions about the price elasticities of metal inputs in the investment goods industries are responsible for the result of slightly rising prices for investment goods, which diffuse through the economy and might slightly raise consumer prices. We also find a correspondence to our discussion on GDP effects and employment effects for the information scenario. We there argued that prices have to fall stronger in the GINFORS simulation than in the E3ME simulation, which is approved here.

Table 7-9 summarizes the results for TMR. The **taxation scenario** has some smaller side effects on biomass and non-metallic minerals. The point of interest is of course the effect on metals. For E3ME the impact especially on iron ores is with -0.9% much lower than for GINFORS (-15.1%). This is a surprising result as there is substantial loss of output in the European basic metals and metal goods sectors (Cambridge Econometrics 2011c, p. 34) but is partly due to the relative intensities between Member States and partly to a strong rebound effect (especially as there is no direct incentive for the basic metals sector to improve efficiency).

In the **recycling scenario** both models give similar and expected results for the use of metals. For non- metallic minerals the differences between the models result from differences in scenario assumptions: The E3ME team analysed recycling generally of construction minerals, whereas the GINFORS team considered only the impact of a reduction of the inputs of non-metallic minerals delivered from the mining and quarrying sector to the construction sector. The rise of wood in E3ME results is an artefact, since the furniture sector is part of the recycling sector. This classification will be changed in the next update (Cambridge Econometrics 2011c, p. 31).

The E3ME results for the **information scenario** show strong reductions for biomass. The rise of construction minerals, which dominates the result for non- metallic minerals, is more surprising but is explained by the choice of sectors targeted; construction was not part of the programme but non-metallic mineral products was included, leading to lower prices for construction minerals and an increase in demand. That use of metal ores reduces less than the use of biomass is plausible since the sectors under the program are not metal intensive. GINFORS calculates smaller reductions for biomass, since agriculture is not included in the information program in the GINFORS simulation.

Weigted averages of material impacts (TMR) among the countries

	Taxation		Recycling		Information		Policy mix	
	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS	E3ME	GINFORS
Biomass material requirement	0.1%	-0.1%	1.4%	0.2%	-12.1%	-2.3%	-10.8%	-2.4%
Agriculture		0.0%		0.2%		-4.9%		-4.9%
Feed	-0.2%		0.2%		1.8%		1.7%	
Food	0.0%		0.5%		-14.9%		-14.4%	
Wood	0.4%	0.0%	4.7%	0.3%	-16.7%	-6.7%	-12.5%	-6.6%
Others		-0.1%		0.2%		0.3%		0.2%
Non-metallic minerals material requirement	1.0%	-1.4%	-47.5%	-7.9%	3.2%	-2.0%	-46.4%	-10.8%
Construction minerals	0.7%	-1.5%	-50.4%	-11.0%	4.6%	-2.3%	-48.1%	-14.1%
Industrial minerals	3.6%	-2.5%	-13.0%	-5.9%	-13.1%	-3.2%	-25.4%	-11.2%
Others		-0.6%		-0.3%		-0.9%		-2.2%
Metal ores material requirement	-3.1%	-10.9%	-37.0%	-35.3%	-4.8%	-2.9%	-42.1%	-44.7%
Iron ores	-0.9%	-15.1%	-38.0%	-25.0%	-3.7%	-3.3%	-41.9%	-39.0%
Non-ferrous metals	-5.0%	-11.6%	-36.1%	-38.2%	-5.9%	-3.6%	-42.3%	-47.8%
Others		-2.6%		-42.1%		-0.3%		-44.0%
Others (MF 5)		-1.0%		0.3%		-2.3%		-3.3%
Total material requirement	-0.5%	-4.0%	-21.7%	-12.3%	-2.4%	-2.1%	-24.7%	-17.1%

Source(s): E3ME, Cambridge Econometrics; GINFORS, GWS

Table 7-9 Impact on material use. Weighted averages of the country specific results. Deviations from the baseline in the year 2030 in per cent.

Generally the reductions are lower than for E3ME (exception: construction minerals). The reason is that sectoral and economy wide rebound effects play a bigger role, because price reductions are stronger for GINFORS than for E3ME.

Taking the differences in scenario formulations into account we observe for both models similar reactions. Of course the similarities are greater where the driving forces are more exogenous – as in the recycling scenario – and they are smaller the more endogenous the adjustment mechanisms are – as in the information scenario.

The impact on **CO2 emissions** are not a focus of this project, but of course have been calculated. For the policy mix scenario E3ME measures a reduction of -0.4%, which gives with rising GDP an increase of energy efficiency of 2.2%. In the case of GINFORS The input of fossil energy carriers, which are not subject of the policy instruments, are reduced by -3.9% in spite of the positive GDP effect. This means that our policy mix for a higher material efficiency indirectly raises efficiency for fossil energy carriers by +7.2%. In other words, there are strong co-benefits in the sense that resources policy will also deliver climate change benefits.

In terms of **decoupling**, the baselines from both models show material consumption continuing to rise (especially after recovery from the recession). The GINFORS baseline has a strong rise in metal use in particular and also of TMR. The question therefore arises of whether decoupling can be reached in the policy mix scenario.

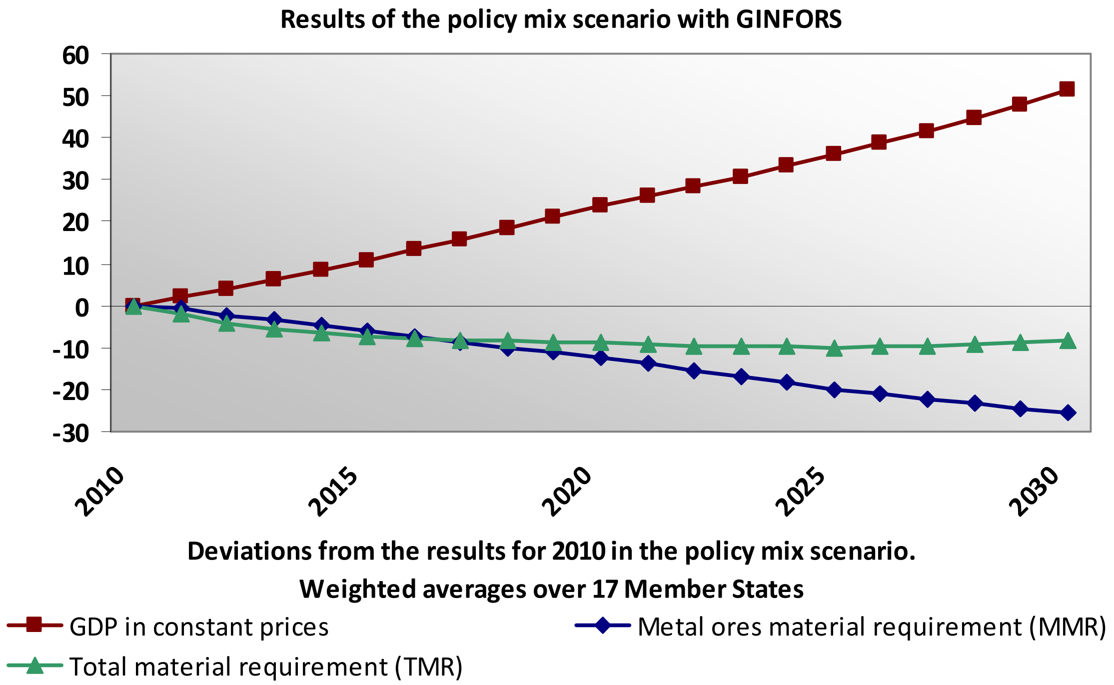

Figure 7-3: Results of the policy mix scenario with GINFORS

Figure 7-3 shows the results for the **policy mix scenario** calculated with GINFORS starting with 2011, the first year of simulation. Shown are indices for GDP in constant prices and for metals material requirement, both set to 100 in 2010. In 2030 GDP is 51% higher and the material requirement of metals including the hidden flows is 26% lower than in 2010. That is absolute decoupling! There is also absolute decoupling for TMR: Total Material Requirement in 2030 is 8.1% lower than in 2010.

8 SUGGESTIONS FOR FURTHER RESEARCH

In summary, the results from the two models show many similarities but also some differences. The baseline assumptions are the same for both models. The economic elements of the models show not identical but similar reactions. This is the experience from the discussion of the impacts of the alternative scenarios in this project and also in the PETRE project (Ekins and Speck 2011). The data on material use has been the same for both models. However, there are differences in the modelling of material use and especially the link between the economy and the physical material inputs. The implications of these different approaches could be explored further, particularly in the context of the available data and the assumptions that this entails. Further research on the data itself is also recommended.

Our project has shown that **market failures** and their avoidance is a strong issue for the design of a successful material efficiency policy. But the modelling of this topic is always confronted with a lack of data concerning the direct gains of consulting and the direct costs concerning the sectoral and also country details. There is now much experience in the efficiency agencies like demea and others that could be collected and analysed by a research project.

A critique of our project may argue that the modelling approach is not able to analyse the impact of the environmental pressures on the state of the environment and the feed back to the economy. This is true, but until now there is no modelling approach that tried this based on a complex modelling of the economy as E3ME and GINFORS achieve.

Economic environmental modelling is faced with a dilemma: On the one side a comprehensive analysis of the pressures on the environment is demanded. This requires a very detailed and complex economic structure: To analyse green house gas emissions needs a different economic sector focus than the extraction of different kinds of materials and the use of fresh water, and all these different sectors have to be depicted in their interdependency including the macro-economic closure. Furthermore, a global perspective is desired without loss of the country detail. On the other hand it has to be mentioned that the impact of the pressures on the state of the environment and the feedback of changes in ecosystem services on the economy demand an additional complex and large system with a very different biophysical logic and different regional and time scales.

Two – way linkage of the economy and the environment is therefore either carried out with a high degree of abstraction or it requires scaling back the scope of questions analysed. An example for the first type is the UNEP GER (Bassi et al. 2010). This model has been taken by the UN for its Global Modelling Work from the Millennium Institute. UNEP GER is a global version of the T21 model, which exists for several countries as stand-alone models that "integrate economic, environmental and social elements using a system dynamics approach" (Herren 2005, p. 10). The strength of the modelling approach is that it allows analysing simultaneously the three dimensions of sustainability, its weakness is the poor modelling of the economy: The global model UNEP GER has no country structure and differentiates only three economic sectors: agriculture, industry and services. Central topics of green growth like international competition, structural change induced by technological change inside the industry sector cannot be addressed. Further, the technology is given with Cobb Douglas production functions, which have the implication that all elasticities of substitution are -1, describing an extremely flexible economy. It can be doubted whether this high level of abstraction can be the basis for policy analysis.

A better research strategy has been followed with the IMAGE model (Bouwman et al. 2006), which in its version 2.4 has been linked with the GTAP model. The model is focussed on energy, climate, land use and agricultural questions. This allows a sectoral structure that differentiates in respect to energy questions the sectors industry, transport, residential, services, other sectors and with respect to agricultural questions industry, services, agriculture, and the last differentiated into 12 product groups. With its powerful biophysical modules IMAGE is a useful instrument for the analysis of policy questions concerning energy, land use and agriculture. But for the analysis of material use this is aggregated by far too much.

A modelling approach including different materials, energy, water, land use that will be able to answer the complex questions concerning biotic material inputs (biomass) and their interrelationships to population growth, water availability, energy supply and material use in the needed disaggregation by sector and country can only be analysed adequately with a hard link between models like E3ME or GINFORS on the one side and a global bio-physical model like LPJmL (Beringer et al. 2011) on the other side. One important technical precondition for the success of such an exercise is the fact that these models are solving year by year and that the deep regional disaggregation of LPJmL can be aggregated to the country structures. With the realistic assumption that nature reacts with a lag of at least one year on the impacts of the economic system, both systems could be solved in a technical sense independently year by year; but have the full two way linkage.

A further critique could be that E3ME and GINFORS present point forecasts without confidence intervals, which means that uncertainty is not mentioned in the results. The models are best prepared for such an extension because the parameters are estimated econometrically and insofar the standard errors are available. But to run the necessary Monte Carlo simulations requires a substantial technical effort, which could not be undertaken within the resources of this project. As far as we know such an exercise with large econometric models has not been undertaken to date, but it could be carried out with E3ME and GINFORS in the future.

9 CONCLUSIONS

Our findings from the long run policy simulations till 2030 show a **high potential for resource efficiency strategies to reduce material consumption and to decouple it from economic growth**.

Without any border adjustments the Member States of the EU might be able to install a policy mix of recycling, taxation and information and consulting that has the potential to initiate win-win situations with rising GDP and employment and falling material requirements, especially for metals, in almost all countries. This study suggests that absolute decoupling of economic growth from material consumption does not necessarily need a general global agreement.

On the global level a sectoral agreement on **recycling of metals** could achieve a lot, and would be in the economic interests of all countries.

Taxation on the use of metals without border adjustments could be chosen for later stages of production as the investment goods industries, where the reduction of metal inputs is rather flexible. Of course the revenue of the additional tax has to be recycled by the reduction of other taxes. A resource tax on ores without border adjustment would be inefficient, because the domestic production of basic metals would be substituted by imports.

Information and consulting programs for SME's for the abatement of material inputs reduce costs, create value added for the firms under the program, but reduce sales and value added of the producers of the materials. The total effect of this is positive and induces an economy wide rebound effect, which means a rise in GDP and employment.

The analyzed policy instruments create material efficiency and economic efficiency gains. The latter reduce prices accompanied by rising domestic and international demand triggering domestic production and imports and thus TMR. But the fear of Jackson (2009) and others that resource efficiency policies create such strong **rebound effects** that all material efficiency gains are more or less compensated or even overcompensated (backfire) and thus impede decoupling is not confirmed.

A resource efficiency policy would also **support climate policy**, reducing energy emissions. For the policy mix scenario E3ME measures a reduction of -0.4%, which gives with rising GDP an increase of energy efficiency of 2.2%. In the case of GINFORS The input of fossil energy carriers, which are not subject of the policy instruments, are reduced by -3.9% in spite of the positive GDP effect. This means that our policy mix for a higher material efficiency indirectly raises efficiency for fossil energy carriers by +7.2%. In other words, there are strong co-benefits in the sense that resources policy will also deliver climate change benfits.

The **baseline forecast** of E3ME gives a fairly neutral view of Europe's future resource consumption. In a world with rising raw material prices, a moderate economic growth more or less as in the past in Europe, and an active but by no means ambitious European climate policy, TMR of Member States continue to grow (post recovery from the current recession) but only slowly. The requirement for metals, which has been particularly affected during the crisis due to the loss of demand for metal-intensive investment goods, follows this pattern. However, it should be remembered that the rising prices that cause this pattern of consumption are themselves an indicator of constrained supply, so the model results still highlight potential risks to future growth.

The main conclusion from the project is that **EU Member States face the risk of importing more and more materials**. In this regard metals, biomass and industrial minerals seem to constitute a major problem as they contribute the largest share to Total Material Requirements of Member States of the EU. Europe is therefore outsourcing environmental pressures. A development which tends to intensify economic and geopolitical risks, such as supply restrictions and dependency on few companies and countries for access to natural resources. Only a policy that actively addresses those inputs and the material consumption that goes along with it can ensure the needed absolute decoupling of GDP growth from total material requirements.

Given our overall findings we therefore see strong arguments in favour of a **policy mix** to stimulate an increase in resource productivity. Even without border adjustments a policy mix of recycling by smart regulation, taxation and information instruments will be able to induce falling material requirements in European Member States. The rebound effects would be rather low so that the efficiency gains reduce absolutely material inputs. For GDP and employment positive effects are likely. Summarizing the results of the simulation experiments with both models the following rule of thumb can be derived as an average for the Member States of the EU: A reduction of TMR by 1% is accompanied by rise of GDP between 12 and 23 billion € and a rise of employment between 0.04% and 0.08%, which for EU27 means a number between 100000 and 200000 people. With the calibration of the policy measures that we have chosen in our experiments TMR in all Member States would in the average reduce between 17 and 24 %. GDP in constant prices would rise in the European Union totally between 240 and 380 billion € and employment would improve by 1.4 to 2.8 million people.

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11 APPENDIX A: DETAILED TMR TABLES

	Austria	Belgium	Bulgaria	Cyprus	Czech Republic	Denmark	Estonia	Finland	France
TOTAL MATERIAL REQUIREMENT (TMR)	626.8	1546.9	461.1	42.1	1114.1	442.1	190.6	561.7	2858.2
A. DOMESTIC EXTRACTION USED (DEU)	134.8	126.6	80.2	15.0	181.4	136.6	29.3	164.1	685.2
MF 1 Biomass (DEU)	42.5	36.0	17.2	1.5	33.2	31.2	5.0	37.2	246.5
Biomass: Agriculture (DEU)	31.8	33.3	13.6	1.5	24.1	28.5	2.1	6.8	221.0
Biomass: Wood (DEU)	10.7	2.7	3.6	0.0	9.2	1.8	2.8	30.2	25.0
Biomass: Other (DEU)	0.0	0.0	0.0	0.0	0.0	0.9	0.1	0.1	0.6
MF 2 Metal ores (DEU)	2.5	0.0	0.0	0.0	0.1	0.0	0.0	3.6	0.1
Metal ores: Iron (DEU)	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal ores: Non-ferrous metals (DEU)	0.5	0.0	0.0	0.0	0.1	0.0	0.0	3.6	0.1
MF 3 Non metallic minerals (DEU)	87.6	90.5	37.9	13.5	85.6	78.0	10.9	114.3	436.2
Non metallic minerals: Construction minerals (DEU)	78.8	90.5	37.6	13.5	82.9	77.1	10.8	102.7	425.3
Non metallic minerals: Industrial minerals (DEU)	8.8	0.0	0.3	0.0	2.6	0.9	0.1	11.6	10.9
MF 4 Fossil Energy Materials/Carriers (DEU)	2.2	0.0	25.1	0.0	62.5	27.3	13.4	9.0	2.4
B. UNUSED DOMESTIC EXTRACTION (UDE)	67.2	71.7	243.8	4.0	610.5	52.8	125.8	137.6	543.7
MF 1 Biomass (UDE)	27.1	25.4	11.2	1.1	20.9	21.8	2.6	15.7	206.9
Biomass: Agriculture (UDE)	5.1	5.3	2.2	0.2	3.9	4.6	0.3	1.1	45.6
Biomass: Erosion (UDE)	18.2	19.1	7.8	0.8	13.8	16.3	1.2	3.9	149.8
Biomass: Wood (UDE)	3.8	0.9	1.3	0.0	3.2	0.6	1.0	10.6	11.3
Biomass: Other (UDE)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1
MF 2 Metal ores (UDE)	2.3	0.0	0.0	0.0	0.2	0.0	0.0	8.2	0.5
Metal ores: Iron (UDE)	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal ores: Non-ferrous metals (UDE)	1.1	0.0	0.0	0.0	0.2	0.0	0.0	8.2	0.5
MF 3 Non metallic minerals (UDE)	37.8	46.3	6.7	3.0	27.0	29.7	2.4	32.7	335.9
Non metallic minerals: Construction minerals (UDE)	8.9	10.3	4.3	1.5	9.4	8.7	1.2	11.6	63.9
Non metallic minerals: Excavation and Dredging (UDE)	28.0	36.0	2.4	1.4	17.3	20.9	1.2	20.0	271.0
Non metallic minerals: Industrial minerals (UDE)	0.8	0.0	0.0	0.0	0.2	0.1	0.0	1.1	1.0
MF 4 Fossil Energy Materials/Carriers (UDE)	0.1	0.0	225.8	0.0	562.5	1.3	120.8	81.0	0.5
C. IMPORTS (IMP)	89.5	277.8	26.0	5.4	57.9	59.8	9.4	58.2	363.0
MF 1 Biomass (IMP)	20.7	50.8	2.0	1.3	8.2	14.4	3.3	19.4	59.3
Biomass: Agriculture (IMP)	4.0	19.5	1.0	0.7	2.3	6.6	0.4	1.2	20.2
Biomass: Wood (IMP)	10.1	7.2	0.3	0.2	1.9	3.9	2.4	16.2	8.9
Biomass: Other products mainly from biomass (IMP)	6.5	24.1	0.7	0.4	4.1	3.9	0.5	2.0	30.2
MF 2 Metal ores (IMP)	18.0	39.5	5.1	0.6	16.6	6.3	1.3	9.2	59.7
Metal ores: Iron + Products mainly from iron/steel (IMP)	15.5	25.1	3.0	0.3	11.9	3.6	0.8	6.2	38.1
Metal ores: Non-ferrous metals + products mainly from non-fereeous metals (IMP)	1.3	4.9	1.0	0.0	1.0	0.4	0.0	1.5	6.6
Metal ores: Other metals and products mainly from metals (IMP)	1.2	9.5	1.1	0.2	3.8	2.3	0.5	1.6	15.0
MF 3 Non metallic minerals (IMP)	9.6	42.5	2.5	0.5	6.4	8.1	1.8	3.7	42.9
Non metallic minerals: Construction minerals (IMP)	3.7	29.0	0.7	0.2	2.2	4.5	1.1	2.0	16.9
Non metallic minerals: Industrial minerals (IMP)	2.1	7.4	0.8	0.1	1.7	1.6	0.3	0.6	10.5
Non metallic minerals: Other products mainly non-metallic mineral products (IMP)	3.8	6.0	0.9	0.2	2.5	2.0	0.3	1.0	15.5
MF 4 Fossil Energy Materials/Carriers (IMP)	35.6	131.2	15.8	2.8	22.2	28.1	2.5	22.6	187.6
MF 5 Others (IMP)	5.5	13.8	0.7	0.2	4.4	2.9	0.4	3.3	13.5
D. HIDDEN FLOWS ASSOCIATED TO THE IMPORTS (HF-IMP)	335.2	1070.8	111.1	17.7	264.3	193.0	26.0	201.8	1266.2
MF 1 Biomass (HF-IMP)	84.0	329.0	12.1	7.6	50.5	71.5	7.7	28.0	308.4
Biomass: Agriculture (HF-IMP)	21.1	102.8	5.5	3.4	11.9	34.6	2.1	6.2	55.6
Biomass: Wood (HF-IMP)	2.2	1.6	0.1	0.0	0.4	0.9	0.5	3.5	1.5
Biomass: Other products mainly from biomass (HF-IMP)	60.7	224.6	6.5	4.2	38.2	36.1	5.1	18.3	251.3
MF 2 Metal ores (HF-IMP)	157.5	455.6	74.8	4.7	146.6	60.7	10.5	118.8	629.1
Metal ores: Iron + Products mainly from iron/steel (HF-IMP)	83.7	135.6	16.1	1.9	64.0	19.7	4.2	33.4	197.0
Metal ores: Non-ferrous metals + products mainly from non-fereeous metals (HF-IMP)	62.5	232.9	48.8	1.0	47.9	20.2	1.9	71.0	296.1
Metal ores: Other metals and products mainly from metals (HF-IMP)	11.3	87.1	9.9	1.9	34.7	20.9	4.4	14.5	136.0
MF 3 Non metallic minerals (HF-IMP)	8.4	30.9	2.1	0.4	5.6	6.3	1.3	3.0	29.9
Non metallic minerals: Construction minerals (HF-IMP)	2.4	19.0	0.5	0.2	1.4	2.9	0.7	1.3	10.1
Non metallic minerals: Industrial minerals (HF-IMP)	1.2	4.3	0.5	0.0	1.0	0.9	0.2	0.4	5.3
Non metallic minerals: Other products mainly non-metallic mineral products (HF-IMP)	4.8	7.6	1.2	0.2	3.2	2.5	0.4	1.3	14.6
MF 4 Fossil Energy Materials/Carriers (HF-IMP)	36.2	133.2	16.0	2.9	22.5	28.5	2.6	23.0	153.0
MF 5 Others (HF-IMP)	49.1	122.2	6.1	2.1	39.0	25.9	3.9	29.0	145.8

Data sources: own calculations

Table A-1: Detailed TMR data for the year 2005 in millions of tons – Austria to France

	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta
TOTAL MATERIAL REQUIREMENT (TMR)	6017.4	1064.4	430.2	597.9	2686.1	99.2	134.0	86.7	9.6
A. DOMESTIC EXTRACTION USED (DEU)	1087.6	156.4	151.0	180.3	608.2	43.9	36.3	2.5	0.1
MF 1 Biomass (DEU)	246.1	29.0	34.7	40.3	140.2	30.3	17.6	1.2	0.1
Biomass: Agriculture (DEU)	219.5	27.6	30.7	38.6	133.1	5.1	13.1	1.1	0.1
Biomass: Wood (DEU)	26.6	1.3	3.9	1.4	6.8	25.1	4.4	0.1	0.0
Biomass: Other (DEU)	0.1	0.1	0.0	0.3	0.3	0.2	0.1	0.0	0.0
MF 2 Metal ores (DEU)	0.4	8.4	0.6	4.4	0.0	0.0	0.0	0.0	0.0
Metal ores: Iron (DEU)	0.4	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal ores: Non-ferrous metals (DEU)	0.0	6.1	0.6	4.4	0.0	0.0	0.0	0.0	0.0
MF 3 Non metallic minerals (DEU)	620.2	49.5	102.0	131.2	451.7	12.8	18.0	1.3	0.0
Non metallic minerals: Construction minerals (DEU)	581.9	48.0	101.0	52.8	441.5	12.8	18.0	1.3	0.0
Non metallic minerals: Industrial minerals (DEU)	38.3	1.5	1.0	78.4	10.2	0.0	0.0	0.0	0.0
MF 4 Fossil Energy Materials/Carriers (DEU)	220.9	69.5	13.7	4.4	16.3	0.8	0.7	0.0	0.0
B. UNUSED DOMESTIC EXTRACTION (UDE)	2124.1	685.2	75.3	111.9	168.6	15.4	17.0	4.2	0.6
MF 1 Biomass (UDE)	166.5	20.7	23.9	28.9	82.4	12.6	11.2	0.8	0.1
Biomass: Agriculture (UDE)	29.8	4.4	4.9	6.2	18.4	0.8	2.1	0.2	0.0
Biomass: Erosion (UDE)	124.6	15.8	17.6	22.1	62.9	2.9	7.5	0.6	0.1
Biomass: Wood (UDE)	12.0	0.5	1.4	0.5	1.0	8.8	1.5	0.1	0.0
Biomass: Other (UDE)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
MF 2 Metal ores (UDE)	0.2	15.3	1.3	10.0	0.0	0.0	0.0	0.0	0.0
Metal ores: Iron (UDE)	0.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal ores: Non-ferrous metals (UDE)	0.0	13.9	1.3	10.0	0.0	0.0	0.0	0.0	0.0
MF 3 Non metallic minerals (UDE)	239.0	23.6	18.7	41.2	85.5	2.8	4.2	3.4	0.5
Non metallic minerals: Construction minerals (UDE)	95.0	5.4	11.5	6.0	11.7	1.4	2.0	0.1	0.0
Non metallic minerals: Excavation and Dredging (UDE)	140.6	18.0	7.2	27.8	72.7	1.4	2.2	3.3	0.5
Non metallic minerals: Industrial minerals (UDE)	3.3	0.1	0.1	7.4	1.1	0.0	0.0	0.0	0.0
MF 4 Fossil Energy Materials/Carriers (UDE)	1718.4	625.6	31.4	31.8	0.7	0.0	1.6	0.0	0.0
C. IMPORTS (IMP)	547.4	49.3	40.8	35.2	367.0	11.3	23.9	16.9	1.9
MF 1 Biomass (IMP)	85.2	8.0	8.0	6.7	56.9	2.7	2.9	2.4	0.5
Biomass: Agriculture (IMP)	29.1	3.5	3.2	2.5	18.0	0.5	0.6	0.3	0.3
Biomass: Wood (IMP)	11.2	1.3	1.7	1.2	14.0	1.5	1.2	1.3	0.0
Biomass: Other products mainly from biomass (IMP)	45.0	3.2	3.2	3.0	25.0	0.6	1.1	0.8	0.2
MF 2 Metal ores (IMP)	106.3	6.0	6.8	6.5	61.5	1.2	2.0	4.9	0.2
Metal ores: Iron + Products mainly from iron/steel (IMP)	71.1	3.7	3.6	1.0	44.8	0.8	0.8	4.2	0.1
Metal ores: Non-ferrous metals + products mainly from non-ferreous metals (IMP)	12.5	0.7	0.7	3.8	6.9	0.0	0.0	0.3	0.0
Metal ores: Other metals and products mainly from metals (IMP)	22.7	1.6	2.5	1.8	9.8	0.4	1.2	0.4	0.1
MF 3 Non metallic minerals (IMP)	40.0	3.3	4.0	5.8	28.7	3.3	4.9	6.2	0.4
Non metallic minerals: Construction minerals (IMP)	22.0	1.3	1.3	2.2	13.7	1.9	1.6	3.2	0.1
Non metallic minerals: Industrial minerals (IMP)	9.5	1.3	0.6	1.8	4.3	0.4	2.3	1.7	0.0
Non metallic minerals: Other products mainly non-metallic mineral products (IMP)	8.5	0.6	2.2	1.9	10.8	0.9	1.0	1.3	0.4
MF 4 Fossil Energy Materials/Carriers (IMP)	293.1	29.1	20.1	15.5	209.4	3.7	13.0	2.5	0.7
MF 5 Others (IMP)	22.7	2.8	1.9	0.8	10.5	0.5	1.0	0.9	0.1
D. HIDDEN FLOWS ASSOCIATED TO THE IMPORTS (HF-IMP)	2258.4	173.6	163.1	270.5	1542.3	28.7	56.8	63.0	6.9
MF 1 Biomass (HF-IMP)	603.8	48.7	46.6	41.1	381.8	9.0	14.0	9.2	3.3
Biomass: Agriculture (HF-IMP)	192.8	18.5	16.7	13.2	115.8	2.7	3.3	1.7	1.5
Biomass: Wood (HF-IMP)	2.3	0.3	0.4	0.3	3.9	0.3	0.3	0.3	0.0
Biomass: Other products mainly from biomass (HF-IMP)	408.7	29.9	29.6	27.6	262.2	5.9	10.5	7.3	1.8
MF 2 Metal ores (HF-IMP)	1135.2	68.3	75.1	201.9	810.0	8.9	16.6	38.5	1.4
Metal ores: Iron + Products mainly from iron/steel (HF-IMP)	341.5	20.0	19.3	5.2	268.5	4.2	4.2	22.7	0.3
Metal ores: Non-ferrous metals + products mainly from non-ferreous metals (HF-IMP)	631.6	33.4	32.7	180.3	449.6	1.4	1.1	12.0	0.2
Metal ores: Other metals and products mainly from metals (HF-IMP)	162.1	14.8	23.1	16.5	92.0	3.3	11.4	3.7	0.9
MF 3 Non metallic minerals (HF-IMP)	30.8	2.5	3.9	4.8	28.5	2.7	3.6	4.8	0.5
Non metallic minerals: Construction minerals (HF-IMP)	14.0	0.9	0.8	1.4	10.0	1.3	1.1	2.1	0.0
Non metallic minerals: Industrial minerals (HF-IMP)	4.7	0.8	0.3	1.0	3.2	0.2	1.3	1.0	0.0
Non metallic minerals: Other products mainly non-metallic mineral products (HF-IMP)	12.2	0.8	2.8	2.4	15.3	1.2	1.2	1.7	0.5
MF 4 Fossil Energy Materials/Carriers (HF-IMP)	335.3	29.6	20.4	15.7	227.2	3.8	13.2	2.5	0.7
MF 5 Others (HF-IMP)	153.2	24.6	17.0	7.1	94.8	4.4	9.3	8.0	1.0

Data sources: own calculations

Table A-2: Detailed TMR data for the year 2005 in millions of tons – Germany to Malta

	Netherlands	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	United Kingdom
TOTAL MATERIAL REQUIREMENT (TMR)	1586.0	2784.7	473.3	783.0	266.7	206.4	2669.7	636.2	2381.5
A. DOMESTIC EXTRACTION USED (DEU)	135.9	536.3	155.5	319.2	54.9	42.0	681.5	189.2	649.8
MF 1 Biomass (DEU)	40.4	162.5	25.8	67.2	23.7	7.9	110.2	75.7	165.4
Biomass: Agriculture (DEU)	39.4	142.3	13.9	57.6	14.1	6.4	99.1	19.1	149.7
Biomass: Wood (DEU)	0.7	20.1	11.6	9.6	9.6	1.5	10.3	56.3	15.0
Biomass: Other (DEU)	0.3	0.1	0.3	0.0	0.0	0.0	0.8	0.3	0.7
MF 2 Metal ores (DEU)	0.0	30.0	0.4	4.3	0.0	0.0	0.4	24.3	0.0
Metal ores: Iron (DEU)	0.0	0.0	0.0	0.2	0.0	0.0	0.0	23.5	0.0
Metal ores: Non-ferrous metals (DEU)	0.0	30.0	0.4	4.0	0.0	0.0	0.4	0.8	0.0
MF 3 Non metallic minerals (DEU)	32.3	182.9	129.3	203.2	28.7	29.6	551.0	88.6	290.3
Non metallic minerals: Construction minerals (DEU)	25.9	174.3	127.6	201.6	28.6	29.1	536.2	88.3	283.7
Non metallic minerals: Industrial minerals (DEU)	6.4	8.6	1.7	1.7	0.1	0.5	14.8	0.3	6.7
MF 4 Fossil Energy Materials/Carriers (DEU)	63.1	160.8	0.0	44.5	2.5	4.5	19.9	0.5	194.1
B. UNUSED DOMESTIC EXTRACTION (UDE)	89.0	1676.9	52.0	187.5	22.2	52.5	528.8	87.3	356.9
MF 1 Biomass (UDE)	29.2	111.4	14.3	45.6	13.7	5.2	76.5	33.9	115.2
Biomass: Agriculture (UDE)	6.3	22.8	2.2	9.2	2.3	1.0	15.9	3.1	24.0
Biomass: Erosion (UDE)	22.6	81.5	7.9	33.0	8.1	3.6	56.8	11.0	85.7
Biomass: Wood (UDE)	0.2	7.1	4.1	3.4	3.4	0.5	3.6	19.8	5.3
Biomass: Other (UDE)	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.2
MF 2 Metal ores (UDE)	0.0	68.3	0.8	9.3	0.0	0.0	0.8	15.9	0.0
Metal ores: Iron (UDE)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	13.9	0.0
Metal ores: Non-ferrous metals (UDE)	0.0	68.3	0.8	9.2	0.0	0.0	0.8	1.9	0.0
MF 3 Non metallic minerals (UDE)	56.9	49.6	36.8	31.4	8.3	6.4	272.8	32.7	225.7
Non metallic minerals: Construction minerals (UDE)	2.9	19.8	14.5	22.8	3.2	3.3	60.8	10.0	32.2
Non metallic minerals: Excavation and Dredging (UDE)	53.4	29.0	22.2	8.4	5.1	3.0	210.6	22.6	192.9
Non metallic minerals: Industrial minerals (UDE)	0.6	0.8	0.2	0.2	0.0	0.0	1.4	0.0	0.6
MF 4 Fossil Energy Materials/Carriers (UDE)	2.8	1447.6	0.0	101.1	0.1	40.9	178.7	4.8	16.0
C. IMPORTS (IMP)	318.8	107.2	56.9	40.8	37.4	15.3	274.7	77.0	278.4
MF 1 Biomass (IMP)	63.1	19.0	14.3	4.1	3.5	4.3	51.4	20.4	54.2
Biomass: Agriculture (IMP)	30.1	3.3	7.4	2.1	0.8	0.9	26.7	2.4	17.6
Biomass: Wood (IMP)	5.3	4.0	1.0	0.3	0.8	0.9	7.3	12.0	8.9
Biomass: Other products mainly from biomass (IMP)	27.7	11.7	5.8	1.7	1.9	2.4	17.4	6.0	27.7
MF 2 Metal ores (IMP)	31.2	32.1	5.5	12.0	9.5	3.1	45.6	9.5	43.6
Metal ores: Iron + Products mainly from iron/steel (IMP)	21.1	25.1	3.7	8.3	7.0	1.5	27.6	4.3	24.5
Metal ores: Non-ferrous metals + products mainly from non-fereeous metals (IMP)	3.3	1.2	0.5	2.3	0.8	0.8	8.1	1.5	3.2
Metal ores: Other metals and products mainly from metals (IMP)	6.8	5.9	1.2	1.4	1.6	0.8	9.9	3.7	15.9
MF 3 Non metallic minerals (IMP)	60.5	11.8	5.8	3.5	2.8	2.1	25.0	6.5	15.6
Non metallic minerals: Construction minerals (IMP)	38.2	4.0	1.8	1.6	1.1	0.7	5.4	3.3	7.5
Non metallic minerals: Industrial minerals (IMP)	4.8	3.9	1.4	0.7	0.5	0.5	4.7	1.9	4.2
Non metallic minerals: Other products mainly non-metallic mineral products (IMP)	17.4	3.9	2.5	1.2	1.2	0.8	15.0	1.3	3.9
MF 4 Fossil Energy Materials/Carriers (IMP)	154.6	39.5	28.4	19.2	19.7	4.9	143.3	36.0	148.1
MF 5 Others (IMP)	9.5	4.8	3.0	2.1	1.8	0.9	9.4	4.8	16.9
D. HIDDEN FLOWS ASSOCIATED TO THE IMPORTS (HF-IMP)	1042.4	464.3	208.8	235.6	152.2	96.7	1184.8	282.7	1096.4
MF 1 Biomass (HF-IMP)	417.6	126.9	93.4	26.6	22.4	27.7	304.6	71.3	352.8
Biomass: Agriculture (HF-IMP)	158.8	17.7	39.3	11.1	4.1	4.9	141.0	12.5	92.9
Biomass: Wood (HF-IMP)	1.2	0.9	0.2	0.1	0.2	0.2	1.6	2.6	1.9
Biomass: Other products mainly from biomass (HF-IMP)	257.7	108.4	53.9	15.4	18.1	22.7	162.0	56.2	257.9
MF 2 Metal ores (HF-IMP)	334.0	244.8	54.7	167.9	90.9	53.9	626.3	127.6	430.7
Metal ores: Iron + Products mainly from iron/steel (HF-IMP)	113.9	135.2	20.2	44.6	38.0	8.1	148.8	23.0	132.2
Metal ores: Non-ferrous metals + products mainly from non-fereeous metals (HF-IMP)	157.6	54.9	23.1	110.7	38.0	38.7	386.2	70.2	152.3
Metal ores: Other metals and products mainly from metals (HF-IMP)	62.5	54.7	11.4	12.5	14.9	7.1	91.4	34.4	146.2
MF 3 Non metallic minerals (HF-IMP)	49.8	9.8	5.2	2.9	2.5	1.8	25.1	4.9	12.2
Non metallic minerals: Construction minerals (HF-IMP)	25.0	2.6	1.2	1.0	0.7	0.5	3.5	2.1	4.9
Non metallic minerals: Industrial minerals (HF-IMP)	2.8	2.3	0.8	0.4	0.3	0.3	2.7	1.1	2.4
Non metallic minerals: Other products mainly non-metallic mineral products (HF-IMP)	22.0	4.9	3.1	1.5	1.5	1.0	18.9	1.7	4.9
MF 4 Fossil Energy Materials/Carriers (HF-IMP)	156.9	40.1	28.9	19.5	20.0	5.0	145.4	36.5	150.3
MF 5 Others (HF-IMP)	84.1	42.7	26.7	18.7	16.4	8.2	83.3	42.3	150.4

Data sources: own calculations

Table A-3: Detailed TMR data for the year 2005 in millions of tons – Netherlands to United Kingdom

12 APPENDIX B: SUMMARY INFORMATION WITH REGARDS TO THE DISTELKAMP ET AL. (2005) STUDY

Several studies have indicated that resource use is heavily concentrated on certain products, technologies and economic sectors (Distelkamp et al. 2005, Acosta-Fernandez 2008, Rohn et al. 2010). Distelkamp et al. (2005) analysed the effects of a change of each input coefficient on the **direct and indirect** resource use of the German economy. In a 59x59 sector framework they ran 3481 separate simulations with a monetary input output model enlarged with material inputs in physical terms. Each simulation considered the individual effects of a variation in a single input-coefficient on resource consumption. A ranking of the most important coefficients for resource use showed that a 1% change of the 30 most important input coefficients induces 60 % of the effect on total material requirement of the German economy that would result, if all 3481 input coefficients would have changed by 1%. These 30 resource relevant input coefficients and their relative ranking have been summarised on the following page.

In the disaggregation of OECD tables we have to speak of 37 coefficients. One may argue that they cannot be representative for European countries because Germany has a specific structure of production. This argument may hold for the ranking inside the group of the resource relevant coefficients, but not for the question whether they belong to the group or not.

So it is only necessary to test the influence of these 30 (37) input coefficients on all other coefficients.

Delivering sector	**receiving sector**
coal	electricity
metals	metals
stones and earths	construction
agriculture	food
stones and earths	glass, ceramics
glass, ceramics	construction
metals	metal products
coal	coal
manufacturing of cars	manufacturing of cars
food	food
coal	coke, refined petroleum products
metals	manufacturing of cars
construction	real estate activities
coal	glass, ceramics
oil and gas	coke, refined petroleum products
ores	metals
chemicals	chemicals
metal products	metal products
finance and insurance	finance and insurance
food	hotels and restaurants
glass, ceramics	glass, ceramics
electricity	chemicals
electricity	metals
metals	manufacturing of machinery
manufacturing of machinery	coal
manufacturing of machinery	manufacturing of machinery
electricity	electricity
electricity	retail trade
coal	metals
pulp, paper, paper products	pulp, paper, paper products

Table B-1: Distelkamp et al.'s (2005) set of 30 most important input coefficients