THE INTERACTION OF RESOURCE AND LABOUR PRODUCTIVITY

Scientific background report to the Scoping Study

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1 Introduction/Motivation

This final report summarizes the findings of the project „The interaction of resource and labour productivity".

The report addresses three main tasks:

- the assessment of existing empirical studies regarding how resource productivity impacts employment,
- a sectorial data analysis of material versus labour and capital productivity,
- the integration of resource productivity in the economic model.

The main messages and findings of these tasks are summarized and connected to each other in an extra document (titled as "scoping study"), based on a storyline that refers to the relationships between resource productivity and labour productivity, economic growth, employment and resource use. This scoping study also draws common conclusions to show how resource policies could be better integrated in economic policy making and provides information about the limitations as well as further research needs.

The purpose of this scoping study is to work out how resource efficiency affects labour productivity and employment. The link is analysed on an empirical and a conceptual basis focussing on the macro-economic and sectorial level. The study looks for real-life evidence in business and the economy as well as for conceptual arguments in economic theory. It aims at taking stock and drawing lessons for better policies that both enhance resource efficiency and employment.

While the scoping study presents the results in a very concise way – in the manner of an extended executive summary - this final report provides more information. The results are described for each of the three tasks respectively. Based on the overall findings we draw conclusions on how resource policies could be better integrated in economic policy making in a clear and concise manner for decision makers. Finally, we identify the largest gaps and hence ideas for further research.

This document is structured as follows: After a short theoretical and conceptual explanation of the relationships that will be considered in this scoping study we present the historical trends of labour and resource productivity and its main determinants. Then, we analyse the effects of resource productivity on growth, resource use and in particular on employment. After that we provide an empirical analysis in order to give an overview of the development of material use and of labour intensity in different Member States. The objective is to provide an analysis of different **sectors** on their material, labour and capital productivity, and to understand the reasons for differences across Member States. Furthermore, we explore the impact of material productivity on employment outcomes at the macro level. After that, we come back to theoretical considerations how to better integrate resource productivity in the economic model. Based on the overall findings we draw conclusions on how resource policies could be better integrated in economic policy making in a clear and concise manner for decision makers. Finally, we identify the largest gaps and hence ideas for further research.

2 Definitions

In order to interpret and compare the results, the exact meaning and definition of the indicators must be clear. From the review one can conclude that the literature dealing with resource efficiency/productivity is fragmented, sometimes uses different definitions and misleading terms and conceptual unity is missing, which seems to hinder knowledge transfer within academics and from academics to policy makers (Besco 2014).

2.1 Resource productivity and resource efficiency

The literature review focuses on the indicators resource productivity as well as resource efficiency. Although these two terms are often used synonymously, they do not mean the same thing.

Resource efficiency focuses typically either on augmenting economic output with a given resource input (increasing resource productivity), or on minimising resource input with a given economic output (decreasing resource intensity); or sometimes on both (as in the case of Factor x) (Gjoksi and Sedlacko 2011). Besides the amount of resource use, resource efficiency also covers the consumption of natural resources in relation to economic benefits and environmental impacts. This is reflected in “A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy“ (EC 2011), which aims at both decoupling resource use from GDP growth as well as decoupling environmental impacts from resource use (AMEC and BIO 2013).

Resource productivity is the efficiency of using natural resources to produce goods and services in the economy (Bleischwitz 2010). In analogy to labour or capital productivity it describes the relation between economic outputs in monetary terms and a physical indicator for material or resource inputs (OECD 2010). The monetary component refers to the economic gains achieved through efficiency.

While the definition of resource productivity in general includes among others water, land, biodiversity and ecosystem services, in this scoping study **resource productivity is defined as material productivity.** Materials/material resources comprises biotic materials/biomass (from agriculture, forestry, fishery and hunting as well as biomass products) and abiotic material resources (metal ores and metal products; non-metallic minerals and mineral products; fossil energy materials/carriers used for energetic and non-energetic purposes) that are used in production processes or for energy production. As fossil fuels are also materials, they are also part of this scoping study.

Depending on the scale of interest, resource productivity can be calculated at different levels. At the macro level (for whole economies), for example, GDP (Gross Domestic Product) is usually applied as the economic variable, while at the meso-level GVA (Gross Value Added) is most commonly used.

In general, **economy-wide material flow analysis (MFA)** is applied to quantify the level of material and resource use. Thus, for representing the physical indicator for material or resource inputs different MFA indicators can be used.
The following box comprises the most important indicators used in the discussion on material use.

Box 1: MFA indicators

Direct Material Input (DMI): comprises all materials with economic value which are directly used in production and consumption activities. DMI equals the sum of domestic extraction and direct imports.

Domestic Material Consumption (DMC): measures all materials used within an economic system, excluding indirect flows. DMC is calculated by subtracting direct exports from DMI. In economic terms, DMC reflects consumption by the residents of a national economy.

Raw Material Equivalents (RMEs) of a product indicate how much primary extraction of material from the environment was necessary over the whole production chain in order to produce the import.

Raw Material Consumption (RMC): next to domestic extraction, the RMC indicator comprises imports expressed or converted into their raw material equivalents (RME), i.e. into equivalents of domestic extractions that have been induced in the rest of the world to produce the respective good. RMC is calculated by subtracting the RME of exports from RMI.

Raw Material Input (RMI): adds the used part of the raw material equivalents (RME) of imports to DMI.

In contrast to these indicators that only account for materials used for the production of goods and services, the Total Material Requirements (TMR) and Total Material Consumption (TMC) also account for the indirect resource use that is associated with producing goods for a certain economy including their 'ecological rucksacks' that account for the unused earth masses moved during extraction and production processes.

Total Material Requirement (TMR) considers all materials used for a certain product, including indirect material input requirements associated with intermediate imports.

Total Material Consumption (TMC) measures the total primary material requirement associated with domestic consumption activities. TMC equals Total Material Requirement minus exports and their hidden flows

Sources: Stricks et al. (2014), Bleischwitz (2010), Eurostat (2001).

Physical and monetary input-output tables are used to relate the economy-wide resource requirements to sectors and/or to different categories of final use that are responsible for material use (Bleischwitz et al. 2007).

On the micro level, where resource productivity can either be quantified by a product-based or a company-based approach, resource productivity is not always related to economic output but can also be connected to the use (service units, mechanical output) of the produced goods and services *(*Bleischwitz et al. 2007). Data on the level of firms is typically not available on a MFA basis.

There are also several related indicators that are commonly used. The concept of the **ecological rucksack**, brought forward by the Wuppertal Institute, measures the hidden material use of a product expressed in tons of any material, which is extracted, processed, transported or deposited during production of the given product and its transport to the point of sale (Schmidt-Bleek 1999, Lettenmeier et al. 2010).

Moreover, the Wuppertal Institute uses the concept of the **material footprint**[1] and thus provides a measure of the cradle-to-cradle material input (the MI in MIPS – see above) needed to generate a service or benefit (Lettenmeier et al. 2010). Recent research uses this consumption perspective of resource use at the macro level. For instance, Wiedmann et al. (2013), define the material footprint (MF) as "the global allocation of used raw material extraction to the final demand of an economy. In contrast to indicators of standard economy-wide material flow accounting, which are based on apparent physical consumption the MF does not record the actual physical movement of materials within and among countries but, instead, enumerates the link between the beginning of a production chain (where raw materials are extracted from the natural environment) and its end (where a product or service is consumed)."

2.2 Other concepts of productivity

Labour productivity means the quantity of production obtained per unit of labour, which can be represented by the number of hours worked, the number of employees or the number of employed persons (employees plus other categories). In general, the number of hours worked is the most used denominator (Ovidiu et al. 2011). In this sense, labour productivity can be expressed as the product of working hour productivity and average working hours per capita. It rises with increasing labour productivity per hour and decreases with reduced working hours (Hinterberger et al. 2013). Labour productivity can be determined for total production (e.g. GDP) or gross value added.

Capital productivity measures the level of output (in euros) obtained for each euro invested in manufactured capital. Capital productivity indicates how well this capital type is used in providing goods and services. An increase of capital productivity means that for a given level of production less capital is needed. To estimate the capital stock used in a production process, the literature and empirical analyses recommend several methods: the flow of productive services provided by an asset in the production process, the gross stock of capital obtained by cumulating the investment flow, adjusted by the rate of removal from service of capital goods, or the net stock of capital obtained by correcting the gross stock of capital (Ovidiu et al. 2011).

Total factor productivity (TFP) covers different production inputs (or factors) and thus enables the identification of distinct contributions of labour, capital, intermediate consumption and technology/efficiency to the final product. It measures productivity more comprehensively; however, it is also more difficult to calculate (Hinterberger et al. 1999).

[1] The material footprint is part of the broader concept of Ecological Footprint, introduced by Wackernagel and Rees (1996) who combined material, water and land, into one indicator. The Ecological Footprint is " a measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices. The Ecological Footprint is usually measured in global hectares. Because trade is global, an individual or country's Footprint includes land or sea from all over the world."
(see http://www.footprintnetwork.org/en/index.php/gfn/page/glossary/#efstandards)

3 The storyline

Due to the relatively broad scope of this study it seems helpful to integrate all relevant questions in a storyline that shows the “red thread” and provides an insight on the links between all aspects addressed. The approach is centred on economic output/economic growth (measured in Gross Domestic Product – GDP or Gross Value Added - GVA) and incorporates the influences of the production factors (capital, labour and resources) as well as the impact of their productivities on growth. To some extent, the relations between the productivities and the production factors are also taken into account.

3.1 Drivers of economic growth

Labour, capital and resources are important drivers of economic growth

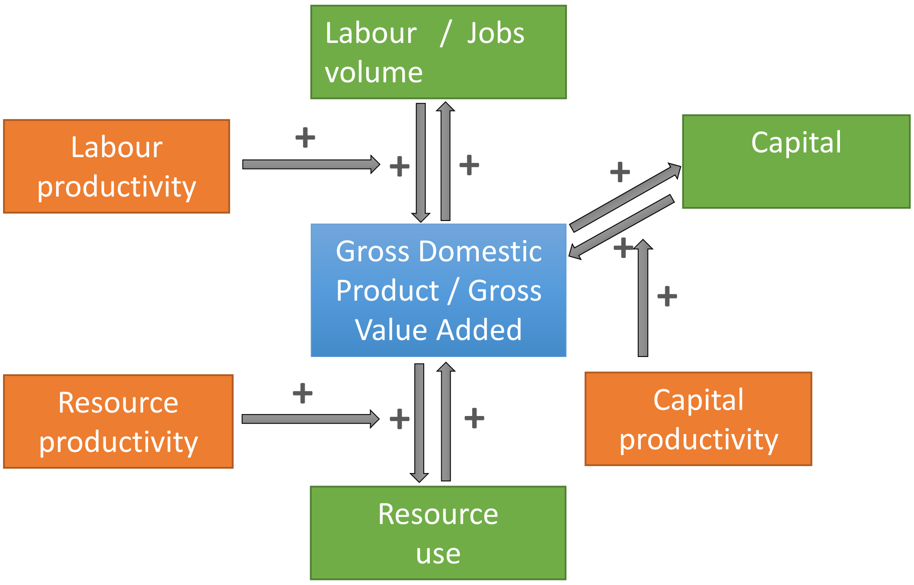
In neoclassical economic **theory,** economic growth is mainly explained by labour, capital (factor expansion/accumulation and productivity growth) and a residual that cannot be explained by the amount of inputs used in production, usually referred to as Total Factor Productivity (TFP). TFP refers to the shift in the production function for a given level of production inputs. Many factors might cause this shift, e.g. technical innovation, organizational or institutional changes, changes in factor shares, changes in labour skills, scale effects or variations in work intensity. Estimates show that more than half of growth can be traced back to TFP (see e.g. Allianz Dresdner Economic Research 2008), which means that the components of TFP are main determinants of growth[2]. One of these growth sources are improvements in resource use, another is the productivity of using all production factors, labour, capital, *and* resources. The question is to what extent growth comes from improved resource productivity and what the implications are when resource use is treated as separate input factor.

Resource use has long been neglected in economic theory and has entered the stage only recently. However, for providing adequate policy advice, it is important to take into account natural resources as an input factor in the production process and to make explicit the role of resource productivity for economic growth.

The following figure illustrates the main driving forces of economic output (measured in terms of GDP for the whole economy and in terms of GVA on the sectoral level) in a very simplified manner. It can be seen that economic growth is directly affected by the production factors labour, capital and resource use. Furthermore the productivities of these production factors influence their relationship with economic output (note that the arrows from the productivities do not directly point to GDP/GVA, but to the arrow that shows the relationship between economic output and the production factor). “+” indicate positive relationships. For the sake of completeness it has to be mentioned that economic output also affects the quantity and quality of the input factors.

[2] TFP accounted for some 80% of factor-related growth in the early growth theory of Solow; the use of more sophisticated models has reduced the share to roughly 20% (Bleischwitz, 2001).

Figure 1. Simplified illustration of the impacts of production factors and productivities on GDP/GVA.



Source: Own illustration

From this follows that not only becoming more efficient in the ways labour and capital are used, but also natural resources drives economic growth. Although capital productivity is an important driver of economic growth, this scoping study focuses on the role of resource and labour productivity.

From a supply-side perspective, long-term economic growth is on the one hand determined by an increase in working population and/or rising labour productivity (e.g. through better education or improved technology).

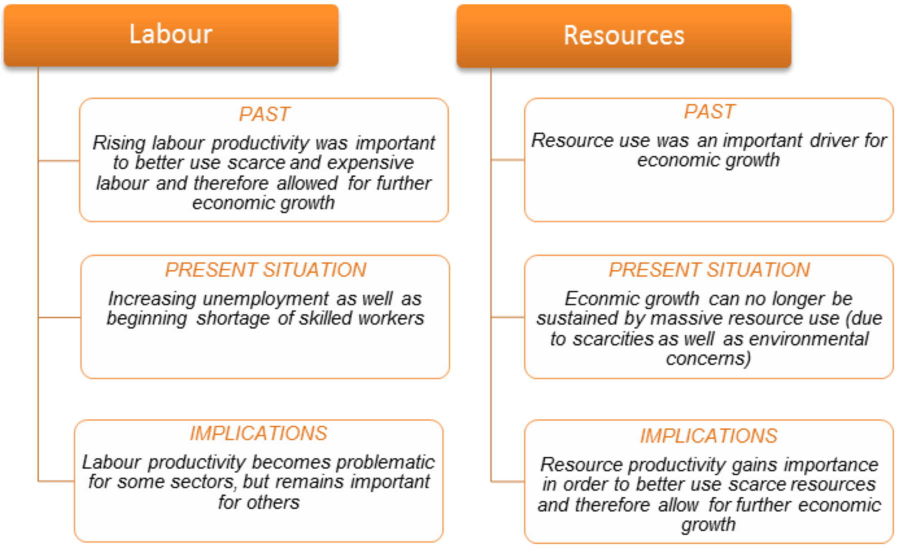
In the past, the increase of labour productivity has been the main strategy to better use scarce and expensive labour and therefore allowed for further economic growth and competitiveness. Today, we are facing a situation where increasing unemployment as well as a beginning shortage of skilled workers can be observed. Furthermore, labour productivity is often related to higher labour intensity which often imply stressful working conditions. Thus, further increasing labour productivity becomes problematic in some sectors (e.g. care and education), but is important for others (e.g. manufacturing), in order to remain competitive. On the other hand, resource use is an important driver for economic growth. However, due to resource scarcities associated with price increases, as well as environmental concerns, we are not able to rely on the employment of natural resources as the main contributing factor to economic growth anymore. Thus, resource productivity gains in importance in order to better use scarce resources and therefore allow for further economic growth.

Capital investment plays a crucial role to achieve cost reduction in the other two factors: labour and materials. For example, (substantial) economic investment will be needed to achieve increases in resource productivity. Thus, the question of capital productivity is especially crucial for ecological investments and investments in natural capital. The rates and periods of return for such investments are likely to be ‘less productive’ in conventional terms (Jackson 2009).

The decision which of the other two factors should be targeted largely depends on the relative price of labour and materials. Whereas wages rise in real terms when the economy grows, in the past material costs have usually increased slower than labour costs. For this reason, companies have preferably invested in technologies reducing labour costs, irrespective of the effect on material costs. These processes have clearly counteracted the trend of resource productivity (ibid.).

Figure 2 summarises the mentioned facts and relationships with regard to labour and resource productivity.

Figure 2. Labour (productivity) and resources (productivity) as drivers of growth.



Source: Own illustration

3.2 The role of labour and resource productivity increases to improve the conditions for growth

Labour *and* resource productivity increases can help to improve the conditions for growth

As outlined above, labour productivity and resource productivity are both important determinants of growth, both on the level of a single enterprise as well as from a macroeconomic point of view. The challenge for any enterprise is to efficiently manage the simultaneous **use of resources, labour and capital** in order to create added value and thus income.

Economic policy therefore tries to create favourable framework conditions that efficiently use these production factors. From a sustainability point of view, its task is to transform the economic system into a more sustainable one, which means to stimulate the creation of jobs and to reduce the consumption of natural resources, thereby enabling prosperity and a high quality of life.

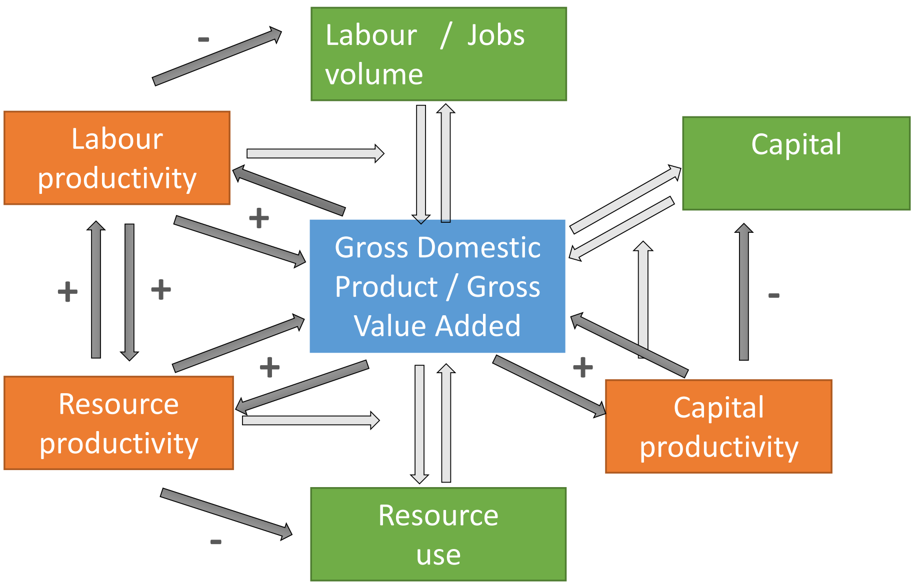
In order to achieve these goals, productivity is key as factors of production (labour, capital and natural resources) are limited both from an environmental as well as from an economic point of view.

Figure 1 is incomplete in the sense that the relations between the production factors and the productivities are not taken into account and no feedback loops are considered. In general, substitution between different production factors occurs due to changes in the relative prices of inputs. An increase in resource prices tends to speed up the development of resource- and energy-saving technologies. Conversely, periods of growing resource prices may result in technological development tending toward less intense use of resources and also toward economic growth. Thus, resource productivity not only (directly) influences resource use but also indirectly affects capital and labour via its direct impact on economic output.

More generally: Depending on relative prices, an increase in the productivity of using one of the production factors can also change the use of other factors, since it creates an incentive to use the first more intensively. Labour, capital and resource productivities may also influence each other since better technologies or structural changes might affect the productivities of all production factors at the same time.

These relationships are illustrated in Figure 3. Positive relationships are indicated by “+”, negative relationships by “-“. For clarity, the arrows presented in Figure 1 are transparent.

Figure 3. Simplified illustration of the impacts of productivities on production inputs and outputs



Source: Own illustration

Since the beginning of the industrial revolution, labour productivity has steadily risen and has thus, inter alia, secured rising living standards. To maintain and further increase social welfare in the context of planetary boundaries (see Rockström et al. 2009 and Steffen et al 2015), growing population, rising global average incomes and the associated demand for food, water, energy and all sorts of materials, the **improvement of resource productivity** also has to be firmly anchored in future political, economic and social discourses and must be mainstreamed in all aspects of life.

While labour productivity is already an important part of EU's policy activities, resource productivity has so far been a relatively untapped opportunity. EU initiatives (e.g. EU Roadmap to a Resource Efficient Europe[3]) were established to change this situation and to ensure that Europe will become more resource efficient. Theoretically, improvements of resource productivity offer the possibility to reach win-win-win situations: a reduction of resource use, an increase in economic growth and an increase in employment.

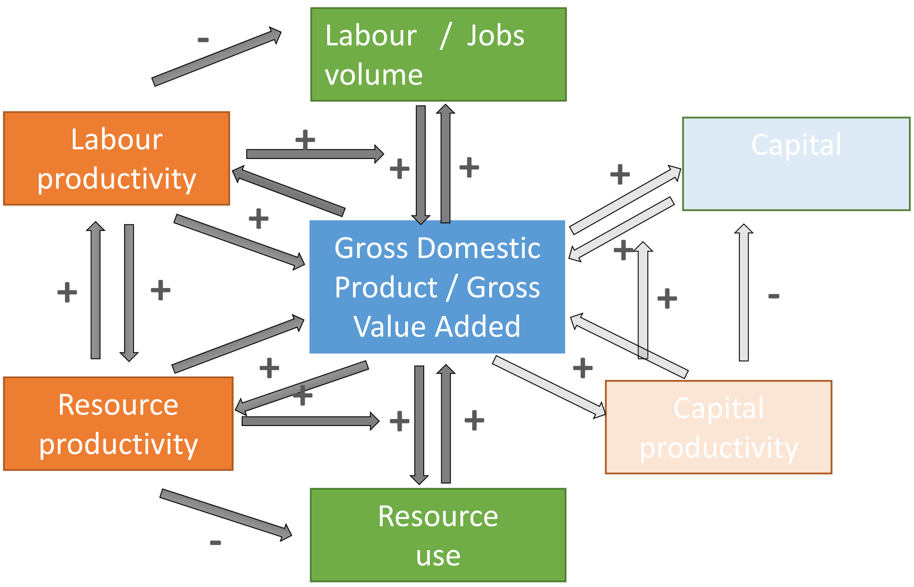
In order to understand the role resource productivity can play to support the Juncker Commission's top priority of boosting jobs, growth and investment[4], all three angles should be addressed:

- How and to what extent does (an increase in) resource productivity contribute to economic growth?
- How and to what extent does (an increase in) resource productivity contribute to environmental improvements and decreasing resource use?
- How and to what extent does (an increase in) resource productivity contribute to job creation?

All three questions are considered in this report, although the focus is on the third question, which relates to the employment effects of resource productivity improvements and also takes into account the relationship between resource and labour productivity.

The following figure shows the relationships of Figures 1 and 3 that are part of this scoping study. The transparent arrows and boxes are not considered.

Figure 4. Simplified illustration of the relationships considered in this scoping study



Source: Own illustration

Before we analyse these relations in detail, we provide a short overview about the historical trends of labour, capital and resource productivity and of some of their determinants (prices and costs).

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[3] The Resource Efficiency Roadmap is part of the Resource Efficiency Flagship of the Europe 2020 Strategy. See: EC (2011).

[4] See http://ec.europa.eu/priorities/jobs-growth-investment/index_en.htm

4 Historical trends of labour, capital and resource productivities and their determinants

In this section we analyse productivity trends on a macro as well as on a sectoral level. The description of the macro level is based on a literature review, while the investigation of the sectoral level is based on an empirical analysis carried out within this scoping study. We also describe the development of resource prices and costs, which are both important determinants for resource productivity.

4.1 Productivity trends

Resource productivity has been increasing in the past decades, however at a lower rate than labour productivity

Empirical studies reveal that technological progress and capital accumulation have augmented both the productivity of labour and resources. However, labour productivity has increased more strongly than resource productivity.

0 shows the development of labour productivity (measured by GDP per hours worked), resource productivity (ratio of GDP and DMC[5]) and capital productivity (measured by GDP over consumption of manufactured capital) in several EU countries.

While **labour productivity**[6] constantly rose from 2000 until 2007, it slightly decreased during the economic crisis because less GDP was generated with an almost constant labour input. While there was a decline in 2010, labour productivity increased again from 2011 onwards. **Resource productivity** improved by 17% between 2000 and 2009. In 2009 resource productivity rose significantly during the economic crisis, which affected the material-intensive industries much more than the services industries, leading to a reduction in overall material consumption. As in the case of labour productivity, resource productivity decreased in 2010, but increased again after this decline. **Capital productivity** remained almost constant from 2000 until 2007. With the economic crisis, it dropped considerably implying that more or less the same level of annual physical capital consumption generated less GDP (Moll et al. 2012). After 2009, it developed constantly, at a lower level than before the crises.

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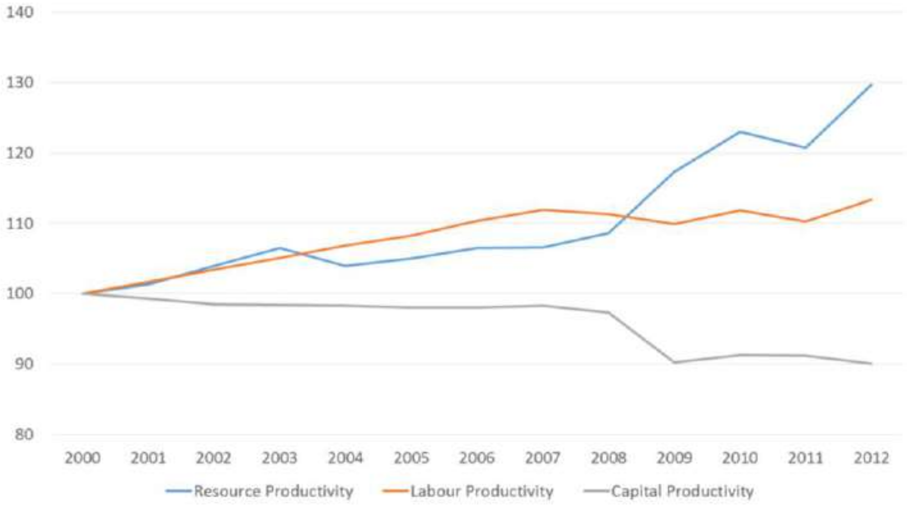
[5] Domestic Material Consumption (DMC): measures all materials used within an economic system, excluding indirect flows.

[6] For the development of labour productivity in services sector see Annex 1.

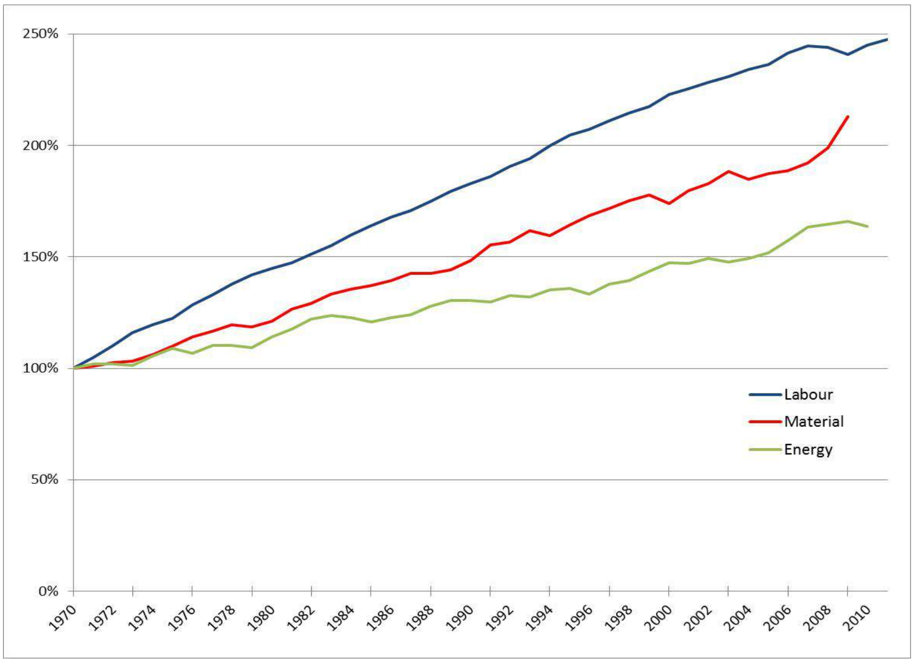
Figure 5. Comparison of resource, labour and capital productivity in the EU-27.



Source: Own illustration, based on Eurostat data.

As can be seen from Figure 6, material productivity (GDP/DMC) in the EU-15 has grown much slower than labour productivity between 1970 and 2009. While labour productivity increased by 141%, productivity of materials only grew by 113%.

Figure 6. Productivity of labour, energy and material in the EU-15.
Index development (1970 = 100)

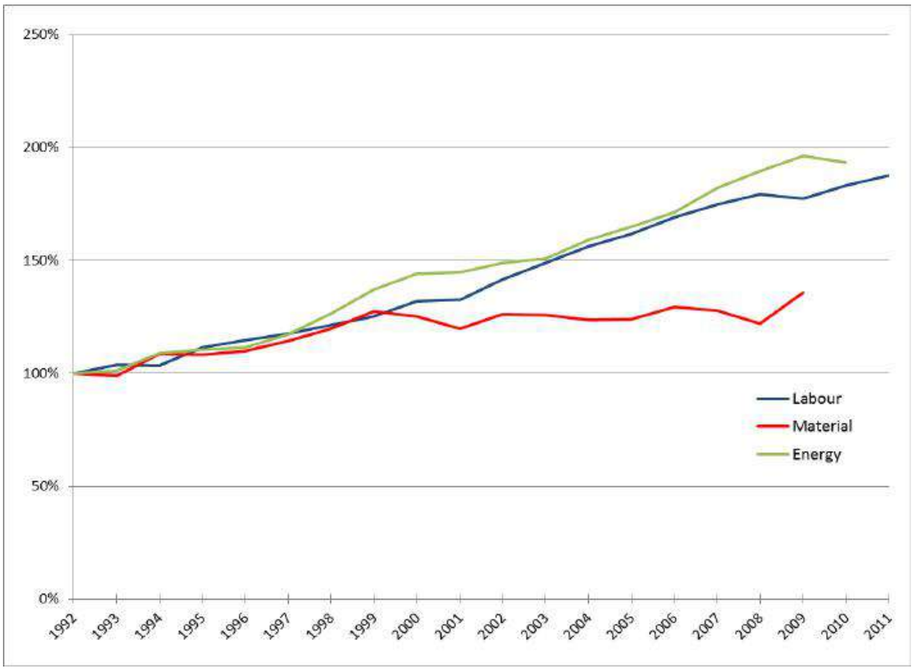


Source: EEA (2012).

In the EU-12, the new member states (see Figure 7), this gap is even higher: Between 1992 and 2009, material productivity increased by 36% and labour productivity by 77% (EEA 2012). Until 1998, all kinds of productivities developed rather similar; thereafter, the growth in resource productivity could not keep pace with labour and energy productivity. Whereas material productivity in the EU-15 has increased constantly since 2000, it has remained static or even decreased in the EU-12.

In the case of the EU-12, the fast increase in energy productivity may have been caused by the shutdown of energy-inefficient heavy industries, the privatisation of energy utilities and a switch to fuels with higher energy content. Together these factors resulted in lower overall energy consumption (ibid.).

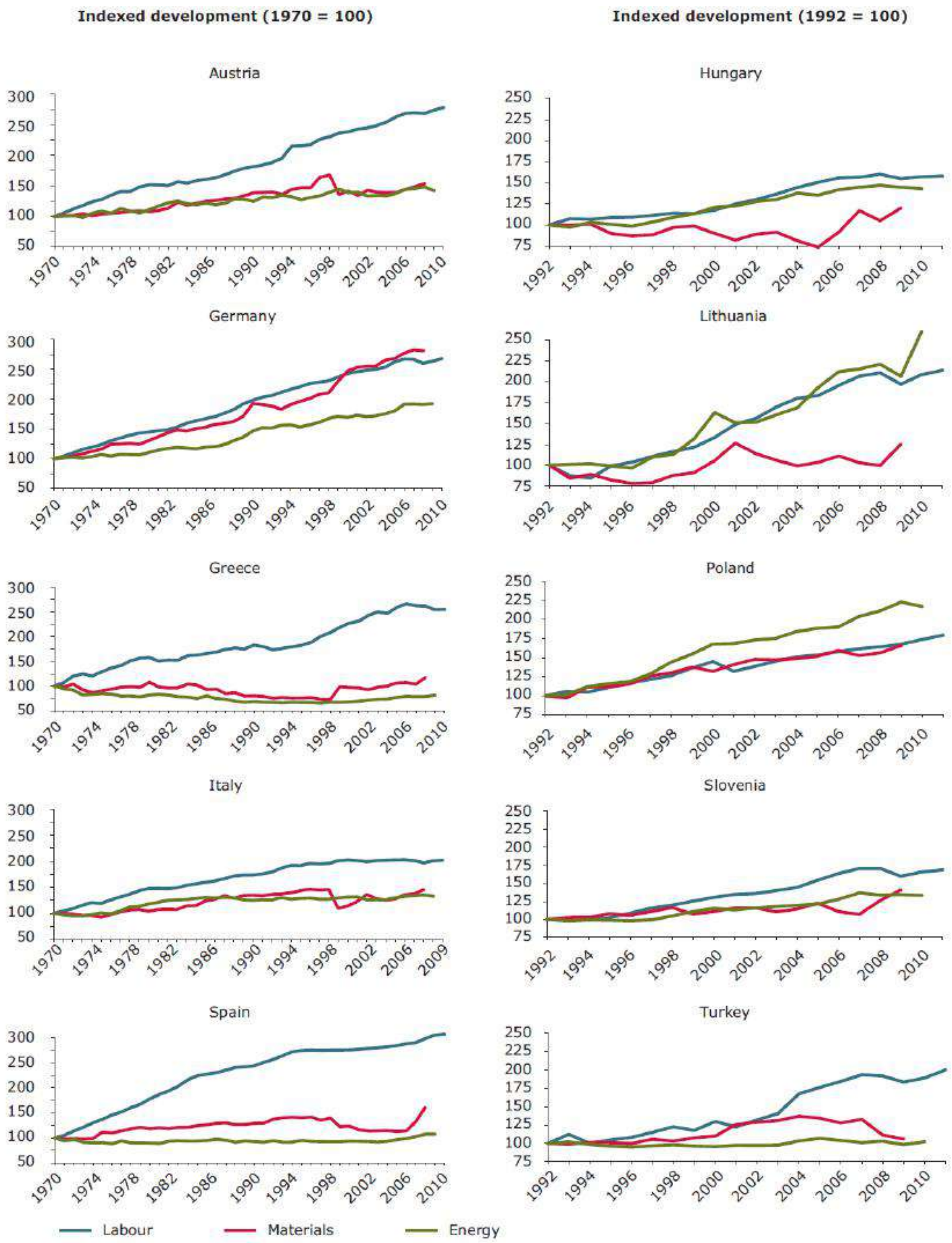
Figure 7. Productivity of labour, energy and material in the EU-12. Index development (1070 = 100)



Source: EEA (2012).

There are also large variations between individual countries. Figure 8 shows that there was a wide range of diverging trends, although in most cases labour productivity shows the highest growth. Differences in the development of the three types of productivities also can be seen across countries with similar levels of industrialisation and income. Therefore, it is important to analyse the relevant socio-economic variables of economies and their innovation systems in more detail that lay behind these results (Bleischwitz 2010).

Figure 8. Trends in the productivity of labour, energy and materials for selected EU Member States and Turkey.



Source: EEA (2012).

The presented results in this sub-section reveal that in the past, economies, sectors and firms have mostly focused on improving labour productivity. However, in the light of socially unfavourable consequences, such as intensification of work, dismissals, growing burden on the remaining employees (i.e. because they might fear job losses, or have to fulfill more tasks in shorter time periods), and the overconsumption of natural resources, the objective should rather be to increase the level of resource productivity (Bleischwitz, 2007).

In general, the dynamics between labour and resource productivity must be further elaborated by future research (Bleischwitz 2010).

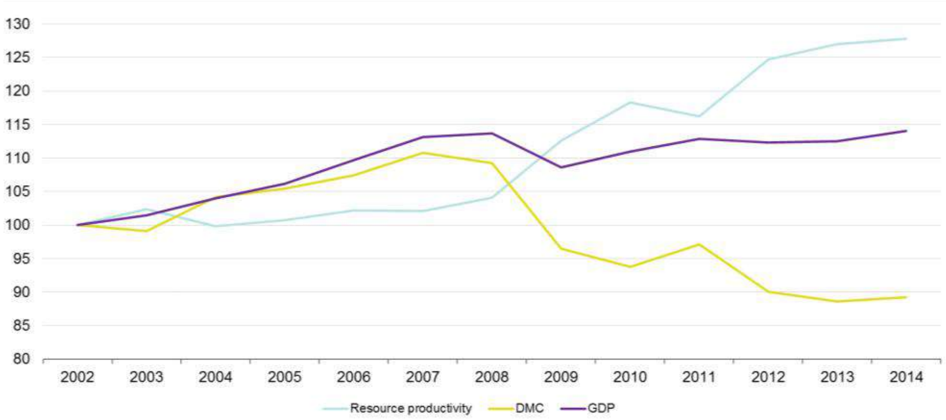
4.2 Historical trends of resource productivity compared to economic growth and resource use

Figure 9 shows the evolution of the EU-28's economic growth (GDP), resource use expressed in terms of DMC and resource productivity (GDP/DMC).

Before the economic crisis, resource productivity grew slower than GDP, leading to increasing material use

In the time period covered the EU's resource productivity has increased by 27% from 1.43 EUR/kg in 2002 to 1.81 EUR/kg in 2013. This corresponds to an average annual increase of 2.2%, which is still slightly below the growth rate of GDP during the reporting period (Eurostat, 2015).
The significant increases in resource productivity between 2008 and 2009 were caused by the economic crisis (see also above). In 2010, resource productivity decreased, while it again strongly increased from 2011 onwards.

Figure 9. Evolution of resource productivity, resource use (DMC) and growth (GDP) of the EU-28 between 2002 and 2014 (Index 2002=100)



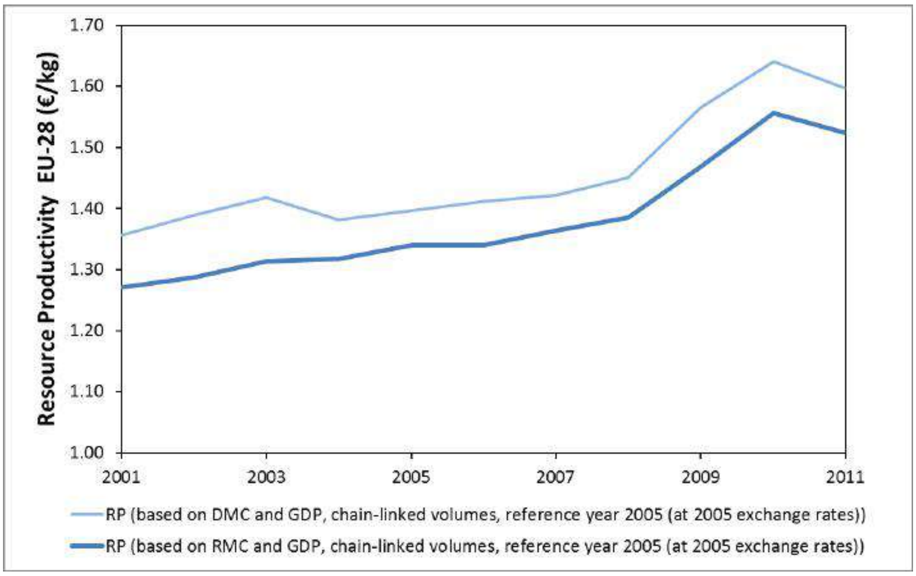
Source: Eurostat (2015).

DMC does not consider the displacement of dirty industries to other regions of the world

It has to be noted that these improvements might partly result from the fact that material-intensive production has been removed to other countries, which reduces DMC. The indicator **Domestic Material Consumption (DMC)**, used to calculate resource productivity in the graph above, does not consider the resources embodied in the goods and services produced abroad, but consumed domestically. DMC thus also does not reflect the displacement of dirty industries to other regions of the world. Using instead consumption-based indicators, such as **Raw Material Consumption (RMC)** or the **material footprint** the results could be different. RMC comprises imports expressed or converted into their raw material equivalents (RME), i.e. into equivalents of domestic extractions that have been induced in the rest of the world to produce the respective good. Both RMC and material footprints thus consider the effects of the displacement of dirty industries to other regions of the world.

The following graph indeed shows that resource productivity in terms of GDP/RMC has always been lower in the EU-28 between 2001 and 2011 compared to resource productivity measured as GDP/DMC.

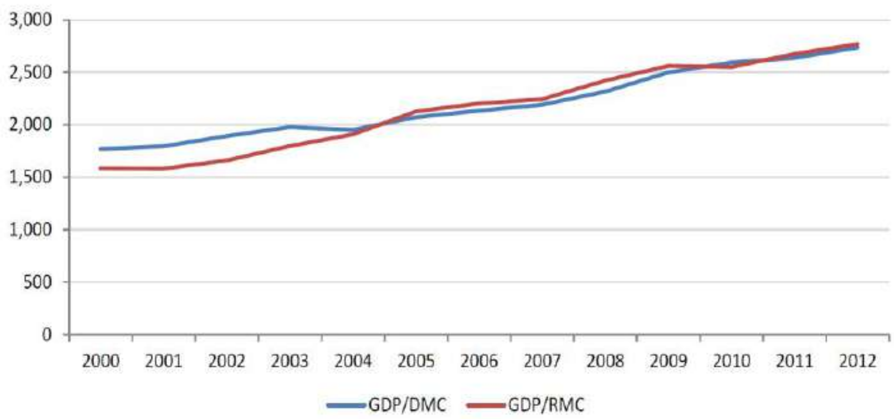
Figure 10. Evolution of resource productivity (RP) of EU-28 between 2001 and 2011, based on DMC and RMC



Source: Cambridge Econometrics et al. (2014)

However, in the UK resource productivity based on RMC was lower than productivity based on DMC only between 2000 and 2003. Between 2004 and 2008, GDP/RMC exceeded GDP/DMC, and after a small decline in 2009, the two indicators developed similarly (see Figure 11 and DEFRA 2015). In contrast to the EU-27 data, this data excludes fossil energy fuels.

Figure 11. Evolution of UK's resource productivity (RP) between 2001 and 2012, based on DMC and RMC



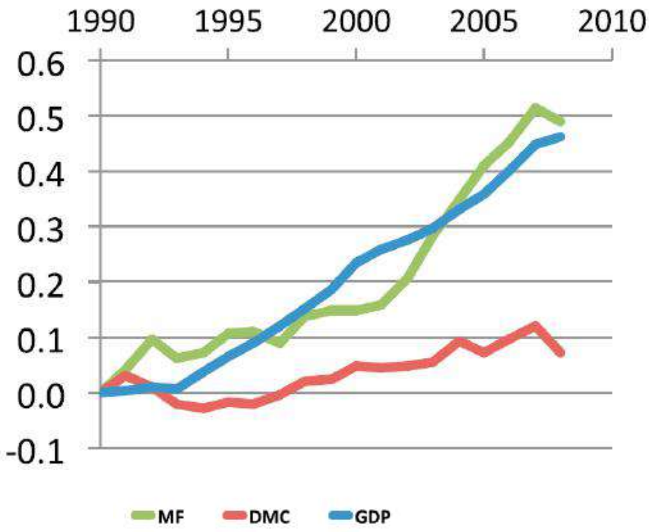
Source: DEFRA (2015)

The picture is even worse when considering material or carbon footprinting, pointing towards a continuing increase of material consumption in high de-

Based on a consumption perspective the EU was not able to improve its resource productivity

veloped economies, also during the last two or three decades (Hoekstra and Wiedmann, 2014). For instance, based on the analysis of the material footprint (MF), Wiedmann et al. (2013) found that advanced economies were less successful in decoupling than usually reported. Figure 12 shows the development of total resource use (MF and DMC) and GDP for the EU-27. The red line (DMC) runs significantly below the blue line (GDP), which implies that relative decoupling has been achieved between 1990 and 2008. However, this does not hold true for the green line indicating the development of the MF. Based on a consumption perspective, covering all upstream material movements along global supply chains, the EU-27 was thus not able to improve its resource productivity. The study shows that, as affluence rises, countries tend to decrease domestic materials extraction and manufacturing by off-shoring those activities to other regions of the world, whereas the overall amount of material consumption generally grows. A multivariate regression analysis shows that a 10% increase in GDP is associated with a 6% rise of the average national MF (Wiedmann et al. 2013).

Figure 12. Relative changes in total resource use (MF and DMC) and GDP-PPP-2005 between 1990 and 2008 for the EU-27.



Source: Wiedmann et al. 2013.

In general GDP/DMC is a good measure of the resource productivity of a county or a group of countries such as the EU in the above case, while GDP/RMC measures the resource productivity of the whole value chain. From a local or regional point of view, DMC is a suitable indicator for resource-related environmental impacts, while for global environmental impacts, such as climate change or biodiversity loss, RMC is a more appropriate measure. Furthermore, DMC is adequate with regard to domestic input factors that are important for economic growth, while RMC is more relevant if environmental concerns are analysed (Giljum et al., 2014). [7]

[7] Another aspect not considered in DMC is unused material extraction, such as overburden from metal or coal mining or harvest residues in agriculture. However, these unused material flows are responsible for different environmental burdens, such as water pollution and landscape changes. Indicators such as Total Material Requirement (TMR) or Total Material Consumption (TMC) are able to capture these flows (Giljum et al. 2014).

However, due to data limitations, trends of resource productivity are mostly based on DMC data, since most studies use this indicator to express resource productivity. [8]
For a more conclusive analysis, further efforts are necessary to improve the data situation.

A main reason for the presented productivity trends can be seen in the **relative pricing of labour, energy and resource inputs** and the current tax systems, as increasing labour costs over time induces firms to focus on improving labour productivity (see next chapter).

Another explanation can be found in structural changes of economies. Countries usually firstly specialize in buildings, infrastructure and heavy industry, while with higher economic development, they tend to shift towards a more service oriented economy (de Bruyn et al. 2009).

In chapter 8.2 we provide sectoral data for labour, capital and resource productivity that were calculated in the empirical part of this scoping study. Resource productivity is calculated on the basis of RMI.

4.3 Development of resource prices

Increases in resource productivity were mainly driven by changes in the relative prices of production inputs

De Bruyn et al. (2009) argue that the amount of resources used in production is directly determined by the price. The slower increase of resource productivity might thus (partly) be explained by the fact that the costs of labour grew faster than the costs of materials inputs over the last 50 years. The price of resources remained more or less constant over the past decades - except for the period since the turn of the millennium, when commodity prices began to rise due to rapidly growing demand from emerging economies, such as China (de Bruyn et al. 2009).

In general, in the past (and still today), the prices of raw materials and energy have not adequately reflected external costs, leading to an overuse of resources. This overuse has driven economic growth, and at the same time, resulted from economic growth.

In highly industrialised countries, such as most EU Member States, labour costs have been more expensive than material costs from a perspective of relative prices (and current tax systems). The result was that labour productivity increased, which has helped to reduce costs.

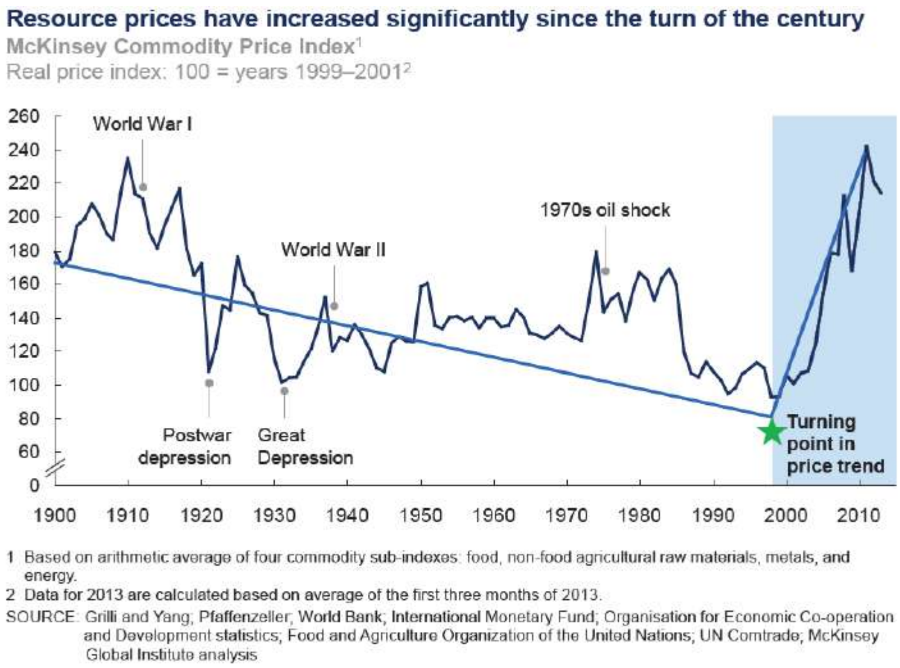
Thus, in the past, the focus was mainly on reducing labour costs via increasing labour productivity. However, if resource prices were reflect the real social (external plus internal) costs, material costs would become increasingly important. With growing scarcity, environmental problems and the subsequent need to internalise external costs, improving material productivity is a key to decrease resource use, reduce costs and increase competitiveness.

Resource prices have increased significantly between 2000 and 2010, accompanied by high levels of volatility across the commodity markets

The development of resource prices has decisively altered since the turn of the century: after 2000, resource prices have more than doubled and the average volatility has been about three times higher than in the 1990s (see Figure 13).

[8] The official indicator of resource productivity reported by Eurostat is still DMC. This is due to data limitations with respect to RMC.

Figure 13. Changing trends in resource prices



Source: McKinsey (2013)

Although resource prices have slightly declined since 2011 with a strong decrease in 2014 (see recent development of the IMF Primary Commodity Price Indices in Figure 14), on average commodity prices remained almost at the level of 2008, the starting point of the global financial crisis. In the future, the prices of commodities are expected to rise further due to the growing resource demand, which is in turn driven by an increase of the world population and the world economy[9] (EC 2014). However, the World Bank Commodities Price Indices Outlook[10] shows that in 2025 the real prices of most commodities will be below 2013 levels.

Thus, although it is likely that resource prices may increase in the future, there is no reliable evidence of how they will actually develop. 87% of European companies expect material input prices to continue rising (see Flash Eurobarometer[11]), making resource use to a significant cost factor for business.

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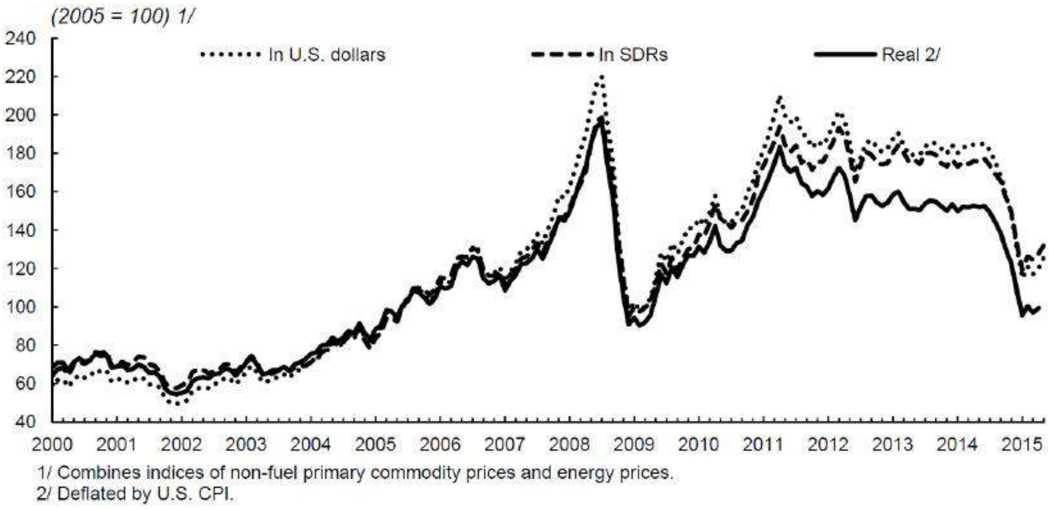
[9] This can be concluded from Eurobarometer surveys of business: Despite the current slowdown in price increases it is expected that resource prices will rise as growth approaches a more normal level (EC 2014).

[10] See ,page 3.

[11] EC (2011). Attitudes of European entrepreneurs towards eco-innovation. Flash EB Series #315. Survey conducted by The Gallup Organization, Hungary upon the request of Directorate-General Environment. http://ec.europa.eu/public_opinion/flash/fl_315_en.pdf

Figure 14. IMF Indices of Primary Commodity Prices



Source: IMF[12]

Cainelli et al. (2009) state that only strong resource price changes have an influence on structural economic transformations. In general, technology has a more important role in changing factor combinations and capital intensity.
Mulder and de Groot (2007) show that energy prices and wages positively affect energy and labour productivity growth, respectively. While the investment share, openness and specialisation seem to be negligible regarding the variation of energy and labour productivity growth across countries, economies of scale play a central role.

4.4 Share of material costs on whole production costs

Material costs have become a main cost factor for business

One argument in favour of focusing on the increase of resource productivity is the high share of material costs in the production process of many companies.
On the firm level, higher material productivity decreases the cost of purchase and usage for materials, which in turn improves competitiveness and enables expenses for further qualification and innovation to be raised. At the same time, the scope for income increases and job security can be extended (Bleischwitz, 2009).

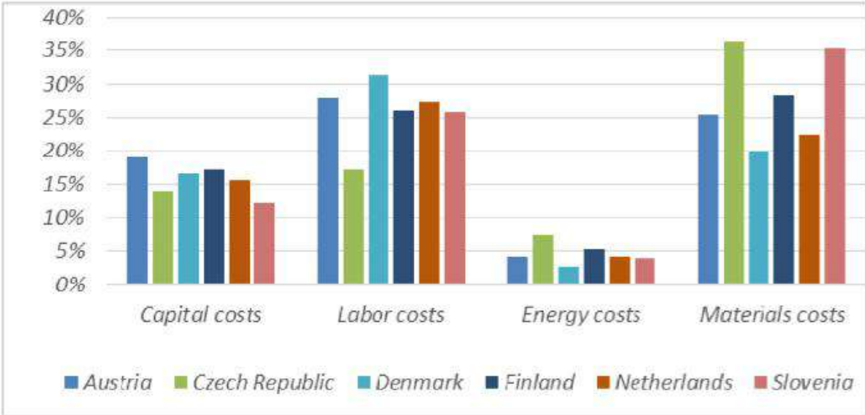
Fischer-Kowalski and Wiedenhofer (2014) show for different European countries that material costs are equal or higher than labour costs, while energy costs only account for a small share in the cost structure (see Figure 15). In all countries under consideration, material costs exceed 20% of total production costs. This share is slightly surpassed by labour costs only in high-income countries such as Austria or the Netherlands. In the agricultural sector, the share of materials costs is higher than 40% in all countries under consideration. In manufacturing and construction, this share exceeds 50% in the majority of countries (EUKLEMS 2008).

Although efficiency measures are mostly targeted towards energy and GHG emissions, the potential for cost savings is substantially larger regarding improvements of material efficiency. Only in the most energy intensive sec-

[12] See http://www.imf.org/external/np/res/commod/Charts.pdf

tors, energy costs account for around 10% of total costs (Hennicke/Sewerin 2009).

Figure 15. Factor costs for selected European economies in 2004 (costs as share of total production).



Source: Fischer-Kowalski and Wiedenhofer (2014) based on EUKLEMS 2008.

However, de Bruyn et al. (2009) claim that such figures overestimate actual material costs, since they comprise all costs that are known as ‘intermediate use’ of economic sectors. The authors thus conclude that material costs do not only include the costs for raw materials, but also labour and energy costs embodied in these materials. Using an input-output factorisation, de Bruyn et al. (2009) found that the share of energy and material costs (e.g. fossil fuels, ores, mineral extraction, etc.) in the costs of all inputs necessary to satisfy final consumer demands is below 5%.

Literature does not provide much information on the respective shares of labour and capital costs embodied in material costs

Previous studies do not provide much information on the respective shares of labour and capital costs embodied in material costs. Further research is thus needed in order to give an estimate of the actual share material costs have on the entire production costs. Nevertheless, it can be assumed that the share of material costs has increased over the last years, as the case of Germany shows, making material costs a stronger cost factor. According to the German Federal Statistical Office, the share of material costs in gross production value in the manufacturing industry has increased from 37.4% in 1995 to 42.9% in 2006, while labour costs have decreased from 24.7% to 18.2% (Bleischwitz 2009).

The extent to which costs can be reduced greatly depends on the sector and products produced. Of course higher resource prices influence resource and energy-intensive sectors the most. Thus, a shift to labour-intensive activities may increase substitution between resource and labour and has positive impacts on employment. In theory, substitution between inputs is the result of changes in their relative prices and is spurred by technical change, depending on whether those inputs are substitutable or complementary. For example, rising resource prices increase the incentive to develop resource-saving technologies, whereas technological development will tend to create rather resource intensive technologies in times of decreasing resource prices.

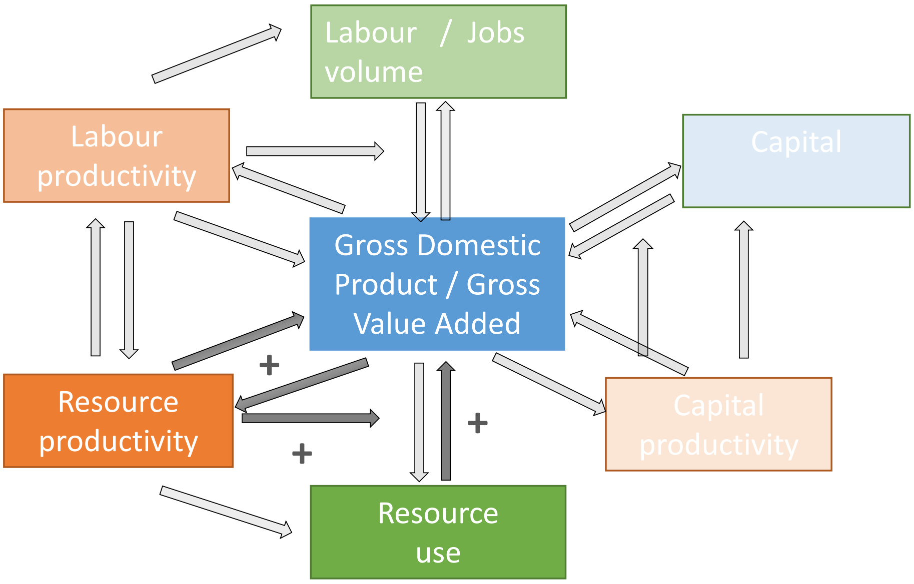
A substitution effect between material use and labour is evident inter alia in the cases of eco-design, reparability, circularity and higher service orientation of products, leading to material cost savings and potential employment gains (AMEC/BIO 2013).

All trends and facts presented in this sub-chapter suggest that economic outcomes – today and in the future – do not only depend on labour and capital productivity, but also on resource efficiency.

5 How and to what extent does resource productivity contribute to economic growth?

In this chapter we summarise the findings from the literature review concerning the contribution of resource productivity to economic growth. Figure 16 illustrates which relationships are considered (see dark arrows).

Figure 16. Simplified illustration of the impacts of resource productivity on economic output (GDP, GVA).



Source: Own illustration

Increases in resource productivity can help both to improve the environment by reducing the use of resources required by human economic activity (see next chapter), and to enhance the conditions for economic growth.

5.1 Impacts of resource productivity on growth

Findings of academics commonly show that higher levels of resource and energy productivity would yield positive economic effects. A cross-sectional analysis of GDP growth in the EU-15 countries for 2004 reveals that energy productivity and economic growth are positively correlated (Allianz Dresdner Economic Research 2008). This result is confirmed by a more recent IEA report estimating that doubling energy productivity gains by 2030 would create at least 1.1% of additional GDP in the EU (IEA 2012).

First simulations for the POLFREE project[13] show that resource efficiency increases will lead to remarkable possibilities for aggregated win-win outcomes: Distelkamp and Meyer (2014) illustrate that a reduction of global resource extractions by 1.5 to 2.0 billion of tons can be achieved in the EU27 within only five years by decreasing the most resource relevant intermediate inputs in industrial processes to a limited extent. These resource reductions would also have positive effects on GDP (0.1 to 0.6% p.a.).

[13] See http://www.polfree.eu

On the macro level, higher level of resource productivity has positive impacts on growth, as long as abatement costs are not too high

Positive net effects of improved resource productivity on GDP arise if the benefits of higher productivity levels outweigh the costs of achieving greater efficiency. According to a scenario analysis by Cambridge Econometrics et al. (2014), for the EU this is the case for resource productivity improvements up to 2.5% p.a. Beyond this rate, however, further improvements in resource productivity would lead to net costs for GDP as the abatement options become more expensive.

According to a study by Bleischwitz et al. (2007), higher growth rates only seem to be possible at the expense of a further increase in the use of resources. However, there are huge differences between countries; while Italy and the UK, for example, illustrate that relatively high per capita incomes can be attained with a comparatively low level of resource consumption, there are also countries such as Finland and Estonia, which show high levels of resource use but low resource productivity. The main reason for this is that the latter carry out a lot of raw material processing while exporting a large share of these products later. High levels of resource productivity are not necessarily connected to strong dynamics in improving resource productivity. The fact that countries with similar per capita incomes show huge differences in resource use implies that there is still room for improvements (Bleischwitz et al. 2007).

There are several further studies based on scenario analyses (e.g. Stocker et al. 2007, Giljum et al. 2008, Wuppertal Institute 2010; Meyer et al. 2011, Cambridge Econometrics et al. 2014, etc.), evaluating the economic impacts of policies to increase resource productivity. Apart from baseline scenarios, these studies assess the economic effects of various alternative scenarios leading to higher resource productivity. Most of these studies come to the conclusion that an increase in resource productivity is associated with GDP growth.

However, de Bruyn et al. (2009) cannot justify the claim that policies oriented towards resource productivity are able to enhance economic growth. The authors show that richer countries tend to be more competitive and at the same, they tend to be more resource-productive than poorer countries. Yet they were not able to find any relationship at all between competitiveness and energy/resource productivity.

On the firm level, there is huge potential to increase resource productivity and save costs

Besides these studies examining the effects on the macro level, a range of studies analyse the cost-saving potential of implementing low-carbon and resource efficient technologies on the **firm level** (see e.g. Aachener Stiftung Kathy Beys 2005). By applying production-integrated environmental protection techniques, material throughput costs can be decreased by about 20% (Arthur D. Little et al. 2005, Fischer et al. 2004). It has been estimated that the current inefficient use of resources are associated with costs of EUR 630 billion per year for the European industry (Greenovate! Europe 2012).

5.2 Impacts of growth on resource productivity

Mainstream macroeconomic theory is deeply oriented towards the goal of continuous and exponential economic growth. Economic growth is seen as a prerequisite for achieving rapid changes in energy technology and industrial patterns. Neoclassical economists are thus highly optimistic about technological change and suggest that economic growth increases (eco-)innovation and resource efficiency and thus helps to tackle environmental pressures. What has to be achieved is ‘getting the prices right’ in order to fully internalise external costs and to decouple economic growth from negative environmental impacts (Pollitt et al. 2010).

In contrast to neoclassical positions, other schools such as Ecological Economics argue that for several reasons, it can be assumed that there are limits to growth, e.g. resource scarcities, commodity price shocks, instability of financial markets, government debts, or a decline in consumer confidence but also aging populations in early industrialised countries. These causes have a severe impact on our long-term ability to sustain prosperity. Based on these arguments, it may occur that economic growth rates will be low in developed economies in the near and also in the far future.

It is therefore crucial to know how low growth rates will affect resource productivity, or respectively, how resource productivity can be raised despite low growth rates, as well as their labour market implications. First scenario analyses show that adequate measures are able to mitigate the negative impacts that are associated with low growth (see e.g. Stocker et al. 2014; Jackson and Victor 2011). However, further research is needed in this respect.

Without systemic changes, substantial resource use reductions and full employment are incompatible.

What role do resource and labour productivity play when growth is low? In order to answer this question Antal (2014) combines two empirical correlations that have rarely been studied together, namely the one between economic growth and environmental impacts, and the other between economic growth and unemployment. He concludes that without systemic changes, green goals and full employment are incompatible. If there is strong economic growth, high resource use is unlikely to be reduced quickly enough to avoid severe consequences. If there is no economic growth (or it is negative), unemployment can be expected to increase considerably in most market economies with negative impacts on well-being.

What is the historical observation for these two correlations? In the past, decoupling of resource use and environmental impacts from GDP was not very successful (see chapter 4.2). The empirically observed relationship between unemployment and economic growth is termed Okun's Law. According to Okun's Law, an increase of 2% in real GDP leads to a 1% reduction in unemployment (Samuelson/Nordhaus 2001). From this follows that unemployment drops if production (output) increases faster than productivity. This connection has been empirically proven for several economies and is relatively stable (see e.g. Hinterberger et al. 2012).

Antal (2014) suggests two main options that should be combined in order to reconcile environmental and socio-economic objectives: speeding up the decoupling of environmental impacts from GDP and reducing unemployment without growth to make low or negative growth more socially sustainable. The author concludes that "very significant efforts are needed to put questions of non-growing economies on the public agenda. In particular, employment strategies such as a systematic reduction of the cost of labor (e.g., through an environmental tax reform), increasing wage flexibility at high income levels, public employment, nonwage employment aimed at self-sufficiency, and the reduction of working hours (see also chapter 0) deserve much more attention in research and policy. More generally, a major increase of research efforts about reducing dependence on growth is necessary to address the many problems of growth-constrained economies" (Antal 2014).

The aim of the research by Auzina-Emsinaa (2014) was to examine recent trends of labour productivity and economic growth in the post-crisis period in comparison with the trends in pre-crisis and crisis periods in Latvia, Lithuania and Estonia. The article shows that the relation between labour productivity and economic growth differs substantially. There are weak or no links between labour productivity and economic growth before the crisis and immediately after crisis. However, labour productivity growth during the crisis is an important driving force of economic growth after a period of time. Due to the increase of labour productivity and positive impacts of other factors, the countries recovered regarding their global competitiveness that was lost during the crisis.

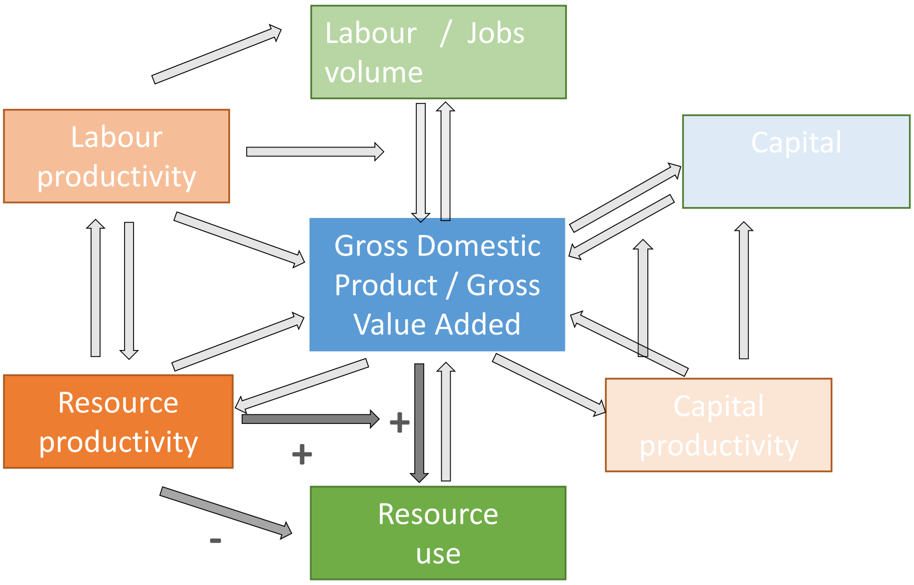
Research efforts must be broadened in order to show the low growth consequences on resource and labour productivity.

6 How and to what extent does resource productivity contribute to environmental improvements and decreases in resource use?

Natural resources, including materials, water, energy and fertile land are the basis for our life on earth, as well as for our economy. However, humanity's rapidly growing consumption of resources is causing severe environmental damage, such as climate change, air pollution, shrinking fresh water reserves, loss of biodiversity etc.

In this chapter we describe the influence of resource productivity on resource use (see Figure 17). We analyse whether an increase in resource productivity has the potential to reduce resource use to a sustainable level.

Figure 17. Simplified illustration of the impacts of resource productivity on resource use



Source: Own illustration

On the firm level, increases in resource productivity have the potential to reduce resource use.

On the **firm level**, empirical evidence shows that improvements in resource productivity have the potential to lower resource use. The ENWORKS partnership, for example, promotes waste minimisation and resource efficiency among SMEs in North West England. Between 2001 and 2012, the companies participating in the ENWORKS programme could achieve 157,800 tonnes of annual savings, and another 740,600 are in the pipeline. From these already 617,500 tonnes of cumulative savings have been accrued. Regarding the use of water, since 2001 1.8 million m^3 could have been saved annually, with another 4.8 million m^3 in the pipeline. ENWORKS also helped to save 2.4 million tonnes of materials per year; another 698,000 tonnes are in the pipeline (ENWORKS 2012).

Also the case study by IDEA et al. (2014) provides evidence for the impacts of resource efficiency improvements at the firm level. Accordingly, firms in various sectors with different employee numbers were able to reduce their environmental footprint and increase resource efficiency. The more efficient use of materials and improvements in energy efficiency/reduction of GHG emissions are the most frequently reported impact categories.

However, the question is whether these positive effects found on the micro level are also evident on the **macro level**.

A recent report by EEA (2014) shows that – despite resource productivity has steadily increased, an absolute decline in resource use/emissions (absolute decoupling) has been realised only with respect to emissions to air caused by domestic final use in the EU-27 between 2000 and 2007. However, TMR and DMI only saw relative decoupling (resource impacts decline relative to GDP). Not a single sector achieved an absolute reduction in material demand, although the mining and quarrying sectors and refineries came close. Out of the 20 most material demanding sectors, 15 sectors saw not even, or almost no, relative decoupling (EEA 2014).

A study by Steinberger et al. (2009) covering 175 countries shows similar result for the global economy: rich countries tend to have higher levels of domestic material consumption than poor countries and higher physical imports. Similarly, material productivity is highly correlated with income for most material categories, except of fossil fuels and ores/industrial minerals. The increase in material productivity over time is related to growing GDP (Steinberger et al. 2009).

Giljum et al. (2014) analysed patterns of resource flows and productivity on a global level. Material extraction and consumption increased by 94% between 1980 and 2009 while material productivity improved by an aggregated 27%. Thus, on a global scale relative decoupling of economic growth from material extraction and consumption has been achieved over the past three decades. However, since 2000 material consumption increased almost in parallel to GDP, so for the past decade not even relative decoupling has been achieved on a global scale. Still, Giljum et al. noted that absolute decoupling, i.e., GDP growth and falling DMC, only occurred in countries with relatively low economic growth across the observed period. Among this group, there are European countries such as Germany, UK, Finland, Hungary and the Netherlands. As the DMC indicator does not account for resources which are embodied in trade, these examples of absolute decoupling must be questioned, given that in many cases material-intensive production was outsourced to other countries.

The authors conclude that “with an increase of 27% during the past three decades or annually 1% on the global level, the improvements of material productivity are still much too slow to achieve an absolute reduction of material use, which would be needed to reduce the pressures put on the global ecosystems” (Giljum et al. 2014).

On the macro level, resource productivity improvements might be partially outweighed due to the overall growth of our economies

These results indicate that, on a macroeconomic level, it is important, to consider economic responses to higher productivity – so-called **rebound effects.** This effect refers to the situation where the beneficial effects from new technologies increasing the efficiency of resource use are offset due to behavioural or other systemic responses. For example, changes in the consumption mix and in the total volume of consumption could to some extent offset the efficiency improvements. The literature mainly focuses on rebound effects associated with energy consumption; however, this concept can generally be applied to any other production inputs, such as natural resources or labour. The rebound effect is generally defined as the ratio between the lost benefit and the expected environmental gain (Grubb 1990).

Regarding the overall rebound effect, it is necessary to distinguish two different aspects. First, the **direct rebound effect** refers to the substitution effect, i.e. the cost of consumption declines due to increased efficiency, and as a result consumption rises. Second, **indirect rebound effects** are associated with income effects, meaning that the lower costs of one good allow for increased consumption of other goods and services (Chitnis et al. 2014).

In theory, the size of the rebound effect is driven by the degree of substitution between production factors (labour, capital, and energy/materials). The interactions between these factors (e.g. technological improvements enhancing resource efficiency and simultaneously or afterwards increasing labour productivity) may produce a strong rebound – that is the case if environmental impacts are greater compared to a situation where no efficiency improvement had been made (also referred to as Jevons paradox or 'backfire').

A broad range of empirical studies provide evidence for the existence of rebound effects. It could be shown that while resource efficiency has improved, resource consumption has also increased through rising demands and more intense use. This phenomenon can be found in any EU country, especially after EU efficiency standards have been implemented. "The strength of the rebound effect is different in each situation because it is dependent on the policies in place and the strengths of the incentives from resource efficiency acting on the market economy" (UNEP 2014).

Antal (2014) demonstrates that, at a global level, economic growth is strongly correlated with environmental impacts, and barriers to fast decoupling are large and numerous. Ayres and Warr (2009) even go a step further in their argumentation. They argue that efficiency gains especially in the field of energy have been a key driver for economic growth. They state that a positive feedback loop has been created in which increasing efficiency reduces the unit costs of (energy) inputs, leading to increasing consumer demand and stimulating investment in labour-saving technologies, which leads to further energy efficiency improvements and unit cost reductions. The problem here is also that a significant part of resource productivity increases is caused by economic growth, which in turn has the major disadvantage that these kind of productivity improvements are not directly targeted at environmental benchmarks (Fischer-Kowalski/Wiedenhofer 2014). This implies that although productivity improves, the overall resource use cannot be reduced.

In this context, two challenges seem to be relevant. First, it is of great importance to further improve the resource efficiency performance of the EU by promoting eco-innovation and by ensuring that the benefits of new solutions are widely disseminated. And second, it has to be guaranteed that the efficiency gains are not offset by absolute growth in the consumption of natural resources (EIO 2013).

Therefore, some policies enabling greater resource efficiency will need to include additional measures to avoid higher overall resource use (see e.g. UNEP, CSIRO 2011). In order to ensure that efficiency enhancing technologies actually result in reduced resource consumption, Wackernagel and Rees (1997) propose to tax away any cost savings from efficiency gains or to remove them in another way from further economic circulation. The authors suggest reinvesting the tax revenue in natural capital rehabilitation.

Another option in this context is to apply taxation or subsidies in order to align the price of a specific resource with documented improvements in resource productivity. Prices could fluctuate within a defined "corridor", making interventions only necessary when prices leave this corridor. This measure would ensure the predictability of prices for investors, manufacturers, and consumers (UNEP 2014).

Moving to a sustainable society also requires innovation that goes beyond the traditional technological solutions. In fact, innovation should be supported by a corresponding evolution of social arrangements, institutional support structures, and associated with human nature and cultural values.

However, there are also several scenario analyses suggesting that suitable (policy) measures would be able to increase resource productivity while at the same time reduce resource use. For example, a study on the macro level carried out by WRAP (2010) examined the possible positive trade-offs between increased resource efficiency and the reduced environmental pressures for the UK. By introducing WRAP's measures to increase resource efficiency in the UK resource consumption could be reduced by 15% a year until 2020, with the base year being 2010. At the same time the reliance on specific materials, such as rare earths, cobalt and lithium could be reduced by 10-15% by 2020. A reduction by almost 6% by 2020 against baseline projections could be achieved in the water abstraction associated with UK's consumption. Reductions could also be realised in the UK's Ecological Footprint by 5-7% by 2020.

A broad range of studies emphasise that the use of single instruments is not able to effectively promote a sustainable economy. The transformation to a sustainable economy requires a comprehensive policy strategy considering both demand and supply aspects. Governments have to find a mix of instruments that include market-based instruments (such as environmental taxes and charges, tradable permits, environmental subsidies and incentives), regulatory policies (such as standard setting) and non-economic measures (such as voluntary approaches and information provision) in order to reduce resource consumption (Hinterberger et al. 2013). Whether such a policy mix could also positively affect employment will be analysed in the next chapter.

According to several writers, eco-efficiency strategies can be combined with sufficiency activities, i.e. the reduction of the level of production and consumption in affluent parts of the world, in order to tackle with rebound effects. One possibility in this context is to **channel labour productivity gains into reduced working time rather than higher wages**. In this way, employees would benefit from the improvements in labour productivity in terms of greater "time affluence" rather than an increase in material affluence (Hayden/Shandra 2009). Box 2 deals with the question how working hour reductions do impact on resource use.

Box 2: The impact of working hour reductions on resource use reduction

There are two possible mechanisms through which a reduction in working time might lead to less environmental pressures. First, shorter work hours could reduce the scale of the economy, i.e. less work hours on the macro level reduces economic output, income and consumption (scale effect). Second, the resource intensity of consumption patterns might change as a result of shorter work hours. More free time would enable people to engage less in time-saving activities which are often assumed to be more environmentally intensive, such as fast transportation (compositional effect).

A first attempt to provide empirical evidence on the positive link between work hours and resource consumption was Schor's (2005) bivariate linear regression analysis covering 18 OECD countries. The results show a positive and significant relationship between annual work hours per employee and the ecological footprint.
Rosnick and Weisbrot (2006) showed in a multivariate regression analysis that higher annual work hours per worker are related to higher levels of energy consumption, even when controlling for labour productivity, employment to population ratio, climate, and population. If annual work hours in the EU were the same as in the US, energy consumption would be 18% higher in the EU. This study provides evidence on the scale effect of working time reductions; however, it does not address the compositional effect.

In contrast, the results of a cross-sectional analysis of 45 countries (Hayden/Shandra) support the relevance of both scale and compositional effects. The study reveals that annual hours per worker has a positive significant effect on the ecological footprint, controlling for the employment to population ration, labour productivity and net of GDP per capita.

The most extensive analysis thus far examined the effect of working hours on the ecological footprint, the carbon footprint, as well as on carbon dioxide emissions (Knight et al. 2013). The results of this panel analysis of 29 high-income OECD countries using data for 1970-2007 reveal that work hours have a positive and significant effect on all three indicators. Testing for the underlying mechanisms, they find strong empirical support for scale effects, but only moderate support for compositional effects.

A French study (Devetter/Rousseau 2011) finds that, net of income, longer work hours are associated with greater consumption of environmentally intensive goods. They thus provide evidence on the compositional effect of work hours, by showing that unsustainable consumption patterns emerge as a result of time scarcities, encouraging the consumption of relatively more environmentally harmful goods and services.

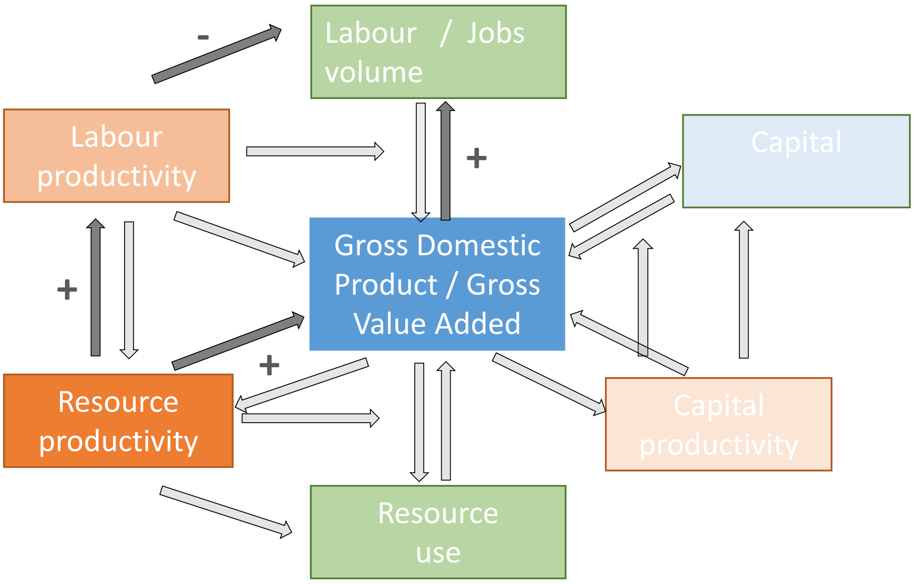
Of course, one could also think about the possibility that the reduction of working time increases environmental pressures. First, labour productivity and thus wages may rise as a result of shorter work hours, which in turn would raise consumption demand. A second possibility is that the additional leisure time is used for more instead of less resource intensive consumption activities, for example more short trips by plane (Knight et al. 2013).

As pointed out above, previous research does not support these possible reverse effects of working time reduction. However, there is a strong need for further research to assess the potential pathways among work hours, income, productivity and environmental impacts more comprehensively.

7 How and to what extent does resource productivity contribute to job creation?

The following figure shows the entirety of (possible) interrelations, which can be briefly summarized as follows: Resource productivity influences employment either via its impact on labour productivity or on the economic output (GDP or GVA).

Figure 18. Simplified illustration of the impacts of resource productivity on labour/jobs (via labour productivity and economic output)



Source: Own illustration

With growing environmental problems and resource scarcity on the one hand and increasing negative impacts related to efforts to enhance labour productivity (intensification of labour, i.e. more tasks have to be completed within shorter time periods which increases working pressure, thus leading to stress, burn-out, etc.) on the other hand, resource productivity has gained importance, not only in academics but also in policy making.

7.1 Theoretical and conceptual considerations

It is commonly argued that the high pace of productivity growth leads to unemployment, especially in manufacturing. This might be true in the short run, or for particular firms or industries. However, in the longer run, macroeconomic policies can influence the level of jobs rather than productivity growth. Although technological change can have significant impacts on the microeconomic level (depending on the bias of technological change, the prices of competing goods and services, the price elasticity of demand), the effect on aggregate unemployment or employment in the long run is negligible (Nordhaus 2005). Based on data for the G7 nations, Gordon (1995) shows that in the short term, a positive trade-off between productivity and unemployment may emerge. However, in the long run adjustment processes (regarding capital accumulation or decumulation) can contribute to eliminating this trade-off. Based on data for the US economy, Nordhaus demonstrates that more rapid productivity growth leads to higher rather than lower employment in manufacturing.

Building on this empirical evidence regarding the link between productivity and employment, the question arises what kind of role resource productivity in particular plays in creating jobs.

The more easily labour can substitute materials, the better is the chance that employment increases.

As the literature indicates, both the production structure and the elasticity of substitution between input factors are important determinants regarding the effects of resource productivity improvements on employment. The more easily labour can substitute material inputs, the better is the chance that employment increases (see e.g. Bovenberg 1999).

In the following analysis we attempt to empirically answer whether an improvement in resource productivity and environmental policy leads to more jobs. We analyse whether different types of drivers for resource productivity have different impacts and what are the measures best suited for managing the transition to a resource-efficient economy. Other important questions to be considered refer to the kind of jobs that are created and lost, the impacts on a sectoral level as well as the differences over time.

In general, increases in resource efficiency can have different effects on jobs, depending on the respective sector, the drivers, the country or region under consideration, and whether it is a short-term or a long-term stimulus.

Thus, for a comprehensive analysis there is a need

- to study the impacts of different drivers of resource productivity,
- to show the impacts on a sectoral level, and
- to show short-term and long-term effects

Depending on the **respective factors driving resource productivity, the effects on employment may vary substantially**. Therefore it is important to separately investigate the job creation potential of different driving forces, such as technical (and social) innovation, structural change, increase in recycling and circularity, resource efficient business models, or environmental policies (e.g., market based instruments or information, consulting and support programs, etc.).

The predicted effects of higher resource efficiency on labour markets will also **vary significantly over time** (Fankhauser et al.2008):

In the **short term,** employment is expected to decline in directly affected sectors and to rise in replacement industries. Jobs will be lost in carbon and resource-intensive sectors, which will grow slower or possibly shrink. New jobs will be generated in low-carbon and resource-efficient sectors, which tend to be more labour-intensive than conventional sectors (e.g. renewable energy vs. conventional energy). However, the expected net job creation might shrink over time as the competitiveness of energy and resource-efficient technologies rises and technologies develop. Consequently, employment gains of this type cannot be sustained over a long period. Moreover, structural unemployment may occur as a result of the reduced labour mobility and the need to address skills gaps in emerging sectors.

In the **medium term,** resource productivity policies will entail behavioural changes and adjustments in the value chains, resulting in both job creation and losses. External factors such as prices for raw materials and oil as well as regulation policies will determine the overall impact on employment. Input prices influence price differentials between resource-efficient and conventional technologies; regulation policies induce companies to modify their production practices. These factors will increase the competitiveness of resource-efficient and renewable energy technologies and improve employment in these sectors.

In the **long run**, investment and growth opportunities are generated by innovation and emerging technologies. Especially R&D jobs for low-carbon and resource-efficient technologies will arise, of which the research results in turn might create additional investment and jobs. This virtuous cycle illustrates the positive effects of innovation and technological change on economic growth and restructuring. However, it also reflects the need for highly skilled and qualified labour that is able to deal with the technological and innovation demands associated with a shift towards a green economy.

Within the reviewed studies we consider such differences over time, resulting from different drivers of resource productivity.

In order to be precise about the job creation potential of resource productivity, it is furthermore important to distinguish between **gross** and **net employment effects.** The gross number of new jobs only accounts for the persons employed in the sector under consideration (e.g. the environmental goods and services sector - EGSS) and also includes employment in supplying industries, while the net calculation also includes job losses in other sectors, thus showing the change in the total number of jobs for the whole economy by taking into account economy-wide price, income and substitution effects (Meyer/Sommer 2014).

Gross employment effects can be assigned to direct, indirect and induced job effects. Direct employment effects refer to the jobs created in one specific sector. Indirect effects stem from the use of intermediate goods from other sectors. Induced jobs are generated through additional consumer spending due to direct and indirect job earnings (Meyer/Sommer 2014).

The net employment effect is more difficult to calculate and mainly depends on three factors. First, it is determined by the relative labour intensity of the sector where additional jobs are created. As the labour intensity is relatively high in the environmental goods and services sector, environmental policies stimulating job creation in this sector might have a positive net effect. Second, if there is a certain level of unemployment at the outset and the skills of those unemployed match the requirements of the newly created jobs, employment would rise. Third, the net employment effect is also determined by the level and trend in global demand for (competitive) environmental technologies or environmentally friendly goods and services produced in the EU (EC 2005).

Since we are interested in the employment effects on the firm, the sectoral and the macro level, we have reviewed studies that report both gross and net job creation.
Before analysing all these influencing factors in more detail, we first address the question whether resource productivity has led to employment increases in the **past.** Then, we describe some findings from **scenario analyses** that deal with employment effects of resource productivity improvements.

7.2 Experience from the past

In the past businesses have increased resource productivity with positive side effects on net employment

Various examples show that in the past businesses have managed to increase resource productivity with positive side effects on net employment. A study recently commissioned by the European Commission (IDEA et al. 2014) provides a set of 21 case studies on industry's improvements in resource efficiency and the consequences in terms of environmental, social and economic impacts. The results reveal that the improvements in environmental footprint and resource efficiency are accompanied by net job creation in some companies, ranging from 1.3% for a large company to 8.4% for a small one. Other firms reported that jobs could be sustained due to the resource efficiency measure(s) implemented.

Positive employment impacts on the **macro level** of increasing resource productivity become evident when comparing the effects of investments in green technologies on the one hand, and traditional technologies on the other. It has been shown that twice as many jobs can be created per dollar invested in green energies (which in turn has a positive impact on resource productivity), compared to investments in fossil fuel-based energy. Also the employment effects of improving energy efficiency and investments into green power are more persistent than those of tax cuts or traditional infrastructure investments, which only create employment during the project funding period (Renner et al. 2008).

Labour and resource productivity varies across manufacturing sectors

Empirical evidence reveals huge **differences between sectors**. Marin and Mazzanti (2009) found that the relationship between environmental efficiency and labour productivity varies, sometimes considerably, across manufacturing sectors. Explanations can be found in varying eco-innovation opportunities of branches, different reactions to (policy) events and structural differences in production and energy processes.

A panel regression by Bleischwitz et al. (2007) analyses the factors determining resource productivity for the EU-15 countries for the period from 1980 to 2000. It shows that increasing the share of employment in the **manufacturing sector** in total employment would decrease resource productivity by 1.17%. This result can be explained by the fact that resource-intensity in the industrial sector is considerably higher compared to the service sector. However, taking into account the intermediate demand from upstream sectors, the service sector turns out to be more resource intensive than usually assumed. An increase in labour productivity in the industrial sector would lead to a decrease in resource productivity. This can be explained by the fact that highly productive industrial sectors are very effective, have high shares of GVA (gross value added) and employment levels, which results into high amounts of resource consumption originating from high volumes of industrial production.

Mulder and de Groot (2007) empirically investigated the development of **cross-country and sector differences** in energy and labour productivity from 1970 to 1997. For 14 OECD countries, they show that the productivity development differs across sectors as well as across different levels of aggregation. Variations between the investigated countries are typically larger for energy than for labour productivity. In most sectors lagging countries are likely to catch up with technological leaders, in particular with regard to energy productivity.

Positive employment developments can be observed in the **environmental goods and services sector** (EGSS) that seem to have a relatively high labour intensity. EGSS in the EU has recorded an increase in employment from 3 to 4.2 million between 2002 and 2011 (EC 2014). Electricity, gas, steam and air conditioning supply, water supply, sewerage, waste management and remediation as well as construction activities account for the largest share of EGSS jobs. Even during the economic downturn, job creation in these industries has notably been positive. The increase in EGSS jobs thus seems to have occurred despite decreasing levels of investment and employment in other sectors. Also, programs and initiatives in the EGSS sector have been cut, e.g. in the renewable energy sector. The rising demand for economic recovery based on green and sustainable growth can be regarded as the main driver for the better performance of the green sector during the economic crisis, compared to other sectors (OECD 2011).

While the majority of services has a low material intensity, manufacturing sectors have a medium material intensity and primary sectors have a high material intensity

Whereas employment of the total EU-27 eco-industry increased by 2.8% p.a. between 2000 and 2008, the recycling sub-sector exhibited a growth rate of 7.5% p.a., which is only comparable with the growth rate in the renewable energy sub-sector (7.3% p.a.) (Ecorys 2012). Those economic sectors dominating air emissions from EU production play a relatively minor role for economic output and employment. Although representing 56% of total GHGs, agriculture, the electricity industry and transport services contribute only 11% to employment and 10% to gross output. In contrast, many service sectors are quite resource efficient and contribute to a disproportionally large degree to employment and economic output. While the majority of services has a low material intensity, products of primary sectors (i.e. agriculture, forestry, mining etc.) have the highest material intensities, since they are close to material extraction and are sold at low prices. Products of manufacturing sectors have a medium material intensity, while they require substantial labour inputs (EEA 2014).

Industries increased their resource efficiency over the past few years mainly through the adoption of various first and second order measures (Cambridge Econometrics et al. 2011), with positive side effects on employment (see e.g. RPA 2015). First order measures comprise increasing or maintaining the high share of recycling of materials rates, the use of green and intelligent information technology along the production cycle, or the use of green business models, etc. Second order measures refer to the introduction of new substitutes of material, e.g. the use of renewable (bio-based) materials; or investment in R&D, etc.

Barriers, such as lack of access to finance, information deficits, etc., have hindered stronger resource efficiency increases

However, **a wider use has been inhibited by several factors**, .e.g. the lack of access to finance, information deficits, lack of knowledge and of sharing and dissemination of best practices. Furthermore, many sectors do not exhaust their innovation potentials for the development and diffusion of resource efficient products. Bleischwitz et al. (2010) explain that “this underutilization is due, on the one hand, to the inherent incentive structures of innovations (unforeseeable risks, missing capital, spill-over-effects, missing infrastructure, etc.) and, on the other hand, to positive externalities: the benefits of innovations are realized by society as a whole. As a result, there are too few incentives for private actors, especially to induce far reaching system innovations”. But also the failure to internalise environmental costs has impeded resource productivity to raise more strongly. There is thus still considerable potential to increase the further adoption. A study by Cambridge Econometrics et al. (2011) observed that EU companies have mainly adopted measures that increased their efficiency rather than their effectiveness, which means that they concentrated on using the resources “right” (i.e. optimising the use of the ‘same’ resources) instead of using the “right resources”.

The following table provides an overview of the results of selected studies.

Table 1. Overview of studies dealing with employment effects of resource productivity improvements (experience from the past)

Description /Findings	Topic / policy	Effect on employment / jobs	Regional level	Macro-meso-micro level	Methodology / Model
IDEA et al. (2014). Cases of implementing resource efficient policies by the EU industry. Final report.					
This paper provides a set of 21 case studies on how industry has improved its resource efficiency and the result in terms of environmental, social and economic impacts. Results: wide scope of improvements in environmental footprint and resource efficiency, cost savings; most companies reported net job creation or jobs have been sustained.	resource efficiency measures in some manufacturing sectors	improvements in environmental footprint and resource efficiency are accompanied by net job creation in some companies, ranging from 1.3% for a large company to 8.4% for a small one.	EU	micro/meso	Case studies, that illustrate how, in practice, industry has improved its resource efficiency and the results obtained in terms of environmental, social and economic impacts.
RPA (2015). Assessing the Potential Cost Savings and Resource Savings of Investments in 4 SME sectors.					
Assessment of potential benefits from implementing business support programmes targeted at SMEs investing in resource efficiency based on ENWORKS data. Calculation of cost savings, reductions in resource use, creation and safeguarding of jobs, that could be realised by €4 billion of public investment.	public investments in resource efficiency of EUR 4 billion for SMEs	around 128,000 jobs created, around 360,000 jobs safeguarded	EU-28	macro/meso	Generalisation of ENWORKS data for all EU member states
RPA (2014). Study on Economic and Social Benefits of Environmental Protection and Resource Efficiency Related to the European Semester.					
Investigates the effects of programmes to support SMEs regarding resource efficiency, potentials for cost savings, reductions in energy use and CO2 emissions, job creation in environmental goods and services sector (EGSS).	SME support, EGSS	In past: EGSS or green sector has fared better than others in terms of employment; many green sub-sectors ar more labour intensive than traditional equivalents. Environmental goods and services sector jobs are estimated at 4,194 thousand for EU-28 (2011)	EU-28	meso	Review of key data concerning: potential of SME support on resource efficiency and relative environmental expenditure.
Ecorys (2012). The number of Jobs dependent on the Environment and Resource Efficiency improvements.					
The background of this study is the emerging discussion on how environmental protection and resource efficiency goes hand-in-hand with job creation. The results show the heavy influence of scope, methodology and data availability. However, whatever the choices about how to measure 'green jobs', the number seems to be increasing and the debate is only over how fast and how many. Provides an UPDATE of Ecorys and IDEA, 2009 and GHK et al., 2007	Technological improvements, link between environmental protection/resource efficiency and job creation	For six sub-sectors (covering insulation, electric vehicles (hybrids), copper, cement, drip irrigation, heat pumps) educations in energy and/or resource use could have a positive employment effect. About 2,7 million people worked in the EU-27 eco-industry in 2008 which represented 0,81% of the total workforce (people age 15 - 64). The average annual growth (2000 - 2008) in eco-industry jobs is approximately 2,72 % corrected for inflation.	EU	macro/meso	A few key studies on the green job debate and eco-industries have been made over the last decade. In this report the authors have refined and updated the numbers and methodologies from these studies.
Ecorys, Cambridge Econometrics and COWI (2011). The role of market-based instruments in achieving a resource efficient economy, Study for the European Commission, DG Environment					
This study investigated how market based instruments (MBIs), can support and drive the move towards resource efficiency. The objective was to identify the market based instruments being used, particularly those that demonstrate best practice in promoting resource efficiency, and examine how they can be improved, what lessons can be drawn and the recommendations for the future, taking into account the cost, competitiveness and other impacts. Presents employment effects for some case studies.	market based instruments (especially tradable permits) are applied relatively rarely to resources: waste and emissions are the major focus of existing instruments	With the exception of the UK none of the existing policies assessed had a direct impact on employment. In the case of the UK, however, a double dividend has been realized by transferring an aggregates levy to firms, which reduced labour costs. The aggregates levy resulted into small increases in GDP and employment in the aggregates sector.	EU member states	macro/meso	Case study review. The scope of the study excluded energy, carbon emissions and other air pollution emissions, where considerable work already exists. The focus was on other resources, products and services.

Description /Findings	Topic / policy	Effect on employment / jobs	Regional level	Macro-meso-micro level	Methodology / Model
Cambridge Econometrics and Ecorys (2011). Assessing the Implementation and Impact of Green Elements of Member State's National Recovery Plans, Final report for European Commission, Directorate-General Environment, Brussels.					
Assessment of the green elements of the fiscal stimulus packages that were implemented in response to the economic and financial crisis. It provides an overview of the green elements of the recovery plans of each of the EU"s Member States (where data are available) and considers the measures in nine countries in more detail. Most policies resulted in a temporary boost to employment as a result of increases in economic activity. Very few of the policies were explicitly targeted at vulnerable groups and some which required co-financing, including car scrappage schemes, may have excluded them.	green elements of fiscal stimulus packages	None of the observed measures had a direct impact on employment. However, many of the policies were directed at sectors that are both labour intensive and were impacted severely by the crisis (such as motor vehicles, construction and engineering). The policies therefore had a positive impact on net employment, although this was more likely to be in jobs saved rather than in jobs created. The types of jobs that were saved are likely to have been a combination of basic and high-skilled jobs. Many of them would have been in traditionally male-dominated occupations.	nine EU countries (BE, CR, EST, FR, GE, PO, SL, SE, UK,. Four non-EU countries (Australia, China, South Korea and the USA)	macro	Combination of qualitative and quantitative assessment methodologies with the acroeconometric E3ME model to provide an assessment of the economic and environmental impacts of the green elements of the recovery plans.
Strand, J. and Toman, M. (2010). Green Stimulus, Economic Recovery, and Long-Term Sustainable Development. World Bank Policy Research.					
This paper discusses short-run and long-run effects of "green stimulus" efforts, and compares these effects with "non-green" fiscal stimuli. The authors categorize effects according to their a) short-run employment effects, b) long-run growth effects, c) effects on carbon emissions, and d) "co-benefit" effects (on the environment, natural resources, and for other externalities). The most beneficial "green" programs in times of crisis are those that can stimulate employment in the short run, and lead to large "learning curve" effects via lower production costs in the longer term.	green stimulus efforts	Most "green stimulus" programs that have large short-run employment and environmental effects are likely to have less significant positive effects for long-run growth, and vice versa. There are also trade-offs for employment generation in that programs that yield larger (smaller) employment effects tend to lead to more employment gains for largely lower-skilled (higher-skilled) workers, so that the long-term growth effects are relatively small (large). Different instruments are needed for addressing different problems.	global, EU and Member States	macro	Literature review. Summary of empirical evidence.
EEA - European Environment Agency (2011). Earnings, jobs and innovation: the role of recycling in a green economy. EEA Report No8/2011.					
This report examines the economic benefits that recycling offers. Recycling creates more jobs at higher income levels than landfilling or incinerating waste. Recycling can meet a large proportion of the economy's demand for resources, alleviating pressure on ecosystems to provide resources and assimilate waste. Already recycling meets substantial proportions of demand for some resource groups, notably paper and cardboard, and iron and steel.	Recycling	The overall employment related to the recycling of materials in European countries has increased steadily from 422 per million inhabitants in 2000 to 611 in 2007. This represents an increase of 45 % between 2000 and 2007, corresponding to an annual increase of 7 %.	EU-27	macro/meso	Review of studies and data
BIO, IFF, VITO (2011). Analysis of the key contributions to resource efficiency, Final Report, for the European Commission.					
Compilation of the correlation between recycling rates, and the level of employment in the recycling sector. This study makes an appraisal of the contribution of existing areas and policies to resource savings and resource efficiency. Recycling has a larger contribution than waste prevention and product design (easier to measure). Radical and fundamental restructuring of economic activity and scoietal structures in the medium to long term. Related to this, need for skills development.	Waste prevention, recycling, product design.	Higher investments in sectors related to material savings efforts might create new employment opportunities. Employment rate in the recycled materials and weast management sectors in 2008 (in % of eco-industries employment): Italy 59%, France 38%, UK 28%, Germany 17%, EU-15 55%, EU-27 35%. More remanufacturing might have negative employment effects, as the fabrication phase is skipped. Jobs losses through re-use. No employment effects might result from improving product design.	national	meso	State-of-the-art overview of studies, reports and relevant literature for recycling, waste prevention and product design

7.3 Insights from scenario analyses

Scenario analyses can help to understand potential impacts of resource efficiency policies on the number of jobs. Scenarios can be regarded as illustrations of possible future developments – plausible and consistent, but not necessarily presenting a forward projection of historical and current trends. Therefore, they should not be seen as forecasts (Jäger et al. 2008). In particular, scenarios can be useful to understand uncertainties in a complex system.

In this chapter we summarise some studies that explore the relationship between resource productivity and employment and analyse the (simulated) employment effects in some scenarios that have recently been developed in order to improve resource productivity.[14] In sum, the results indicate that the EU economy would gain with regard to employment.

First simulations for the POLFREE project[15] show that resource efficiency increases will lead to remarkable possibilities for aggregated win-win outcomes: Meyer et al. (2015) calculated three alternative scenarios that comprise policy intervention as well as behavioural changes induced by intrinsic motivation, using the macro-econometric model GINFORS[16] that was linked with the vegetation model LPJmL[17]. These scenarios intend to reach different targets for 2050 (CO_2 emissions reduction by 80% compared with 1990, reduction of the cropland footprint by 30 % compared with 2005, raw material consumption 5 tonnes per capita, water exploitation index below 20% in all EU countries).

The ambitious environmental targets of the POLFREE project can be reached globally and in the EU with employment gains

The results of the simulations show that in all scenarios the targets more or less can be reached with positive impacts on employment. In the scenario “Global Cooperation”, a wide range of policy instruments induces strong investments in new resource efficient technologies that lead to economic growth and job creation globally as well as within the EU via less extraction of resources and falling resource prices. However, extracting and resource exporting countries are the losers in this scenario.

In the scenario “EU Goes Ahead” the EU introduces primarily economic instruments in addition to regulations that are designed in a way to avoid problems with international competitiveness. With the strategy to tax imports of certain goods with the same rate as sales from domestic production, the scenario yields higher GDP and employment figures for the EU than scenario Global Cooperation. The reason is that the EU realizes first mover advantages in the introduction of new technologies.

Scenario “Civil Society Leads” assumes that intrinsic motivation of consumers and employees induces structural changes of the economy and enables societies of the EU (and all over the world) to achieve ambitious environmental targets. Moreover, working time reductions by 20% and consumption decreases (to the level of 1995) are presumed. Although this scenario has negative impacts on GDP growth (which means zero growth of GDP for the EU), it has higher employment effects than the other two scenarios.

[14] For an analysis of further resource productivity scenarios see chapter 8.6 of the scientific background report of this scoping study.

[15] See http://www.polfree.eu

[16] See chapter 9.3 for a short description of the model GINFORS

[17] The model LPJmL ("Lund-Potsdam-Jena managed Land") is built to simulate vegetation composition and distribution as well as stocks and land-atmosphere exchange flows of carbon and water, for both natural and agricultural ecosystems (see https://www.pik-potsdam.de/research/projects/activities/biosphere-water-modelling/lpjml).

Within the NEUJOBS project[18] Boitier et al. (2015) used the macro-econometric model NEMESIS in order to investigate the employment implications of a socio-ecological transition. Assuming that the European Union has to face major employment and environmental challenges in order to manage a socio-ecological transformation, the authors propose two policy response scenarios in order to tackle these challenges, both in a "friendly" and a "tough" economic context. The first scenario called "Ecological modernization" only comprises **market-based instruments**. The bundle of instruments consists of a carbon tax, a decrease of labour cost and R&D subsidies. Compared to the reference scenario, it is possible to create 4 million additional jobs in the "friendly" context until 2030, corresponding to an increase of 1.7%. These **positive employment effects result from higher economic activity** (+1.9% for GDP in 2030) **and the reduced labour costs**, which incentivise firms to hire employees. In the "tough" context, only 1.3 million additional jobs can be created.

A policy mix that comprises market based instruments, awareness campaigns and regulations increases employment via a higher demand for labour intensive services

In the second scenario, called "Sustainable transformation", behavioural economics-based instruments are added to the market-based instruments. These **additional instruments comprise awareness campaigns and new norms and regulations**, aiming at favouring goods and services which foster the reduction of GHG emissions, and decreasing services and goods whose consumption is highly GHG intensive. The results of this scenario show that in the "Friendly" context, 4.4 million jobs can be created compared to the baseline, which is 400.000 more than in the "Ecological modernization" scenario. This effect does not stem from GDP growth (which is lower than in the "Ecological modernization" scenario), but from substituting energy by more labour-intensive technologies in production, and by modified consumption behaviours, i.e. a higher demand for services than for goods. As the labour intensity of the service sector is relatively high, employment is enhanced. In the "tough" context, even 6 million additional jobs can be created, however also unemployment is high (Boitier et al. 2015).

Cambridge Econometrics et al. (2014) provide an analysis of different resource productivity targets for the EU, based on RMC data. The improvement targets range from 1% to 3% a year (cumulative 15-30% by 2030). Policies to improve resource productivity are assumed to comprise three categories: private-funded measures (such as recycling systems e.g. investment in machinery to cut down raw material consumption per unit of production), public-funded capital investment to improve efficiency and market-based instruments (such as a tax on the consumption of raw materials - biomass, minerals, metals and energy sources where applicable). Revenues from the market-based instruments are assumed to be reinvested, with the remainder used to lower labour taxes. The modelling results suggest that improvements of 2-2.5% a year could have a net positive impact on EU-28 GDP. An annual resource productivity improvement of 2% could create two million jobs.

For the project WWWforEurope[19] Kratena and Sommer (2014) quantify different resource use scenarios for Europe with a disaggregated dynamic New Keynesian (DYNK[20]) model covering 59 industries and five income groups of households. One scenario assumes a focus shift in technological change from labour/capital saving towards energy/resource saving (without any change in the overall TFP growth), which could be reached either by en-

[18] See www.neujobs.eu
[19] See www.foreurope.eu
[20] For a description of the DYNK model approach see chapter 9.3.1 and/or Kratena and Sommer (2014).

hanced investment in R&D or by the taxation of energy and resources. Such a shift leads to more employment and higher disposable household income. Energy demand and greenhouse gas (GHG) emissions increase less than in a business as usual scenario, while DMC/capita is (only) slightly decreased (due to rebound effects from increased household income).

Another scenario predicting a radical reduction of resource use per capita introduces a price for CO_2 (tax or auctioned permits) where the revenues are redistributed via lower employers' and employees' social security contributions. The price for CO_2 starts with 25 EUR/t in 2011 and increases linearly to 250 EUR/t (in 2005 prices) in 2050. Consequently, GDP is negatively affected. However, this does not mean that GDP actually declines, but that the average annual growth rate of GDP is lower, i.e. the decrease in DMC and emissions is not only a result of decoupling. Greenhouse gas emissions decline by almost 50% until 2050, and DMC by about 20%. The modelling results show that a policy of GHG reduction has additional benefits for DMC reduction. In sum, the results of the scenario imply that absolute decoupling is possible and compatible with **positive employment effects in the mid-term**. However, the results for the labour market are different in the short- and in the long-run. Until 2030, the amount of jobs rises although GDP is affected negatively, while beyond 2030 the employment effects turn negative due to the increasingly negative GDP effect (compared with the business as usual scenario) (Kratena/Sommer 2014).

Positive employment effects of a green tax reform are the result of sectoral shifts

Furthermore, Kratena and Sommer (2014) show that the positive employment effects of 0.33% (compared to the reference scenario) are the result of **major sectoral shifts:** Whereas the public sector and the transport sector lose, employment is created in the electricity sector as well as in some manufacturing and service sectors.

Meyer et al. (2011) illustrate that a policy mix of recycling, taxation and information and consulting has the potential to initiate win-win situations with rising GDP and employment on the one hand, and falling material requirements, especially for metals, in almost all countries on the other hand. This study suggests that absolute decoupling of economic growth from material consumption does not necessarily need a general global agreement. A reduction of Total Material Requirement (TMR) by 1% is accompanied by an increase in employment of 0.04 to 0.08%, which corresponds to 100,000 up to 200,000 jobs for the EU-27.

Table 2 summarises the presented scenario modelling results with respect to employment.

Table 2. Selection of studies dealing with employment effects of resource productivity improvements (insights from scenario modelling)

Scenarios	Description	Target	Employment effects	Geographical coverage	Time span	Modelling approach
Project POLFREE (see Meyer, B., Distelkamp, M., Beringer, T. (2015). WP 3 – Report about integrated scenario interpretation. GINFORS results. Delilverable of the project POLFREE)						
Scenario "Global Cooperation": a mix of policy instruments is installed globally that can be characterized as "Everything, but hard market interventions".	The scenario does not exclude economic instruments completely, but it does without those which need strong administrative interventions, which may not be accepted worldwide.	• CO_2 emissions reduction by 80% compared with 1990, • reduction of the cropland footprint by 30 % compared with 2005, • raw material consumption 5 tonnes per capita, • water exploitation index below 20% in all EU countries.	The necessary investment in new technologies creates economic growth and more jobs globally and in the EU via less extractions of resources and falling resource prices. The extracting and resource exporting countries are losers of this development.	EU-28 and EU countries	2050	Integrated assessment modelling exercise: GINFORS was linked with the vegetation model LPJmL
Scenario "EU Goes Ahead": the EU countries meet their ambitious targets by a policy mix that is dominated by economic instruments.	The instruments like taxes and subsidies mainly induce changes on the supply side of the economy, on energy and material inputs and on the entire structure of production of the economy.	• CO_2 emissions reduction by 80% compared with 1990, • reduction of the cropland footprint by 30 % compared with 2005, • raw material consumption 5 tonnes per capita, • water exploitation index below 20% in all EU countries.	With the strategy to tax only final demand with the exclusion of exports the scenario EU Goes Ahead yields higher GDP and employment figures for the EU than scenario Global Cooperation. The reason is that the EU realizes first mover advantages in the introduction of new technologies.	EU-28 and EU countries	2050	Integrated assessment modelling exercise: GINFORS was linked with the vegetation model LPJmL
Scenario "Civil Society Leads": The EU countries meet their ambitious targets by "bottom-up" instruments, which means that intrinsic motivation of agents is ruling structural change.	On the demand side of the economy and the supply side of the labor market behavioral change of consumers and employees being part of the civil society induces structural change.	• CO_2 emissions reduction by 80% compared with 1990, • reduction of the cropland footprint by 30 % compared with 2005, • raw material consumption 5 tonnes per capita, • water exploitation index below 20% in all EU countries.	Scenario Civil Society Leads has the highest employment figures of all three POLFREE scenarios. This fits with the preferences of Civil Society of this scenario whereas the lower GDP will not be counted in this "Beyond GDP" world.	EU-28 and EU countries	2050	Integrated assessment modelling exercise: GINFORS was linked with the vegetation model LPJmL
Project WWWforEurope (see Kratena, K., Sommer, M., (2014). Model Simulations of Resource Use Scenarios for Europe, WWWforEurope Deliverable)						
Scenario "Best practice": assumes a shift in focus of technological change from labour/capital saving to energy/resource saving (without any change in the overall TFP growth), which could be reached by investment in R&D or taxation of energy and resources.	This scenario is implemented in the DYNK model by assuming a shift in the factor bias of technological change without any changes in TFP growth	Scenario designs for Europe that allow the economy to meet targets of considerable reduction of resource use. The latter refers to energy use and greenhouse gas emissions, to the input of metals and industrial minerals as well as of construction minerals.	positive employment effects: 23.26% compared to the baseline scenario in 2050	EU-27	2050	Scenario analysis with the Dynamic Neo-Keynesian (DYNK) model
Scenario "Radical transformation" introduces a price for CO2 (tax or auctioned permits), where the revenues are redistributed by lower employers' and employees' social security contributions.	The price for CO2 is taken from a scenario in the EU roadmap for radical GHG emission reduction and starts with 25 Eur/t CO2 in 2011 and linearly increases 250 EUR/t CO2 in 2050.	Scenario designs for Europe that allow the economy to meet targets of considerable reduction of resource use. The latter refers to energy use and greenhouse gas emissions, to the input of metals and industrial minerals as well as of construction minerals.	positive employment effects in the mid-term, negative effects in the long-term (–1%); unemployment reduces until 2020, and increases afterwards	EU-27	2050	Scenario analysis with the Dynamic Neo-Keynesian (DYNK) model

Scenarios	Description	Target	Employment effects	Geographical coverage	Time span	Modelling approach
Project NEUJOBS (see Boitier, B., Lancesseur, N., Paul, Z. (2015). Modelling the European policy response to the challenges arising from the socio-ecological transition. NEUJOBS Working Paper No. D.9.3.)						
Scenario "Ecological modernization" both in a "Friendly" and a "Tough" economic context. The bundle of instruments only comprises market-based instruments and consists of a carbon tax, a decrease of labour cost and R&D subsidies.	In the "Friendly" context a fast economic upturn is assumed, allowed by the restart of the world demand and the moderate constraints relative to deleveraging and energy cost. The "Tough" version assumes a lasting economic stagnation, induced by the recent debt crisis, along with a high unemployment rate up to 2030. The strong decline of European population, and especially of the working age population, is an additional weight for European economies.	In order to choose the best policy mix for the scenario, an optimization program was designed in which employment was the variable to be maximized. Furthermore, three constraints were imposed, namely the respect of the -40% GHG emissions objective and the non deterioration of both the public and the external balances.	4 million additional jobs in the "Friendly" context until 2030, corresponding to an increase of 1.7% compared to reference scenario (1.3 million additional jobs in 2030 in the Tough scenario)	EU-28	2030	Scenario analysis with the macro-econometric model NEMESIS
Scenario "Sustainable transformation": behavioural economics-based instruments are added to the policy mix of "Ecological modernization" both in a "Friendly" and a "Tough" economic context.	For Friendly and Tough see scenario Ecological modernization. Additional instruments comprise awareness campaigns and new norms and regulations, aiming at favouring goods and services which foster the reduction of GHG emissions, and less services and goods whose consumption is highly GHG emitting.	Before implementing these instruments, a theoretical framework is provided (mainly references from the behavioural economics and from the decision theory) to justify the modification of the utility functions of consumers and producers in the NEMESIS model.	The results of this scenario show that in the "Friendly" context, 4.4 million jobs can be created compared to the baseline, which is 400.000 more than in the "Ecological modernization" scenario. In the Though context, 6 million additional jobs can be created. High structural shifts on the labour market, leading to a reorientation of employment from industrial sectors to services sectors.	EU-28	2030	Scenario analysis with the macro-econometric model NEMESIS
Cambridge Econometrics et al. (2014). Study on modelling of the economic and environmental impacts of raw material consumption						
Analysis of **resource productivity targets** for the EU, based on RMC data.	Policies to improve resource productivity are assumed to comprise three categories: private-funded measures (investment in machinery to cut down raw material consumption per unit of production), public-funded capital investment to improve efficiency and market-based instruments (tax on the consumption of raw materials - biomass, minerals, metals and energy where applicable).	Improvement targets for resource productivity range from 1% to 3% a year (cumulative 15-30% by 2030).	The modelling results suggest that improvements of 2-2.5% a year could have net positive impact on EU-28 GDP. An annual resource productivity improvement of 2% could create two million jobs.	EU-28	2030	Macro-econometric modelling (model E3ME)
Project MACMOD (see Meyer, B., ., Bleischwitz, R., Giljum, St., Pollitt, H. (2011). Macroeconomic modelling of sustainable development and the links between the economy and the environment. Final project report. GWS, Osnabrück)						
Scenario "Recycling, taxation and information and consulting"	The scenario assumes 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. Absolute decoupling of economic growth from material consumption does not necessarily need a general global agreement.	TMR reduction of 1%p.a.	A TMR reduction of 1% is accompanied by an increase in employment of 0.04 to 0.08%, which corresponds to 100,000 to 200,000 people for the EU-27.	EU-27	2030	Macro-econometric modelling (Comparison of GINFORS and E3ME)

As mentioned before, scenario analysis enables to evaluate different projections for political actions under certain socio-economic conditions and circumstances. In the following chapter we analyse the employment effects of different types of drivers that have the potential to increase resource productivity in more detail.

7.4 The impact of different types of drivers for resource productivity on employment

Improvements in resource productivity might result from a broad variety of factors, such as structural change, technological change and (eco-) innovation, environmental policy or price development of raw materials and energy fuels. Other drivers may be recycling strategies, material efficient production processes, substitution of materials, life-time extension of products, light-weight construction and new business models (Walz 2011). Depending on the respective factors driving resource productivity, the effects on employment may vary substantially.

For each driver we provide a short theoretical explanation of the expected impacts on employment and then show whether these impacts can be confirmed by empirics.

We distinguish between

- firms, sectors and economy-wide effects
- short term and long term effects
- past development and future estimates based on scenario modelling.

The drivers to be described are:

- Structural change
- Technical change and eco-innovation
- Circular economy
- Environmental policies
    - Market based instruments (MBIs), including environmental tax reforms and tradable permits
    - Regulation
    - Promotion of green investments
    - Promotion of information, consulting and support programs

7.4.1 Employment effects and skills challenges of structural change

Economic development is usually accompanied with rising share of value added in sectors that are intensive in high-skill labour

The transformation to a low-carbon and resource-efficient economy is associated with restructuring impacts throughout the economy, both in the short and long term. Whereas some sectors will experience a higher demand for specific goods and services, others will have to face increased resource costs and a drop in demand.

In addition, the structural shifts are associated with changes in the skills requirement (qualitative impacts).

7.2.1.1 Quantitative impacts on employment

Increases in GDP per capita are generally accompanied with structural changes, with a typically rising share of the tertiary sector, while the primary and secondary sectors lose in importance. This of course also affects employment and skill requirements. It can be shown that economic development is usually accompanied with rising shares of value added in sectors that are intensive in high-skill labour (Buera et al. 2015). But also technical change, which has traditionally been viewed as factor-neutral, in fact tends to favour skilled over unskilled labour by raising its relative productivity, and in turn its relative demand. These developments are captured by the concept of skill-biased technical change (SBTC), which might also result in unemployment as machines substitute for certain tasks previously carried out by workers (e.g. Acemoglu/Autor 2011).

Job gains from ecological driven structural change are likely to occur in those manufacturing sectors that are labour intensive

Not all sectors are equally prone to experience efficiency gains. Ecologically driven structural change creates very good growth possibilities for the **environmental goods and services sector** (EGSS). Environmental Business International (EBI 2012) estimated that the global environmental goods and services market accounts for US$ 866 billion. By 2020, the size of the global market is expected to rise to US$ 1.9 trillion (Blazejczak et al. 2009). On a global scale, solid waste management, water treatment works, water utilities and clean energy systems and power were the largest markets in 2011. The fastest growing sub-sectors were resource recovery, clean energy systems and power and waste management equipment (EBI 2012).

Those countries, regions and companies taking the lead in developing and deploying such new technologies are expected to benefit the most.
Whereas the biggest markets of environmental goods and services are located in highly industrialized countries (US, Western Europe, Japan), the highest growth rates can be observed in Asian, Middle East and African countries. In Western Europe, the environmental goods and services sector is estimated at 256.0 US$ billion in 2011 with a growth rate of 2% during 2011. The market size in Central and Eastern Europe amounts to 13.7 US$ billion and has grown by 4% in 2011 compared to 2010 (ibid.).

The labour intensity of many green sub-sectors is higher than conventional equivalents, which can be a driver for employment.

The **labour intensity of many green sub-sectors is higher than conventional equivalents**, which can be a driver for employment. For example, in the case of farming it was shown that organic farming requires 10-20% more workers per hectare compared to intensive farming (Sustain Labour 2013). GHK et al. (2007) estimated that a 10% substitution of bio-fuels for manufactured fuels results into 140,000 new jobs because of the relatively high labour-intensity of the agriculture sector and its supplying industries. The same study illustrates that increasing the energy efficiency of the manufacturing sector (modelled as a 10% reduction in purchases of inputs from the energy sector with a substitution to more energy efficient technologies) led to a net increase in output of EUR 480m and an increase of 140,000 jobs (energy sectors have a low labour intensity).

Thus, at least in the **short term**, environmental policies boost demand in labour-intensive industries and thus have positive effects on employment (GHK et al. 2007). In addition, other labour intensive activities, such as the construction of infrastructure for sustainable transport options, are able to create temporary employment (Sustain Labour 2013) – see also chapter 7.2.4.3). **Long-term employment effects** depend on the availability of highly skilled and qualified labour and thus on suitable training and education (see chapter 7.2.1.2).

In general, the time horizon of the employment effects is important since firms take some time to adjust their behaviour (Bowen/Kuralbayeva 2015). Studying the impact of carbon price policies on industry in the United States Ho et al. (2008) observe that, employment losses due to output declines in the short run can be fully offset by longer term employment gains in other industries.

According to UNEP (2011a), repair, reconditioning, remanufacturing and recycling are fairly labour-intensive activities, requiring relatively little capital investment. Thus, investments in **remanufacturing** seem to augment labour intensity.

However, more remanufacturing might have negative indirect employment effects, as the fabrication phase is skipped. Even more jobs might be lost due to **re-using things**, as this also circumvents remanufacturing and, to some extent, recycling. No employment effects might result from **improving product design**, assuming the designers are able to consider environmental problems for the product design with little additional training (Bio et al. 2011). In addition, life-cycle approaches and secondary production are able to secure jobs, for which safe and decent working conditions are very relevant (UNEP, 2011a).

Job losses can be expected in resource and energy intensive sectors

As shifts towards environmental protection and greener technologies take place, certain “dirty” operations might become undesirable in some industries. This can result in job losses because of shrinking demand or prohibiting specific operations and processes.

Energy prices and tradable emission certificates have already forced the energy-intensive cement and copper sector to improve their productivity. These industries are not expected to have any significant increase in employment in the near future *(*Ecorys 2012). The aluminium industry, which is capital intensive, has not the potential to create a plurality of green jobs. Furthermore, the less labour-intensive European cement industry is expected to suffer from job losses at the expense of China and India (UNEP 2011a).

This result is confirmed by a study examining the effects of the implementation of the EU 20-20-20 targets that finds that especially energy intensive sectors, such as iron, steel, cement and petroleum, are experiencing job losses. Employment gains are expected to occur in sectors such as construction and transport, as well as in sectors where Europe is able to achieve a leading edge (e.g. renewables, environmental technology) (Cambridge Econometrics et al. 2011).

According to microeconomic theory, the support for energy efficiency measures, which results in lower energy costs is preferable over renewable energy technologies, which may lead to an increase in energy prices unless covered by government support (UNEP 2010). This assumption is supported by another study stating that building insulation and other energy efficiency programs would result into higher employment effects compared to the promotion of renewables (UNEP 2009).

Substitution effects within a sector are also consequences of resource productivity improvements

It should also be noted that not only sectoral shifts from resource productivity increases will occur but also **substitution effects within a sector**. A study assessing the opportunities to business of improving resource efficiency (AMEC/BIO 2013) finds that resource efficiency measures might lead to a substitution of materials by labour. In the case of eco-design, for example, time spent designing is compensated by material savings. Instead of materials, firms might be able to buy more eco-design services. More focus on the reparability of products would enhance the product quality, extend the lifespan and increase the labour share of some products (i.e. the proportion of labour among production inputs rises), while reducing the material requirements in the production process.

Concerning substitution effects there is further research needed in order to determine substitution elasticities between the use of materials and labour by sector.

7.2.1.2 Skill requirements

The increase in environmental protection activities makes it necessary to relocate employees from non-green jobs to green jobs. In this context, the problem of skills matching may arise, creating the **need for increased job training** (OECD 2011). This need for the provision of training in turn generates new temporary green employment.

The development of new products and processes acquires new skills

In those sectors in which job losses are expected as a result of structural shifts (iron, steel, cement and petroleum), falling demand will create an incentive to develop new products and processes, which are more resource and energy efficient. This might increase the need for managers, professionals, and associate professionals to acquire new skills in their existing jobs. If there are potentials to move into new sectors of activities, the development of R&D skills will be highly important (Cambridge Econometrics et al. 2011).

Education and training should focus on short run and long run strategies

In addition, a coherent education and training response to the structural change is key to avert skill bottlenecks that may delay the development of new value chains or the deployment of new technologies. In the **short run**, strategies should mainly focus on fostering existing workforce skills in order to react to the increased demand resulting from the expansion of green economic activities and emerging clean technologies. In the **longer term**, the promotion of innovation necessary to advance the transition to an environmentally sustainable economy is seen as a critical factor. In this context, education and training strategies should concentrate on overcoming systemic deficiencies in management and science, technology, engineering and mathematics (STEM) skills (EC 2013b).

In general, skill levels are being raised as a consequence of technical change and eco-innovation, although they vary in different sectors

Regarding skill requirements, it can be assumed that **skill levels are being raised** as a consequence of technical change and (eco-)innovation (Slingenberg 2009; Boitier et al. 2015). This tendency can be explained by the fact that technical change is associated with the need for higher-level skills, which also holds true for green technical change. The results of a simulation study reveal that the higher the investments in new technologies (of which many are energy-saving or related to new forms of energy generation), the greater the demand for people in higher skilled jobs. This particularly applies to professional and associate professional ones. This study supports the assumption that greening the economy is able to increase the demand for highly skilled (and well-paid) employees, although the overall effect is relatively small. It also has to be considered that, whereas new functional requirements arise, also loss of skills or skills obsolescence might occur (Cambridge Econometrics et al. 2011). Another study suggests that in the EU-15, the share of high-skilled labour in low-carbon intensive sectors is higher compared to the share in high-carbon intensive sectors (EC-ILO 2011).

However, it has to be borne in mind that there are large variations in skills requirements, depending on the respective sub-sector affected. Whereas jobs in photovoltaics, for example, require rather high skilled labour, supporting biomass production will most likely lead to the creation of low skilled jobs (UNEP 2010). In general, there is the tendency that measures resulting in larger employment effects cause additional low skilled jobs, and vice versa (Strand/Toman 2010).

Labour market adjustments and employment transition will particularly affect low-skilled and older employees. Therefore, it is essential to address this adjustment process with an appropriate policy mix to ease the negative consequences on those most affected by a green transition.

First, **preventative action** should be taken by supporting employers in identifying early potential adjustment pressures in high emitting sectors. Collaboration between governments, worker representatives and firms could help to recognise potential skills deficiencies and develop preventative strategies.

Second, some workers might suffer from income losses that may persist over time due to the restructuring process. In this context it is essential that governments provide appropriate **income support systems** that are in line with employment objectives.

Third, in order to reach higher employment levels, better employment conditions and higher resource productivity, it is necessary to **adapt the existing education and vocational training systems** to evolving occupational skills requirements. Strategies on skills upgrading and training should especially focus on employees in the high emitting sectors, as many of those workers will be either forced to adapt their skills and worker practices to less carbon-intensive technologies, or to find a job in other low emitting sectors. In the top 15 emitting industries almost 30 percent of employees are low skilled (EC-ILO 2011, p. 47). In order to take full advantage of new technologies, the effective knowledge creation and transmission between educational institutions and business sector have to be ensured. Human capital strategies should also focus on R&D activities and the generation of new technical skills, particularly in natural sciences and engineering (EC-ILO 2011).

Finally, the successful implementation of these strategies crucially depends on a well-resourced, **effective public employment service,** which has a comprehensive understanding of the employment needs of a low-carbon economy (EC-ILO 2011).

7.4.2 (Eco-)Innovation and its employment effects

The **promotion of eco-technology and eco-innovation**[21] can also be viewed as an important factor to job creation. Innovation (especially eco-innovation) as well as investments in green technologies are a vital part for augmenting resource productivity. In this context, public finance is important. On the one hand, direct public spending, e.g. investments in R&D for environmental technologies or cleaner infrastructure provision, plays a central role (for the impact of R&D on resource productivity see also the results of the empirical analysis of this study, described in chapter 8.3). On the other hand, also indirect instruments (e.g. different forms of public guarantees)

[21] The Eco-innovation Observatory defines eco-innovation as „any innovation that reduces the use of natural resources and decreases the release of harmful substances across the whole life-cycle" (see http://www.eco-innovation.eu/).

should not be neglected, as they are able to promote green investments by households and firms (UNEP 2010).

The effects of **(eco-)innovation** on employment within a company depend on the kind of innovation (especially whether process or product innovation is implemented), technology and country.

Employment effects of **process innovation** are closely **related to productivity changes**. New production processes often induce labor productivity improvements since the same amount of output could be produced with less labor input and, ceteris paribus, lower unit costs (Licht/Peters 2014).

If process innovation results in higher labour productivity within the company (for a given output), negative employment effects might be the result. **In theory**, the total employment impact of each type of environmental innovation is not explicitly deductible and depends on a number of product-, technology-, firm-, sector- as well as country-specific factors.

The employment effects of process innovation depend on the individual case

In the case of **environmentally oriented process innovations,** it is important to distinguish between end-of-pipe and cleaner production technologies: **Cleaner technologies** contribute to less pollution, as well as material or energy savings, leading to cost savings that may increase factor productivity (including labour, capital and energy) in the company. Horbach et al. (2015) explains that it „depends on the individual case whether the cost-saving process innovations also affect the share of labour of the corresponding production process. A higher efficiency of capital induced by cleaner technologies may lead to a substitution of labour by capital since labour becomes relatively less valuable to the company which is accompanied by lower wages. Lower wages may moderate negative employment effects. Cleaner technologies may also be supported by organizational innovations and/or human capital growth. Then, the cost-saving effects may be achieved by recruiting more specialized and high qualified employees who are able to reorganize production processes in a more resource-efficient way. All in all, depending on the specific cleaner production technology, a higher, constant or lower labour share is the potential result. In any case, an increase in total factor productivity caused by cleaner technologies strengthens the competitiveness of companies and thus may lead to positive employment effects by lower prices and a higher demand“ (Horbach et al. 2015, 9).

The introduction of **end-of-pipe** oriented process innovations may require additional jobs for its construction, installation and maintenance, resulting in positive direct employment effects. The indirect effects, however, may be negative since end-of-pipe technologies cause higher costs linked with a decline of output and employment. All in all, according to Horbach et al. (2015), the impacts of environmental process innovations on employment remain an empirical question.

The same holds for the employment **effects of environmental product innovations**.
Product innovation induces employment growth mainly via demand for the new or improved product. Additional demand for a company's products can be generated if product innovations lead to the creation of completely new markets or the substitution of competitors' products. In this case, the result would be a positive employment effect at the company level. The **macroeconomic effect**, however, is unclear and i.a. influenced by the labour intensity of the substituted products. If the introduction of the new product results in a monopolistic position associated with a decrease in overall output, this

may be another case where product innovations yield negative employment effects (Hall et al. 2006).

On the **micro level**, it can be assumed that bigger employment effects can be achieved in firms where customer demand is particularly relevant for the realization of eco-innovations. A possible reason might be that these innovations are driven by the motivation to increase the performance and profitability of a firm. In contrast, firms introducing eco-innovations in response to regulations and subsidies are not always able to create a substantial number of new jobs. This might be explained by the fact that regulations often lead to additional end-of-pipe measures which increases production costs. The employment effects of eco-innovations driven by self-commitments of firms in order to prevent future regulations are even worse. In contrast, firms which are internationally oriented and R&D intensive show a better employment performance (Horbach/Rennings 2013).

From an **empirical point of view**, there are various papers investigating the general link between innovation and employment, but relatively few analyses regarding the particularities of eco-innovations.

Most econometric studies focusing on the link between **general innovations** and employment detect positive effects of product innovations on labour demand, while the effect of process innovation is ambiguous, ranging from significantly negative to positive (see Horbach et al. 2015 for an overview).

Analyses on the employment effects of **environmental product innovations** are still rare due to data gaps. In general, these studies reveal positive employment effects.

On the firm level, eco-product innovation tend to have positive employment effects

On the **firm level**, for example, Horbach (2010) finds a positive and significant influence of **eco-product innovations** on employment. He also illustrates that the positive effects of eco-innovation appear to be greater compared to other non-environmental innovation fields. Licht and Peters (2013; 2014) detect that both environmental and non-environmental product innovations cause positive net employment effects. In manufacturing they are even the main source of employment growth, but also stimulate employment increases in services. The authors find similar **gross employment effects** of environmental and non-environmental product innovations. However non-environmental product innovations are still more likely to increase **net employment**. This can be explained by differences in the average innovation engagement and innovation success of both types of new products. However, if environmental policy create incentives for firms to engage in green product innovation activities and supports them in better commercializing green product innovations, eco-product innovation will most likely not have different employment impacts (Licht/Peters 2014).

In contrast to product innovation, environmental and non-environmental **process innovation plays no conducive role for employment growth**. However, according to the estimation results of Licht and Peters (2014), process innovations seem to induce only small displacement effects (job losses). The econometric analysis of Horbach and Rennings (2013) of the employment effects of environmental process innovation on the company level shows that innovative firms, especially those implementing cleaner technologies, exhibit more dynamic employment developments. The reason for this might be that this type of process innovation causes cost savings, which enhances the competitiveness of firms. This in turn positively affects demand and thus employment. Conversely, process innovations in the field of air and water still focusing on end-of-pipe technologies lead to negative employment effects. However, the results of Licht and Peters (2014) do not confirm that the employment effects of the introduction of cleaner process technologies seem to be more advantageous compared to end-of-pipe oriented technologies.

On the sector level, small positive net employment effects are accompanied by substantial job turnovers

Concerning **sectoral consequences**, positive net employment effects of eco-innovation are connected with **job turnovers**. A case study looking at six sub-sectors (covering insulation, electric vehicles (hybrids), copper, cement, drip irrigation, heat pumps) analyses the potential for job creation by boosting resource efficiency. With respect to all six cases it was shown that reductions in energy and/or resource use could have a positive employment effect (Ecorys 2012).

A study by Walz (2011) examining the employment impacts of five innovations (plastic and paper recycling, increased life span of automobiles, car sharing, bio-based products) finds that the resulting (small) positive employment effects are associated with substantial job turnovers. In all cases, job losses especially occur in the sectors related to (traditional) basic materials. In the car related strategies, jobs are particularly created in service-oriented sectors. Except for car related strategies, employment is increased for investment goods. In the case of bio-based products, it is the agricultural sector which gains the most. The analysed cases illustrate the **substantial labour market adjustments** induced by the transition to a resource efficient economy.

Licht and Peters (2014) conclude that environmental innovation, e.g. induced by industrial or environmental policies will probably not undermine firms' competitiveness and destroy jobs but may contribute to job creation.

7.4.3 Transition to a circular economy and its employment effects

The term circular economy refers to an economy „in which material flows are either made up of biological nutrients designed to re-enter the biosphere, or materials designed to circulate without entering the biosphere“ (UNEP 2012), with reuse and technical recycling as key strategies. Thus, the aim is to eliminate waste.

Many authors consider a transition to a circular (instead of a linear) economy to be a promising strategy to meet the environmental and economic challenges (among others: EMF 2013, TNO 2013, Preston 2012), since numerous possible advantages can be expected, including material cost savings, reduced price volatility, improved security of supply, potential job gains (e.g. with respect to service providers and recycling companies), as well as reduced resource use and environmental impacts.

Although a transition to a circular economy will create winners and losers, the net employment effect tends to be positive

However, such a transition will create both winners and losers. Since more goods are reused and repaired and more services than products are demanded, product manufacturers, transporters and dealers will suffer from less production. The EC (2014) explores some priority materials (agricultural products and waste, wood and paper, plastics, metals and phosphorus) and priority sectors (packaging, food, electronic and electrical equipment, transport, furniture, buildings and construction), where the transition to a circular economy seems particularly beneficial and should be supported by EU policy.

The latest research of the Ellen MacArthur Foundation and others (EMF et al. 2015) presents a vision of how the circular economy could look for three of **Europe's** most resource-intensive basic needs: food, mobility, and the built environment, which together account for 60% of household costs. The report concludes that the circular economy that combines efficiency and effectiveness can increase European competitiveness, and deliver better outcomes for society, including employment gains.

Another report of the Ellen MacArthur Foundation reveals that over 100,000 new jobs can be created **globally** for the next five years if companies focused on building-up circular supply chains to increase the rate of recycling, reuse and remanufacture (EMF 2014).

For the UK, it has been assessed that the transition to a circular economy would encourage 50,000 new jobs and EUR 12 billion of investment (ESA, 2013), whereas in the Netherlands a circular economy could generate 54,000 jobs and numerous environmental benefits (TNO 2013). These figures represent conservative and prudent estimates, and mirror the fact that in the Netherlands some action toward a circular economy has already occurred. Another study by Wijkman and Skånberg (2015) finds that a manufacturing sector according to a materially efficient circular/performance-based economy would (in combination with energy efficiency measures and the use of renewable energy) create 100,000 additional jobs in Sweden, accounting for 2-3% of the labour force.

Recycling is an important element of a circular economy. In theory, recycling can create employment in areas where waste materials are more prevalent. As this is a labour-intensive activity involving sorting and processing of waste materials, money spent on recycling activities leads to more jobs than if the same amount was spent on garbage disposal.

For some resource groups, notably paper and cardboard, as well as iron and steel, recycling is already heavily used. In fact, **countries with high rates of waste recycled**, such as Germany, also have a relatively high employment rate in the recycled materials and waste management sectors. Conversely, countries with lower recycling rates tend to have lower employment rates in those sectors (Bio et al. 2011).

In the EU, more than 400,000 new jobs could be created by the implementation of existing legislation on waste prevention and management (Bio 2012); and an estimated further 180,000 jobs considering the proposed review of the waste legislation (EC 2014).

Job losses in some sectors are compensated by job creation in others.

Efforts resulting in increased recycling activities affect all phases of the production process (from exploration to smelting and refining), thus leading **to job losses in the respective sectors**. However, the question is in how far these losses are compensated by **job creation in other sectors**. For example, material recycling of WEEE (waste electrical and electronic equipment) would create 5 to 7 times more jobs compared to disposal by incineration and 10 times more jobs than disposal in landfills (EC 2008). Higher rates of recycling in the pulp and paper industry, where modernisation processes reduced employment over time, are a substantial source for new green jobs (Renner et al. 2008). Related regulations on, for example, packaging will strengthen job creation in the recycling industry (UNEP, 2011a).

Moving waste up the hierarchy can create jobs

Scenario modelling show positive employment effects of higher recycling rates on the macro level. A study from EEB (2014) estimates the EU's employment effects based on higher recycling and reuse by 2025 and 2030, with the result that many additional jobs could be created (see Table 3). The authors point out that "greater emphasis on actions further up the hierarchy, especially in reuse and repair, could become a high-employment strategy. The impact of more intense reuse on job creation potential is high – at least one-third of new resources jobs in Europe could come from reuse" (EEB 2014). This is because the labour intensity in the upper tiers of the waste hierarchy, such as preparation for reuse and recycling, is much higher compared to disposal and incineration. Employment opportunities are thus created by moving waste up the hierarchy (EC 2014c).

Table 3. Employment opportunities in the European Union – potential impact

Scenario	Additional jobs by 2025	Additional jobs by 2030
Modest	55% recycling – 442,350 Furniture reuse – 179,369 Textile reuse – 13,050 Total – 634,769	60% recycling – 482,570 Furniture reuse – 209,205 Textile reuse – 17,400 Total – 709,175
Medium	60% recycling - 482,570 Furniture reuse – 209,205 Textile reuse – 21,750 Total – 713,525	70% recycling[14] - 567,500 Furniture reuse - 239,159 Textile reuse - 26,100 Total – 832,759
Ambitious	60% recycling baseline – 482,570 Furniture reuse – 239,159 Textile reuse – 26,100 Total – 747,829	70% recycling baseline – 567,500 Furniture reuse – 269,053 Textile reuse – 30,450 Total – 867,003

Source: EEB 2014.

A study by Friends of the Earth Europe (2010) finds that meeting the target of recycling 70% of key materials by 2020 could create up to 322,000 jobs across the EU-27. Moreover, there is the potential to generate 160,900 new indirect jobs and 80,400 induced jobs by meeting this recycling target, resulting in an overall net job creation of around 563,000.

Recycling can generate more jobs at higher income levels than landfilling or incinerating waste

Although the studies investigating the employment potential of higher levels of recycling and reuse are based on wide variations in methodology and availability of data, their key messages are very similar – namely that "recycling creates significantly more jobs than waste disposal through landfill or incineration and that reuse has the potential to create even more when measured on a per tonnes basis, given the relative labour intensity of many reuse activities" (EEB, 2014).

Fischer-Kowalski and Wiedenhofer (2014) emphasise that recycling is generally seen as a waste management policy, while it would be much more effective as regulation of the input side (e.g. a certain share of construction materials or metals is required to come from secondary sources).

However, recycling covers only one relevant element for a circular economy. Other important aspects are new **resource-efficient business models** that focus on leasing and sharing, life-time extensions, refurbishment, reparability, product upgrades, modularity and remanufacturing. However, empirical research on the employment effects of these factors is rare.

For example, resource-efficient business models directed towards service instead of the product ownership can increase product-life, reuse and recycling and save resources, thus promoting the realisation of a circular economy. As an example, car sharing may result in a higher utilization rate of cars and thus in less material consumption. Furthermore, such business models stimulate economic activity in the areas of product and service innovation, remanufacturing and refurbishment, and in turn may generate employment (WRAP 2013).

The assessment of the employment effects of resource-efficient business models needs further research

So far, not many studies have analysed the effects of such business models on employment. One exception is a study by WRAP (2013), assessing potential impacts of resource efficient business models in four key product sectors (white goods, clothing, electronics and furniture) of the UK's economy. Using the Multisectoral Dynamic Model, Energy-Environment-Economy (MDM-E3), they found that in particular, the take-back for re-sale business models for TVs and clothing provide the most significant beneficial employment impact, increasing UK employment in 2020 by 3,000 to 4,000 jobs respectively.

However, to determine the total macroeconomic effect for resource efficiency of different new business models they need to be further tested and confirmed. Moreover, new sustainable business models face a range of internal or external **barriers** on their way to implementation and diffusion. Among the most important internal barriers encountered by companies is a lack of knowledge about new business models, and knowledge about how to create them. External barriers for firms to introduce new business models are e.g. still a lack of incentive to change as a consequence of market failures and systemic lock-ins (EIO, 2012).

The degree of circularity is rather low, on global as well as on EU level

According to a recent analysis by Haas et al. (2014), the **degree of circularity** in the global economy (measured as the share of actually recycled materials in total processed materials) seems to be at 6% which is rather low. If all biomass is also assumed to be a circular flow, regardless of production conditions, the degree of circularity raises to 37%. The circularity rates for the EU-27 only slightly exceed those of the global economy.

These relatively modest rates could be increased by using a higher share of energy from non-material sources (sun, wind), by a shift towards using more biodegradable materials and by expanding re-use and recycling (Haas et al. 2014). The authors conclude that although recycling rates for some materials are already high, considerable improvements can be achieved, e.g. via product designs that extend life-times, deliver the same service with less material requirement, and facilitate repair and resale, product upgrades, modularity and remanufacturing.

7.4.4 Environmental policy and related employment effects

Ensuring high employment levels is generally the target of employment policies. These include, first, demand policy, aiming at increasing the demand for employees. Demand policies contain demand- and supply-side economic policies, technology policy, reduction and flexibilisation of working time, as well as employment-oriented wage policy. Second, supply policy refers to the adjustment of labour supply to existing workplaces, involving a reduction of the professional life (e.g. by prolonging periods of education or sabbaticals), policies towards foreigners and migration policies. Third, labour market policies, in the narrow sense, are targeted at balancing supply and demand on the labour market. Instruments used are employment services, training policies as well as job creation schemes (Springer Gabler Verlag 2015).

Having in mind that Europe does not only have to deal with difficult labour market conditions, but is also facing severe environmental challenges, the question arises whether environmental policies could also help to enhance employment.

In this chapter, we summarise the literature that estimated the employment effects of some policy options that are mainly designed to reduce environmental degradation and resource use and thus increase resource productivity.

The actual effects of environmental policy vary according to the respective firm, national circumstances and policies, the economic situation and the time horizon

Environmental policies may induce a change in relative prices of raw materials or set new green-oriented standards. This may result in increasing resource and environmental productivity due to investments in innovation (in a broad sense) and new capital stocks (Mohnen and Hall 2013). The actual effects of environmental policies, however, always vary according to the respective firm, national circumstances and policies, the economic situation and the time horizon. For example, the reactions may turn out to be defensive or proactive, short or longer term. In order to compensate the increasing compliance costs associated with new environmental regulation, firms may reduce other costs (labour, investment, innovation). Another possible strategy would be to relocate or outsource part of their activity. Especially in the medium or longer term, it is conceivable that firms decide to shift their activities to new products and markets, or try to enhance the efficiency of their processes by investing in (environmental) innovation. In the long run, firms' environmental and economic performance will be influenced by the set of strategies adopted (OECD 2015a).

In the following, market based instruments (environmental tax reforms and tradable permits), standards and regulations, fostering green investments, as well as information and consulting programs are considered.

7.2.4.1 Employment effects of market based instruments

For achieving a double dividend it is essential to re-channel the revenues of resource taxes back to the labour market in order to decrease

Market based instruments aim at the reduction or elimination of negative environmental externalities (such as pollution) by internalising the environmental cost of production or consumption activities. Examples include environmental taxes, charges and subsidies or tradable permits. In contrast to legislation or regulation aiming at more resource productivity, market based instruments (MBIs) are generally more economically efficient. MBIs are designed to 'get the prices right', which implies that markets are better able to reflect environmental impacts (externalities) and resource scarcity in prices. This allows producers and consumer to respond accordingly. However, the overall effects of MBIs always depend on the respective design and accompanying measures. A case study on several MBIs has shown that for achieving positive effects on both resource productivity and employment (so-called **double dividend**), it is essential to re-channel the revenues gained from resource taxes back to the labour market in order to decrease labour costs (Ecorys et al. 2011).

Both, empirical evidence and scenario modelling show a small double dividend of environmental tax reforms

With respect to employment effects, ***environmental tax reforms*** shift taxation away from labour (or profits) to pollution or resource use, thereby inducing firms to substitute resources and energy by other factors of production, such as labour. Environmental taxes are expected to deliver a double dividend, both stimulating employment and decreasing environmentally harmful activities.

The empirical evidence for a small double dividend (see e.g. Bach et al. (2002) who use both an econometric input-output-model and a dynamic computable general equilibrium model to investigate the effects of the German environmental tax reform) goes hand in hand with the results of many scenario simulation studies.

Kratena and Sommer (2014) quantify different resource use scenarios for Europe and conclude that environmental tax reforms have the potential to reach
absolute decoupling with **positive employment effects in the mid-term** and major sectoral shifts (see chapter 7.3 for details).

Ekins (2009) summarises the impacts of an environmental tax reform (ETR) until 2020 that are calculated with two different macro-econometric models (GINFORS and E3ME[22]). The overall outcomes reveal that ETR is able to effectively reduce CO_2 emissions in the EU. Both models find that an environmental tax reform that is in line with the 20% GHG emissions reduction target will have positive employment effects and will decrease resource use. While the two models have confirmed the positive employment effect of ETR, the impact of ETR on output is divergent, except that both models find only small effects (GINFORS: slightly negative impacts on GDP, E3ME: slightly positive impacts on GDP).

The results regarding labour and resource productivity are almost identical in both models. Whereas energy, carbon and material productivity will rise in all scenarios compared with the baselines, **labour productivity will decline** mainly because of the sectoral shifts from energy- and carbon-intensive to labour-intensive industries (Ekins 2009).

Employment effects are not driven by labour productivity, but mainly by GDP

If tax revenues are used to reduce social security payments - which reduces labour costs - both models find a reasonable reduction of labour productivity against the baseline. If only 90% of the tax revenue is channelled in social security and the remaining proportion of revenues is spent on eco-innovation measures, both models react with an increase of labour productivity. So the **differences in the results for employment are not driven by labour productivity, but mainly by GDP** (Ekins 2009).

A case study assessing the environmental and economic effects of market-based instruments in several EU countries supports this assumption. With the exception of the UK none of the policies assessed had a direct impact on employment. In the case of the UK, however, a double dividend has been realized by transferring an aggregates levy to firms, which reduced labour costs. Modelling results suggest that the aggregates levy resulted into small increases in GDP and employment in the aggregates sector (Ecorys et al. 2011). Another study shows that the German eco-tax was able to create 250,000 jobs since 1999. The revenue from this additional tax on fuel and electricity is used to reduce employers' welfare contributions, thus decreasing the costs of jobs (Kohlhaas 2005). Positive employment effects on the macro level are also found in a simulation study by Aachener Stiftung Kathy Beys (2005). Accordingly, a material input tax up to EUR 10 per ton of all materials in combination with other instruments, such as consulting and information services would increase material productivity by 20% and employment by more than 2%. These examples illustrate the relevance of accompanying labour market measures and knowledge development strategies regarding employment effects.

[22] For a description of GINFORS see Chapter 9.3.1 or Distelkamp and Meyer (2014). For more information on E3ME see http://www.camecon.com/EnergyEnvironment/EnergyEnvironmentEurope/ModellingCapability/E3ME.aspx

No significant relationship between cap and trade and employment can be observed

In contrast, employment effects of ***cap and trade (tradable permits)*** seem to be insignificant. Calel and Dechezleprêtre (2014) study the economic impacts of the European Union's Emission Trading Scheme (EU ETS). According to an **ex ante evaluation** of the European Commission, it was predicted that EU ETS would not lead to any considerable employment effects in the **short term**. In the **long term**, competitiveness could be increased by induced innovation (EC 2001).

More recent studies show that the EU ETS has indeed substantially promoted innovation activities in regulated companies (Martin et al. 2011). With respect to the economic and labour market effects, some preliminary **ex post assessments** (Anger and Oberndorfer 2008; Commins et al. 2011; Zachmann et al. 2011; Chan et al. 2013; Petrick and Wagner 2014; Jaraite and Maria 2014) have been conducted in order to study a few selected countries and economic sectors. The most consistent result across all studies is that no robust relationship between the EU ETS on the one hand, and economic performance or employment effects on the other hand can be observed.

There are also some studies assessing the ***effects of a bundle of market based instruments*** (see e.g. the studies by Boitier et al. 2015, Meyer et al. 2015 that were cited in chapter 7.3), showing positive net employment effects.

If market based instruments were accompanied by regulation, innovations can be best stimulated

The results by Boitier et al. (2015) indicate that market based instruments are central, but environmental regulation must maintain its important role regarding the transition to a resource-efficient society. This conclusion is supported by the findings of the PETRE project that relative price changes, irrespective of the underlying drivers (taxes, subsidies, or market dynamics) had the largest steering impact. Although subsidies (including feed in tariffs) are important, environmental tax reforms accompanied by regulation is found to be the most appropriate way to stimulate a variety of innovations (see Ekins 2009).

7.2.4.2 Employment effects of environmental regulation

Empirical evidence does not show job losses due to environmental regulation

The fear that jobs will be lost because of higher costs related to environmental regulation cannot be confirmed by empirical evidence (see Dechezleprêtre/Sato 2014). Although significant adjustment costs may occur as employees change from declining (resource-intensive or polluting) to expanding (clean) sectors, in the long run, environmental regulations might just evoke a substitution between resource-intensive and resource-efficient activities. The effect of this substitution on net employment is uncertain (Brahmbhatt, 2014). Evidence so far has been mixed, but, if at all, reveals statistically insignificant or small effects on employment in regulated sectors. Using data for 1999 to 2003 for the UK, Cole and Elliott (2007) find no evidence that pollution abatement costs reduce employment. Belova et al. (2013) also observed no large adverse effects from environmental regulations.

Small and transitory effects of environmental regulations on employment and productivity may occur in pollution- and energy-intensive sectors. Over the longer run, the impacts tend to be smaller than in the short run, indicating that government policies such as labour markets regulations can help to decrease or offset the transitory impacts (Dechezleprêtre/Sato 2014).

An interesting question is also whether environmental policy stringency does influence employment and productivity. Environmental policy stringency can be defined as the "scope and success in implementation of environmental policy" (Harring 2008) and indicates "how ambitious the environmental policy target is, relative to the baseline standard and the determination of the government to enforce the environmental regulation" (Chen 2008).

Research results show small to significant effects of the stringency of environmental regulation on employment.

In a study by Morgenstern et al. (2002), pollution abatement operating costs are used as a proxy for the stringency of environmental regulation. The authors find no significant effects of higher environmental spending on employment. Although statistically significant and positive effects can be found in two industries, the total number of jobs affected is negligible. During the period from 1984 to 1994, the study suggests that environmental regulation accounted for at most 2% of the observed reduction in employment.

The results of a scenario analysis of Boitier et al. (2015) – already mentioned above – demonstrate that environmental stringency is not detrimental, but indeed beneficial for net employment, as both in the "Friendly" and in the "Tough" context, most jobs can be created in the "Sustainable transformation" scenario. However, as previously mentioned, also this report emphasises the high structural shifts in the labour market, leading to a reorientation of employment from industrial sectors to service sectors (Boitier et al. 2015).

More stringent environmental policies have had little effect on overall productivity growth

Evidence from the OECD (Koźluk/Zipperer 2013; Albrizio et al. 2014, 2014a; Botta/Koźluk 2014) shows that more stringent environmental policies of recent years have had little effect on overall productivity growth, adapting mainly to short term adjustments. There may be winners and losers, but any effects have tended to fade away fastly. The most productive, technologically advanced firms saw a temporary boost in productivity after rules became more stringent, being in the best position to adapt. Less productive firms have seen their productivity falling, while some may have terminated activity.

7.2.4.3 Employment effects of public green investments

Public finance has a crucial role to play in fostering green investments. Direct public expenditure, e.g. through support for research and development in environmental technologies or cleaner infrastructure provision, as well as indirect support (e.g. through different forms of public guarantees) can force green investment by households and firms and also stimulate employment (UNEP 2010).

In this chapter we briefly discuss the employment effects of public investments in infrastructure that supports the transition to a resource-efficient economy as well as green stimulus programs that aim to serve an environmental purpose in a situation of crisis characterized by temporary underemployment.

Infrastructure investments are mostly made in economic sectors (especially improving transportation, including roads, railways and waterways) and social sectors (education, water, sewage, and other services), which provides the foundation for long-term development. At the moment, investment in fossil-fuel intensive infrastructure is increasing annually and is higher than clean-energy investment. Thus, a shift in long-term investment from conventional to green alternatives is needed to avoid the continuation of less resource-efficient, emissions-intensive technologies for decades (World Economic Forum 2013).

Counter-cyclical public spending on green **infrastructure** can be seen as an appropriate tool to create jobs. In times of low private demand, governments can be viewed as employers of last resort, able to support both jobs and aggregate demand.

Green investments and subsidies for green activities may yield positive employment effects, but might also lead to job losses in resource intensive sectors

It is commonly assumed that green investment programs and subsidies for green activities may yield positive employment effects, thereby generating both short-term employment and long-term productivity improvement. However, it also has to be born in mind that such policies might crowd out jobs elsewhere and lead to job layoffs in resource intensive sectors.

With regard to the employment effects of investments in infrastructure the **timing and the duration of job creation** is an important topic (Bowen/Kuralbayeva 2015). It has to be differentiated between construction, manufacture and installation, where jobs may be temporary, and ongoing operation, maintenance and fuel processing, where the duration of jobs depends on the durability of the relevant investment.

A report by the Economic Policy Institute (2014) assesses the likely **short- and long-term economic impacts** of investing annually U$92 billion in the energy efficiency of buildings and a “smart grid” for the US economy over the next decade.

In the **short term**, this spending would lead to GDP growth by U$147 billion, and generate nearly 888,000 jobs, with over 599,000 directly in industries receiving the spending flows and 288,000 in industries that supply intermediate goods to the final industries (induced jobs not included). These results can be expected, **if financed with government debt**. If these investments were made in a deficit-neutral way, the positive impacts on output and employment would be reduced.

Over the long term, only the impact **on the composition**, not the overall level, of labor demand can be predicted, as the impact of infrastructure investments on the overall level of economic activity depends on the degree of productive slack in the economy, the stance of monetary policy, and how the investments are financed. Jobs created are disproportionately middle- and/or high-wage and filled by workers without a university degree. As it is also expected that these investments would mainly benefit men and Latinos, while disfavouring younger workers the authors recommend implementing accompanying measures to ensure that traditionally underserved groups benefit from these investments. The study is in line with other research, suggesting that infrastructure investment might also enhance productivity in the private sector.

However, it has to bear in mind that the results of the study by the Economic Policy Institute relate to situations of unemployment and that the relative labor-intensity of infrastructure investments in the US is not necessarily comparable with that in other countries.

In general, the investments in green infrastructure should support such activities and sectors that are labour intensive in order to increase the employment gains.

Green stimulus programs mainly create short term employment effects

Public investment in green infrastructure became a common feature of fiscal stimulus packages. **Green stimulus programs** should help to overcome shocks or crises. The objective is to create a multiplier effect which generates further income and employment growth. Such packages are able to create employment in the **short term** by **using currently idle labour**. This especially applies to cyclical sectors such as construction.

Green stimulus measures comprise the support for the clean energy sector (i.e. energy efficiency and renewable energy) as well as policies related to water, waste and pollution control (Pew Charitable Trusts 2009).

During the recent economic crisis, green stimulus programs have been frequently applied to safeguard jobs and to simultaneously bring environmental benefits.

Houser et al. (2009) have found that USD 1 billion invested in green fiscal programs has the potential to create about 30,000 jobs. Cambridge Econometrics and Ecorys (2011) have evaluated the effects of green elements of the fiscal stimulus packages as a response to the economic and financial crisis in EU Member States and four non-EU countries. The study shows that most policies temporarily boosted employment as a result of increases in economic activity. However, in many cases this positive employment effects took the form of saving rather than creating jobs.

7.2.4.4 Employment effects of information based programs

Businesses that want to enhance their resource efficiency have been offered a broad range of **public and private information based programs**. These programs involve direct consulting and auditing services, training workshops, and self-help tools and guides. Other effective ways to encourage resource efficiency are voluntary schemes (e.g. ecolabels) and environmental management systems (e.g. EMAS) (AMEC/BIO 2013).

Information based programs require no or low investment

Most of these measures would be associated with no or only low investment, or they could be paid off within a few years. The actual costs of resources and waste treatment (depending on commodity prices, and water and waste management taxes) are an important factor in determining the degree of savings. This implies that the same measure can have different economic and employment benefits across Europe and over time.

One example is the UK's National Industrial Symbiosis Programme (NISP) that was established to enhance the cooperation between normally separate companies from all industrial sectors and of all sizes. This programme mainly aims at recovering, reprocessing and re-using previously unused or discarded resources (energy, water and/or materials) that are re-used by other companies. In the time period 2005-10 the programme created 3,683 and secured 5,087 jobs (RPA 2015).

Information based programs help businesses to reduce resource use and material costs as well as create and safeguard jobs

Another often cited example is **ENWORKS**, a partnership that provides resource efficiency support to businesses across the North West of England since 2001. The aim of ENWORKS is to improve the environment and economy for North West England, by engaging businesses of all sizes and sectors in sustainable business practice. Main activities comprise reducing energy, water, fuel and material use at all stages in the value chain – from product design to manufacture and distribution and within the business premises – through simple changes in behaviour as well as more advanced technological solutions. Between 2001 and 2012, this programme has contributed to safeguard 6,276 jobs and create 1,701 new ones. Moreover, ENWORKS has offered workshops and courses to 3,585 employees of participating firms.

ICF GHK (2013) evaluated the ENWORKS Project: “Embedding Resource Efficiency in Key Sectors” 2009-2013. The study found that the ENWORKS project “has successfully supported business growth and jobs in beneficiary firms in the North West. The beneficiary survey, outputs verified by beneficiaries and the ENWORKS Efficiency Toolkit provide strong evidence that the support resulted in increased sales and jobs (as well as jobs and sales safeguarded) that would not have occurred without the project“. As a result of the support provided, 232 new jobs could be created and 512 jobs have been secured. Overall, the project was evaluated as being highly successful in meeting its objectives of addressing market failures and realising high levels of economic and environmental benefits.

RPA (2015) assesses the potential benefits from implementing business support programs targeted at SMEs to promote resource efficiency investments across EU Member States. The study investigates the impacts of a proposed EUR 4 billion public investment, which aims to stimulate the uptake of resource efficiency measures in SMEs across four sectors *(*Food and Beverages, Construction, Energy, Power and Utilities, and Environmental Technology*)* in the EU-28. It employs the ENWORKS program’s data on cost and resource savings to generalise the impacts inter alia on resource use and employment if similar programs were implemented across all EU Member States.

The (conservative) calculations indicate that public investments of EUR 4 billion in the implementation of an ENWORKS-type program across the EU-28 could have considerable effects on employment, resulting in around 128,180 new and 360,630 safeguarded jobs.
However, these figures do not take into account differences in the labour market situations within the EU Member States, but assume similar labour market conditions to those of the UK.

With regard to the selected sectors, the highest employment gains could be realised in the construction sector. However the returns per EUR invested in this sector are low compared to the sectors Energy, Power and Utilities, and Environmental Technologies. It could thus be possible that targeting other sectors than the four included in this study could generate higher overall resource cost savings.

For Germany, it has been found that cost savings can be realised in public administration, manufacturing and construction (see e.g. Aachener Stiftung 2005). However, sectors associated with domestic resource extraction or material- and energy-intensive production are expected to experience output losses. In contrast, manufacturing sectors are able to increase productivity and competitiveness, which results into a rising overall share in total gross value added and positive employment effects (Stocker et al. 2007; Fischer et al. 2004, Arthur D’ Little 2005, Giljum et al. 2008).

Systematically applying information and consulting initiatives throughout the EU could positively affect environment, economy and employment.

In general, as resource efficiency programs are not systemically realised throughout the EU, it can be inferred that there is some scope for scaling up these kind of information and consulting initiatives (AMEC/BIO 2013).

8 Sectoral data analysis of material versus labour and capital productivity

In this chapter we present an overview of the development of material use and of labour intensity in different Member States. The objective is to provide an analysis of different sectors on their material and labour productivity, and to understand the reasons for differences across Member States. Furthermore, the chapter aims to explore the relationships between resource and capital productivity as well as to assess the impact of material productivity on employment outcomes.

The conceptualization of material flows is an important part of the process used for informing policy and mainly concerns the interrelation between socio-economic activities. Resource productivity as well as labour and capital productivity are indicators that could reflect both the economic and environmental development. However, the interrelationships between socio-economic and environmental processes are highly complex and available information, judgement of experts and public awareness are often controversial. Therefore, the criterion of policy relevance from this study refers to a reduction of this complexity rather than to a full understanding. In other words, it refers to the capacity to reduce this complexity and provide relevant and useful information for decision making and public discourse.

The general objective of this scoping study was to highlight and further work out the different productivity trends as well as limitations and methodological issues at stake. It was also envisaged to analyse empirically the relationship between labour and resource productivity.

This chapter complements the literature findings with empirics at the EU level using **Raw Material Input (RMI)** data for 28 Member States. As part of the analysis, an econometric analysis is performed to assess the relationship between resource productivity and employment at the EU level, using RMI data. Meanwhile, the literature review presented in the first part of the study is primarily based on Domestic Material Consumption (DMC). However, as indicated above (a.o. in section 4.3), RMC or RMI and material footprints would be more appropriate indicators to measure resource productivity. Using RMI is a step forward in exploring the subject of resource productivity, since it is a better indicator for raw material flows analysis. This point is discussed further in section 8.1.1.

This chapter is organized in the following sections:

- **Section 8.1 Data and Methodology:** This section presents the data sources and methodology used to calculate resource productivity, labour productivity and capital productivity. In line with the terms of references, the study is based on existing data and readily available additional data, where relevant. Data availability and considerations to address the limitations of the study are discussed and future research opportunities for the case of better data availability are discussed.
- **Section 8.2 Resource, labour and capital Productivity across Sectors**: An analysis of the productivity indices for ten EU countries on a sectoral basis is presented, establishing possible relationships between capital and resource productivity and labour and resource productivity[23]. The project presents empirical data of ten countries,

[23] This section corresponds with Task A and C of the tender which calls for an analysis of different sectors on their material and labour productivity over time as well

discusses its relevancy and whether it coincides with literature findings from chapter 7.

- **Section 8.3 Drivers for the use of materials across countries:** This section comprises an econometric and statistical analysis on the determinants of resource productivity, looking at the relationship between energy consumption, employment, R&D and resource productivity at the EU level and using RMI data for 28 Member States. The objective of this section is to assess which relationships can be established between different drivers, on average, across the EU. This analysis supports the following section on the policy relevant questions linking resource productivity to jobs while also providing avenues for further research.
- **Section 8.4 Policy Relevant Questions linking resource productivity to jobs:** In this section, the study explores the statistical outcomes of Section 8.3 to understand whether the relationship between employment and resource productivity coincides with the findings from the literature. It provides empirics to support theoretical discussions on relationships between employment and resource productivity.
- **Section 8.5 Number of jobs and job potential from resource productivity:** This section aims to assess the impact of resource policy measures on employment, focusing on the improvement of resource productivity. This section summarises previous studies, while providing new insights in a number of areas. In particular, the goal is to identify the main policy rationales for a policy aiming to improve resource productivity.
- **Section 8.6 Implementing scenario analysis:** Based on the results of the existing literature, the aim of this section is to look at the trends of employment of different scenarios
- **Section 8.7 Summary and conclusions:** This sections summarises the main findings of this chapter.
- **Section 8.8 Limitations and way forward:** Because of limitations in data availability and time constraints, it was not possible to fully investigate all potentially relevant pathways during this study. This section describes the main limitations of the underlying analysis and proposes several potential ways forward to get new insights.

At the end of the report, the Annex includes additional figures and descriptive text on Member States, data for labour capital and resource productivity.

8.1 Data and Methodology

In order to examine the relationship between resource, labour and capital productivity and employment on a sectoral level, detailed information on resource use by sector are required:

- Resource productivity - EW-MFA indicators (DMC, RMC, TMC, etc.)
- Labour productivity
- Capital productivity
- Employment data

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as assessing which relationship can be established between resource and capital productivity, respectively.

Ideally, this data should be available at country and sector level and for a series of time. Table 4 summarizes available information about the main indicators, along with their limitations.

Table 4. Overview of possible indicators and their limitation

Indicator	Source	Level of detail	Limitations
Resource productivity *(Measured as GDP/DMC)*	DMC data from EW-MFA (Eurostat) DMC data from materialflows.net GDP/GVA from Eurostat	By main material category, by Member State By main material category, by Member State	The existing accounts do not allow for disaggregation by economic sector. This would require a detailed analysis using input-output tables within a time series which would require a larger study than this scoping study.
Resource productivity *(Measured as GDP/RMC)*	RME (raw material equivalent) coefficients allowing to calculate RMC for the main material categories (Eurostat) GDP and GVA from Eurostat	By main material category, by Member State (not readily available data, but straightforward to calculate on an aggregated level)	The existing accounts do not allow to disaggregate by economic sector. This would require an input-output analysis. Material use (i.e. DMC or RMC) would need to be allocated to the monetary values of the sectors in IO tables.
Resource productivity: *Productivity of Raw Material Input (Measured as GVA per sector/ RMI)*	Resource Sectoral Maps (SERI and BIO, 2013)	By Member State, by economic sector Readily available for years 1997 and 2007 to the project team.	Does not include data on exports, limited to RMI and available only for the years 1997 and 2007 (no time series).
Labour productivity *(Measured as GVA per hour worked and as GDP in EUKLEMS and as GDP per hour worked for the rest)*	EUKLEMS Eurostat OECD World Bank Data	By Member State, by economic sector	Limitations can be related to the matching of sectors defined in the resource data base[24] and labour data base (different classifications).
Capital Productivity	EUKLEMS	By Member State, by economic sector	Limitations can be related to the matching of the sectors defined in the resource data base and labour data base (different classifications).
Employment data	EUKLEMS	By Member State, by economic sector	Limitations can be related to the matching of the sectors defined in the resource data base and

[24] The data source of resource use is BIO/SERI (2013).

Indicator	Source	Level of detail	Limitations
			labour data base (different classifications).

The primary data sources for this chapter are the EUKLEMS Growth and Productivity Accounts and the Resource Sectoral Maps Study (2013) for resource productivity, which will be elaborated further in the following sub-sections. Table 5 shows a summary of data that is accessible to the project team and their respective sources.

Table 5. Readily available indicators and their source

Indicator	Level	Countries	Time	Source
DMC	Material Category[25] (A.1-4)	27 Member States	2000-2013	Eurostat (EW-MFA)
RMC	Material Category (A.1-4)	EU-27 level	2000-2013	Eurostat (EW-MFA)
RMI	Sectoral Level	27 Member States	1997, 2007	SERI & Bio (Resource Sectoral Maps)
Gross Value Added	Sectoral Level	27 Member States	1970-2007	EUKLEMS
Labour Productivity	Sectoral Level	10 Member States[26] 25 Member States	1995-2011[27] 1970-2007	EUKLEMS
Capital Productivity	Sectoral Level	10 Member States 25 Member States	1995-2011 1970-2007	EUKLEMS
Employment	Sectoral Level	10 Member States 25 Member States	1995-2011 1970-2007	EUKLEMS

The EUKLEMS Growth and Productivity Accounts are publicly available and include measures of output and input growth, as well as derived variables such as total factor productivity (TFP) at the industry level. The input measures include different categories of capital (K), labour (L), energy (E), material (M) and service inputs (S) and are provided on a sector-level.

The measures are developed for 25 individual EU Member States[28], the US and Japan and cover the period from 1970 to 2005. The variables are organised around the growth accounting methodology, which is rooted in neo-classical production theory. It provides a conceptual framework in which the interaction between variables can be analysed in a consistent way (Mahony

[25] Biomass, Metal ores, non-metallic minerals, fossil energy resources
[26] Sweden, Finland, Belgium, Netherlands, United Kingdom, Germany, Italy, Austria, France, Spain
[27] Some years for some countries have back-casted estimates
[28] See Table A2.8, Annex 3, for complete list of EU KLEMS Database: country, period and variable coverage

and Timmer, 2009). The following subsections describe the indicators analysed in this study.

Table A2.1 to Table A2.8 in Annex 2 present the definitions of the variables used for the analysis and descriptive statistics for some productivity measures for the countries chosen for the analysis.

8.1.1 Resource Productivity

Resource productivity on the macro level is commonly defined as GDP per unit of Domestic Material Consumption[29] and on the meso level (sectors) the GVA is used as the numerator instead of GDP (see chapter 2).
The DMC indicator[30], however, is restricted to consumption of economically valued primary materials, without taking into account unused domestic extraction[31] or indirect flows associated with imports and exports. Taking only this indicator as a measure of resource productivity use can be misleading, since a part of the resource use and environmental pressures in other parts of the world are not accounted for. This might shift the consequences of domestic consumption from a country to another. DMC risks overstating the resource productivity of an import-intensive economy, thus allowing countries to reduce their national material consumption and improving their resource productivity by shifting material-intensive industries or processes to other countries and substituting domestic extraction by imports.

As a result, different methodologies, such as input-output (e.g. Multi-Regional Input-Output - MRIO) or coefficient and hybrid approaches have been developed aiming at calculating indicators that embrace direct as well as indirect material flows related to international trade, in the form of Raw Material Input (RMI) or Raw Material Consumption (RMC) indicators (Bruckner et al., 2012, Muñoz et al. 2009, Schoer et al. 2013). RMC and RMI essentially embody the raw material equivalents it takes to produce a particular product. Furthermore there are input-output models that cover the interactions between the energy and economic systems, material demand and the environment. Examples cover GINFORS, which is a global model (51 countries and two regions; OPEC and rest of the world) and the E3ME model which covers only Europe.[32]
Whenever it is possible, RMI (which includes all materials used in imports) or RMC (which includes all materials used in imports and exports) should be used to overcome the shortcomings of DMC and DMI (Domestic Material Input[33]).

From a methodological point of view, it was investigated whether using RMI instead of RMC would be statistically accurate when measuring resource productivity. Peer reviewed literature supported the notion that resource productivity can accurately be measured based on RMI. The issue in question was: "…whether the resource efficiency indicator should indicate only progress with regard to products which are domestically consumed, or

[29] For further information on MRIO modelling methodologies see section 1.2 in the Sectoral Resource Maps Study (BIO/SERI 2013).
http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/report_Resource_Sectoral_Maps.pdf
[30] See section 2.1.1.1 for a definition of the indicator
[31] Unused domestic extraction is the part of the materials extracted that does not enter into the economy
[32] The GINFORS model((**G**lobal **IN**terindustry **FOR**ecasting **S**ystem)) is described in Distelkamp/Meyer (2014)., and the E3ME model (energy-environment-economy) is described in Cambridge Econometrics (2009).
[33] DMI faces the same shortcomings as DMC, it only excludes exports from the DMC indicator.

whether resource efficiency should also be relevant for the production of exports. For the latter, also the materials used for the production of the exports need to be accounted for. This would require a shift from consumption to input-based indicators, i.e. from DMC to DMI, RMC to RMI …as the first of those indicators subtract exports (and their related upstream flows). **In general, it seems advisable to calculate resource efficiency indicators for economies as the relation of GDP to input indicators [RMI, DMI], to take full account of the materials involved in both production and consumption."** (Ekins/Spangenberg, 2013).

Available time-series data for RMC and RMI via the economy-wide Material Flow Accounts (EW-MFA) can be obtained from Eurostat (Chapter 8.1). However, this database is only tracking materials entering and leaving the economy and not the material resource consumption by sector.

As a result, the Sectoral Resource Maps Study[34] served for first estimates of RMI in individual economic sectors in all Member States for the years 1997 and 2007, based on a MRIO model. The calculation of the RMI indicator was performed by applying a global, multiregional input-output model based on the Global Trade Analysis Project (GTAP) database and extended by material extraction data. Since this data was readily available to the project team, it was used for the analysis of resource productivity in this study.

In order to be consistent with the other indicators, Gross Value Added (GVA) instead of GDP was used for the productivity indicators. Gross Value Added is often preferred to GDP as an indicator at the meso-level (by sector), as discussed in chapter 2.1 and in section 8.1.4.

Therefore, resource productivity in this analysis is defined as Gross Value Added (GVA) per unit of Raw Material Input (RMI), instead of GDP per unit of Domestic Material Consumption (DMC) or Domestic Material Input (DMI).

8.1.2 Labour Productivity

Labour productivity is usually defined as the ratio GVA to the number of hours worked or number of persons employed. The indicator provides a measure of the efficiency with which inputs (in this case labour hours) are used in an economy to produce goods and services.
Just like resource productivity indices, labour productivity measures face their own limitations for both input measures, hours worked and number of persons employed. For example, the mix of skilled and unskilled workers that are employed in the same sector can underestimate or overestimate average labour productivity, since the contribution of workers varies across production. In addition, the number of hours stated to be worked in different countries is reported differently and might therefore be a source of inconsistencies.

For this reason, the appropriate labour measure would require incorporating the quality of labour inputs accounting for the education level of the worker, the employment status etc. (Mahadevan, 2003). **To the best of our knowledge, no publicly available data reaching this detail is available for the moment.**

[34] Sectoral Resource Maps produced for DG Environment, March 2013, by SERI and BIO Intelligence Services.

To accommodate for this, Eurostat, in collaboration with the JRC-IPTS, is currently (2015) running a project that aims at improving labour productivity indices by disseminating time series of productivity indicators for Member States. The project will give Quality Labour Adjusted Indices for 10 industries. Labour productivity is examined according to age groups (3 age groups) and skill levels (high, medium, low). According to sources from EUROSTAT, the first data will be available in spring 2016 for the years 2002 to 2012. Data on capital productivity should follow in 2016. Once the JRC-IPTS data will be made available, a more in-depth analysis could be performed in order to better understand how the types of skill levels and age groups may impact resource productivity.

In general, the variable "number of hours worked" is the most often used denominator in literature (Ovidiu et al. 2011) and will also be applied in this study. As this study calls for an analysis at the sectoral level, the best publicly available dataset to calculate labour productivity for Member States by sector and over time is considered to be EUKLEMS.

Accordingly, **this study defines labour productivity as the ratio of gross value added per hour worked**, expressed in volume indices where the year 1995 serves as basis (1995=100).

8.1.3 Capital productivity

As explained in the introductory part of Task 2, capital productivity measures the level of output (in euro or dollar) obtained for each euro/dollar invested in manufactured capital. Capital productivity indicates how well capital is used in providing goods and services. An increase of capital productivity means that less capital is needed to reach a certain level of production.
The OECD published two manuals related to productivity and capital[35], and both manuals state that volume indices of capital services constitute the appropriate measure of capital input for activity and production analysis.
Only recently have time series of capital services become available through the construction of databases such as EUKLEMS. Before, at best, capital stocks were estimated for aggregate investment without distinguishing different asset types (Schreyer, 2004).

In EUKLEMS, capital inputs are measured as capital services. The index of capital services is derived by aggregating the productive capital stocks of each type of asset[36] with the user costs of capital as weights[37]. In addition, EUKLEMS breaks down capital services by industry.

This data source was essentially used as a primary source because of its availability, the content and comparability for both capital and labour productivity. The same definition is used in several other studies, such as Blatour et al (2007) - "*capital productivity growth is defined as value added growth at constant prices divided by the growth of the volume index of capital services".*

[35] For the latest OECD *Productivity Manual* and *Measuring Capital* Manual, see: http://www.oecd.org/std/productivity-stats/

[36] These assets are residential structures, non-residential structures, transport equipment, information technology equipment, communication technology equipment, other machinery and equipment, software and other fixed capital assets.

[37] Weights are based on the rental price of each asset, consisting of a nominal rate of return, depreciation and capital gains (excluding taxes). For a more detailed outline of the calculation methodology, see Mahony and Timmer (2009)

Unfortunately, EUKLEMS lacks information on capital services for certain countries, mostly for a Eastern-Europe countries (i.e. Estonia, Latvia, Lithuania, Poland or Slovakia). For this reason the choice of countries to analyse needed to be restricted (see 8.1.4).

The definition used for this study for Capital Productivity is measured as the ratio of gross value added and capital services, expressed in volume indices, where the year 1995 serves as basis (1995=100).

8.1.4 Data considerations and correspondence tables

Given the data availability of the two primary sources, EUKLEMS and the Sectoral Resource Maps Study, GVA instead of GDP was used to calculate the three productivity indicators – capital, labour and resource productivity.
According to the OECD, "although both output measures can be used [GDP or GVA], there is normally a strong correlation between the two… (in addition) there is a preference for value added as taxes are excluded" (Freeman, 2008).
The EUKLEMS Growth and Productivity Accounts were explored for data on labour and capital productivity and data from the Sectoral Resource Maps study was used for inputs for resource productivity. It is important to notice that the two databases are based on different sector classifications, which led to initial comparability issues that needed to be rectified.

The Sectoral Resource Maps data are based on a multi-regional input-output model derived from the Global Trade Analysis Project (GTAP) database. The GTAP Data Base currently includes 57 sectors. One of the main tasks in using the GTAP I-O table is matching the data with the GTAP sectoral classification (GSC). To do so, a concordance or mapping needs to be constructed between the sectoral classification used in the source data (in the case of this study: Labour and Capital data and the GSC.

The two national classifications that correspond to the GSC are the Central Product Classification (CPC) and the International Standard Industry Classification (ISIC). The CPC corresponds to GSC agricultural and food processing sectors and the ISIC to the other GSC sectors. The ISIC is used for most sectors because it is the reference point for sectoral classifications in most of I-O statistics. But for agriculture and food processing, the ISIC does not provide the details GSC requires. The CPC was developed by the Statistical office of the United Nations to serve as a bridge between the ISIC and other sectoral classifications (United Nation 1990, 1991).
Using different classifications should not be a major problem in theory, since correspondences for the agricultural sectors between the GSC, CPC and ISIC codes have been elaborated, enabling the harmonization between the databases[38].

EUKLEMS provides data for labour and capital services with the reference to the ISIC classification. As mentioned in the previous paragraph, ISIC classifications have less detailed information on commodities for the agricultural sector and thus are not going to the same detail in commodities than GSC. To the best of our knowledge, no data is available at present in the details of GSC for labour and capital services by reference to CPC and ISIC as shown in

[38] Two concordance tables (Table A2.10 and Table A2.11) between GTAP sectors (GSC) classification and standard classifications (CPC and ISIC Rev. 3) are included in Annex 3.

Table A2.9, Annex 2. For this reason, specific industries had to be aggregated to accommodate for the differences between sector classifications (Illustrated in Table A2.12 of Annex 2)[39]. EUKLEMS, although less detailed at product level, aggregates **more** data on products. This means that EUKLEMS includes more commodities than GTAP. As a result, labour productivity and resource productivity in the agricultural sector might not be entirely comparable. It is possible that resource productivity is overstated for the agricultural sector, since there are less inputs relative to the GVA data provided by EUKLEMS.

In short, the GTAP database aggregates less agricultural products than EUKLEMS. Although the *level* of resource productivity may be overstated for agriculture, the *trends* in resource productivity are considered to be still relevant for analysis, since data is analysed over time. The correspondence in the agricultural sector is not perfect (

[39] Correspondence between GTAP sectors (GSC) classification and standard classifications (CPC and ISIC Rev. 3) are included in Annex 3 (Table A3.9).

Table A2.9, Annex 2) and in order to overcome this drawback, more details would be needed for agriculture and food processing from national classifications i.e. ISIC, CPC. With these limitations in mind, the analysis was conducted using the correspondences presented in Annex 2 Table A2.12.

The EUKLEMS database has two different data releases, ISIC Rev. 3 and ISIC Rev. 4. Since ISIC Rev.3 data is available for more countries, and data is disaggregated to 72 industries instead of 32 (as it is the case for ISIC Rev. 4) the older version was used in this study.
After aggregating sectors, the team decided to eliminate the *trade and services sector*, since EUKLEMS and the GTAP database did not correspond close enough one to another. After all, the following sectors were retained for the analysis:

- Agriculture, hunting, forestry and fishing
- Construction
- Electricity, gas and water supply
- Mining and quarrying
- Manufacturing
- Transport

As stated earlier, the EUKLEMS database has largely been constructed using data from national statistical institutes and processed in order to ensure international comparability, publishing information for 25 Member States. However, it only provides information on capital productivity for 12 of those countries. Cross-checking with data availability for resource productivity (from the GTAP-sourced database) and considering the resource intensity by sector, GDP representativeness, and geographical location, the following sample of countries were chosen:

- France
- Spain
- Germany
- Italy
- United Kingdom
- Hungary
- Czech Republic (lacking data for resource productivity for 1997)
- Netherlands
- Finland
- Ireland

Table 6 illustrates the top ten countries with the greatest raw material input by sector. Due to the large proportion of minerals, sand and gravel of the overall material flows in the economy, the construction sector is the most material resource intensive in the economy. Agriculture, due to the high portion of biomass use, is the second most intensive sector followed by the food manufacturing sector with high percentage of biomass use and a significant portion of fossil fuels. Fossil fuels are also used extensively in the manufacture of petroleum and coal sector, which is the fourth most intensive sector in the economy. Energy supply sector follows closely, again with a high portion of fossil fuels input. The business services sector is the sixth most material resource intensive with high portion of material inputs like minerals and fossil fuels. Transport follows as the seventh most intensive sector with high portion of fossil fuels inputs. It can be observed from Table 6 that the most material intensive countries are those with the biggest economies like Germany, France, Italy, United Kingdom and Spain. (Sectoral Resource Maps Report, 2013).

Table 6. Top ten countries with the greatest resource input

Sector	Countries
Construction	Spain, Germany, France, Italy, United Kingdom, Poland, Belgium, Portugal, Ireland, Finland.
Agriculture	France, Germany, United Kingdom , Poland, Spain, Italy, Greece, Romania, Netherlands, Denmark
Food manufacture	France, Germany, United Kingdom, Italy, Spain, Poland, Greece, Netherlands, Belgium, Ireland
Petroleum and coal products	Germany, Italy, France, United, Kingdom, Spain, Netherlands, Poland, Belgium, Romania, Greece
Energy supply	Germany, Poland, United Kingdom, Italy, Spain, Greece, Romania, Czech Republic, France, Bulgaria
Business services	Germany, France, United Kingdom, Spain, Italy, Poland, Sweden, Belgium, Finland, Netherlands
Transport	Germany, France, Italy, United Kingdom, Spain, Greece, Poland, Belgium, Netherlands, Sweden

Note: The sequence of the countries is sorted from greatest input to lowest

Source: Sectoral Resource Maps Report, 2013

8.2 Resource, labour and capital productivity across sectors

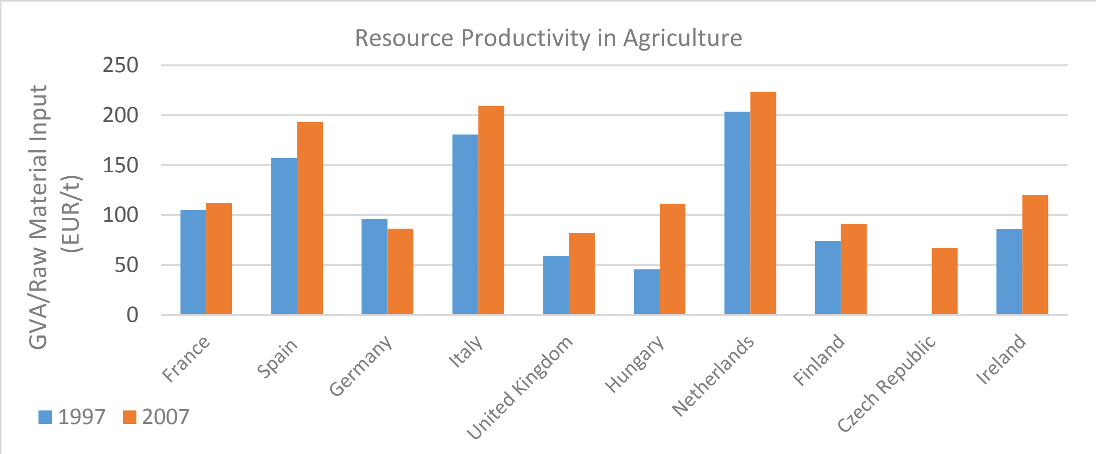
This section provides a descriptive overview of resource, capital and labour productivity across sectors and Member States, to understand if similar or different patterns across states can be observed.

8.2.1 Agriculture

8.2.1.1 Resource Productivity

Of the countries under investigation, the Netherlands, Italy and Spain were the most resource productive economies in agriculture (see Figure 19). For example, with 224 EUR of gross value generated per tonne of material input, the Netherlands has been almost 2.75 times more resource productive than the UK and 3.35 than the Czech Republic in 2007. In Hungary, material productivity in agriculture more than doubled over the 10 year period, going from 45 EUR to 111 EUR of gross value generated per tonne of material input. Meanwhile, resource productivity nearly remained stagnant in the rest of the countries and dropped slightly in Germany. Excluding Hungary, the annual average growth rate was around 1-2%, whereas Hungary's productivity grew on average 9% per year between 1997 and 2007.

Figure 19. Resource productivity in agriculture in 1997 and 2007 (GVA/RMI)

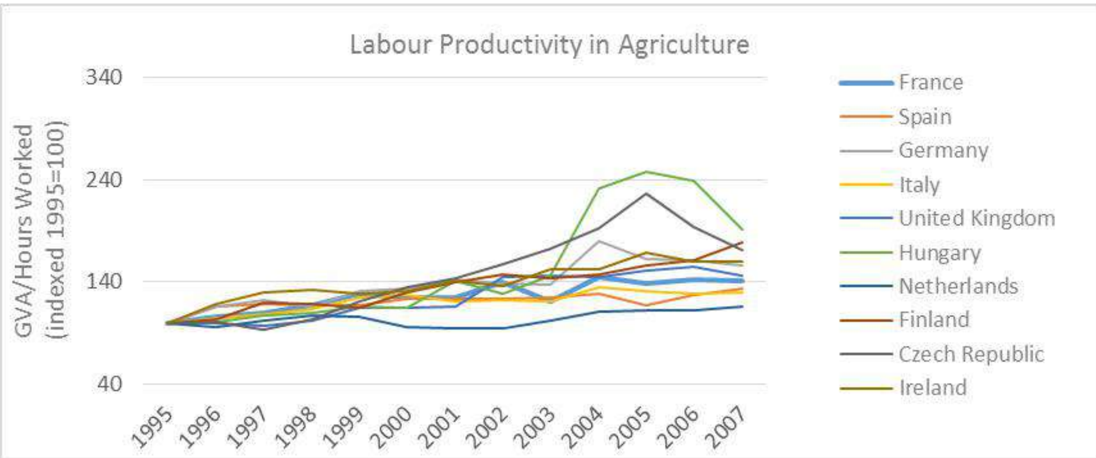


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.1.2 Labour Productivity

Labour productivity in agriculture increased on average 3% a year as compared to 1995 levels for the sampled countries. Hungary had the highest value for labour productivity of all, being 90% more productive in 2007 than in 1995. Both Hungary and the Czech Republic had a jump in productivity between 2003 and 2006 (see Figure 20).

Figure 20. Development of labour productivity in agriculture (GVA/hours worked)

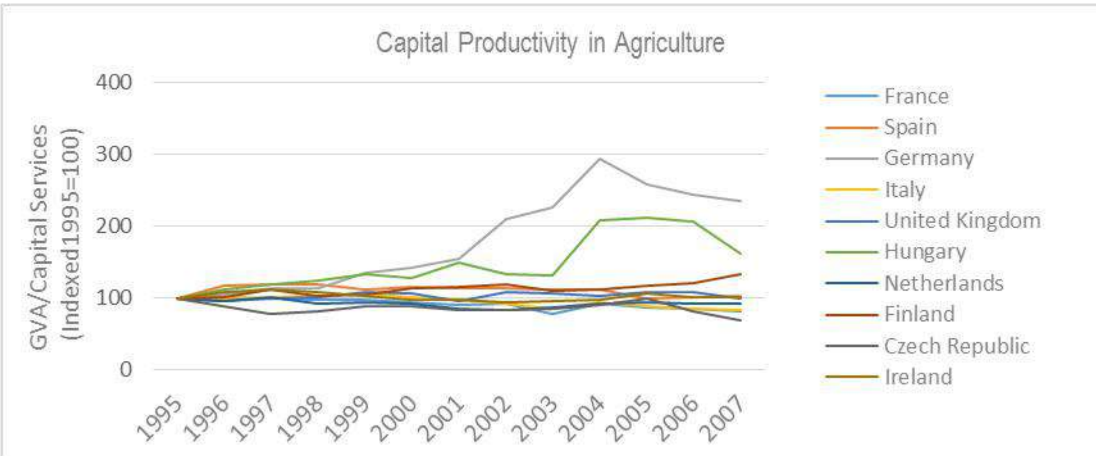


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.1.3 Capital Productivity

In general, capital productivity stagnated in agriculture, apart from Hungary and Germany, which experienced a peak in capital productivity in 2004, doubling and tripling their efficiency compared to 1995 levels, respectively.

Figure 21. Development of capital productivity in agriculture (GVA/capital services)



Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.1.4 Discussion

Both resource and labour productivity grew in agriculture over the time period, while in general, capital productivity stagnated with the exception of Hungary and Germany.

The first of the five objectives for the Common Agricultural Policy set out in the Treaty of Rome is “to increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production and the optimum utilisation of the factors of production, in particular labour”[40]. The problem with analysing the productivity growth in agriculture is that labour productivity does not capture ‘true’ productivity growth, as labour only partially explains increases in output. Other factors, such as using higher amounts of fertilizer or better planting methods impacts output is only captured in an index like total factor productivity (TFP), which would be more appropriate. TFP measures the effects in total output that is not caused by labour or capital, meaning it captures an economy’s long term technological change over time. Labour productivity levels are determined by many causes that can range from factor endowment, technology to institutions or geography which is not captured in the index.

Labour productivity differences in agriculture across Europe could be explained by the endowment of fertilizers, machinery, irrigated land or livestock capital per worker (Martín-Retortillo and Pinilla, 2012). In other words, capital has explanatory power when looking at labour productivity differences across countries.

These statements coincide with our findings, where for example Hungary had jumps in labour productivity coinciding with increases in capital productivity, consequently experiencing a significant increase in resource productivity between 1997 and 2007. We can infer that the relationship between capital and technology to be significant, which therefore increases the output per worker while also increasing the efficiency of resources through technological change.

8.2.2 Construction

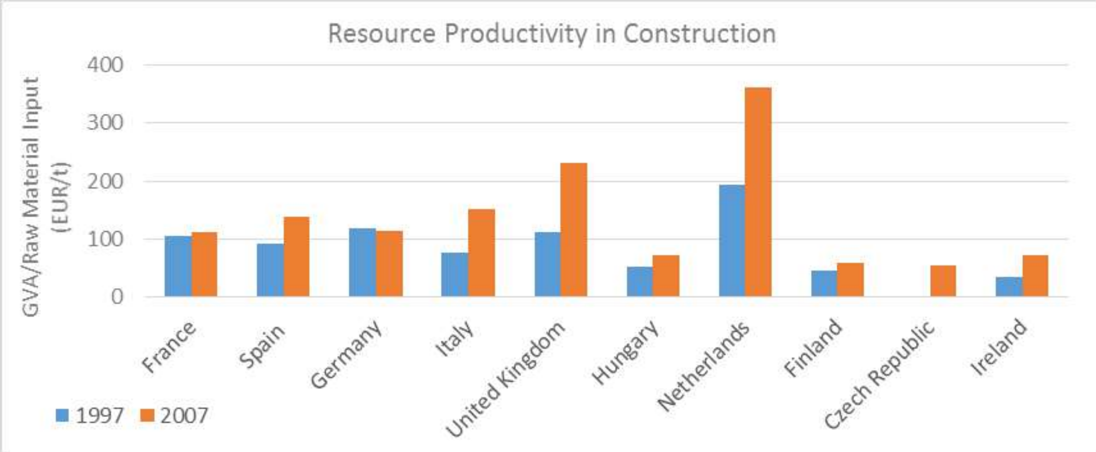
8.2.2.1 Resource Productivity

Overall, the selected Member States experienced an increase in resource productivity in the construction sector (see 0) between 1997 and 2007. In this analysis, the Netherlands is the most resource-efficient country, followed by the UK. Resource productivity more than doubled in UK, going from 111 EUR to 231 EUR of gross value added per tonne of material input in 1997 and 2007, respectively. In other words, the UK on average grew 7% per year over the time period in terms of resource productivity. The Netherlands also increased their productivity by 86%, going from 193 EUR of gross value added per tonne of material input to 360 EUR, with an average annual growth rate of 6%. Italy, with 151 EUR of gross value generated per tonne of material input in 2007, grew at a rate of about 7% in terms of resource productivity.

The less resource-efficient economies in construction are Hungary, the Czech Republic, Finland and Ireland, which are as much as six times less efficient than the Netherlands, although they still grew an average of about 3% a year. The only countries that experienced little or negative change were Germany and France.

[40] Article 33 of Treating establishing the European Community http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:12002E/TXT

Figure 22. Resource productivity in construction, in 1997 and 2007 (GVA/RMI)

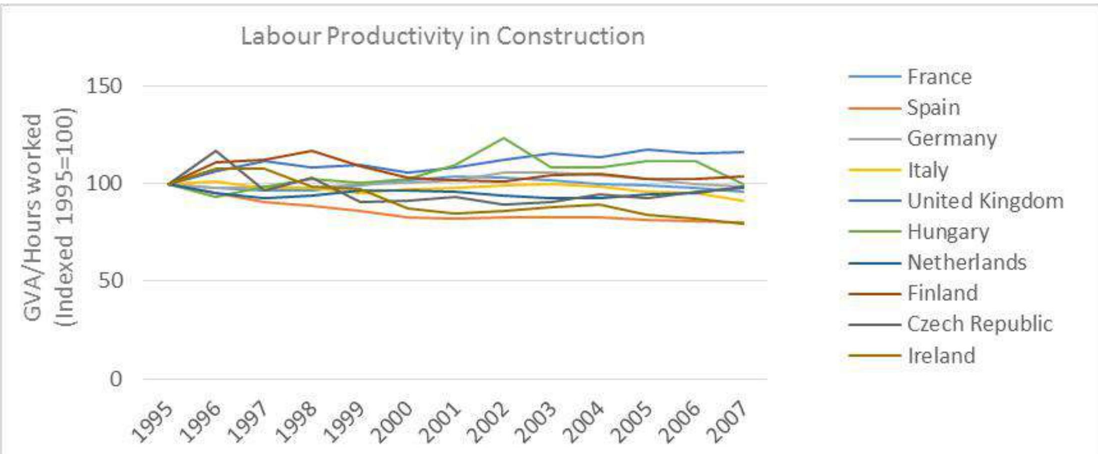


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.2.2 Labour Productivity

The countries under consideration had varying labour productivity in the construction sector (see Figure 23), but have on average not improved their productivity levels since 1995 apart from the UK and with Hungary and Finland having brief jumps only to return to original levels. Spain and Ireland had the largest decreases, with an average of 2% decrease per year as compared to 1995 levels, ending up at a level of productivity that was 20% below 1995 levels. On the other hand, the country of the sample that experienced a positive trend was the United Kingdom that steadily increased to 16% above productivity levels of 1995. Meanwhile, Hungary experienced a sharp jump in 2002, but then levelling off and later declining in 2007 back to 1995 levels. The other Member States hovered around the same labour productive level as 1995.

Figure 23. Development of labour productivity in construction (GVA/hours worked)

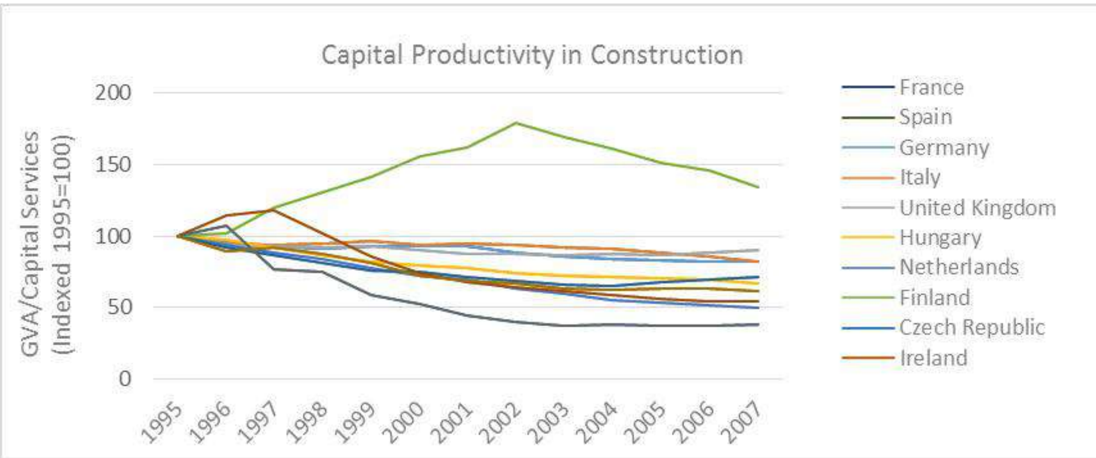


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.2.3 Capital productivity

Figure 24 shows that nine of the ten observed countries have experienced a negative trend in capital productivity for the construction sector, decreasing to levels between 37% (the Czech Republic) to 90% (Germany) of productivity levels compared to 1995. Hungary, on the other hand, peaked in 2002, with a level of capital productivity 70% higher than its 1995 levels, decreasing thereafter but still remaining at a higher level of capital productivity than in 1995.

Figure 24. Development of capital productivity in construction (GVA/capital services)



Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.2.4 Discussion

Most Member States have seen an overall increase in their resource productivity in construction. Meanwhile, their labour productivity remained flat or decreased, like their capital productivity (with the exception of Hungary – see the following box).

Box 3: Results from the empirical analysis for different countries in the construction sector. The example of Hungary

In the analysed datasets Hungary was found to be an outlier throughout different sectors. In Hungary, resource productivity in agriculture more than doubled over the 10 year period between 1997 and 2007, ranging from 45 EUR to 111 EUR of gross value generated per ton of material input. However, in terms of materials it was the less resource-efficient economy in the construction sector. In this sector, the Member States analysed have seen either a small change or an overall increase in their resource productivity.

As Harasztosi (2011) explains, Hungary had a particular experience with productivity coinciding with the stages of Hungarian transition following the collapse of the Soviet Union.

The period from 1998 to 2001 was driven by investment, whereas during the time between 2002 and 2007 growth was led by technology, as reported in the study by Harasztosi (2011). Between 1998 and 2001 a continuation of the monetary framework of the stabilisation package and encouraged foreign investments could be observed, while the following period started with a shift in the monetary regime and a substantial increase in the minimum wage, coinciding with a decrease in capital and labour productivity.

The construction sector is responsible for 2.5-3% of the Hungarian GDP. The sector exhibited boom and bust periods lagging the market demand considerably. It demonstrated strong growth from 1998 to 2001, followed by a period of negative growth and job destruction. It was during this period when most of the investments occurred in Hungary's construction sector.

The role of labour reallocation is relatively high in construction for Hungary. Before 1998, aggregate productivity growth was driven by this reallocation. As such, before 1997, aggregate employment and wages fell in this sector. Labour reallocation can be attributed to the downsizing and closing down of the least efficient firms.

In the last two periods, the role of reallocations is smaller, and aggregate productivity growth is almost solely determined by technical efficiency changes. This implies that the sector, over time, became more homogenous and firms employed labour and capital input more efficiently.

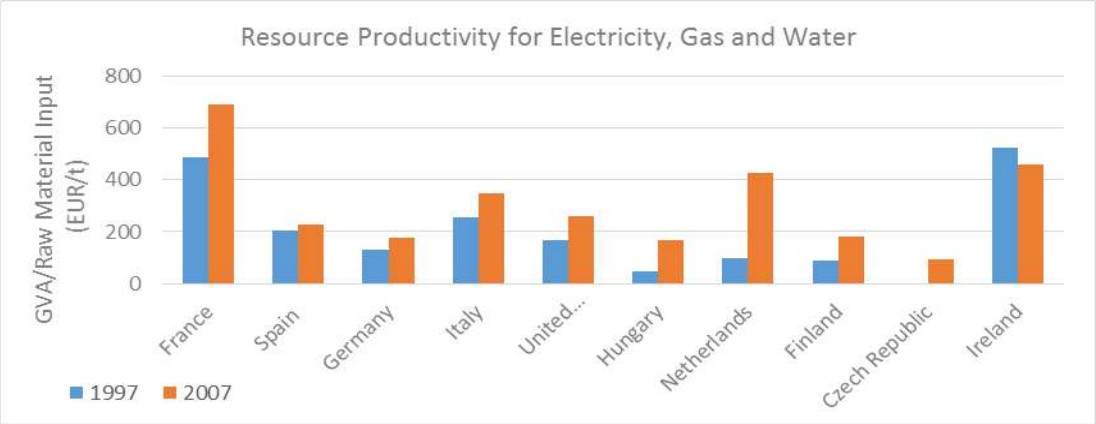
Nonetheless, resource productivity in the construction sector for Hungary only mildly increased, suggesting that high investments in the sector did not have a proportionate - although positive - impact on resource productivity.

8.2.3 *Electricity, Gas and Water*

8.2.3.1 Resource Productivity

The energy sector has seen an overall increasing trend in resource productivity (see 0). France is the most resource productive in the energy sector among the observed countries, with almost 700 EUR of gross value generated per tonne of material input. The Netherlands experienced the highest increase in resource productivity over the period rising efficiency by a factor of 4 over the 10 year period, becoming one of the most resource efficient countries, in terms of raw material inputs. In other words, the Netherlands became on average 14% more resource efficient per year throughout the time period. Ireland, on the other hand, became less resource efficient in the energy sector (on average 1% less resource productive per year), but is still at a high 461 EUR gross value added per ton of material input.

Figure 25. Resource productivity for electricity, gas and water, in 1997 and 2007 (GVA/RMI)

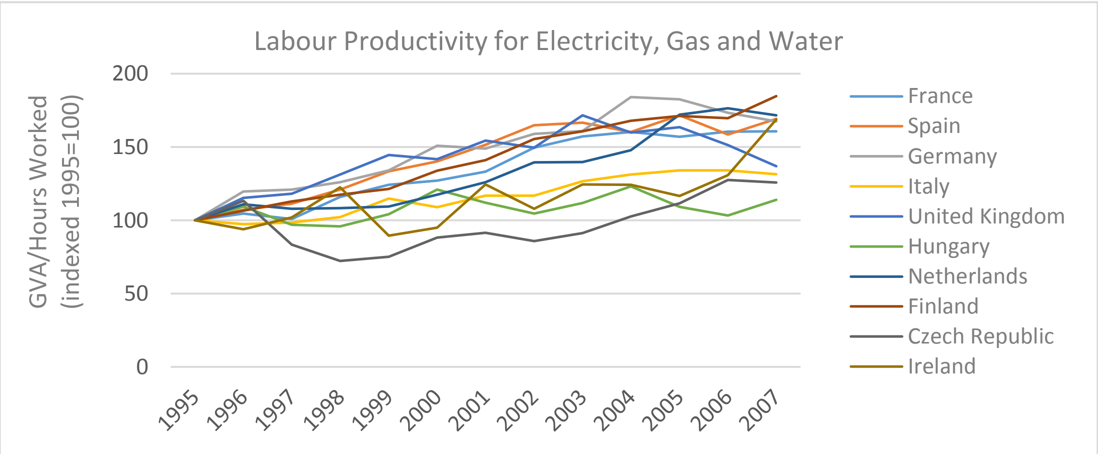


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.3.2 Labour Productivity

Overall, the selected Member States have increasing, although fluctuating, trends in labour productivity in the energy sector. All of them had higher levels of labour productivity in 2007 as compared to 1995 (see Figure 26). Although the Czech Republic had an initial decline in productivity between 1995 and 1998, it made a recovery back to 1995 levels. The Netherlands, Spain, Germany, Ireland and France had the highest increases compared to 1995.

Figure 26. Development of labour productivity in electricity, gas and water (GVA/hours worked)

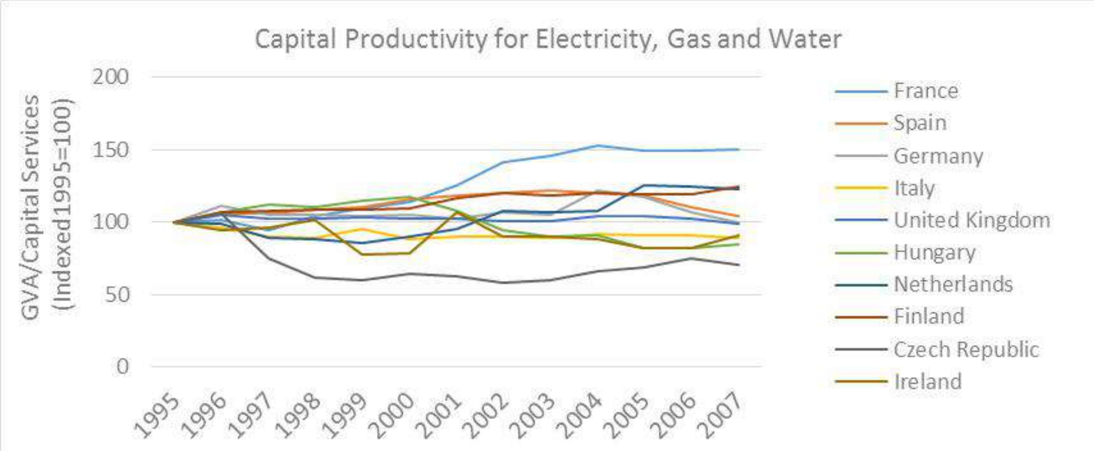


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.3.3 Capital productivity

As can be seen from Figure 27 the 10 Member States had varying experiences with capital productivity in the energy sector, with some countries (Czech Republic) experiencing a 30% decrease in their productivity compared to 1995 levels, while other countries (e.g. the Netherlands) had a 50% increase in their capital productivity over the time period. Capital productivity in general saw average annual growth rates ranging between -3% and 3% for the concerned countries.

Figure 27. Development of productivity in electricity, gas and water (GVA/capital services)



Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.3.4 Discussion

Just like resource productivity, labour productivity saw in general a positive trend in the energy sector. However, capital productivity had ranging effects when compared to 1995 levels, with no discernible trend. Resource productivity in electricity, water and gas is highly diverse, and reflects the Member States various energy mixes. However, the resource productivity indicator does not consider renewable energy as a material input, for example. This could be considered as an issue, as it may misrepresent actual resource productivity levels in the concerned countries.

8.2.4 Mining

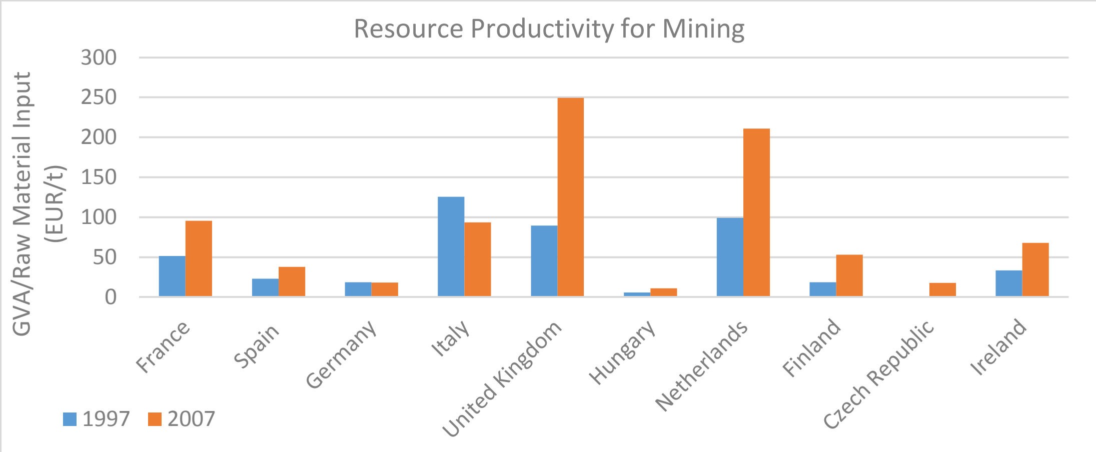
8.2.4.1 Resource productivity

In general, resource productivity in the mining sector saw an increase for the eight[41] selected Member States, except for Italy (see Figure 28). The UK and Netherlands were the most resource productive economies in mining over the ten year period, with 250 EUR and 210 EUR value generated per tonne of material input. The UK, Netherlands and Finland grew on average 10% more productive every year. Ireland and Hungary doubled their productivity

[41] As reported on section 8.1 there is no available data on RMI for Czech Republic for the year 1997.

over the time period. In Italy on the other hand, resource productivity decreased by 26% over the time period, while Germany stagnated throughout the period.

Figure 28. Resource productivity for mining, in 1997 and 2007 (GVA/RMI)

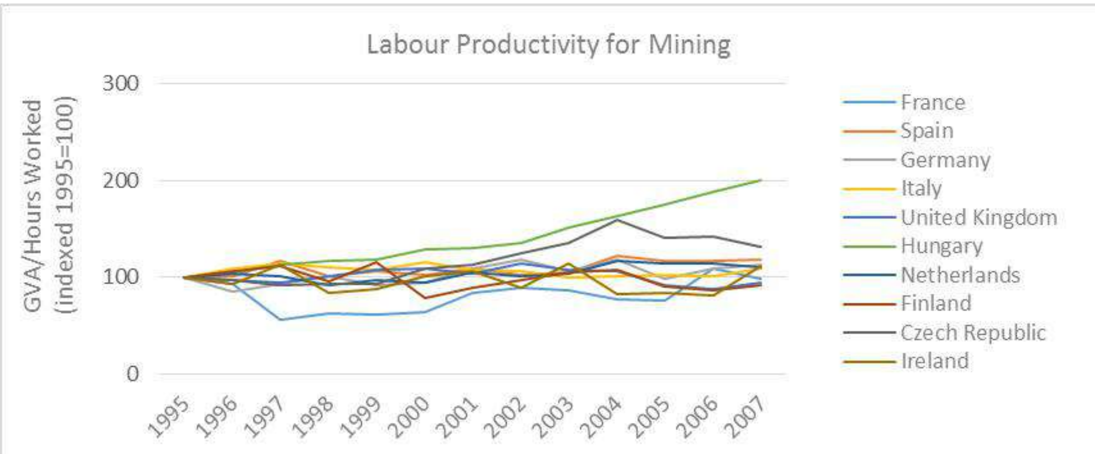


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.4.2 Labour productivity

For the majority of the sampled countries, labour productivity has more or less stagnated, with an average annual increase of one percent. Hungary is an exception, where labour productivity increased on average 5% a year. France initially had a sharp dip in labour productivity in mining, but later recovered to 1995 levels in 2007 (see Figure 29).

Figure 29. Development of labour productivity in mining (GVA/hours worked)

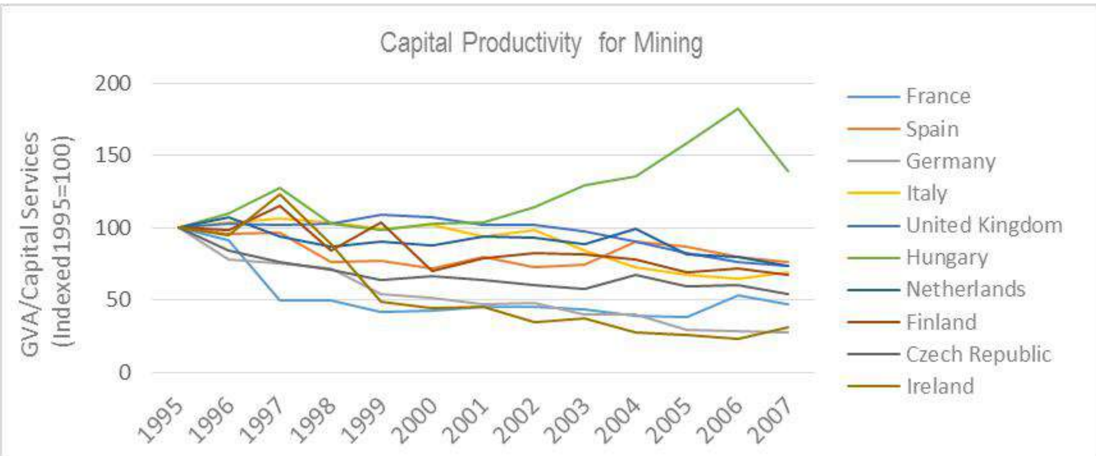


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.4.3 Capital Productivity

Overall, the selected countries experienced a negative trend in capital productivity, with the exception of Hungary (see Figure 30). On average, the nine countries experienced a 5% annual decrease in capital productivity in mining, while Hungary on average increased more than 3% a year.

Figure 30. Development of capital productivity in mining (GVA/capital services)



Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.4.4 Discussion

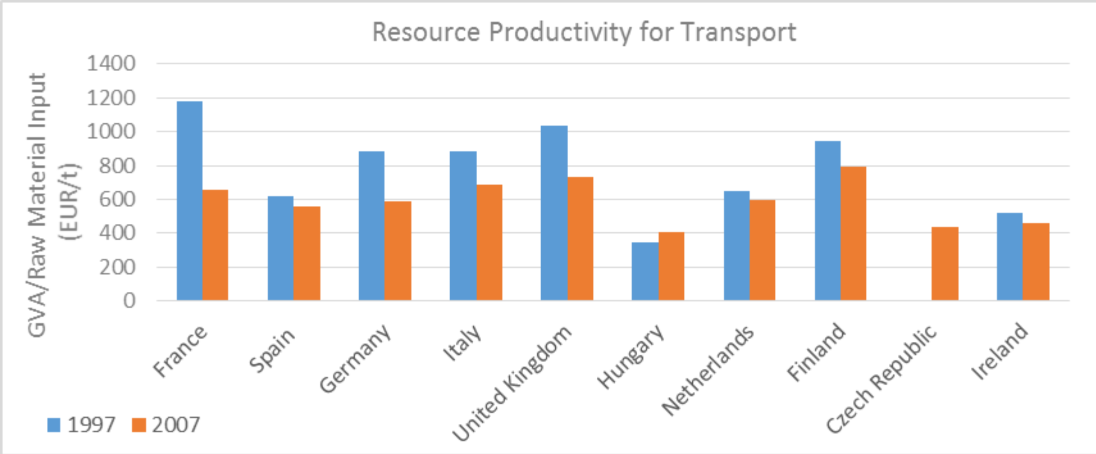
Hungary is the only exception when it comes to capital and labour productivity in mining when looking at the sample countries. While it experienced an overall increase in productivity over the time period the other Member States saw a decline or stagnated, respectively. However, Hungary was the least resource productive of all the sampled Member States.

8.2.5 Transport

8.2.5.1 Resource Productivity

Transport is the only sector where a downward could be observed for all the economies, with an average decline of 2% annually in resource productivity (see 0). The only exception is Hungary that experienced a mild annual growth of 2% on average over the period, leading to a total 17% increase in productivity over those years. France experienced the sharpest decline. Transport provides interesting insight, because even though resource productivity decreased in eight of the nine observed countries, all countries seem to be converging to a similar level of productivity. In 1997, we can observe a difference of 830 EUR of value added per ton of material input between the most (France) and least (Hungary) productive countries. Whereas in 2007, this difference is only 386 EUR of value added per ton of material input between the most (Finland) and least (Hungary) resource productive countries in transport.

Figure 31. Resource productivity for transport, in 1997 and 2007 (GVA/RMI)



Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.5.2 Labour productivity

Overall, labour productivity in the transport sector increased with the exception of Ireland, that saw a 10% decrease in labour productivity when compared to 1995 levels. Spain and Italy stagnated, only marginally increasing their productivity over the period. Meanwhile, labour productivity increased in the Czech Republic, Finland, the Netherlands, Hungary, UK, Germany and France at least between 20% up to 40% higher than compared to 1995 levels.

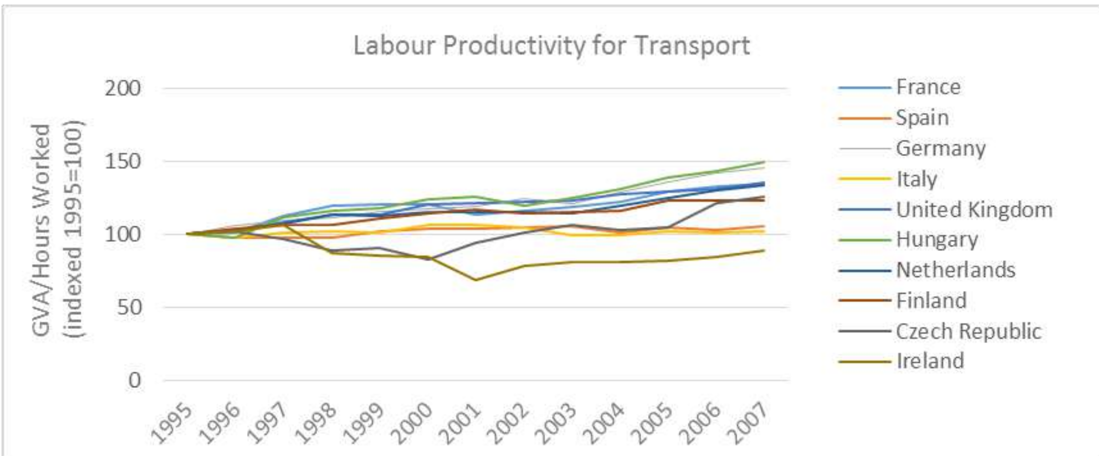


Figure 32. Development of labour productivity in transport (GVA/hours worked)

Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.5.3 Capital productivity

The sampled Member States had no discernible trends in capital productivity for transport, with some increase of their capital productivity by as much as 60% compared to 1995 levels (Hungary), while others decreased by as much as 50% (Ireland). In four of the ten sampled countries productivity increased (albeit marginally) while in the other six it decreased (see Figure 33).

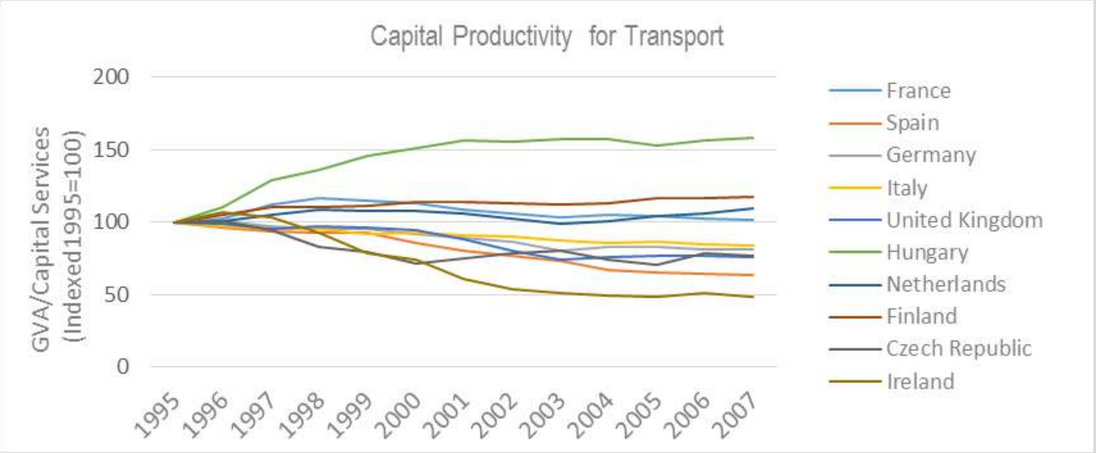


Figure 33. Development of capital productivity in transport (GVA/capital services)

Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.5.4 Discussion

Hungary had the highest growth in capital productivity over the time period in transport, and maintained its position as the most labour productive Member State of the sample, and yet was the least resource productive country in the sector.

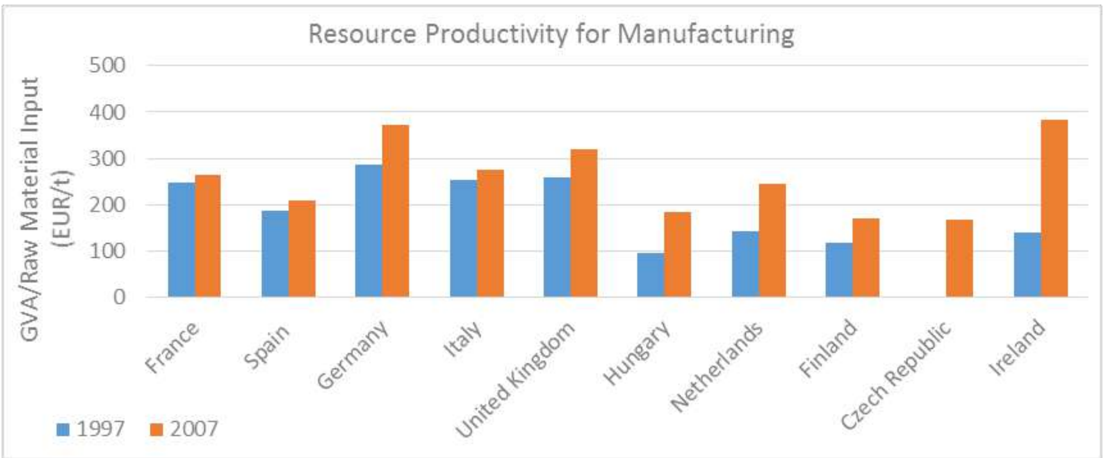
The transportation industry in Europe accounts for about 4.5% of the GVA and employs about 9.1 million people. Both passenger and freight transport activities have increased by more than 40% (measured in passenger- and tonne- kilometres) between 1990 and 2010. The sector is still dominated by oil and oil products that account for 96% of energy needs, although there have been some improvements through technological progress. Krautzberger et al. (2012) suggest that on average Member States showed efficiency losses and decreases in productivity in the transport sector which could not be counteracted by technological improvements. This coincides with our findings on transport resource productivity.

8.2.6 Manufacturing

8.2.6.1 Resource Productivity

Overall, all countries experienced an increase in resource productivity in manufacturing between 1997 and 2007 with an average annual growth rate of 4% (see Figure 34). Ireland had the highest increase in resource productivity in the manufacturing sector compared to other countries with an increase of 172% over the total period, going from 140 EUR value added per ton of material input to 382 EUR - an average of 10% increase in resource productivity a year. Resource productivity follows the same trends for all the countries with Germany being more resource productive over the years until 2007 where Ireland reached the same level as Germany in terms of value added per raw material input.

Figure 34. Resource productivity for manufacturing, in 1997 and 2007 (GVA/RMI)

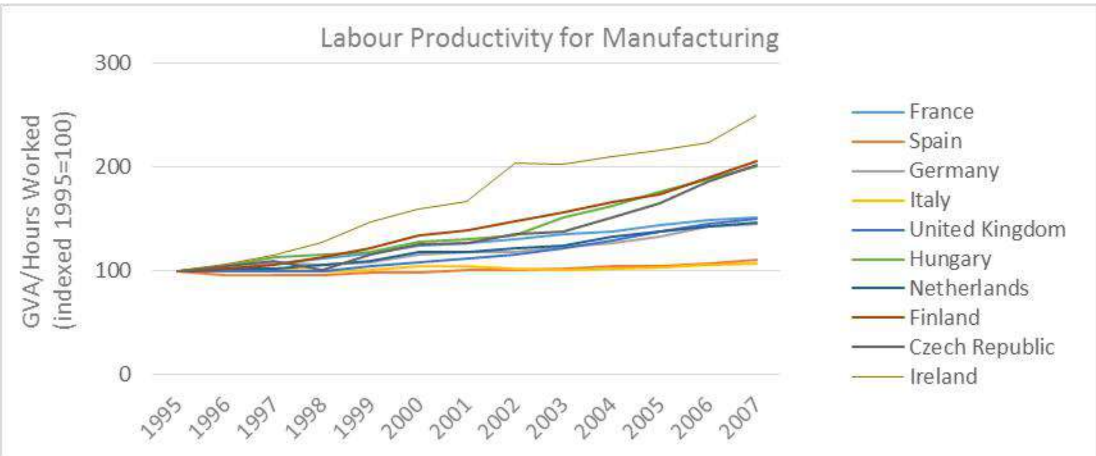


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.6.2 Labour productivity

Labour productivity increased for all the sampled Member States, albeit at different rates (see 0). Some countries (e.g. Ireland) had an average annual growth rate of 7% of increased labour productivity compared to 1995 levels, while others such as Spain and Italy only marginally increased. Only Spain saw a very small dip in labour productivity in 1997 to 2000 (of 2%) before recovering to a level higher than 1995 levels, while the rest only saw increases.

Figure 35. Development of labour productivity for manufacturing (GVA/hours worked)

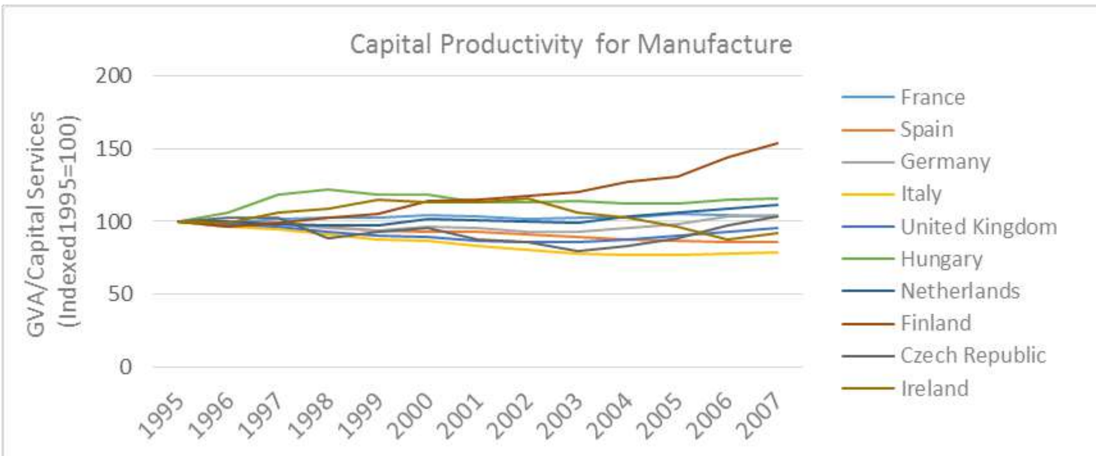


Data source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.6.3 Capital Productivity

Capital productivity in manufacturing did not have a discernible trend. Four states experienced increases of up to 20% in capital productivity, while another four experienced decreases of up to 20%. Finland, however, saw a remarkable increase in capital productivity 50% above 1995 levels.

Figure 36. Development of capital productivity for manufacturing (GVA/capital services)



Data Source: BIO/SERI (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

8.2.6.4 Discussion

Resource and labour productivity increased in the manufacturing sector, while capital did not have an overall trend for the selected countries.

Ireland has experienced the fastest growth in resource productivity, as well as leading labour productivity in the sector. Manufacturing comprised 24% of the value of output in the Irish economy in 2009, slightly higher than in Germany. Modern manufacturing makes up the majority of this figure (Forfàs, 2012). Having such high labour productivity, however, may partly be explained by changes in prices of certain products (such as pharmaceutical products in chemical manufacturing)—which have no tangible impact on the real productivity of labour, but only on the numerator of the fraction (GVA). Ireland leads the world in pharmaceutical manufacturing, being one of the world's largest exporters of pharmaceutical products in the world.

The same holds for Germany's high resource productivity in the manufacturing sector with Germany being one of the largest European exporters of manufactured goods.

8.2.7 Discussion: Labour, resource and capital productivity across Member States

8.2.7.1 Resource productivity

Productivity indicators show considerable variation between countries and sectors from 1997 to 2004. On average, resource productivity improved, except in the transport sector – in other words, economies have in general been creating more value per ton of resources used.

The Netherlands has experienced different trends in resource productivity, but presents a significant improvement compared to other countries' material productivity. While energy in 1997 was the least productive sector in the Netherlands, by 2007 it grew fourfold and became the second most productive sector in Netherlands after transport. In addition, the Netherlands has the highest resource productivity in agriculture and in construction.

Finland and Ireland are relatively less productive in terms of raw materials in the construction sector. One reason might be the increase of investments in new buildings and transport infrastructure which created the need for more materials in this sector, however this would need to be further investigated. In 1997, the share of DMC in DMI was 93% in Ireland (Bringezu et al. 2004) while the resource productivity amounted to 71.7 EUR of value added per ton of raw material input. The high level of DMI was mainly due to high inputs of construction minerals according to the study by Bringezu et al. (2004).

In the case of Germany, the total material input increased considerably after reunification in 1990, mainly due to a closure of large parts of lignite mining (Bringezu et al. 2004). Our study shows a 35.8 percentage change from 1997 to 2007 in resource productivity for the energy sector.

Similarly, the Czech Republic shifted from lignite to other energy sources. However, for the Czech Republic we cannot observe resource productivity trend due to the lack of data in raw material inputs in 1997. According to literature, material intensity dropped by 30% in the Czech Republic for 1990-2004 (Scansy et al. 2003) and decreasing levels of material intensities can be observed over the period 1991–2004 (Kovanda et al. 2012). Furthermore, Bringezu et al. (2004) report an absolute, but not continuous, decline of material use by Czech Republic for 1990-2004, mainly because of the breakdown of socialist state planning economies in East Europe.

Overall, in terms of resource productivity transport is the most productive of the compared sectors in all countries, although a deceleration occurred from

1997 to 2007 with Hungary being a very mild exception. Mining and construction sectors presented the least productive levels for all countries, except the Netherlands.

The manufacturing sector improved in terms of resource input over the time period in Ireland while it was the second most productive sector in Germany, for reasons previously discussed. Growth in the productivity of material resources in the energy sector in France has been significantly faster than growth in the other sectors where in 2007 it became the most productive sector.

The Kovanda et al. (2012) study revealed an increase in the efficiency of transforming the material inputs into economic output as indicated in decreasing levels of material intensities, but in an aggregate level DMI and Total Material Requirement[42] indicators did not show any clear movement over the period 1991–2004 for the Czech Republic, Germany and the EU-15.

8.2.7.2 Labour Productivity and Resource Productivity

Growth in labour productivity in the observed countries has been significantly faster over the time period than growth in the productivity of material resources.

The most productive sectors across states were energy, agriculture and manufacturing, where the increase in labour productivity was more than 50% and sometimes doubled. In other words, just over half of the increase in gross value-added came as a result of increased labour productivity and just less than one half was the result of increased labour inputs in these sectors.

A major reason for this can be seen in the relative prices of labour, energy and resource inputs and the current tax systems, as increasing labour costs over time induces firms to focus on improving labour productivity, as described in chapter 4.1.

The one sector that had experienced stagnant labour productivity growth, however, was the construction sector, with only the UK experiencing mild growth in labour productivity. Resource productivity grew at a higher rate in construction, compared to labour productivity, with the UK being one of the top resource productive (and fasted growing resource productive) countries.

8.2.7.3 Capital Productivity and Resource Productivity

The relationship between capital and resource productivity has varying trends depending on the sector but has in general experienced a deceleration in growth between 1995 and 2007. Capital productivity had the most wide-ranging trends across countries, making it difficult to discern relationships between the indicators, calling for a sector-by-sector analysis by Member State for further explanation.

8.2.7.4 Labour Productivity and Capital Productivity

In general labour productivity increased as compared to 1995 levels, but differences in the sectors can be observed. Capital productivity has seen

[42] TMR expresses the mass of materials required to sustain an economy.

tepid growth or a decline. However, the more interesting point is to look at growth levels of labour productivity and how it is impacted by capital investments. Overall labour productivity growth has been declining steadily since the 1970s for EU-15 Countries, albeit to varying degrees on a sectoral basis.[43]

In the literature, two main reasons are identified for declining total productivity growth in Europe: changes in total factor productivity (TFP) and changes in capital deepening (Cette et al., 2010). “Capital deepening” is a situation where capital per worker is increasing in the economy, often measured by the rate of change in capital stock per labour hour. MFP is a variable that accounts for effects in total output not usually caused by measured inputs of labour and capital—it therefore accounts for an economy’s technological change.

For example, the Office of National Statistics (ONS) of the United Kingdom explains the relationship between labour and capital productivity trends over time. Before 1997, ‘capital deepening’ contributed to 1.5 percentage points a year to labour productivity growth in the UK whereas afterwards, this has fallen to 0.5 percentage points a year on average and since 2010, capital deepening reduced to around zero.[44] **In other words, before 1997, Britain’s growth was driven by a more rapidly growing capital stock, implying that workers had more and better machinery and better workplaces, enabling higher output.** As the ONS states: “essentially all of the reduction in the growth of labour productivity between [the pre- and the post-1997 period] can be accounted for by the decline in the rate of capital deepening.”

Since 1980, in France, overall employee and hourly productivity has also continually slowed down compared to previous years. The slowdown in productivity can be attributed to the slowdown in both capital deepening and total factor productivity (TFP). In other words, the decline in labour productivity growth for France is due to the decline in capital deepening, which offsets the technological gains (Cette et al., 2010). In addition, capital investments may be skewed towards sectors and areas that employ unskilled labour. As we have seen in our analysis, some sectors may have higher capital input and higher technological change, which explains the variations in labour productivity growth.

In general, capital productivity in the selected Member States has seen tepid growth or a decline in productivity, which supports the reviewed literature. A study by Koeniger and Leonardi (2006), explains that gradual declines in the contribution from capital deepening in Europe have been a key feature in labour productivity growth since the early 1990’s. The movement of resources between sectors can contribute to aggregate productivity growth. If resources move from industries with high productivity levels to those with low productivity levels, this would be reflected in a negative contribution to aggregate productivity growth, even if productivity within individual industries is unchanged. Either way, the productivity performance of individual services sub-sectors is also not uniform, suggesting that an interesting exercise would be to analyse where capital is being invested, and if it is being used in labour productive or resource productive sectors. See Annex 2 for further analysis on labour and capital productivity between Member States.

[43] Slowing Productivity Growth-A developed economy comparison (2013) http://www.treasury.gov.au/PublicationsAndMedia/Publications/2013/Economic-Roundup-Issue-2/Economic-Roundup/Slowing-productivity-growth

[44] Multi-factor Productivity (experimental), Estimates to 2013, see http://www.ons.gov.uk/ons/rel/icp/multi-factor-productivity--experimental-/2013/art-mfp-15.html?format=print

8.3 Identification of drivers for resource productivity across countries

In order to better understand the system dynamics of raw material use, beyond the analysis of productivity indicators presented in the previous section, **this study applies regression analysis to identify the major drivers for resource use and to assess as well the interactions between such drivers over time and across countries.**

The objective of this section is to study the relationship between resource productivity and employment in order to provide empirical evidence to the existing literature and theory, on a macro level. Furthermore, this section also aims to identify control variables to determine empirically-supported relationships between resource productivity and employment. Given the limitations of this study with its focus on literature findings, population density, energy consumption and Research and Development (R&D) variables were considered relevant as drivers for resource productivity. These results will then be used to discuss policy relevant questions linked to jobs in section 8.4.

A study by Steger and Bleischwitz (2011) found that the main drivers of resource use were energy efficiency, new dwellings and roads construction activities. The same study discusses also the interactions between theories and empirical analysis. They provide a general background of theories of socioeconomic changes and how countries follow a pathway of industrialization according to which they specializes first in heavy industry to meet the demand for houses and infrastructure and gradually shift to lighter industries and services.

Another study by Auci and Vignani (2013) analyses if there exists a relationship similar to the Environmental Kuznets Curve (EKC) between per capita DMC Indicator, assumed as a potential environmental degradation indicator, and per capita GDP by using a cross–European panel of countries over the period 2000-2010. By controlling for national R&D expenditure, the study revealed a negative effect on DMC by total R&D expenditure variable. To this end, with a panel analysis we test some potentially important drivers for resource productivity, focusing on the interaction between the use of materials and employment levels over a longer time period.

An effective approach is to work on developing theoretical models while using empirical models to observe real data. The existing literature on the field of the theoretical analysis of raw material use is limited and in an early stage, which means that many potential drivers can be used to explain patterns in raw material production and consumption in different economies (Steger and Bleischwitz 2011). The typical production function often used in productivity analysis includes labour and produced capital as input factors. There are some studies that mainly focused on total factor productivity growth measures to capture the role of the environment incorporating natural capital as an additional input factor into the production function. (Brandt et al. 2013; Brandt et al 2014).

As this is a scoping study and the aim was to perform an econometric/statistical analysis with existing data, an empirical model that postulates relationships between data series was examined.

Using employment in terms of number of employees as a dependent variable, creates its own complexity in a macro level analysis. Among a variety of determinants of employment numbers, appropriate labour measures would also require incorporating the quality of labour inputs accounting for the education level, skills and the employment status. In section 3.1.2 we describe the limitations on the availability of these data. With a panel analysis we test the potentially important drivers for resource productivity. Our attempt is to derive empirical evidence on the interactions of a limited selected set of drivers. Future work could incorporate more drivers and study different conditions, such as different market conditions. As an example, it depends on the degree of competition in factor and product markets how changes in productivity will be distributed. In perfect labour markets, a rise in labour productivity could give rise to an increase in real wages of the same order.

The identification of causal relationships is a challenging task in terms of methodology and is beyond the scope of this study.[45] Thus, the team did not seek for causal relationships but empirically-supported relationships (if they are positive, or negative, for example).

8.3.1 Data and variable selection

Here, the interaction between the use of materials and employment levels is analysed. Furthermore, the potential for efficient use of raw materials to boost employment levels is explored. Other variables are introduced in the analysis that are most likely to influence material use and resource productivity. This analysis was based on Eurostat data.

Panel data-sets follow a random sample of individuals (countries, households, firms, etc.) over time. Panel data contains information on the same cross section units. The main advantage of working with panel data is that it is possible to control for individual-specific, time-invariant, unobserved heterogeneity, the presence of which could lead to a bias in standard estimators. To this purpose a panel dataset for EU-28 countries for the years 2000 – 2012 was created and used in order to compare resource productivity with respect to Raw Material Input (RMI)[46].

Eurostat provides annual data of RME for imports and exports at a country level for the years 2000-2012. The estimation of RME is based on the Leontief approach, which is a well-established method for environmental economic analysis. This methodology applies Input-Output analysis for assigning direct environmental pressures – measured in physical units – by the individual production activities to the products of final use and of imports.

In the analysis, an approximation of RME coefficients was used for the 28 countries. We calculated the RME coefficients of imports, for each of the four material groups, as a ratio of RME (1000 tonnes) and imports (simple product weight) at the EU-28 level. To obtain the equivalent for each country, we multiplied the coefficients with the imports of each country. Trade data was also extracted from Eurostat.

As dependent variable, we calculated the resource productivity indicator using the RMI as expressed in the previous paragraph and the Gross Domestic Product at current prices figures expressed in Euros:

[45] Most of empirical analyses are motivated to estimate the causal effect of an independent variable on a dependent variable. The most appropriate design for this task is a randomized experiment. However, when experimental designs are impossible, researchers must resort to the use of observational data from surveys. Because assignment to the independent variables of observational data is usually non-random, the challenge of estimating causal effects with observational data can be complex and the problems arising are considerable (Winship et al. 1999).

[46] RMI for each of the for material groups (Biomass, Metal Ores, Non-Metallic Minerals, Fossil Energy Carriers) was calculated as the sum of the total Domestic Extraction (DE) and imports in Raw Material Equivalent (RME).

$$Resource\ Productivity = \frac{GDP(thousands\ of\ euros)}{Raw\ Material\ Input(tonne)}$$

Data on employment, population density and energy consumption was taken from Eurostat. Employment data is presented in (thousands of) persons. Population density per km^2 is measured as the ratio between the annual average population and the land area. Final energy consumption by sector (1 000 tonnes of oil equivalent) indicator expresses the sum of the energy supplied to the final consumer for all energy uses. It is the sum of final energy consumption in different sectors (such as industry, transport, households, services, agriculture, etc.). Table 7 and Table A2.16 in the Annex present the descriptive statistics and the definitions of the variables used in this empirical analysis.

Table 7. Descriptive Statistics (EU28, 2000-2012)

Variables	Mean	St. Dev.	Min	Max
RMI (1 000 tonnes)	490 379	565 149	5 024	2 683 112
Gross Domestic Production (millions Euro)	423 480	651844	4395	2 749 900
Resource productivity (1 000 Euros/t)	0.626	0.357	0.108	1.869
Employment (1 000 persons)	7946	10238	146	42 033
Population density (person km^2)	169	237	17	1 327
R&D expenditure (millions Euro)	7 785	13 345	17	76 501
Energy Consumption (1 000 TOE)	63 101	85326.84	801.4	352 236

Source: own calculations

8.3.2 Empirical analysis

The goal of this section is to apply statistical and analytical methods in order to quantify the influence of socioeconomic and other drivers (i.e. energy consumption and R&D) on international material use. Throughout the analysis logarithms of the variables were used as a solution for asymmetry and non-linearity. Stata version 13 was used to run the calculations.
The equations for a simple regression are:

$$\log(Y) = \log(A) + B \bullet \log(X) \iff Y = A \bullet X^B \quad (1)$$

where X and Y are the independent and dependent variables, respectively, and the coefficients A and B are the results of the regression (the double arrow signifies that the two equations are equivalent).

In this study we are interested in analysing the impact of variables that vary over time, thus a fixed-effects (FE) model is appropriate for our panel dataset with 28 countries for the time period 2000 to 2012. FE models explore the relationship between predictor and outcome variables within an entity (country). Each entity has its own individual characteristics that may influence the predictor variables (for example the political system of a particular country could have some effect on trade or GDP, etc.).

When using FE we assume these individual characteristics within the entity (i.e country) may impact or bias the predictor or outcome variables and we need to control for this. This is the rationale behind the assumption of the correlation between entity's error term and predictor variables. FE remove the effect of those time-invariant characteristics and by adding a dummy variable for each country it becomes possible to assess the net effect of the predictors on the outcome variable. Each dummy is absorbing the effects that are particular to each country. The key insight is that if the unobserved variable does not change over time, then any changes in the dependent variable must be due to influences other than these fixed characteristics (Stock and Watson, 2003).

Another important assumption of the FE model is that those time-invariant characteristics are unique to the individual and should not be correlated with other individual characteristics. Each entity is different, therefore the entity's error term and the constant (which captures individual characteristics) should not be correlated with the others.

Demeaning variables is a common approach in fixed-effects model and also used in this analysis. In this method the within-subject means for each variable (both the Xs and the Y) are subtracted from the observed values of the variables. Hence, within each subject, the demeaned variables all have a mean of zero. For time-invariant variables, the demeaned variables will have a value of 0 for every case, and since they are constants they will drop out of any further analysis. This basically controls for all between-subject variability (which may be contaminated by omitted variable bias) and leaves only the within-subject variability to analyse.

By including fixed effects, we control for the average differences across countries. In other words, the mean for higher-level entity (equation 3) is removed from both sides of equation 2 below. The fixed effect coefficients absorb all across-group action. What is left over is the within-group action. Because FE models only estimate within effects, they cannot suffer from heterogeneity and this approach reduces the threat of omitted variable bias.

Consider fitting models of the form:

$$y_{it} = \alpha_i + x_{it}\beta + v_i + u_{it} \quad (2)$$

Where,

- Y_{it} is the dependent variable where i = entity and t = time.
- α_i (i=1....n) is the unknown intercept for each entity (n entity-specific intercepts).
- X_{it} represents one independent variable,
- β_1 is the coefficient for that independent variable,
- u_{it} is the error term

In this model, $u_{it} = v_i + \varepsilon_{it}$ is the residual and the more interesting coefficient for the analysis is β. The component v_i is the entity-specific residual; it differs between entities, but for any particular entity, its value is constant. The component ε_{it} is the "usual" residual with the usual properties (mean 0, uncorrelated with itself, uncorrelated with x, uncorrelated with v, and homoskedastic).

Whatever the properties of the components v_i and ε_{it}, if (2) is true, it must also be true that:

$$\overline{y_{it}} = \alpha_i + \overline{x_{it}}\,\beta + v_i + \overline{\varepsilon_{it}} \quad (3)$$

Where $\boldsymbol{y_{it}} = \Sigma_t \mathbf{y_{it}} / T_i$, $\overline{\boldsymbol{x_{it}}} = \Sigma_t \mathbf{x_{it}} / T_i$ and $\overline{\boldsymbol{\varepsilon_{it}}} = \Sigma_t \boldsymbol{\varepsilon_{it}} / T_i$, subtracting (3) from (2), it must be equally true that

$$(y_{it} - \overline{y_{it}}) = (x_{it} - \overline{x_{it}})\,\beta + (\varepsilon_{it} - \overline{\varepsilon_{it}}) \quad (4)$$

These three equations provide the basis for estimating β. In particular they provide what is known as the fixed-effects estimator - also known as the within estimator - and amount to using OLS to perform the estimation of (4). For more technical and complete presentations of fixed-effects estimation techniques applications see Baltagi (2008), Wooldridge (2002), Hausman and Taylor (1981), Winship and Morgan (1999) and Hsiao (1986).

8.3.3 Discussion of the results

The aim of the analysis was to understand the differences between countries with regard to expected future changes in the course of technological and socio-economic development in relation to resource productivity. In the simplest terms, past relationships among such variables are measured, and then it is forecasted how changes in some variables might affect the future course of others. However, econometric forecasting for these variables is out of the scope of this study.

We are particularly interested in exploring whether variations in the resource productivity (around their means) are related to variations in employment (around their means) and for this purpose we use a fixed-effects model, considering also differences over time. The basic approach to estimating the effect of a control variable on some outcome is to estimate the cross-sectional correlations between the two over a period of time. We performed a fixed–effect panel data analysis with robust standard errors to account for heterogeneity and lack of normality. We regressed employment level of country i (i = 1, 2,…, 28) over the time period t (2000-2012) on resource productivity[47].

0 summarizes the results of a fixed-effects regression specification model as described in section 8.3.2. The purpose of this first specification is mainly to explore the relationship between resource productivity and employment. A second fixed-effect regression specification (Table 9) adds more control variables in order to capture the impact of other drivers on resource productivity. The reported intercept is the average value of the 28 countries. For instance, 0 shows the intercept of the model (constant term), which is the average of individual group intercepts (-9.14).

This study shows a statistically significant positive correlation between resource productivity and employment (0 and Table 9). In general, there are some concerns that a decrease in the use of resources might cause a drop in the employment level. Resource productivity increases may cause a drop in employment for sectors that are more material dependent, but it may

[47] In a comment provided to the project team after the study, it has been noted that since the estimation period is 2000 – 2012 it includes the severe economic downturn of 2008. There might be a risk that the relatively strong one/two year change of the recession may influence the estimation outcomes. The project team agrees that the financial crisis might have an effect on the estimation. In a follow-up study the exercise could be performed to split the sample in two parts in order to test whether the relationships remain the same.

increase employment level in sectors that are more resource productive, such as recycling industries or industries that use or produce resource efficient technology leading to an overall increase in employment levels.

As mentioned in section 7.2.3, a study by Friends of the Earth Europe (2010) shows that meeting the target of recycling 70% of key materials by 2020 could create up to 322,000 jobs across the EU-27. Observing the relationship of resource productivity and employment in different sectors would give a more comprehensive view.

Table 8. Fixed-effects regression model results (resource productivity dependent variable)

Resource Productivity for EU-28 (2000 – 2012)		
Independent Variables	**Coefficient**	**t-statistic**
Employment per (1000) person	1,04	3.02*** (0.006)
Constant term	-9,14	-3.24 *** (0, 003)
Observations		359
Number of countries		28
Number of years		13
Robust standard errors are in parentheses		
*Significance levels: *** = 1%, **= 5%, * =10%*		
Notes: All variables are in logs. Results are two-step estimates with heteroskedasticity-consistent standard errors.		

Source: own calculation.

Chapter 7 provides several studies that report how industry has improved its resource productivity and the results in terms of environmental, social and economic impacts. Along these lines, it is important to observe the impact of other drivers on resource productivity. For this purpose, we introduced in the model the parameters R&D and energy consumption. Table 9 shows the results of the regression.

The second regression model (Table 9) demonstrates the same relationship between resource productivity and employment. The correlation remains positive and statistically significant, but the effect of employment on resource productivity is smaller when we introduce other control variables in the model. Examining the parameter estimates and their associated statistics, we see that employment, the contemporaneous measure of research and development expenditures has a highly significant effect on the resource productivity, with a coefficient of 0.60. To interpret this result, we have to keep in mind that both the dependent variable (resource productivity) and the independent variable (employment) are expressed in logarithms. **Therefore, it can be said that according to above results a one percent increase in employment numbers is associated with a 0.60 percent increase in the expected levels of resource productivity in the same year.**

The high impact of final energy consumption on resource productivity is surprising, both in magnitude and significance. The value of the coefficient tells us that that if energy consumption were increased by 1%, resource productivity would fall to at least 80%[48]. This could be reflected by the energy mix in Europe, which is based on fossil energy sources and mainly coal for most of the countries. Higher energy consumption influences resource productivity more in the countries that are more dependent on conventional energy sources than in other countries that use alternative sources of energy such as France (which has a high proportion of nuclear power) or Scandinavian countries and Austria (with a large share of hydropower). A panel data anal-

[48] The fixed effect of this variable is the average of the entire sample of countries, expressed by the regression coefficient.

ysis by Steger et al. (2011) suggests that total energy mix in the EU-27 is based more on fossil fuels than in EU-15 countries and thus an increase in primary energy generation per capita leads to decline in material productivity (measured as DMC in kilograms per 1000 US$) in the total panel of the EU-27.

In recent years, R&D has contributed substantially to technological progress. Investing in R&D and using advanced technologies could increase resource and energy efficiency. According to the literature review of Chapter 7.2, innovation (especially eco-innovation) as well as investments in green technologies are a vital part for augmenting resource productivity. The results of this analysis show evidence of a positive and statistically significant correlation between R&D and resource productivity. This means that an increase in the R&D expenditure has a high positive impact on resource productivity.

Our attempt to control for population density in the model revealed a low and not significant impact on resource productivity. The variation of population density is very low over the observed time period and as the fixed-effect model, by default, controls for the time-invariant characteristics, so after this preliminary analysis we decided to exclude that variable from the model.

Table 9. Fixed-effects regression model results (Resource productivity dependent Variable

Resource Productivity for EU-28 (2000 – 2012)		
Independent Variables	**Coefficients**	**t-statistic**
Employment per (1000) person	0,60	2.14 *** (0 .29)
R&D expenditure	0,38	5,99*** (0,064)
Energy Consumption	-0,80	-3,15*** (0,26)
Constant term	-0,24	-0,08 (3,05)
Observations		340
Number of countries		27
Number of years		13
Robust standard errors are in parentheses.		
*Significance levels: *** = 1%, **= 5%, * =10%*		
Notes: All variables are in logs. Results are two-step estimates with heteroskedasticity-consistent standard errors.		

Source: own calculation.

The estimated coefficients show how resource productivity varies with the explanatory variables ("factor effect"). While this approach is an improvement over modelling resource productivity without fixed effects, a direct use of the figures for policy making is not suggested. Studying the relationships between resource productivity and employment in different sectors would give a more comprehensive view and result in more precise estimates. Further analysis, once sectoral resource use data becomes available for each country, would therefore provide a more nuanced understanding of the interaction between employment and resource productivity.

Beyond data availability, the relatively short timeline of the study limited the project team to conduct an in-depth statistical or econometric analysis. Nonetheless, this analysis has the purpose to act as a scoping study and to indicate a way forward for future studies once data becomes available.

8.4 Policy relevant questions linking resource efficiency to jobs

Chapter 7 assessed existing empirical studies regarding how resource efficiency impacts employment. A series of studies report that an increase in resource productivity not only reduces the depletion of natural resources but also supports employment (Chapter 7.2). These findings vary for different activities and sectors. Mainly studies have addressed the relationship between resource productivity, investments in green technologies and job generation. As reported investments in green energies can create more jobs.

Our empirical analysis from chapter 8.3.2 demonstrates a statistically significant positive correlation between resource productivity and employment. In general, there are some concerns that a decrease in the use of resources might cause a drop in the employment level. However, resource efficiency increases may cause a drop in employment for sectors that are more material dependent, whereas it may increase employment level in sectors that are more resource productive, such as recycling industries or industries that use or produce resource efficient technology leading to an overall increase in employment levels. Again, observing the relationship between resource productivity and employment in different sectors would give a more comprehensive view.

The empirical analysis also reveals interesting results that coincide with literature and theoretical analysis as reported in Chapter 7. The results highlight that different types of drivers for resource productivity have different impacts and could therefore be of particular value to policy makers.

- Luintel et al. (2010), by studying 16 OECD countries, showed that R&D was the main determinant of productivity for the period 1982-2004. This study found a significant positive relationship of R&D expenditure and resource productivity for the 28 European member states for the period 2000-2012. Along with the literature and the results of the empirical analysis, R&D expenditure seems to confirm that innovations can reduce the quantity of raw materials used in production and consumption processes and should be of concern to policy makers as expansion of these sources may contribute to resource productivity increase[49].
- Energy consumption is an important driver for resource productivity and indicates the importance of energy efficiency. The study by Kratena and Sommer (2014) suggests that a shift in technological change could also be the outcome of certain policies, such as investment in R&D or taxation of energy and resources.

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[49] R&D and advanced technologies are also of critical importance for resource use and resource productivity and also for energy efficiency. Those countries with higher R&D spending have better resource efficiency. Of course, we cannot exclude third variable biases, such as those countries that use less resources may also be the ones that are funding R&D. For this reason, a more comprehensive analysis should be considered in the future.

Various studies also used scenario analysis to examine the effect of policies increasing resource efficiency and their effects on resource use and employment (see Chapter 7). The majority of these studies conclude that enhanced resource productivity leads to more jobs or, respectively, lowers unemployment.

The three drivers (energy, employment and R&D) which were examined (chapter 8.3) are veritably linked to public policy considerations: energy and R&D are key issues of climate change and a low carbon economy-society, and in response to “green” economy employment opportunities will probably occur in environmentally-friendly sectors. Further detailed analysis, using more potential drivers and applying statistical analysis within sectors, is required to deepen the understanding of resource use and resource efficiency. Moreover, in order to further illuminate the relationship between employment and resource productivity, an explanation on whether employment levels vary across different resource productivity/efficiency policies would be required.

8.5 Number of jobs and job potential

The aim of this section is to assess the impact of resource policy measures on employment, focusing on the improvement of resource productivity and to identify the main policy rationales for a policy aiming to improve resource productivity.

This section also provides examples of how scenario analyses have been applied to cumulative effects assessments and resource managing planning in Europe. This section concludes by presenting a package of scenario strategies that could possibly strengthen the EU-28 economy, promote innovation and resource efficiency which could contribute in a positive way to sustainable development and employment.

A number of studies provide evidence of a positive link between environmental performance and job creation (see chapter 7). The labour intensity of many green sub-sectors is higher than conventional equivalents, which can be a driver for employment.

Based on the results of chapter 7, we ascertained that employment levels demonstrate a high correlation with - and significant effect on - resource productivity (GDP/RMC). High employment levels usually show relatively high resource productivity values. According to the literature review, high employment levels are more likely to arise in sectors where resources are used in a more sustainable way and in general where more sustainable activities are developed. Furthermore, policies stimulating resource productivity often focus on the environmental goods and services sector (EGSS), for instance improvement of the management of waste and resource by promoting the recycling of raw materials. A study from the International Labour Organization (2011) reports examples of sectors and activities that could potentially create new jobs:

- Agriculture, forestry and fisheries i.e. sustainable use of natural resources, organic farming, certified forests
- Waste and resource management i.e. recycling of raw materials
- Energy production and distribution i.e. including biofuels and renewable technology

- Construction, infrastructure and land-related sectors i.e. climate adaptation activities, eco construction, energy and resource efficiency activities
- Transportation i.e. sustainable mobility activities, manufacture of vehicles/equipment, urban transit schemes
- “Eco-friendly” services i.e. eco-tourism, conservation.

Some activities identified above might cut across a number of sectors (e.g. climate adaptation activities and natural resources management). The sectors and activities should be categorized according to the key environment–economy linkages. For example, tourism is an activity that depends on high environmental quality of the destination. Agriculture and fisheries also depend on the sustainable use of natural resources. A study by GHK et al. (2007) describes and quantifies a wide range of links between the environment, economy and jobs. Table 10presents the number of people involved in environmental related jobs[50] in the EU27 for the year 2000 as reported in the study GHK et al. (2007).

Ecorys (2012), found that in 2008, 3.1 million people were employed in the eco-industries[51] in the EU 27. The eco-industry “produces” goods and services to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems. This includes technologies, products and services that reduce environmental risk and minimize pollution and resources”. The sectors fall into two general categories, pollution management and resource management. Additionally, according to the European Observatory of Renewable Energy latest data, in 2010 the Renewable Energy Sector employed about 1.1 million workers in the EU27 (0.5% of total employment).

Even more importantly, according to Eurostat, ‘environment dependent’ activities based on natural resources[52] represent a further important source of direct, indirect and induced employment. In 2007, these sectors employed about 28.4 million FTE individuals, or about 16.7% of the EU working age population. Agriculture on its own employed about 10.7 million. The employment share of environment-dependent sectors was highest most notably in Romania (60%), Bulgaria (40%), and Poland (32%) (European Commission 2012)
In their study, about Resource Productivity and Environmental Tax Reform,

Ekins et al. (2009) report that the environment industries[53] (industries defined as those that reduce pollution and increase resource productivity) in the EU-25 countries provided at least 3.4 million fulltime job equivalents in 2004, with Germany, France and the UK being the leading countries. In 2006, employment in environment industries sector was at least 1.8 million in Germany (4.5% of total employment) and 0.9 million in the UK (3.1% of total employment) (BMU 2007, Innovas 2009).

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[50] The estimated direct employment for each of the environment related activities (Table 8) was assigned to NACE sectors as defined in I-O tables in the study by GHK et al. 2007.

[52] Defined as: non-organic agriculture, organic farming, forestry, fishing, as well as mining, extraction and quarrying, renewable and non-renewable electricity generation ad water extraction and supply

[53] “Environment industries” defined as the industries that reduce pollution, increase resource productivity, or encourage a switch from non-renewable to renewable resources (Ekins et al. 2009).

The employment level in recycling activities in European countries was 611 per million inhabitants in 2007 (EEA, 2011). Water collection, sewerage, waste collection and remediation activities counted nearly 1.6 million employees in 2011. The renewable energy sector employed about 1.1 million workers in the EU27.[54]. The implementation of the Swiss energy efficiency programme "EnergySwitzerland" in 2001, and the support by the Swiss Government and the cantons, triggered private investments of CHF 1065 billion in energy-related projects. Approximately CHF 315 billion were invested in energy-efficiency, mainly in the public authority and buildings sectors. The net employment effect was estimated at about 2,800 persons for a 10 years programme (Rayment et al., 2009).

Table 10. Employment ('000 full-time equivalent) in environmental related activities (EU27, 2000)

Environmental activities	Direct Employment ('000 full-time equivalent)	Indirect Employment ('000 full-time equivalent)	Share of Total Environment Related Employment by Broad Class
Economic activity based on natural resources	17,472	8,847	23% (CORE[55] class) 76% (broad exclude CORE)
Environmental management **(Pollution and resource management)**	1,834	894	31% (pollution management) 8% (resource management)
Environment quality **(Environment related Tourism)**	1,589	1,084	38%

Source: GHK et al. (2007). Links between the environment, economy and jobs

A key issue in environmental policy decisions to increase employment, is whether new jobs are created in sectors that are likely to flourish in the future or are rather sectors in decline. Therefore, positive impacts on future employment levels are likely to arise when environmental policy stimulates greater innovation and growth in these sectors. For instance, the renewable energy sector generates more jobs than the conventional energy sectors. Kammen et al. (2004) found that more jobs are generated per unit of renewable energy produced and also that the R&D investments on this sector have greater returns. Additionally, positive impacts might occur when environmental policy affect resource productivity (Rayment et al. 2009), as further explained in Section 7.4.4.

The same study reports that environmental policies that have an impact on employment in the long term, will have a greater impact on the distribution and composition of jobs, rather than the overall employment. Employment levels are determined by a number of factors, including the size of the labour force, the participation rate and the long run equilibrium rate of unemployment. In addition, policies implementation can create transitional costs associated with sectoral reallocation and job losses. For instance, low skill jobs

[54] Green jobs: Employment potential and challenges
http://ec.europa.eu/europe2020/pdf/themes/19_green_jobs.pdf
[55] For a detailed classification of CORE activities see page 9 in the report by OCDE(1996): http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD(96)117&docLanguage=En

could be created, and put back to work people who were previously unemployed (ibid.).

Nonetheless, many studies indicate that the net impact on employment for the economy has so far been either neutral or slightly positive, which coincides with our findings in Section 8.3.

8.6 Implementing scenario analysis

In this chapter we supplement the analysis of chapter 7.3. We assess some scenarios that are developed in order to reduce resource use and draw some conclusions from this review.

8.6.1 Resource productivity scenarios in the literature

Based on the results of the existing literature, the aim of this section is to look at the trends of employment under three scenarios:

i) business as usual; no policy changes or adoption (continuation of current situation)

ii) intermediate policy scenario; with politically realistic policy changes or adoptions

iii) high (ambitious) policy scenario; politically difficult to adopt but beneficial to resource productivity

Following the findings from the previous sections in this study, and identification of policies concerning the relationship between resource efficiency and labour in other literature, different policies and impacts can be examined under each scenario. The main goal is to explore what can happen to the development of external factors such as employment while strategy scenarios encourage resource productivity. Forecasting or modelling based on predetermined elements goes beyond the scope of this study. However, this section attempts to undertake a review of modelling approaches and scenarios analyses, based around different resource productivity targets, and also intends to give examples for different groups of instruments and their effects.

Before doing so, it is important to acknowledge the limitations behind the scenario models. Creating forecasts is challenging due to the complexity of the economies and political systems, not to mention the huge uncertainties involved regarding unforeseen events. In the scenario design, the analysis of a complex system is required, taking into consideration a number of interdependencies occurring within a system. Therefore, a detailed scenario analysis should be the subject of a separate study on resource efficiency. The approach taken in this study shows a number of scenarios which give a first insight about the range of possibilities.

Table 11 provides an overview of how scenario analyses on resource productivity were developed in different studies, and what their overall results implicate on the number of created jobs. The introduction of different policies indicates that the EU economy would gain, especially in employment terms. This occurs for policies that would encourage the increase of resource efficiency. The table summarizes five studies that explore relationship between resource efficiency and employment, three at the EU level and two other studies carried out at a national level (Austria and Germany).

Table 11. The economic impacts of selected policy scenarios

Features of Scenarios Scenario 1 : Baseline scenario, current situation	Geographical coverage	Year	Target	GDP (%)	Employment (difference from baseline scenerio)	Resource use.	Source
Case 1: Baseline ▪ The baseline scenario describes the expected development of the EU28 resource productivity (GDP/RMC) under current trends and policies. ▪ The baseline scenario takes into account the adopted climate and energy targets in the EU, which results in an increase in bioenergy (+80%) and a decrease in fossil fuels (-22%).	EU28	2030	Improve resource productivity by 0,85% pa	1,6% -1,9% pa	NA	RMC : 0,7% p.a (total increase 14%)	,Cambridge Econometrics et al. (2014)
Case 2: Baseline with high energy prices (BH) – Model E3M3 ▪ An Environmental Tax Reform at the EU level to increase (resource productivity ▪ ETS price of €18 / tCO2 in constant 2008 prices is EU level assumed for 2020	EU27	2020	GHG reduction under constant 2008 ETS prices (€18 / tCO2)	NA	NA	NA[56]	Ekins, P. (2009)
Case 3: Baseline scenario –Model DYNK "Trend" scenario based upon population projections and assuming a continuation of catching up in resource use rates per person (metabolic rates) on the part of emerging economies to the level of industrial economies The Total Factor Productivity (TFP) have been set constant	EU27	2050	continuation of catching up in resource use rates	1.4% p.a	NA	DMC per capita stays almost constant at 16.5 t,	Kratena and Sommer (2014)
Case 4: Business as usual Energy efficiency improvements with current policy situation of year 2005	Austria	2020	Increase of the current share of renewables	2,1% pa	198,000	NA	Stocker et al. (2008)
Case 5 :Reference Scenario This scenario assumed that the already established policy instruments with the aim to enforce renewable energies and energy productivity in firms and households will be further developed so that the set targets will be reached.	Germany	2030	A reduction of CO2-emissions of 54%	3.2% p.a	685,500 pers	NA	MaRess project (2010)[57]

[56] In Stocker et al. 2008, all scenarios focus on heat and power generation. Despite the fact that this study focuses on the promotion of renewable energy, it also promotes the sustainable use of energy source (e.g. the decrease of fossil resource imports in the achievement of a significant CO2 reduction).
[57] The selected scenarios described in the Table 12 by MaRess project (2010) have more the character of a sensitivity study.

Features of Scenarios Scenario 2 : Intermediate policy scenario	Geographical coverage	Year	Target	GDP	Employment(difference from baseline)	Resource use	Source
Case 1 :Modest and flexible improvement The intermediate policy scenario describes a target for the EU28, for a modest improvement in RP (1% pa)	EU28	2030	Improve RP 1% pa	0.2% - 0,6% pa	0.2% - 0.7% pa	RMC :total increase 15%	Cambridge Econometrics et al. (2014)
Case 2a: Environmental Tax Reform or mixed strategy – Model E3M3 I. Environmental Tax Reform with revenue recycling designed to meet unilateral EU 2020 GHG target (high energy prices) I. Mixed strategy: Environmental Tax Reform with revenue recycling designed to meet unilateral EU 2020 GHG target (high energy prices) with a proportion of revenues being spent on eco-innovation measures	EU 27	2020	I. 20% GHG reduction under ETS prices increase to €59/tCO2 I. 20% GHG reduction under ETS prices increase to €53/tCO2	I. 0.2% II. 0.8%	I. 1.1 % II. 1.1%	NA	Ekins, P. (2009)
Case 2b: ETR or mixed strategy – Model GINFORS[58] **I.** Ddesigned to meet unilateral EU 2020 GHG target (high energy prices **I.** Mixed strategy: Environmental Tax Reform with revenue recycling designed to meet unilateral EU 2020 GHG target (high energy prices) with a proportion of revenues being spent on eco-innovation measures	EU 27	2020	I. 20% GHG reduction under ETS prices increase to €68/tCO2 I. 20% GHG reduction under ETS prices increase to €61/tCO2	I. - 0.6% II. - 0.3%	I. 0.4% II. 0.4%	Material productivity: I. 0.91% II. 0.84%	Ekins, P. (2009)
Case 3: "Best practice" scenario **This scenario is implemented in the DYNK model by assuming a shift in the factor bias of technological change without any changes in TFP growth**[59]	EU27	2050	A shift in the bias of technological change	-2.00%	23.26%	DMC per capita : −7.65% (15.5 t/cap)	Kratena and Sommer (2014)
Case 4a: BIO (middle-term oriented) focuses on additional biomass capacity, recycling capacity, land use conflicts with wood, paper and food industry, and biofuels, and also biomass imports.	Austria	2020	Increase of the current share of renewables	NA	15,000 more jobs	NA	Stocker et al. (2008)

[58] For information regarding the model see section 3.1.1, page 70.
[59] This scenario assumes exogenous shocks to occur in European countries. This shocks are implemented in the model by shifting the focus of technological change from labour/capital saving to energy/resource saving (without any change in the overall TFP growth).

Case 4b: STA (short-term oriented) focuses on the extension of wind power and small hydropower for power generation, as well as on pellets for heat generation.	Austria	2020	Increase of the current share of renewables with low cost technologies	NA	10,000 more jobs	NA	Stocker et al. (2008)
Case 5a: Change of value added taxes for traffic services, the introduction of the tax on building materials and the compensation of income taxes.	Germany	2030	- The tax rate for rail road transportation is lowered form is lowered from 19% to t0 7% - The tax rate for air transport services is raised from 7% to 19% - The resource tax rate rises by 5% p.a (4.8 € in 2030)	-0.06%	-0,01 (-5,400 pers.)	DMC : -9.7% TMR:-1,5%	MaRess project (2010)
Case 5b: Recycling scenario Introduction of rules for the use of recycling in the production of non-ferrous metals	Germany	2030	Assumed that in final products a certain percentage of non-ferrous metals has to be of recycled material.	0.04%	0.03% (10,600 persons)	TMR: -8.9%	MaRess project (2010)

Features of Scenarios **Scenario 3: High policy scenario**	**Geographical coverage**	**year**	**Target**	**GDP**	**Employ-ment(difference from baseline)**		**Source**
Case 1: Enhanced or Ambitious and flexible Improvement The ambitious policy scenario describes two cases meeting the target for the EU28, I. An enhanced and flexible improvement in RP (2%), or I. Ambitious improvements in RP (3% pa).	EU28	2030	Improve RP : 2% pa 3% pa	NA	I. 0.3%-1% pa II. 0.5%-0.9% pa *- 1 to 2 million additional jobs are created under this scenario*	Total increase of RMC: I. 30% II. 50%	,Cambridge Econometrics et al. (2014)
Case 2a: Environmental Tax Reform and International cooperation – Model E3ME Environmental Tax Reform with revenue recycling designed to meet the higher 2020 GHG reduction target (high energy prices), in the event that international cooperation on mitigating climate change results from the 2009 Copenhagen climate change conference	EU 27	2020	GHG reduction under ETS prices increase to €204/tCO2	0.5%	2.7 (6 million jobs across the EU)	NA	Ekins, P. (2009)
Case 2b: ETR and International cooperation – Model GINFORS Environmental Tax Reform with revenue recycling designed to meet the higher 2020 GHG reduction target (high energy prices), in the event that international cooperation on mitigating climate change results from the 2009 Copenhagen climate change conference	EU 27	2020	GHG reduction under ETS prices increase to €184/tCO2	- 1.9%	0.8	Material productivity: 1.97%	Ekins, P. (2009)
Case 3 : "Radical transformation" scenario **This scenario introduce a price for CO2 (tax or auctioned permits), where the revenues are redistributed by lower employers' and employees' social security contributions. The price for CO2 is taken from a scenario in the EU roadmap for radical GHG emission reduction (European Commission, 2011a) and starts with 25 €/t CO2 in 2011 and linearly increases 250 €/t CO2 (in 2005 €) in 2050.** **This first simulation experiment can be further complemented by other policy elements aiming at a reduction of material use.**	EU27	2050	GHG emission reduction under prices increase to €250/tCO2	–13%[60]	–1%	DMC per capita : – 19% (12t/capita)	Kratena and Sommer (2014)

[60] The negative GDP impact does not mean that GDP actually declines, but that the average annual growth rate of GDP is lower, i.e. not all DMC and emission reduction is a result of decoupling (Kratena and Sommer , 2014)

Case 4: **Think of tomorrow (long-term oriented) is based on a long-term investment strategy, which is provided by the promotion of costly but very promising future technologies (e.g. photovoltaics, geothermal energy).**	Austria	2020	Increase of the current share of renewables with costly but very promising future technologies	NA	19,000 more jobs	NA	Stocker et al. (2008)
Case 5: Information and consulting program	Germany	2030	All firms of the manufacturing sector will participate in the program	14,2%%	1,9% (696,100pers.)	TMR[61]:-9,2%	MaRess project
Notes: NA- Not available data							

[61] The total material requirement indicator TMR, measures the sum of domestic extraction, imported resources and the contents of materials given directly and indirectly with the imported goods.

Intermediate policy scenarios found in the literature are considered to be feasible for Member States because they include more politically realistic policy changes and room for flexibility. In each of the case study areas described in above Table 11 policy intervention – generally through a policy mix of different instruments – is essential to achieve innovation, resource efficiency, growth and employment.

8.6.2 Conclusion from scenario analyses

The scenario analyses described in this chapter, on the basis of a social-ecological model, suggest that policy design encompasses a series of approaches for a more sustainable Europe in terms of resource use. Such approaches can be the decrease of material resources, the promotion of eco-innovations and stimulation of the development of new technologies. By combining the results of different scenarios, described in above Table 11, some insights and conclusions can be drawn:

- Policies that encourage the reduction of greenhouse gases (GHG) simultaneously promote the concept of eco-innovation and stimulate the development of new technologies.
- An environmental tax reform would raise employment, lower resource consumption and have a small effect on GDP. The use of revenues to reduce labour costs can have very important effects on employment levels.
- A shift in technological change could also be the outcome of certain policies, such as investment in R&D or taxation of energy and resources (Best practise scenario in: Kratena/Sommer, 2014)
- Resource efficiency policies might maintain or increase employment levels even when there is a reduction in GDP growth in the formal economy (see Meyer et al. 2015, Kratena/Sommer, 2014). Stocker et al. (2014) examined whether and how policy measures are able to cope with persistent low growth in the Austrian economy by performing a scenario analysis. Under suitable strategies, a negative economic effects could be reduced and result in positive employment effects.
- The combination of a strongly negative impact on GDP in 2050 (–13%) with a negative employment impact of 1% in 2050 reveals the important substitution effect in favour of labour, triggered by the reduction in social security contributions in the “radical transformation” scenario (Kratena/Sommer, 2014).
- The scenarios that stimulate resource productivity are flexible in the sense that resource productivity can increase in various areas where there are potentials (by material category, sector and country) and the (underlying) targets can be adopted by each Member State according to its socio-economic context.
- A broad array of policy instruments can be used to improve resource productivity. The policies analysed here could be complemented by more policies aiming at the reduction of resource use and material flows.

8.7 Summary and conclusions of the empirical analysis

Using sectoral raw material data (RMI) for the time period 1997 to 2007 for 10 European Member States, the study analysed possible reasons for cross-country variations in the levels of material use. At the same time, links between resource, labour and capital productivity were observed.

One overall conclusion of the comparison is that there are large variations between individual countries over time. Furthermore, differences in the development of the three types of productivities can also be seen across sectors. In most cases, labour productivity shows the highest growth while resource productivity has grown, but at a slower rate. Capital productivity developments experienced much larger fluctuations, whereas most of the time an overall downward trend could be observed.

While a vast amount of studies explored the trends of the three productivity measures at a macro level (whole economy), this study puts forward interesting developments at a sectoral level:

- In **agriculture**, both resource and labour productivity have grown over time, while in general, capital productivity stagnated with the exception of Hungary and Germany. Labour productivity in agriculture increased on average by 3% per year, while the annual average growth rate in resource productivity in this sector was around 1-2%. Hungary’s resource productivity grew on average by 9% per year between 1997 and 2007.

- In **construction**, Member States have seen either a small change or an overall increase in their resource productivity. Meanwhile, their labour productivity as well as their capital productivity (with the exception of Hungary) showed a flat or decreasing trend.

- Just like resource productivity, there was in general a positive trend for labour productivity in the **energy** sector. However, capital productivity in the energy sector showed varying developments when compared to 1995 levels, without any discernible trend. Resource productivity in the electricity, water and gas sector is highly diverse, and reflects the Member States’ various energy mixes.

- Hungary had the highest growth in capital productivity in **transport** in the observed period, and it has maintained its position as the most labour-productive Member State of the sample. Yet Hungary was the least resource-productive country regarding the transport sector.

- Resource and labour productivity experienced positive increases in the **manufacturing** sector, while no overall trend regarding capital productivity could be observed for the selected countries.

- Hungary is the only exception when it comes to capital and labour productivity in **mining**. While the other Member States saw a decline or stagnation, respectively, Hungary experienced an overall increase. However, Hungary was the least resource productive among all the sampled Member States.

In addition, an econometric analysis for EU-28 was part of the study (section 8.3) underlining the driving forces for resource productivity dynamics and assessing the interactions between such drivers in a cross-country overview for the period 2000-2012. Resource productivity dynamics were analysed from a perspective that takes into account relevant socio-economic variables of economies and their innovation systems. The empirical analysis showed evidence of a relationship between employment and resource productivity. Examining the parameter estimates and their associated statistics, it could be derived that a one percent increase in employment numbers is associated with a 0.6 percent increase in the expected levels of resource productivity in the same year.

The empirical analysis also revealed interesting results that coincide with literature and theoretical analysis. The results highlight that different types of drivers for resource productivity have different impacts and could therefore be of particular value to policy makers. Such drivers are R&D expenditure and energy consumption.

However, it also indicates the need of assessing such relationships at a sector level. A sectoral analysis would provide a more comprehensive view as resource productivity increases may cause a drop in employment for sectors that are more material dependent. On the other side, it may increase the employment level in sectors that are less material dependent or more resource productive. Furthermore, drivers such as energy consumption and R&D expenditure have a high impact on resource productivity.

The existing literature in the field of the theoretical analysis of raw material use is limited and in an early stage, which means that many potential drivers can be used to explain patterns in raw material production and consumption in different economies (Steger/Bleischwitz 2011). The typical production function often used in productivity analysis includes labour and produced capital as input factors. There are also some studies mainly focusing on Total Factor Productivity (TFP) growth measures to capture the role of the environment incorporating natural capital as an additional input factor into the production function (Brandt et al. 2013; Brandt et al 2014). As this is a scoping study and the aim was to perform a first quantitative analysis, an empirical model that postulates relationships between data series was examined. The specification of the statistical model captures the essence of the economic theory and literature review.

Furthermore, using employment in terms of employee number as a dependent variable creates its own complexity in a macro level analysis. Among a variety of determinants of employment numbers, appropriate labour measures would also require incorporating the quality of labour inputs accounting for the education level, skills and the employment status. We tested potentially important drivers for resource productivity within a panel analysis. The attempt was to derive empirical evidence on the interactions of a selected set of drivers. The identification of causal relationships is a challenging task in terms of methodology and is beyond the scope of this study. Thus, the team did not seek to provide causal interrelations but empirically-supported relationships.

While conducting the analysis, opportunities and limitations of different approaches could be identified. Randomized experiments have major advantages over observational studies in making causal inferences. In non-experimental studies, researchers try to approximate a randomized experiment by controlling for other variables, using methods such as linear regressions, logistic regressions, or propensity scores. While statistical control can be a useful approach, it has its limitations. One main limitation is that, no matter how many variables are controlled for, it is possible that some crucial variable was left out.

With certain kinds of non-experimental data it is possible to get closer to the virtues of a randomized experiment. Specifically, by using **fixed effect methods**, it is possible to control for potential characteristics of the individuals as long as those characteristics do not change over time. If country fixed effects are excluded and if these unobserved characteristics are correlated with both the dependent variable and one or more included independent variables, an omitted variable bias is at present. However, if country fixed effects are integrated, it is possible to control for all characteristics common to a country and constant over time, removing much of the omitting variable bias.

The scenario analyses described in section 8.6, on the basis of a social-ecological model, suggest that policy design encompasses a series of approaches for a more sustainable Europe in terms of resource use.

8.8 Limitations of the empirical analysis

The empirical analysis of this scoping study enriches the literature review by providing a preliminary empirical analysis to resource, labour and capital productivity. Although the section gave insights on the respective relationships, there are important limitations that must be acknowledged.

Firstly, several **limitations to data availability** need to be emphasized. According to the study request, the analysis should be "based on existing data supplemented where possible by any additional data that is readily available".
The best existing data for resource productivity that was available to the project team in the beginning of the study was data on Domestic Material Consumption (DMC). As previously discussed, the DMC indicator is restricted to consumption of economically valued primary materials, without taking into account unused domestic extraction[62] or indirect flows associated with imports and exports. Consequently, RMI or RMC was chosen to overcome the shortcomings of DMC. However, RMC and RMI data are not available on a sectorial basis. As a result, internally available datasets from a previous study were used with estimations only for two years, 1997 and 2007.

The lack of time series data for sectorial resource productivity at a Member State and EU level inhibited the team to provide a profound econometric analysis on a sectorial level to study the relationship between resource productivity and employment.

In mid-June 2015, Eurostat published a 'country RME tool', including a handbook and a set of data input files on the Eurostat website. This tool allows its users to estimate country-level estimates of product flows in raw material equivalents (RME), such as imports and exports in RME, raw material input (RMI) and raw material consumption (RMC). Since the 'country RME tool' was published at a very advanced stage of this study, it was not possible for the project team to take it into consideration.

Another promising project in terms of resource productivity data is Exiobase[63] - a global, detailed Multi-regional Environmentally Extended Supply and Use / Input Output (MR EE SUT/IOT) database. Version three comprises 200 sectors in 44 countries and 5 RoW Regions for the years 1995-2015. Sectorial data will possibly be available in 2016.

Furthermore, there lacks an appropriate labour measure that incorporates the quality of labour inputs, accounting for skills, gender, education and em-

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[62] Unused domestic extraction is the part of the materials extracted that does not enter into the economy
[63] http://www.exiobase.eu/index.php/about-us/partners

ployment status of the workers. Eurostat, in collaboration with the JRC-IPTS, is currently running a project that aims at improving labour productivity indices by disseminating time series of productivity indicators for Member States. The first dataset will be available in spring 2016 for the years 2002 to 2012. Data on capital productivity should follow in 2016.

In addition, further detailed analysis, **using more potential drivers and applying statistical analysis within sectors**, is required to deepen the understanding of resource use and resource efficiency. Moreover, in order to further illuminate the relationship between employment and resource productivity, an explanation on whether employment levels vary across different resource productivity/efficiency policies would be required.

Beyond data availability, the relatively short timeline of the study limited the project team to conduct an in-depth statistical or econometric analysis. **However, the purpose of this study was to act as a scoping study and to indicate a way forward for future studies.**

9 Integration of resources and resource productivity in the economic model

The overall objective of this chapter is to better integrate resource use/productivity in the economic model. It also addresses how the impacts of resource productivity on employment are considered.

We analyse the following questions:

- How are resources considered in growth theory?
- How do environmental limits and resource constraints impact on growth?
- How are resources currently integrated in economic models?
- What relevant aspects should be considered in order to properly integrate resources in economic models and better link resource productivity to jobs?

9.1 How are resources considered in growth theory?

The environment and natural resources have never found a strong footing in the traditional growth theory. In this paradigm, the ecosystem is theorized as a subsystem of the economy whose main functions are extraction (the environment as a source of natural resources) and waste disposal (as a sink for waste products). Herfindahl and Kneese (1974) indicate as another major aspect that the environment also provides amenity services and general life support for individuals and human societies as a whole. However, it is important to note that they also consider natural resources as (a specific type of) capital, or, rather a production factor, and, as a consequence, assume a high degree of substitutability with manufactured capital goods (Pollitt et al. 2010).

In order to inform policy makers properly about employment and growth effects of resource productivity, resource use must be adequately integrated into economic models. One important issue would be to include natural capital and ecosystem services into accounts of capital stocks and into production functions. The production function should be able to show improvements in resource productivity, separately from total factor productivity. This would allow to include the explicit accounting of energy and material resources. Furthermore, the type of the production function should be able to demonstrate the incomplete substitutability between the production factors (Jackson, 2009).

The original neoclassical growth model (Solow, 1956) explains economic growth only via labour and capital and the exogenous driver Total Factor Productivity (TFP). In fact, any factor which is not identified individually within the production function will cause TFP to rise, e.g. technical innovation, organisational or institutional changes, changes in factor shares, changes in labour skills, scale effects or variations in work intensity. The model worked with the so called Cobb-Douglas production function that assumes perfect substitutability between the production factors and that does not explicitly consider material resources[64].

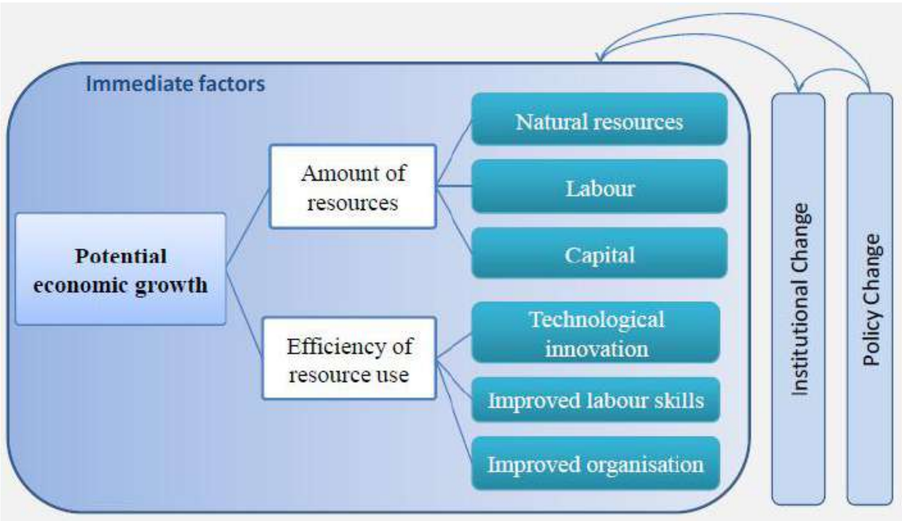
[64] Furthermore, Solow's growth theory assumes that technical progress is exogenous, costless, incremental and automatic, but not necessarily perpetual. So-called endogenous growth theory modifies this assumption.

Generally, the growth model is structured around an approach expressing output as a function of certain factor inputs and of the efficiency with which these inputs are used, i.e. TFP:

Output = F (factors, efficiency)

Thus, two major factors contribute to potential economic growth (output): an increase in factor inputs or resources and an increase in efficiency. Within this equation, resource productivity can either be a new production factor and/or part of TFP (see Figure 37).

Figure 37. Main factors contributing to economic growth



Source: Pollitt et al. 2010.

The question to answer is how much growth comes from improved resource productivity and what are the implications when resource use is treated as separate input factor.

However, adding resource use to the production function in economic models is not straightforward, as the following facts show (see OECD 2015; Baptist/Hepburn 2013):

- In order to consider the environment in measuring productivity growth, one should in principle measure each environmentally related input along with capital, labour and other inputs. Otherwise, measures of TFP growth will be biased by the exclusion of changes in environmental inputs. Similarly, on the output side, the production of environmental externalities such as pollution should be taken into account.
- Some resources are not measured, priced in competitive markets or not even priced at all, in part because many have the characteristics of public goods (non-rivalry and non-excludability). This also relates to the problem that due to externalities social costs are not equal to private costs.
- Market failures may generate measurement difficulties, especially with respect to prices, but are not sufficient to justify excluding non-market resources from a model of productivity growth.

- Many resources are an intermediary product rather than a production factor. Since the processing of materials into (next step) intermediary products is affected by the productivity of labour and capital the question arises how to disentangle resource productivity from labour and capital productivity[65].

In recent years several studies and analyses dealt with the integration of resources in growth models (see Pollitt et al. 2010 for an overview). Early contributions (e.g. Dasgupta/Heal 1979 or Solow 1974) mainly address natural resource inputs as constraint and treat resource consumption as a consequence of growth rather than a factor of production. Di Vita (2007) uses assumptions about the substitution elasticity between primary and secondary material to deduct effects on the growth rate of the economy.

Recent OECD studies (Brandt et al. 2013; Brandt et al 2014) focus on total factor productivity growth measures to capture the role of the environment incorporating natural capital as an additional input factor into the production function. Nonetheless, the impacts on TFP growth have been examined much less than the impacts on output and labour productivity growth, although theory has described possible mechanisms and several studies have explored how environmental policies may have affected innovation and hence TFP growth (OECD 2015).

Concern about the sustainability of growth in the long run has stimulated theoretical research, that is relevant to the impact of the environment and natural resources on long-run productivity growth (see OECD 2015 for an overview). Smulders et al. (2014), for example, analyse the relationship between growth theory and green growth, where longer-term investments in sustaining environmental wealth are balanced against nearer-term income growth to reduce poverty.

Besco (2014) points out that the "literature relating to natural resources and productivity is fragmented, uses different definitions and misleading terms, and lacks conceptual unity. This not only leads to duplication and fragmentation of the research agenda, it is also a barrier to transferring knowledge within the academy and to policy makers" (Besco 2014).

9.2 Resource constraints

9.2.1 How do environmental limits and resource constraints impact on growth?

Natural resources are an important driver of economic growth. If their supply is constrained, negative impacts on growth might be the result. Increases in resource productivity can contribute to improve the environment by reducing the resource use required by human economic activity, and to enhance the conditions for economic growth. Whether such improvements in resource productivity are seen as being necessary depends on the theoretical background that is applied.

[65] Similar arguments can be brought up with regards to disentangling labour productivity from capital productivity. So, this challenge should be manageable.

Hepburn and Bowen (2013) identify three different school of thoughts concerning the extent to which environmental and resource constraints will limit economic growth:

- Economic growth is unbounded,
- economic growth will continue, but will be affected by costs stemming from environmental limits,
- economic growth cannot continue indefinitely.

Depending on the respective viewpoint different policy implications can be derived.

The first perspective supposes that due to technological progress environmental factors constitute **no limitation to economic growth**. This viewpoint forms the basis of most standard **neoclassical and endogenous growth models**. These approaches do not explicitly model environmental limitations and allow for unlimited growth. Thus, there is also no need for political intervention.

As described in chapter 9.1 the original **neoclassical growth model** explains economic growth only via labour and capital and the exogenous driver Total Factor Productivity (TFP). According to Solow sustained growth cannot be supported by capital accumulation only, since returns are diminishing. Indefinite economic growth gets possible in this model trough the introduction of (exogenous) technological progress.

Even the inclusion of natural resources in the neoclassical growth model still allowed for unbounded growth that is supported by exogenous technological progress (e.g. Stiglitz 1974; Dasgupta/Heal 1979).

Over the past 30 years, new **endogenous growth models** (e.g. Romer 1990; Aghion/Howitt 1992) have been developed to consider the fact that the rate of technological progress is itself determined by forces that are internal to the economic system. In these models technical change that is based on the creation of new ideas supports unlimited increase in economic output. Many of these models abstract from environmental limitations. They conclude that infinite growth is not only possible, but a likely outcome.

Some endogenous growth models include environmental limitations, but also conclude that sustained growth is possible. For example, Aghion and Howitt (1998, Chapter 5) and Grimaud (1999) show that, if the elasticity of intertemporal substitution is less than one, growth is sustainable.

The second position presumes that **growth will continue but environmental limits will impose costs to society** (the so called ‘drag’, see Nordhaus 1992). As ‘planetary boundaries’ have been exceeded (Rockström et. al., 2009, Steffen et al., 2015) the consideration of the environmental drag is plausible. This view corresponds to the concept of **Green Growth.** The natural environment is largely provided for free (or too cheap), which leads to market failure. The results are ecosystem degradation, inefficiencies due to waste and a tendency to overexploit natural resources. Growth might be higher, it is argued, if these systematic market failures were corrected. Well-designed market-based policy instruments can move the economy closer to an optimal growth path by improving the efficiency of energy and resource use and creating incentives to develop new environmental technologies and services. These could have a positive impact on both, the environment and economic growth.

Finally, the third perspective assumes that **environmental constraints** will, or at least might, **eventually stop growth**. This viewpoint is widespread in Ecological Economics. Daly, who has advocated “steady state economics” (SSE) and Geourgescu-Roegen (1971), who incorporates the idea of entropic degradation (Second Law of Thermodynamics) as a fundamental constraint on all economic activity, are proponents of such a view. More recently contributions provide Victor (2008) and Jackson (2009).

Daly defines a SSE as “an economy that maintains a constant metabolic flow of resources from depletion to pollution: a throughput that is within the assimilative and regenerative capacities of the ecosystem” (Daly, 2010). It’s a system that permits **qualitative development** but not aggregate quantitative growth. “Growth is more of the same stuff; development is the same amount of better stuff (or at least different stuff)” (Daly, 2008: 1).

Daly criticises the absence of any notion of optimal scale in macroeconomics. Scale has become important because the economic system has grown to a point where its physical demands on the ecosystem are far from trivial. However, macroeconomic theory assumes that environmental sources and sinks are infinite relative to the scale of the economy. According to Daly (1992) the economy is not a closed, isolated system, but a sub-system of the biosphere, receiving and transforming matter and energy. The biosphere serves as both source and sink for the economy. In this context the **decoupling discussion** (see also chapter 6) is relevant, which asks whether a continuous growth evolves along with increasing or decreasing use of nature.

Like Daly, Jackson (2009) argues that, in the long run, **absolute decoupling** is an essential condition for economic activity to remain within ecological limits.

One of the most important messages from Tim Jackson’s analysis is the call for a robust macro-economics for sustainability (Jackson 2009). He highlights that a different kind of macroeconomics that does not rely on ever-increasing consumption growth and that remains within ecological scale is urgently needed but that virtually no attempts have been made to develop an economic model that does not rely on growth. He refers to Daly’s pioneering work to develop the ecological conditions for a SSE, but criticizes the missing ability to establish economic stability under these conditions. As the most notable exception he mentions the work being done by Peter Victor (2009) who shows that even in a rather conventional macroeconomic framework, a new macro-economics for sustainability is not only meaningful but also possible (Pirgmaier et al. 2010).

The work of Ahlert et al. (2014) also provides such a conceptual framework by combining a so-called “positive” model that contains the complex linkages between the environmental, the economic and the social system, and a “normative” model in which the alternatives for action can be located and estimated based on politically, administratively, ethically and socially established goals. The authors explain that within their concept “the notion of social welfare exceeds economic growth and an increase of the GPD as it involves both material and immaterial components of social prosperity. This means that welfare results from the combined application of economic goods and infrastructures (real economic and financial capital), skills and relationships in the society (human and social capital) and the available wealth of a country in the form of resources, ecosystems and their functions (natural capital). In this sense, nature is recognized as an explicit productive factor and not only as a natural resource” (Ahlert et al. 2014).

From this third perspective follows that policy should inter alia comprise measures that aim at a dematerialisation of the economy. This means a focus on the one hand on the input side, as opposed to the emphasis on sinks (emissions). On the other hand, it stresses a broad view of well-being and qualitative development rather than a maximisation of economic value.

9.2.2 How are resource constraints considered in economic models?

Resource constraints are currently not or insufficiently considered, but there are ongoing research activities treating this issue (see e.g. the German SimRess project[66]). Sometimes, the resource scarcity is controlled a posteriori, ensuring that the resource stock will not be passed within the time frame of the simulation. However, the deterioration of the stock does not affect the economy. In the short run this approach might be justifiable, since the negative economic impacts of the overuse of the resources may not be noticed. But in the long term it is unlikely that economic agents do not react to the decrease of the resource stock, especially if physical effects become directly perceivable (TNO 2014).

Some models incorporate the resource constraint by considering resource as an input of the production function (Calzadilla et al. 2010). Since these approaches are rooted in neo-classical equilibrium theory, the demand for the resource is equal to the exogenous given supply at every period. Restricted resources cause lower productivity levels of the other production factors. The restriction of the resource augments marginal costs. If resource availability decreased, the average cost of production increases since a more capital intensive technology has to be applied. As in this approach the supply of the resource is exogenous and the demand follows this level because of the assumption of perfect flexible prices, it is not possible that the demand for the resource is lower than the resource constraint (TNO 2014).

9.3 How are resources currently integrated in economic models?

The assessment of the employment effects of resource productivity improvements carried out in chapter 7 is based on different methods and models, depending on the purpose of the investigation (e.g. assessment on firm, sector or macro level), assessment of long-term or short-term effects, ex post or ex ante assessment, etc.).

No single approach can fulfill every request; the data needed, the levels of details captured differ from approach to approach. The models' abilities to account for interlinkages within the economy and the covered time horizons set the models apart. The used parameters influence data need and outcome: e.g. economy-wide analysis and analysis over longer time horizons have high data requirements, but have only limited resolution (ILO 2013).

It is likely that the debate about resource efficiency policies will gain momentum in the future. For providing adequate policy recommendations the integration of resource use and resource productivity in economic models is essential, but has long been neglected.

This integration is achieved in various ways, ranging from simple parametrisation of resource or emission intensities, to the development of integrated

[66] See simress.de

assessment models which provide feedback into the economy as a result of ecological cost or resource price changes in the wider environment.

Pollitt et al. (2010) state that in contrast to energy, the consumption of (non-energy) resources is barely reflected in existing models, which constitutes an area of potential development. For example, it is often assumed that input factors can be easily substituted for each other. This is however not the case for all types of natural capital (see chapter 9.1 and 9.2).

In the following we describe some modelling approaches that are used to analyse the macro-economic effects of resource productivity increases

9.3.1 Modelling approaches that integrate the environment and resource use

While growth models are generally highly aggregated it seems useful to apply more complex **sectorally disaggregated models** to deal with the sectoral employment consequences of resource productivity increases.

Approaches that are used to analyse the impacts of resource use on the economy (and on employment) comprise input-output (IO) analysis, computable general equilibrium models (CGE), dynamic multi-sector macro-econometric models as well as system dynamics models.

All these modelling approaches are able to combine physical and economic variables. With the development of major global databases, such as WIOD[67] (Dietzenbacher et al., 2013), EORA (Lenzen et al., 2012; 2013) and EXIOBASE (Tukker et al., 2009; 2013) as well as the construction of GTAP-MRIOT (Peters et al., 2011) and GRAM[68] (Bruckner et al., 2012), the possibilities of integrated modelling of the environment and the economy has significantly improved.

Many of the existing models (mainly **Computable General Equilibrium (CGE) models** are derived from **neoclassical or environmental economics and general equilibrium theory**. It is assumed that supply equals demand in all markets by means of market clearing prices. Profit maximization under perfect competition and free market entrance guarantee an optimal allocation and distribution of resources (Dellink 2005).CGE models typically focus on economic relationships, with environmental factors considered as external to the economic system. If external factors are included in the modelling framework, they are often assigned monetary values[69]. In general such macroeconomic models do not properly account for the stocks and flows of natural resources on which economic activity ultimately depends. Some models treat natural resources as (a specific type of) capital or as a production factor, and, as a consequence, assume a high degree of substitution with manufactured capital goods (weak sustainability). (Pollitt et al. 2010).

In general, Computable General Equilibrium (CGE) models have problems to address consistently the price effects of the degradation of the resource stock and the role for anticipation and rational economic behaviour in a context of large uncertainty about the future. Considering these dimensions

[67] The WIOD (World Input Output Database) dataset contains World Input Output Tables (WIOT) in current and previous year's prices, Environmental Accounts (EA), and Socioeconomic Accounts (SEA).
[68] GRAM consists of EE GMRIO tables on the basis of OECD IOTs.
[69] However, CGE models can also include material flow tables and thus integrate physical indicators

increases considerably the complexity of the algebraic and computational resolution since it demands intertemporal maximization resolution techniques (TNO 2014).

There are some efforts to develop modelling approaches that use the advantages of the CGE models, but try to overcome some of their drawbacks. For example, the **Dynamic New Keynesian (DYNK) model** has some connections with DSGE (Dynamic Stochastic General Equilibrium) models that analyse how the economy evolves over time. The term 'New Keynesian' indicates that a long-run full employment equilibrium exists, which cannot be achieved in the short-run, due to institutional rigidities, including liquidity constraints for consumers, wage bargaining and an imperfect capital market. Depending on the distance to the long-run equilibrium, the reaction of macroeconomic aggregates to policy shocks can vary considerably (Kratena/Sommer 2014).

The DYNK model fully integrates satellite systems of physical data of energy and resource use. “The link between monetary and physical data is established at the disaggregated level of single commodities (for monetary data) and energy and material flow categories (for physical data). The model explicitly deals with prices of energy categories and import prices of primary products. The price system of the DYNK model also incorporates consumption taxes (taxes less subsidies) and taxes on factors of production. These model features allow for the implementation of environmental tax policies as one instrument to reduce resource use per unit of output” (Kratena/Sommer 2014).

Parallel to CGE models a second important modelling approach has been developed: **multi-sector macro-econometric models**. In contrast to CGE models, macro-econometric models are based on empirical relationships and are developed using large-scale (usually time-series) data sets. The parameters of the equations are estimated with formal econometric methods which are integrated into a framework based on national accounts and are also often extended into other areas. The main assumption is that historical behavioural relationships remain valid in forward-looking projections. The mentioned example of macro-econometric models, which is a multi-country/multi-sector integrated economy-energy-environment models, is based on ‘complexity economics’ (Beinhocker, 2007), considering institutional, evolutionary, and chaos theory rather than the traditional equilibrium-rationality theory of CGE models.

System Dynamics models have a strong root in Ecological Economics, stemming most notably from the Club of Rome’s ground-breaking Limits to Growth report (Meadows et al 1972). System dynamics models allow to explore key economic relationships, for instance between consumption, savings and investment, between the private and the public sector, between enterprise and households, in an ecologically constrained economy.

System Dynamics most commonly describe “what if” relationships, analysing what would happen in case a policy measure is implemented at a specific point in time and within a specific context. Thus, Systems Dynamics is helpful in exploring scenario development over time that help to understand what the main driving forces for the behaviour of the system analysed are. The selection and representation of causal relations helps to identify feedback loops, nonlinearity and delays (UNEP 2014a).

The structural form of systems dynamics enables a consistent understanding of stocks and flows, and the relationship between them. „It allows considerable user interaction in the specification of exogenous variables and facilitates a collaborative (visual) understanding of both the model structure and the scenario results“ (Jackson et al. 2014). Simulation models propose a theory of their own that is highly customized and tailored around the problems that should be analysed. These simulation models are limited by the correct definition of the system’s boundaries and a realistic description of the interactions and causalities that describe the functions of the analysed system (UNEP 2014a).

In the following, we illustrate in which way resource use and resource productivity are considered in the mentioned different modelling approaches (such as CGE models, macro-econometric models, input-output models, system dynamic models, Dynamic New Keynesian model). For each mentioned modelling approach one model will be considered, that already puts some effort on the **integration of resource use** in the model.

- GEM-E3, a multi-country computable general equilibrium model developed to evaluate the economic impacts of structural policies and the interactions between the economy, the energy system, the environment and the technological progress. GEM-E3 is based on neoclassical theory, assuming an optimal allocation and distribution of resources. [70]
- EXIOMOD, a global multi-country computable general equilibrium model allowing for a comprehensive analysis of the economic pressures on the environment.[71]
- DYNK, Dynamic New Keynesian model for Europe that has some similarities with DSGE (Dynamic Stochastic General Equilibrium) models, as it explicitly describes an adjustment path towards a long-term equilibrium.[72]
- GINFORS$_3$, a global multi-country, multi-sector macro-econometric model (also able to developed to evaluate the economic impacts of structural policies and the interactions between the economy, the energy system, the environment and the technological progress) that does not rely on long run equilibria of competitive markets or Say’s law for a macroeconomic closure; GINFORS assumes that agents have to make their decisions under conditions of bounded rationality on imperfect markets, with information deficits.[73].
- WORLD5, a global single-region System Dynamics model represented by five main modules: a population module, an economy module, a land and food module, an ecology module and a resource module.[74]
- FALSTAFF (Financial Assets and Liabilities in Stock and Flow consistent Framework), a System Dynamics model that combines the real and financial economy in a single model, in the context of ecological and resource constraints.[75]

[70] For a documentation of the model see Capros et al. (2013)
[71] For a short model description see TNO (2014).
[72] For a short model description see Kratena/Sommer (2014).
[73] For a short model description see Distelkamp/Meyer (2014).
[74] For a short model description see Koca/Sverdrup (2014).
[75] For a short model description see Jackson and Victor (2015).

In the following we shortly describe how these models integrate resources. More detailed explanations can be found in the respective model documentations.

The model **GEM-E3** is a multi-regional, multi-sectoral, recursive dynamic computable general equilibrium (CGE) model that provides detailed information on the macro-economy and its interaction with the environment and the energy system. In GEM-E3 the economic system remains in general equilibrium. The model includes micro-economic mechanisms and institutional features within a consistent macro-economic framework. It also provides insights regarding the distributional aspects of long-term structural adjustments.

The GEM-E3 model is broadly used as a tool of policy analysis and impact assessment, mainly with regards to the economics of climate change. It includes a detailed specification of the energy system and greenhouse gases. There are three mechanisms of emission reduction explicitly specified in the model: (1) substitution between fuels and between energetic and non-energetic inputs, (2) emission reduction due to a decline in production and consumption, and (3) purchasing abatement equipment (Capros et al. 2013).

GEM-E3 integrates material inputs in the production function. Production is modelled through KLEM (capital, labour, energy and materials) production functions involving many factors (all intermediate products and three primary factors –capital, natural resources and labour). Their productivities, elasticities, scales, and rates have a stochastic representation. Production functions are based on a CES neoclassical type[76]. The exact nesting scheme of production in GEM-E3 has been selected to match available econometric data on KLEM substitution elasticities. Material inputs are further divided in its component parts (e.g. agriculture, industrial activities, services etc.). Technological change with respect to these materials is an exogenous variable. Sectoral growth also follows exogenous expectations. Reserves of exhaustible resources are considered to be a discrete production factor. The calculation of the international price of fossil fuels enables the balance of total supply and total demand. "Reserves are subject to depletion at an exogenous growth rate. The exogenous growth rate is calculated based on the remaining reserves, the production of fossil fuels and the yet to find reserves" (Capros et al. 2013).

EXIOMOD incorporates the representation of all major environmental effects related to production and consumption choices of households and firms. The model includes 171 different types of material resources, provided by EXIOBASE. Moreover, it includes a physical (in addition to the monetary) representation for each material and resource use per sector and country. It also incorporates the modelling of the treatment of waste and recycling by type of waste. Furthermore the model includes the representation of 28 types GHG and non-GHG emissions and land use (15 types) (TNO 2012).

Production costs of each sector consists labor costs by type of labor, capital costs and the costs of intermediate inputs. The sector's technological constraint determines the production technology of each sector. It describes how many of different units of labor, capital and of the 129 commodities and services, traded in the economy, are necessary for the production of one unit of the composite sectoral output. Technological substitution of sectors exists between different intermediate inputs and production factors. They can sub-

[76] CES means constant elasticity of substitution, i.e. a constant percentage change in factor proportions due to a percentage change in marginal rate of technical substitution.

stitute between the use of different education types and between different occupations within each education type. They are also able to substitute between their consumption of electricity and other energy types such as gas, coal, oil and refined oil (TNO, 2012).

The model is presently calibrated on the data for 2007, but there is ongoing work to recalibrate the model using the available macro-economic data from national accounts for 2012. The model is dynamic and allows simulations until 2030 (TNO 2014).

The global multi-country, multi-sector macro-econometric model **GINFORS** fully integrates economic development with activities in the energy system (supply and demand) and environmental emissions through explicitly defined two-way linkages. This structure has been extended to include industry demand for raw materials. GINFORS includes a resource module that consistently links the resource extractions in physical units to the energy system as well as the whole economic and bilateral trade system.

Distelkamp and Meyer (2014) explain that the general approach used in GINFORS for the modelling of the extraction of 12 kinds of materials in tons is that “first an intensity in relation to an economic driver in local currency and constant prices is defined, which can be observed historically. In the forecast the multiplication of this driver with its corresponding trend dependent intensity gives the extraction in physical terms”.

In contrast to many other models GINFORS covers the whole world: 38 national economies (including 27 EU Member states) and a region “Rest of World” are individually represented within a dynamic Multi-Region Input-Output modelling framework, enabling that the global resource extractions are explained endogenously. “Therefore in scenario analysis all direct and indirect effects are included and there is no need for assumptions like “domestic technology” to derive figures for the resource inputs or consumption in raw material equivalents” and “ […] it is possible to calculate not only the domestic part of the resource use indicators but also the indirect uses due to imports of semi-finished and finished products” (Distelkamp/Meyer 2014). Thus, GINFORS allows to simulate global developments until the year 2050, including national and regional projections of the most important indicators used in the discussion on material use (like RMC or RMI)

However, GINFORS provides lower detail with regard to the classification of resources in comparison to the EXIOMOD model. But up to now availabilities of time-series data especially with regard to detailed economic (input-output) data restrict further developments in this direction. (The current GINFORS version is based on the WIOD database and therefore restricted to WIOD classification schemes).

While EXIOMOD (based on the year 2007) has to follow a fixed input-output structure, in GINFORS rates of material intensity can change over time and in response to price and other economic factors. This allows for ex ante assessments of policies for reducing material consumption within a full macroeconomic framework.

The **DYNK** (Dynamic New Keynesian) model also employs an input-output framework to model the structure of industry and its implications in terms of resource requirements and ecological impacts. The model is characterized through its detailed modelling structure of consumption and production activities. The EU 27 is treated as a single integrated economy and traces the inter-linkages between 59 industries as well as the consumption of five household income groups using 47 consumption categories. Physical input demand in the DYNK model comprises energy inputs (in TJ) by user and energy category as well as material flows (in 1,000 t) for domestic extraction, imports and exports by material flow category. Materials are differentiated following the standard categories of Material Flow Analysis (MFA), as contained in the Environmental Accounts of the WIOD database (biomass, fossil fuels, minerals for construction, metal and other industrial materials).

Kratena and Sommer (2014) explain that “different sources of technical change are modelled at the disaggregate level: TFP, factor-bias and material efficiency in production and energy efficiency in private consumption. These components of technical change drive – together with relative prices – economic growth and resource use and therefore decoupling.”
One main drawback is that technical progress is only partly modelled at a detailed level. Thus, policies can only indirectly be applied (by using some other partial analytical models) in order to redirect technical progress in a resource-saving direction (Kratena/Sommer 2014).

The current version of **WORLD model** from Lund University includes a resource module that Koca/Sverdrup (2014 describe as follows: “With ongoing WORLD model development work, some of the key abiotic and biotic resources are being implemented into the Resources Module. Abiotic materials i.e. metals (iron, aluminum, copper), industrial minerals (i.e. phosphorous) and construction minerals do not disappear from the closed biophysical world system. However, when they are used, they get dissipated further and further until their density gets so low. Hence, recovery of metals, as well as industrial and construction minerals is possible, but limited to the available energy and cost of it. Different from metals and minerals, fossil energy resources (oil, gas, coal, nuclear) do get disappear in the closed biophysical world system once they are used. Thus, recovery of these resources is not possible. These issues are all addressed and calculations are made in a sub-module called abiotic materials within the resource module.

Biotic material i.e. biomass is both a renewable resource and its recovery is possible. In this context sustainably managed biomass resources provide renewable biobased energy sources (biofuel). A submodule called biotic materials quantifies the biobased material and energy. The effect of technological advancements in energy and metal sectors is also accounted in the resource module within the WORLD model. Through more advanced technologies, the use of available resource more efficiently are taken into consideration in the model. However, these efficiencies always stay within the limits of thermodynamics.”

The model **FALSTAFF** has the intention to show the interactions between three important aspects:

- the ecological and resource constraints on economic activity;
- a full account of production, consumption, employment and public finances in the ‘real economy’;
- a comprehensive account of the financial economy, including the main interactions between financial agents, and the creation, flow and destruction of the money supply itself.

The aims of FALSTAFF are the following (Jackson/Victor 2015):

- to show the real and financial implications of the shift towards green investment;
- to develop a coherent financial architecture in the context of changing investment patterns;

- to explore monetary reform to facilitate the transition to a sustainable economy; and
- to test the viability of a transition to a non-growing economy.

The approach is based on post-Keynesian theory in the sense that the model is demand-driven. The relations between six financial sectors (households, firms, banks, government, central bank and the foreign sector) are depicted.

The level of green investment is given exogenously and calibrated against known policy targets and proposals for decarbonisation, resource decoupling and the protection of natural capital and ecosystem services. The productivity of green investment and the degree to which it contributes to the productive capital stock are important determinants in the model. They are set exogenously in order to allow the exploration of the implications of different scenarios.

There are also some **efforts to integrate different models into one modelling framework** in order to improve the integration of resource constraints in economic models: In the POLFREE project the economic environmental models GINFORS and EXIOMOD are linked to the biophysical model LPJmL[77] in order to integrate the use of water and land (see Distelkamp/Meyer (2013) as well as TNO (2013) for details).

In the project WWWforEurope – Welfare.Wealth.Work[78] a purely biophysical approach to scenario development is mixed with macro-economic modelling. The biophysical approach is based on observed dynamics of resource use and emissions and potential reductions due to efficiency gains and changes to consumption and production. Based on the DYNK model taking into account macro-economic feedbacks and endogenous long-run growth paths, it was examined whether these kinds of reductions can be achieved with various policy instruments. This approach allows for a) an assessment if an absolute decoupling and the necessary reductions can be accomplished and which measures are appropriate, and b) an evaluation of the socio-economic impacts and potential disadvantages associated with these instruments.

In the SimRess project the strengths of the both models GINFORS and WORLD5 should be integrated into one dynamic structure, to develop a powerful decision support tool for the analysis of the effectiveness of various resource policy measures in Germany.

All three projects are ongoing. Hence, the final results are not yet available.

[77] The model LPJmL ("Lund-Potsdam-Jena managed Land") is built to simulate vegetation composition and distribution as well as stocks and land-atmosphere exchange flows of carbon and water, for both natural and agricultural ecosystems (see https://www.pik-potsdam.de/research/projects/activities/biosphere-water-modelling/lpjml).
[78] See www.foreurope.eu

9.4 What relevant aspects should be considered in order to properly integrate resources in economic models and better link resource productivity to jobs?

9.4.1 How could policy relevant questions linking resource productivity to jobs be answered?

In section 7.4 we have analysed the employment effects from different drivers of resource productivity changes and stated that the combined use of all measures is relevant for substantial resource productivity increases. For an appropriate assessment of its impacts on growth and employment it is not only necessary to adequately **integrate resource use/productivity, but** also to address the **economic mechanisms** associated with drivers of resource productivity in the modelling framework. Our literature review on the integration of resource productivity in economic models suggests to (better) incorporating the following themes/aspects:

- Consideration of physical limits, resource stocks and constraints
- Production- and consumption based approaches
- Full integration of resource flows (two-way linkages between environment and economy)
- Illustration of technological change
- Consideration of structural change
- Consideration of price and cost effects
- Consideration of different forms of investment
- Allowing for institutional changes
- Detailed representation of the labour market
- Uncertainty and risk

In the following it is described why these themes are important.

9.4.1.1 Consideration of physical limits, resource stocks and constraints

UNEP (2014a) postulates that “models should include the explicit biophysical estimation of natural resource stocks, ecosystem services and ecosystem goods. These three elements should be directly connected to the economic and social sectors, in accordance with the service provided”.

Jackson et al. (2014) state that one of the most notable shortcomings of traditional economic models is „their failure to account properly for the stocks and flows of natural resources on which economic activity ultimately depends“.

Current models are usually based on the assumption that resource use is demand driven and that the supply of resources follows demand. Therefore, a deteriorating resource stock will not be considered in the economic choices of agents. This does not correspond to reality, where economic variables are in fact influenced by certain resource constraints (TNO 2014). If physical limits, such as maximum carrying capacities are not covered, models skip a wide range of factors, such as price changes of scarce material inputs or non-linearities in impact (Pollitt et al. 2010). Furthermore, the environmental consequences of transforming stocks are only simplistically modelled, because of high requirements for detailed data and work-time involved (Pauliuk et al. 2014).

It is important to adequately integrate the demand for natural resources in physical terms into the economic system, which among other things means that the interaction of supply and demand has to be considered. Concerning the integration of resources a commonly used distinction comprises fossil fuels, construction minerals, metallic minerals, biomass, water and land.

Pollitt et al. (2010) point out that a comprehensive analysis must comprise the inclusion of the demands for the most important groups of resources, and, where possible, available stocks or carrying capacities in macroeconomic models as well as allow supplies to influence behaviour (for example in price formation in the model structures). The last point requires a high research effort as "the behavioural responses to extreme outcomes are unpredictable. However, the other steps are all possible with given model frameworks and supplementary analysis, and the modelling approach required is close to that already applied for energy use" (Pollitt et al. 2010).

Currently available (sustainability) models are mainly designed in flow-oriented paradigms that neglect the dynamic interaction with stocks and the important role of the substitution of flows by stocks in order to reduce material throughput. Wiedenhofer/Fischer-Kowalski (2015) point out that "in macro-economic models capital is usually only represented via its monetary value on capital costs, depreciation and relative prices, without much technical or biophysical information on the stocks of capital and infrastructure themselves". Exceptions are System Dynamics approaches, such as the models WORLD5 and FALSTAFF (see chapter 9.3).

9.4.1.2 Production and consumption based approaches

Macroeconomic analysis should include both a production perspective of resource use stressing the use of resources in national production and a consumption perspective covering the appropriation of resources for national consumption (Røpke 2011).

While the production-based approach assesses the resource use taking place within a country/region, including resource use required to produce both domestic final consumption and exports, the consumption perspective includes the domestic production for final consumption as well as the total direct and indirect resource use associated with imports serving domestic final consumption (Giljum et al. 2014). Thus, a consumption based perspective considers whether productivity gains in industrialized economies might in fact be due to outsourcing of material consumption. Both approaches deliver valuable information. The consumption-based perspective provides information how (much) a country depends on foreign resources and the use of global absorptive capacity for emissions (e.g. Schaffartzik et al. 2013, Wiedmann et al. 2013). The production-based perspective enables a comparative analysis of labour, capital and resources on regional and global levels, which can be used to further analyse their respective productivities (see also the discussion on indicators in chapter 4.2).

9.4.1.3 Full integration of resource flows (two-way linkages between environment and economy)

A more systematic way of modelling the two-way linkages between the environment and the economy could lead to a better integration of resource flows in economic models. Pollitt et al. (2010) state that "[…] environmental factors are usually only allowed to influence the economy through price-based measures, such as taxation. Other environmental impacts, such as loss of tourism due to degradation or loss of ecosystem services, are often excluded“ (Pollitt et al. 2010).

While some material inputs are exhaustible natural resources, others are renewable to differing extents. The supply of each renewable input depends on the state of its supporting ecosystem. In principle, one should measure each environment-related input along with capital, labour and other inputs (OECD 2015).

9.4.1.4 Improving the illustration of technological change

The illustration of technological change requires a careful representation of the production process and the use of goods, capital and the appropriate technology. Technological change can be modelled in terms of substitution between different technologies and/or in terms of changes in individual technologies (Luptacik/Stocker 2005).

The way in which energy and materials are transformed in the economic process mainly depends on the state of technological knowledge. This implies that technological progress may change the composition of the material basis and the environmental impacts of economic processes (Mulder et al., 1999). It is connected with material and product substitution, since it can facilitate substitution and recycling. It can also lead to changes in product design or process efficiency, thereby allowing for reductions in the quantity of material used for a product (Elshkaki et al., 2004).

9.4.1.5 Consideration of structural change

The shift to a resource-efficient economy is associated with restructuring impacts throughout the economy, both in the short and long term. Whereas some sectors will experience a higher demand for specific goods and services, others will have to face increased resource costs and a drop in demand. Economic models must be able to show these structural shifts. A sectoral model enables to identify specific burdens to different sectors or societal groups and to offset them by supporting measures. Thus, the transition to sustainable development can be achieved without major social and economic trade-offs (see e.g. Duchin 1998).

It is not only important to take into account the direct changes in resource and labour intensity on the firm level (for example a new production process with higher labour productivity). There are also indirect effects such as interlinkages with other sectors and net changes in investment requirements as well as compensatory effects of cost changes and their transmission into the overall economy that have to be considered (Walz 2011).

9.4.1.6 Consideration of price and cost effects

As many resource productivity policies focus on price changes, an important issue is the capability of the model to show **price and cost effects** and their impacts on the labour market (global resource price dynamics, national cost dynamic of factor inputs, reaction of output prices and wage, resulting income effects).

Furthermore, the costs of additional technological change induced through innovation, environmental or industrial policy etc. should be addressed. The proper assessment of a potential double dividend stemming from the introduction of resource taxes (as part of an environmental tax reform that reduces taxes on labour) will also have to be taken into consideration (Walz 2011).

Compensation effects can be split up into price, income and technology multiplier compensation effects. Assuming a competitive market, the compensation occurs through changes in output prices. The consumption of all goods will adapt according to their price elasticity. Transferred via the adjustment of the wages, this form of compensation will change consumption according to the income elasticity of demand. Finally, if the compensation is transferred via increased profits, effects on investments of firms may result (ibid).

Income multipliers and accelerator effects are relevant, if short term measures are considered (e.g. green stimulus programmes) that may have an impact on the business cycle. However, in general any policy supporting environmental innovations will be designed for the medium to long term. Thus, it is necessary to demonstrate its implications from the beginning.

9.4.1.7 Consideration of different forms of investment

Investments in environmental innovation can crowd out other investments, which may have productivity effects. The overall effects of environmental innovations on productivity are determined both by the direct character of the eco-innovation and by the effects on the volume of investments.

9.4.1.8 Allowing for institutional changes

The transformation towards a resource efficient economy would involve radical institutional changes – implying changes of the causal relationships – that should be incorporated in economic modelling frameworks.

Røpke (2011) points out that “macroeconomic models are based on given institutions. Minor institutional changes may be analysed in the models, such as changes of pension schemes, unemployment benefits or tax rates, but the transformations needed to cope with the large challenges would involve more radical institutional changes – implying changes of the causal relationships. […] Presently, many sensible political measures are ‘shot down’ because they would create problems within the given institutional framework, and this may call for changes of the framework rather than giving up the measure. Free movement of capital across borders is an example of an institutional framework that limit the political space of action“.

9.4.1.9 Detailed representation of the labour market

The representation of the labour market should consider the **quality of labour inputs**, accounting for skills, sex, education and employment status of the workers.

Hepburn and Bowen (2013) ask for “the combination of microeconomic evidence about key labour market parameters with more realistic models of how labour markets actually work at the aggregate level, bearing in mind that there are important differences across countries at different levels of development and subject to different macroeconomic pressures."

Key differences that have often been neglected include (Hepburn/Bowen 2013):

- The reasons for existing unemployment,
- the influence of market institutions on wage setting and the provision of training,
- the ease with which workers can find new jobs in different sectors and locations,
- the competitiveness of labour markets, and
- the reach and terms of public employment promotion, taxation and social benefits.

9.4.1.10 Uncertainty and risk

The impact of risk and uncertainty on environmental and economic processes is another important issue that should be addressed in economic models. For example, the resource use is subject to uncertainty over the future demand for the resource, or over the reserve base that will ultimately be available for exploitation. These uncertainties are likely to be present in most exhaustible resource markets, because of the inherent long-run dynamics involved in resource production.

Most economic models abstract from the problem of uncertainty. In practice, economic agents must deal with changing scarcities of natural resource inputs and, in some cases, volatilities in prices and decide whether these changes must be seen as long-run developments or short-run fluctuations (OECD 2015). Thus, uncertainty has an impact on human behaviour, particularly in the case of investment decisions.

In addition, uncertainty can also result from the model itself and its various assumptions. Using different input assumptions (sensitivity analysis) can help to address this kind of uncertainty (Pollitt et al. 2010).

10 Summary and Conclusions

The aim of this scoping study is to provide an overview on literature findings showing how resource efficiency affects labour productivity and employment. Due to the broad scope of this topic we integrated all relevant questions in a storyline that provides an insight on the links between all aspects addressed. The approach is centred on economic growth and incorporates the influences of the production factors (capital, labour and resources) as well as the impact of their productivities on growth. To some extent, the relations between the productivities and the production factors are also taken into account. This framework is intended to show in what larger context the question can be seen.

10.4 Historical trends

In order to better understand the relationships between resource and labour productivity we first analysed **historical productivity trends** on a macro as well as on a sectoral level. The description of the development of resource and labour productivity reveals that resource productivity has been increasing in the past decades, however at a lower rate than labour productivity.

Recent trends as well as scenario analyses suggest that further progress in resource efficiency is possible and can have positive employment effects.

While **labour productivity** constantly rose from 2000 until 2007, it slightly decreased during the economic crisis because less GDP was generated with an almost constant labour input. While there was a decline in 2010, labour productivity increased again from 2011 onwards. **Resource productivity** improved by 17% between 2000 and 2009. In 2009 resource productivity rose significantly during the economic crisis, which affected the material-intensive industries much more than the services industries, leading to a reduction in overall material consumption. As in the case of labour productivity, resource productivity decreased in 2010, but increased again after this decline. **Capital productivity** remained almost constant from 2000 until 2007. With the economic crisis, it dropped considerably implying that more or less the same level of annual physical capital consumption generated less GDP (Moll et al. 2012). After 2009, it developed constantly, at a lower level than before the crises.

RMC and material footprints would be more appropriate indicators to measure resource productivity, as they include the effects of displacement of resource intensive industries to other regions of the world. Whereas studies based on DMC data have found a relative decoupling of resource use and GDP for developed countries in the last decade, calculations based on RMC or material footprint data could not support this result.

For a more conclusive analysis, further efforts are necessary to improve the data situation.

The amount of resources used in production is directly determined by the price. The slower increase of resource productivity might thus be (partly) explained by the fact that the costs of labour grew faster than the costs of materials inputs over the last 50 years. The price of resources remained more or less constant during the 20th century.

But the development of resource prices has decisively altered since the turn of the century: After 2000, resource prices have more than doubled and the average volatility has been about three times higher than in the 1990s.

It is estimated that labour costs make up around 20% of total costs in manufacturing industries, while **material costs** account for 40%. The latter, however, comprise some labour costs accruing further up the supply chain. It was found that previous studies do not provide much information on the respective shares of labour and capital costs embodied in material costs. Further research is thus needed in order to give an estimate of the actual share material costs have on the entire production costs.

Global consumption growth and the anticipated supply-side challenges might indicate a period of intensified resource stress that has just begun. This situation comes with increasingly high and volatile prices, growing environmental pollution, increased risks of supply shortages and disruptions, as well as political conflicts about controlling and accessing resources (Lee et al. 2012).

Today, one of the most pressing and politically sensitive issues for governments and businesses is how to respond to volatile resource prices. Short periods of high volatility have periodically occurred during the last decades; however, since the early 2000s sustained high levels of volatility across the commodity markets can be observed, which is an unprecedented situation so far (ibid. 2012). Some researchers as well as a wide range of European companies expected resource prices to continue to increase in the next years. However, forecasts of resource and energy price indices until 2025 by the World Bank do not support the assumption of strongly rising prices in the future.

While a large number of studies explored the trends of the three productivity indicators at a macro level (whole economy), only little effort has been made to provide information on a sectoral level. Thus, in the course of this scoping study an **empirical analysis** of resource, labour and capital productivity was carried out for ten EU countries and on a sectoral basis.

Due to the large proportion of minerals, sand and gravel in the overall material flows of the economy, the construction sector is the most resource–intensive sector in the economy. Agriculture, due to the high portion of biomass use, is the second most intensive sector followed by food manufacturing with a high percentage of biomass use and a significant portion of fossil fuels. Fossil fuels are also used extensively in the manufacture of petroleum and coal sector, which is the fourth most intensive sector in the economy. The energy supply sector follows closely, again with a high portion of fossil fuels input. The business services sector is the sixth most resource-intensive with high shares of material inputs like minerals and fossil fuels. Transport follows as the seventh most intensive sector with high portions of fossil fuel inputs. It can be observed from the table above that the most material intensive countries are those with the biggest economies like Germany, France, Italy, United Kingdom and Spain (BIO/SERI 2013).

In general, labour productivity increased as compared to 1995 levels, but differences in the sectors can be observed and are significant. Increases in labour productivity were often higher than 50% and sometimes even doubled in sectors such as energy, agriculture and manufacturing in the observed period (1995-2007) in several countries. The only sector that showed stagnant labour productivity growth was the construction sector, with only mild growth observed in the UK.

From the analysis one can conclude that there are large variations between individual countries over time. Furthermore, differences in the development of the three types of productivities can also be seen across sectors. In most cases, labour productivity shows the highest growth while resource productivity has grown slower. On average, resource productivity has improved, except for the transport sector. In other words, economies were in general able to create more value per ton of resources used. Capital productivity developments experienced much larger fluctuations, whereas most of the time an overall downward trend could be observed. One can compare the differences in each of the productivity indicators between countries, however, the results do not allow for inferring relationships between the indicators.

10.5 How and to what extent does resource productivity impact on growth and resource use?

Concerning the **linkages between resource productivity and growth** it was theoretically and empirically shown that on the one side increases in resource productivity have positive economic effects and on the other side economic growth do also positively affect resource productivity.

Empirical evidence confirms that positive net effects of improved resource productivity on GDP arise if the benefits of higher productivity levels outweigh the costs of achieving greater efficiency: According to a scenario analysis by Cambridge Econometrics et al. (2014), for the EU this is the case for resource productivity improvements up to 2.5% p.a. Beyond this rate, however, further improvements in resource productivity would lead to net costs for GDP as the abatement options become more expensive.

There are several further studies based on scenario analyses (e.g., Stocker et al. 2007; Giljum et al. 2008; Wuppertal Institute 2010; Meyer et al. 2011; Cambridge Econometrics et al. 2014; Meyer et al. 2015; etc.), evaluating the economic impacts of policies to increase resource productivity. Apart from baseline scenarios, these studies assess the economic effects of various alternative scenarios leading to higher resource productivity. Most of these studies come to the conclusion that an increase in resource productivity is associated with GDP growth.

Besides these studies examining the effects on the macro level, a range of studies analyse the cost-saving potential of implementing low-carbon and resource efficient technologies on the **company level** (see e.g. Aachener Stiftung Kathy Beys 2005). By applying production-integrated environmental protection techniques, material throughput costs can be decreased by about 20% (Arthur D. Little et al. 2005, Fischer et al. 2004). It has been estimated that the current inefficient use of resources are associated with costs of EUR 630 billion per year for the European industry (Greenovate! Europe 2012).

With regard to the **impacts of resource productivity on resource use** empirical evidence shows that improvements in resource productivity has the potential to lower resource use on the company level. However, the question is whether these positive effects found on the micro level are also evident on the **macro level**.

As empirical evidence reveals, absolute decoupling of economic output and resource use/impacts has not happened so far (see chapter 4). This indicates that, on a macroeconomic level, it is important, to consider economic responses to higher productivity – so-called **rebound effects.** The rebound effect refers to the situation where the beneficial effects from new technologies increasing the efficiency of resource use are offset due to behavioural or other systemic responses. However, there are also several scenario analyses suggesting that suitable (policy) measures would be able to increase resource productivity while at the same time reduce resource use.

For several reasons, it can be assumed that there are limits to growth, e.g. due to resource scarcities, commodity price shocks, instability of financial markets, or government debts. Also, a decline in consumer confidence or aging populations in early industrialised countries might restrict future growth. These causes have severe impacts on our long-term ability to sustain prosperity. Based on these arguments, it may be the case that developed economies are faced with low economic growth rates, the near but also in the far future.

It is therefore crucial to know how low growth rates will affect resource productivity, or respectively, how resource productivity can be raised despite low growth rates. Knowledge should also be available on the implications of low growth rates on the labour market. First analyses show that adequate measures are able to mitigate the negative impacts associated with low growth. However, further research is needed in this respect.

10.6 How and to what extent does resource productivity impact on employment?

The main aim of the literature review was to explore the **role of resource productivity and its relationship with employment generation**. Starting from empirical evidence of the past and findings of future estimations based on scenario modelling we analysed job opportunities derived from resource efficiency measures on the firm level, the sector level as well as on the macro level.

Various examples show that **in the past** several **businesses** have managed to increase resource productivity with **positive side effects on net employment**, although the results vary according to different activities and sectors. Explanations can be found in varying eco-innovation opportunities of branches, different reactions to the implementation of policy measures and structural differences in production and energy processes.

As to specific sectors and activities, the analysis reveals potential gains, among others for businesses in construction, infrastructure, waste and resource management, recycling, renewable energy technologies, agriculture as well as “eco-friendly” services. However, there are also several **barriers** that have hindered stronger resource efficiency increases, such as the lack of access to finance, information deficits, gaps in knowledge, sharing and dissemination of best practices as well as non-utilized innovation potentials. But also the failure to internalise environmental costs has impeded gains in resource productivity.

Also the results of different scenarios that were recently developed in order to improve resource productivity indicate that the EU economy would gain with regard to employment.

In general, increases in resource productivity might stem from a broad variety of factors, such as price development of raw materials and energy fuels, structural change, technological change and (eco-)innovation, transition to a circular economy, environmental policy or. As shown, the implications on employment may vary and are always influenced by the respective factors leading to higher resource productivity. In the following we shortly explain how the respective driver of resource productivity impacts employment.

Structural change

Material, energy and labour productivity **can considerably differ among sectors** because some activities inherently demand more high-skilled labour, more capital and more material and energy inputs than others. Aggregate productivity developments are therefore not only determined by technological change in individual sectors, but also by changes in the distribution of production factors among sectors (Mulder/de Groot 2007).

Whereas some sectors will benefit from restructuring impacts of resource productivity increases, others will have to face increased resource costs and a drop in demand. Job gains from ecological driven structural change are likely to occur in those manufacturing sectors that are **labour intensive**. Many **green sub-sectors** have a higher labour intensity than conventional equivalents, which **can increase employment**. For example, investments in repair, remanufacturing and reusing seem to augment direct employment, but might have negative indirect employment effects, as the fabrication phase is skipped.

Job losses can also be expected in resource and energy intensive sectors because of shrinking demand or prohibiting specific operations and processes. In this respect it is important to differentiate short-term and long-term effects. Normally, employment losses due to output declines in the short run can be fully offset by longer term employment gains in other industries.

Furthermore, it has to be considered that the increase in resource efficiency activities induces the relocation of employees from non-green jobs to green jobs. Thus, coherent education and training that focus on short and long run strategies are essential to avert skill bottlenecks that may delay the development of new value chains or the deployment of new technologies.

In general, it is expected that skill levels raise as a consequence of structural change. However, it has to be borne in mind that there are large variations in skills requirements, depending on the respective sub-sector affected.

In general, skill levels are being raised as a consequence of technical change and eco-innovation, although they vary in different sectors

Regarding skill requirements, it can be assumed that **skill levels are being raised** as a consequence of technical change and (eco-)innovation (Slingenberg 2009; Boitier et al. 2015). This tendency can be explained by the fact that technical change is associated with the need for higher-level skills, which also holds true for green technical change. The results of a simulation study reveal that the higher the investments in new technologies (of which many are energy-saving or related to new forms of energy generation), the greater the demand for people in higher skilled jobs. This particularly applies to professional and associate professional ones. Another study suggests that in the EU-15, the share of high-skilled labour in low-carbon intensive sectors is higher compared to the share in high-carbon intensive sectors (EC-ILO 2011).

Labour market adjustments and employment transition will particularly affect low-skilled and older employees. Therefore, it is essential to address this adjustment process with an appropriate policy mix to ease the negative consequences on those most affected by a green transition.

Technological change and eco-innovation

The effects of **(eco-)innovation** on employment within a company depend on the kind of innovation (especially whether process or product innovation is implemented), technology and the country-specific context.

Employment effects of **process innovation** are closely related to **productivity changes**, while **product innovation** induces employment growth mainly via **demand** for the new or improved product.

As the total employment impact of each type of innovation is not explicitly deductible and depends on a number of product-, technology-, firm-, sector- as well as country-specific factors, it has to be determined empirically. However, **empirical analyses** on the employment consequences of environmental innovations are still rare due to data gaps. In general, these studies reveal positive effects of eco-innovations on employment, although **product innovations tend to play a more important role than process innovation**.

Most studies detect that especially eco-product innovation is a significant driver of employment growth. Whether non-environmental product innovation is still more likely to increase employment than environmental ones is not so clear.

With regard to process innovation, findings of empirical research are equivocal. Whereas some studies observe that cleaner technologies can create more jobs than end-of-pipe technologies, this cannot be confirmed by others. In general, process innovations seem to induce small displacement effects. Thus, empirical results do not confirm the often feared negative employment effects of environmental process innovation. Hence, there seems to be some potential for increasing the use of cleaner production technologies and end-of-pipe technologies in manufacturing as well as in services. All in all, further research is needed to assess the impacts of environmental process innovations on employment

Circular economy

Although a transition to a circular economy will create winners and losers, the net employment effect tends to be positive. Scenario modelling studies for the global, European and country level (examples of UK, Netherlands and Sweden) all show substantial job gains of a transition to a circular economy on the macro level.

One important element of the circular economy, **recycling**, has been analysed by various studies. Although studies investigating the employment potential of higher levels of recycling and reuse show wide variations in methodology and availability of data, their key messages are very similar – namely that recycling creates significantly more jobs than waste disposal through landfill or incineration.

Efforts resulting in increased recycling activities affect all phases of the production process (from exploration to smelting and refining), thus leading **to job losses in the respective sectors**.

Furthermore, moving waste up the hierarchy increases the potential to create jobs. This is because the labour intensity in the upper tiers of the waste hierarchy, such as preparation for reuse and recycling, is much higher compared to disposal and incineration.

Although recycling rates for some materials are already high, considerable improvements can be achieved, e.g. via product designs that extend lifetimes, deliver the same service with less material requirement, and facilitate repair and resale, product upgrades, modularity and remanufacturing.

So far, recycling is generally seen as a waste management policy, while it would be much more effective as regulation (measure/instrument) on the input side (e.g. a certain share of construction materials or metals is required to come from secondary sources).

While empirical research on recycling is already more advanced, only a few studies have analysed the employment effects of resource-efficient business models that constitute another important element of a circular economy. Further research is needed in order to assess the employment effects of such models.

The magnitude of the employment effect of a transition to a circular economy does not only depend on the **availability of suitable skills** but also on the **labour-intensity of the resource productivity policies**. Some activities require higher labour skills, more capital and higher material and energy inputs compared to others. It has been shown that remanufacturing, recycling and reuse are good strategies to extend employment. This is only one of the reasons why a circular (instead of a linear) economy can be seen as a viable strategy to address environmental and economic challenges. Currently, however, the degree of circularity is relatively low and could be substantially increased by suitable policies.

Environmental policy

Environmental policies that affect employment in the long term, will have a greater impact on the distribution and composition of jobs, rather than the overall employment. Employment levels are determined by a number of factors, including the size of the labour force, the participation rate and the long run equilibrium rate of unemployment. In addition, policies implementation can create transitional costs associated with sectoral reallocation and job losses. For instance, low skill jobs could be created, and put back to work people who were previously unemployed (Rayment et al. 2009).

However, carefully designed policy measures have the potential to yield **positive, albeit small, net effects on employment**. This is mainly based on the overall aim of environmental policies to correcting the prevailing tendency of economic overuse of natural resources and underuse of human resources. Environmental policies might also result in job losses, as they increase the demand for certain sectors or products which causes shifts in the composition of the employment across sectors. Such shifts on the sector or firm level might also lead to transitional costs and indirect effects, including substitution and income effects that depend on changes in relative prices of resources and wages, and in the crowding out of investment.

With regard to environmental policy we considered the employment effects of market based instruments (environmental tax reforms and tradable permits), standards and regulations, fostering green investments, as well as information and consulting programs.

Both, empirical evidence and scenario modelling show a (small) double dividend of ***environmental tax reforms***. However to realise a double dividend, any revenues resulting from emission, energy or resource taxes should be re-channelled to the labour market. As a result, resource productivity will rise, whereas **labour productivity will decline,** mainly because of the sectoral shifts from energy- and carbon-intensive to labour-intensive industries. Thus, the positive effect on employment is not driven by labour productivity, but mainly by GDP.

In contrast, employment effects of ***cap and trade (tradable permits)*** seem to be insignificant. The most consistent result across ex post assessments of the EU ETS is that no significant employment effects can be observed.

There are also studies assessing the employment effects of a ***whole bundle of MBIs***. These studies show positive net employment effects resulting from higher economic activity and reduced labour costs.

Expanding this policy mix of market based instruments by awareness campaigns as well as standards and regulatory instruments would further increase the positive impact on employment via a higher demand for labour intensive services. These results indicate that market based instruments are central, but being supplemented by environmental regulation they are more conducive to employment growth. Especially environmental tax reforms accompanied by regulation are found to be the most appropriate way to stimulate a variety of innovations.

The fear that jobs will be lost because of higher costs related to environmental regulation cannot be confirmed by empirical evidence. Although significant adjustment costs may occur as employees change from declining (resource-intensive or polluting) to expanding (clean) sectors, on the long run, environmental regulations might evoke a substitution between resource-intensive and resource-efficient activities. The effect of this substitution on net employment is uncertain. Empirical evidence on this issue has so far been mixed. If at all, it reveals statistically insignificant or small effects on employment in regulated sectors.

Another interesting question would be, whether environmental policy **stringency** does influence employment and productivity. Research results show small to significant effects of the stringency of environmental regulation on employment, but no negative effects. Furthermore, it has been demonstrated that more stringent environmental policies had little effect on overall productivity growth.

To sum up, the frequently expressed fear that environmental regulation might induce job losses or decreases in competitiveness in most cases is not justified. However, environmental regulation do not necessarily create employment.

Public green investment

Public finance has a crucial role to play in fostering green investments. Direct public expenditure, e.g. through support for research and development in environmental technologies or cleaner infrastructure provision, as well as indirect support (e.g. through different forms of public guarantees) can force green investment by households and firms and also stimulate employment (UNEP 2010).

For example, counter-cyclical public spending on green **infrastructure** can be seen as an appropriate tool to create jobs. In times of low private demand, governments can be viewed as employers of last resort, able to support both jobs and aggregate demand.

It is commonly assumed that green investment programs may yield positive employment effects, thereby generating both short-term employment and long-term productivity improvement. However, it also has to be born in mind that such policies might crowd out jobs elsewhere and lead to job layoffs in resource intensive sectors. Infrastructure investment might also enhance productivity in the private sector.

With regard to the employment effects of investments in infrastructure the **timing and the duration of job creation** is an important topic (Bowen/Kuralbayeva 2015). It has to be differentiated between construction, manufacture and installation, where jobs may be temporary, and ongoing operation, maintenance and fuel processing, where the duration of jobs depends on the durability of the relevant investment.

In general, the investments in green infrastructure should support such activities and sectors that are labour intensive in order to increase the employment gains.

Public investment in green infrastructure became a common feature of fiscal stimulus packages. **Green stimulus programs** should help to overcome shocks or crises. The objective is to create a multiplier effect which generates further income and employment growth. Such packages show potential to create employment in the **short term** by **using labour capacities**.

It can be concluded from the literature that most policies temporarily boosted employment as a result of increases in economic activity. However, in many cases these positive employment effects took the form of saving rather than creating jobs.

Information-based programs

Information, consulting and support help to better use the potentials for resource efficiency improvements at the company level. There is a wide range of programs supporting resource efficiency measures at the business level. Providing some examples for the UK, we have shown that such programs have resulted in substantial employment gains in the past. Systematically applying such programs throughout the EU could positively affect environment, economy and employment.

It has been shown that increased investments in sectors related to material savings are able to generate new employment opportunities. However, in some sectors efforts to improve resource productivity and environmental policies might also result in job losses, as they alter the composition of employment across sectors. For this reason it is important to consider net employment effects when assessing the suitability of environmental policy to create jobs.

10.7 Conclusion from the literature review

The discussion of the employment effects of some selected drivers of resource productivity revealed that there are different ways of assessing the employment-related effects and it is **not easy to generalize the results of the different approaches**.

The evaluation of the consequences of augmenting resource productivity for employment presents a considerable challenge. There is a wide range of different analyses that incorporate many aspects on various levels, such as firms, sectors, and economy as a whole, or individual countries, the European and the global level, short and long term effects as well as ex post and ex ante assessments.

The environmental challenges, as well as the options for addressing them, and labour market conditions differ widely between countries and between economic sectors. Thus, expertise on modelling of aggregate labour markets and macro-economic correlations is crucial for a proper assessment of changes in direct and indirect labour demand, as well as first-round and induced employment effects.

Even more challenging is to draw comprehensive conclusions. It seems to be the case that resource productivity improvements can create sizable additional employment. However, **sometimes only gross effects are taken into account**, ignoring the potential of job losses in resource and energy intensive industries. Also labour market rigidities, reducing the displacement of workers across sectors, contributing to the maintenance of structural unemployment are often not considered. Some analyses solely focus on the short-term effects on employment going hand in hand with involuntary unemployment, but neglect the long-term effects on growth and productivity (Bowen/Kuralbayeva 2015).

There seems to be some evidence that especially low-skilled and older employees are negatively affected by a transition to a resource-efficient society. However, there is also considerable potential to improve the assessment of impacts on job quality (skill requirements) and to differentiate between age, sex as well as qualification and educational level of the affected workers.

Furthermore, there is more research needed in order to better understand sectoral and country differences as well as the effects of individual drivers that have not been in the focus of research so far (e.g. new resource-efficient business models).

Nevertheless it can be concluded that all of the considered drivers of resource productivity have a role to play and must be used together in order to achieve the highest possible employment gains from the transition to a resource-efficient society. In order to avoid negative distributional effects it is thus crucial to manage the adjustment process to a resource efficient economy with the **right policy mix** that goes beyond environmental policy and includes social policy in order to mitigate the negative consequences on those most affected by a green transition.

10.8 What does the empirical analysis reveal?

In addition to the literature review the scoping study comprises an empirical analysis in order to give an overview of the development of material use and of labour intensity in different Member States. The objective is to provide an analysis of different **sectors** on their material, labour productivity, and to understand the reasons for differences across Member States. Furthermore, the relationships between resource and capital productivity were explored as well as to assess the impact of material productivity on employment outcomes.

In the **sectoral data analysis** we observed the links between resource, labour and capital productivity for 10 European Member States during the timespan 1997 to 2007. The development of resource productivity is assessed for six sectors (agriculture, construction, energy, transport, manufacturing and mining sector) on the basis of the indicator **Raw Material Input** (RMI).

One of the main findings is that there are large variations between individual countries over time. Furthermore, differences in the development of the three types of productivities can also be seen across sectors. In most cases, labour productivity shows the highest growth while resource productivity has grown slower. On average, resource productivity has improved, except for the transport sector. In other words, economies were in general able to create more value per ton of resources used. Capital productivity developments experienced much larger fluctuations, whereas most of the time an overall downward trend could be observed. One can compare the differences in each of the productivity indicators between countries, however, the results do not allow for inferring relationships between the indicators.

In order to better understand the system dynamics of raw material use, beyond the analysis of productivity indicators, this study also applied regression analysis to identify the major drivers for resource use and to assess as well the interactions between such drivers over time and across countries.

The **analysis of the driving forces of resource productivity** is based on population density, R&D expenditure, energy consumption and employment and carried out for the EU as a whole during 2000-2012. Due to data limitations it was not possible to carry out this analysis across sectors. Further analyses, once sectoral resource use data becomes available for each country, would provide a more nuanced understanding of the interaction between employment and resource productivity.

Since the main interest was to analyse the impact of variables that vary over time, a **fixed-effects (FE) model** was chosen as appropriate methodology. FE models explore the relationship between predictor and outcome variables within an entity (country). Each entity has its own individual characteristics that are time-invariant and may influence the predictor variables (for example the political system of a particular country could have an effect on trade or GDP). Using demeaning variables is a common approach in fixed-effects models and was also taken for this analysis[79].

[79] In this method the within-subject means for each variable (both the independent variables and the dependent variable) are subtracted from the observed values of the variables. Hence, within each subject, the demeaned variables all have a mean of zero. For time-invariant variables, the demeaned variables will have a value of 0 for every case, and since they are constants they will drop out of any further analysis. This controls for all between-subject variability (which may be affected by omitted variable bias) and leaves only the within-subject variability for the analysis.

The regression model demonstrates a positive and statistically significant relationship between resource productivity and employment. One has to keep in mind that both the dependent variable (resource productivity) and the independent variable (employment) are expressed in logarithms. This means that according to above results a one percent increase in employment numbers is associated with a 0.6 percent increase in the expected levels of resource productivity in the same year.

The estimated coefficients show how resource productivity varies with the explanatory variables (“factor effect”). While this approach is an improvement over modelling resource productivity without fixed effects, **a direct use of these figures by policy makers is not suggested at this stage**. Analysing the relationships between resource productivity and employment in different sectors and would give a more comprehensive view and show room for action.

The empirical results highlight that **R&D expenditure and energy consumption are important drivers for resource productivity** (in addition to the drivers regarded in the literature review). This is also in accordance with the empirical literature. For example, Luintel et al. (2010), by studying 16 OECD countries, established that R&D was the main determinants of productivity for the period 1982-2004. This study found a significant positive relationship of R&D expenditure and resource productivity for the 28 European Member States for the period 2000-2012. Along with the literature and the results of the empirical analysis, R&D expenditure seems to confirm that innovation can reduce the quantity of raw materials used in production and consumption processes and should be of concern to policy makers as expansion of these sources may contribute to resource productivity increase.

Energy consumption is also a relevant factor for resource productivity and indicates the importance of energy efficiency. For instance, Kratena and Sommer (2014) suggest that a shift in technological change could also be the outcome of certain policies, such as investment in R&D or taxation of energy and resources.

Further detailed analysis, using more potential drivers and applying statistical analysis within sectors, is required to deepen the understanding of resource use and resource efficiency.

Even if the overall conclusion is that job impacts were positive, there may still be job losses on the sectoral level and sectoral shifts taking place. Such shifts on the sector or firm level might also lead to transitional costs and indirect effects, including substitution and income effects that depend on changes in relative prices of resources and wages, and in the crowding out of investment. The main question is whether the net (economy-wide) impact as opposed to the gross (firm level) impact of environmental policies is positive. Observing the relationship between resource productivity and employment in different sectors over time would give a more comprehensive view.

Further analysis, once sectoral resource use data becomes available for each country, would therefore provide a more nuanced understanding of the interaction between employment and resource productivity. Moreover, in order to further illuminate the relationship between employment and resource productivity, explanation on whether employment levels vary across different resource productivity/efficiency policies would be required.

It has to be reminded at this stage that this analysis had the purpose to act as a scoping study and to indicate a way forward for future studies once data becomes available. Data availability and time constraints limited the depth of the analysis.

10.9 How are resource use and resource productivity integrated in economic models?

In order to inform policy makers properly about employment and growth effects of resource productivity, resource use must be adequately integrated in economic models. First we have described efforts in **growth accounting and growth theory** concerning the better integration of resources. We have shown that in recent years several studies and analysis dealt with the integration of resources, although adding resources to the production function is not straightforward. Resources are no homogenous category, some are exhaustible while others are renewable, some have a price while others are for free, some are raw materials, while others are intermediary products, etc.

Since most growth models are not suitable to analyse structural effects, more sophisticated modelling approaches (CGE models, macro-econometric models, System Dynamics models) were also investigated. We tried to explain how these modelling approaches integrate resources. The literature review on the integration of resource productivity in economic models suggests to (better) incorporate the following themes/aspects in order to adequate assess the contribution of resource use and resource productivity to economic growth:

- Physical limits, stocks
- Technological change
- Interaction of demand and supply
- Production- and consumption based approaches
- Full integration of resource flows
- Long-term perspective
- Allowing for structural and institutional changes
- Uncertainty and risk

Furthermore we discussed the question how **environmental and resource constraints** impact on growth. Thereby we differentiated three different viewpoints, (1) economic growth is limitless, (2) environmental limits impose a cost on economic growth, and (3) economic growth cannot continue indefinitely. We identified proponents and modelling approaches for all three perspectives and derived different policy implications depending on the respective viewpoint. So it became apparent, that proponents of the first and also the second view argue that high growth rates, achieved by technological progress and shifts in preferences will remove any environmental limits on growth.
In contrast, representatives of the third view call for absolute decoupling of resource use and economic growth in order to maintain our livelihood.

We have also shown that **resource constraints** are currently not or insufficiently considered, but that there are ongoing research activities treating this issue.

Finally we derived some aspects that according to the literature should be integrated in economic models in order to adequately assess the contribution of resource use and resource productivity to economic growth. These include among others the consideration of physical limits and stocks, a proper representation of technological change, the consideration of price and cost effects, allowing for structural and institutional changes, a detailed representation of the labour market as well as uncertainty and risk.

From the theoretical considerations on the suitability of the models investigated we can conclude that all approaches have their strengths and shortcomings. The improvement of data availability and quality is also of crucial importance in order to advance the integration of resource productivity in economic models.

11 Policy implications and recommendations

The evaluation of employment effects of an improved resource productivity represents a considerable challenge. There is a wide range of different analyses that incorporate many aspects on various levels, such as firms, sectors and the economy as a whole as well as for individual countries, the European and the global level. Analysis of short and long term effects as well as ex post and ex ante assessments have been undertaken. Based on the literature review and the empirical work, a number of insights emerged, from which some important policy lessons regarding the interlinkages and better integration of resource productivity on the one hand and economic growth and employment on the other hand can be derived:

- There is a strong link between resource productivity and employment. High levels of employment are usually accompanied by high levels of resource productivity.
- “Well designed” policies aiming at increasing resource productivity can have a positive impact on employment. In brief, socioeconomic factors must be considered when creating policies which aim at increasing resource efficiency, since there is a relationship between the two factors. Resource (efficiency) policy may be designed as one part of an integrated economy policy framework and comprise an appropriate mix of policy instruments, including regulatory, economic and voluntary instruments.
- However, potentials, costs and benefits will have to be evaluated from the very beginning. Even if the overall conclusion is that employment impacts may be positive, job losses within and shifts between certain sectors may occur and have to be considered. Thus, a compensation of the losers may have to be part of the agenda.
- Shifts on the sector or firm level might also lead to transitional costs and indirect effects. These include substitution and income effects that depend on changes in relative prices of resources and wages as well as on the crowding out of investment. The main question is **whether the net (economy-wide) impact** as opposed to the **gross (firm or sector level) impact** of environmental policies will be positive.
- The empirical analysis that was part of this study reveals that R&D expenditure has a highly positive impact on resource productivity, thus the promotion of resource-efficient production patterns is useful for improving resource productivity. This can be achieved through research and technological advancement as well as appropriate economic and policy guidance.
- According to the empirical analysis, sustainable energy consumption is another determining factor for resource productivity. Higher energy consumption influences resource productivity to a greater extent in countries that are more dependent on conventional energies than in those that use a higher share of renewable energy. Alternative energy schemes which lead to less fossil fuels consumption, in general contribute to higher resource productivity and may have positive effects on the labour market. A relevant policy could be to incentivise private and public sectors in using more efficient technologies to reduce the consumption of fossil fuels.
- Our theoretical considerations on the suitability of the models investigated lead us to the conclusion that all approaches have their

strengths and shortcomings. However, the improvement of data availability and quality is also of crucial importance in order to advance the integration of resource productivity in economic models.

- Models used to assess the employment effects of resource productivity improvements often do not adequately address resource constraints and the substitution (im-)possibilities between the different input factors (labour, capital, material, energy) leading to unrealistic results.
- There is more research needed in order to better understand the differences between sectors and countries as well as the effects of individual drivers that have not been in the focus of research so far (e.g. new resource-efficient business models).
- Moreover, the varying labour market conditions between countries and between economic sectors as well as the qualitative impacts on labour (skill requirements) are another important topic for further research, in order to improve policy advice.
- Labour market rigidities that diminish the shift of workers across sectors and do not reduce structural unemployment are very often ignored. Some studies overlook the long-term effects on growth and productivity and do only account for short term employment effects in situations of involuntary unemployment.

Furthermore, from the examination of resource productivity, as the ratio of GVA and RMI for the years 1997 and 2007, some potentially policy relevant answers can be provided for the following questions:

- How global material flows are related to final consumption in different sectors in a country?
- Which economic sectors contribute to the overall material input/consumption of a country?
- How much economic value has been generated with relation to the consumption of raw materials inputs?
- Has a decoupling between economic growth and the consumption of materials used along European Members occurred?

12 Limitations and further research needs

Data availability and quality is essential for assessing the impacts of resource productivity on employment.

Policy demand was expressed recently for establishing RMC[80] as the lead indicator for the EU resource efficiency strategy. For this purpose it is important to supplement figures on a country level[81]. Recently, Eurostat has published the 'Country RME tool' for compiling RME-related estimates at the country level[82].

Since RME-related estimates at the country level are challenging, calculating RME of product flows at sectoral level for all European Member States are rather difficult. However, examining resource productivity on a sectoral level is of great importance as each sector reflects different material use patterns.

A way out might be to focus on some sectors for representative countries. Still, constructing a time series might turn out to be resource and time consuming. Other possibilities include case studies on individual country experiences which could prove to be useful for other Member States. For example, the construction sector is one of the most important sectors in the European Union. It generates about 10% of GDP and positively influences the growth of employment in other related economic activities. Furthermore, the Netherlands could be an interesting country to study for its high resource productivity in the agriculture and construction sector.

An already well established and regularly updated project is the Exiobase[83] - a global, detailed Multi-regional Environmentally Extended Supply and Use / Input Output (MR EE SUT/IOT) database. Version 3 will comprise 200 sectors in 44 countries and 5 RoW Regions for the years 1995-2015. According to involved partners, sectoral data will possibly be available in 2016.

Another approach is to use just direct extraction all over the world data in primarily monetary models (such as GINFORS) and estimate the impact of policies on the extraction in relation to growth and employment effects. Even if this does not explicitly deliver figures for productivity it reveals the relative effects on labour, capital and resources on regional and global levels, which can be used to further analyse the productivities in question.

In addition, there is a lack of an appropriate labour measure that incorporates the quality of labour inputs, accounting for skills, sex, education and employment status of the workers. Eurostat, in collaboration with the JRC-IPTS, is currently running a project that aims at improving labour productivity indices by disseminating time series of productivity indicators for Member States. The first dataset will be available in spring 2016 for the years 2002 to 2012. Data on capital productivity should follow in 2016.

Another way forward would be to better understand the relationship between potential drivers such as R&D and resource productivity through a more

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[80] RMC describes the amount of raw materials which are embodied (over the whole production chain) in the products of domestic final uses of an economy.

[81] Eurostat regularly publishes results on raw material equivalents (RME) of product flows at EU-27 level.

[82] Establishing the full EU calculation model on a country level would be rather resource consuming and suffer from limited data availability (Eurostat 2015). Therefore, applying the full Eurostat RME model or another model with a similar degree of detail would only be an option for a few countries. The country RME tool offers two methods, the “coefficient approach” and the more sophisticated and more data demanding “combined input-output table (IOT) / coefficient approach”.

[83] http://www.exiobase.eu/index.php/about-us/partners

comprehensive econometric analysis. As the examined variables show a significant relationship with resource productivity, going on a sector-by-sector analysis would provide insight as for example to which sectors are receiving more R&D and in which countries R&D is having the most impact on productivity. Accommodating or examine more potential drivers is an integral aspect of a future econometric analysis.

In terms of data, for example, using labour data that incorporates skill level, sex and education would provide useful insights on *who* would be most affected by improvements of resource productivity in specific sectors. On the same note, using resource efficiency (RMC) sectorial time series data would provide insight on which sectors would be most affected by resource efficiency policies. Furthermore, using time series data post-2008 would provide an interesting analysis on the relationship between the crisis and a low-growth situation on resource efficiency.

Additionally, each Member State has an economic context that calls for a detailed analysis to better understand the trends and relationships between resource, capital and labour productivity. Once sectorial resource productivity (RMC) data is made available on a time series, a more in depth econometric analysis will be more telling on the relationship between resource productivity and employment. A sectoral analysis would provide a more comprehensive view as resource productivity increases may cause a drop in employment for sectors that are more material dependent. Furthermore, a time series analysis is essential to establish relationships on drivers for resource productivity across different industries and economies.

Case studies on individual country experiences with resource efficiency (which was beyond the scope of this study) could prove to be useful for other Member States in future studies. For example, the Netherlands would be an interesting country to look at for its high resource productivity in the agriculture and construction sector (while construction is the least productive sector for many economies), and the highest growth rate in energy resource productivity over the time period.

Another way forward would be to better understand the relationship between R&D and resource efficiency through a more comprehensive econometric analysis. As the two variables show a positive relationship, going on a sector-by-sector analysis would provide insight as to which sectors are receiving more R&D and in which countries R&D is having the most impact on productivity. Accommodating possible third variable biases is an integral aspect of a future econometric analysis.

The empirical part of our analysis – as of many other studies - was based on describing correlations rather than the causalities. This is due to the fact that the identification of causal relationships is a difficult task in terms of methodology and is beyond the scope of this study. Finding causalities was left to the literature review, where we described the results of some comprehensive modelling efforts that show the interlinkages between resource productivity improvements and social, environmental and economic indicators.

In conclusion, the empirical part of this scoping study was not only an exercise to provide a preliminary statistical and empirical analysis of resource, labour and capital productivity, but also to open up possibilities for further investigation, once data is available. Some topics that could possibly be explored through future analyses comprise the:

- Investigation of sectors which would be most affected by job losses due to resource efficiency policies, or the transition to a more resource efficient economy in the EU.

- Analysis of who within the labour force would be most susceptible to shifts in employment (which skill level, age group).
- Study which sectors are receiving the most capital investment, and whether those sectors are the most/least resource/labour productive. A question to look at is whether labour is being replaced by capital in these most/least resource productivity sectors.
- Understanding of the effect of R&D on resource productivity on a sector level, comparing between Member States and establishing reasons for differences if there are differences.

Additionally, some further questions that require investigation or not answered by this analysis are presented in the following Table 12.

Table 12. Future research questions

Pending questions	How they can be investigated further	What is currently missing (data, time, etc.)
What kind of jobs are created and lost?	The contribution of workers varies across production and sector. For example, the mix of skilled and unskilled workers that are employed in the same sector can underestimate or overestimate average labour productivity. Thus, the appropriate labour measure would require incorporating the quality of the labour inputs accounting for the education level of the worker, the employment status etc.	Yearly data on employment status by sector (skill level, education, age, etc.)
Does an improvement in resource productivity lead to more or better jobs?	The process begins with a question: what effect does imposing some treatment in resource productivity have on employment? Advanced econometric methods for causal inference from observational data can be used to answer this question. A more comprehensive view of the effect in a sectorial analysis	A narrow literature review and a considerable timeline is needed.
Is there a substitution between the use of materials and labour, to which degree and under which circumstances?	Substitution elasticities between the use of materials and labour need to be examined under a well based economic framework by sector.	A narrow literature review and a considerable timeline to clarify empirically the substitutional relationships based on a theoretical framework. An example of data that probably would be needed are: yearly data on prices and cost shares of material, capital, labour
How are global material flows related to final consumption in different sectors in a country over time?	Further investigation over time in order to better understand the system dynamics of raw material used by sector	Time series data on material flows that are related to final consumption by sector
What are the respective shares of labour and capital costs embodied in material costs?	No suggestion	Appropriate data is missing

13 References

Aachener Stiftung Kathy Beys (Hrsg.) (2005). Ressourcenproduktivität als Chance - Ein langfristiges Konjunkturprogramm für Deutschland. https://www.aachener-stiftung.de/downloads/buch_final.pdf

Acemoglu, D. and D. Autor (2011): “Skills, Tasks and Technologies: Implications for Employment and Earnings,” Elsevier, vol. 4 of Handbook of Labor Economics, chap. 12, 1043–1171.

Aghion, P., and Howitt, P. (1992). A Model of Growth through Creative Destruction, Econometrica, 60, 323–51.

Aghion, P., and Howitt, P. (1998). Endogeneous Growth Theory, Cambridge MA, US: MIT Press.

Aghion, P., Howitt, P. (2007). Capital, innovation, and growth accounting. Oxford Review of Economic Policy, Volume 23, Number 1, 2007, pp.79–93.Albrizio, S. et al. (2014). Do Environmental Policies Matter for Productivity Growth?: Insights from New Cross-Country Measures of Environmental Policies, OECD Economics Department Working Papers, No. 1176, OECD Publishing.

Ahlert, G., Meyer, B., Zieschank, R. & Diefenbacher, H. (2014): Basic Structures and Political Implications of a Sustainable Welfare Model. Journal of Environmen-tal Science and Engineering, A3, pp. 189-203, ISSN 1934-8932.

Albrizio, S., T. Koźluk and V. Zipperer (2014a). Empirical Evidence on the Effects of Environmental Policy Stringency on Productivity Growth, OECD Economics Department Working Papers, No. 1179, OECD Publishing. http://dx.doi.org/10.1787/5jxrjnb36b40-en

Allianz Dresdner Economic Research (2008). European Growth and Jobs Monitor 2008. Indicators for Success in the Knowledge Economy.

AMEC and BIO (2013). The opportunities to business of improving resource efficiency. Final report to European Commission. http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/report_opportunities.pdf.

Anger, N. and Oberndorfer, U. (2008). Firm performance and employment in the EU emissions trading scheme: An empirical assessment for Germany. Energy Policy, 36(1):12-22.

Antal (2014). Green goals and full employment: Are they compatible? http://www.sciencedirect.com/science/article/pii/S0921800914002699

Arthur D. Little / Wuppertal Institute / Frauenhofer ISI (2005). Study for the Conception of a Program to Increase Material Efficiency in Small and Medium Sized Enterprises, final report for the Federal Ministry of Economics and Labour (BMWi)]; Wiesbaden / Wuppertal / Karlsruhe.

Auci S. and Vignani D. (2014). Environmental Kuznets curve and domestic material consumption indicator: an European analysis. MPRA Paper No. 52882,, 11:23 UTC

Auer, L. (1966). Labour productivity in agriculture—a conceptual analysis. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 14: 29–39. doi: 10.1111/j.1744-7976.1966.tb02373.x

Bach, St., Kohlhaas, M., Meyer, B. Praetoriusa, B., Wlsch, H. (2002). The effects of environmental fiscal reform in Germany: a simulation study. Energy Policy, Volume 30, Issue 9, July 2002, Pages 803–811.

Baffes, J. (2010). More on the energy/non-energy commodity price link. Applied Economics Letters, volume 17, number 16, 2010.

Baltagi BH (2008). Econometric Analysis of Panel Data. 4th ed. New York: Wiley.

Baptist S, Hepburn C. (2013). Intermediate inputs and economic productivity. Phil Trans R Soc A 371: 20110565. http://dx.doi.org/10.1098/rsta.2011.0565.

Bayramoğlu A. T. (2014). The Impact of Agricultural Commodity Price Increases on Agricultural Employment in Turkey. Procedia - Social and Behavioral Sciences 143 (2014) 1058 – 1063.

Belova, A., Gray, W. B., Linn, J. and Morgenstern, R. D. (2013). Environmental regulation and industry employment: A reassessment. Paper No. CES- WP-13-36. Washington D.C.: US Census Bureau, Center for Economic Studies.

Besco, L. (2014). Green productivity: clarifying terminology and concepts. International Journal of Sustainable Economy (IJSE), Vol. 6, No. 4, 2014.

Beinhocker, E.D. (2007). The Origin of Wealth: The Radical Remaking of Economics and What It Means for Business and Society.

Biatour B., Fiers J., Kegels C., Michel B. (2007). EU KLEMS Project Productivity in the European Union: A Comparative Industry Approach. Growth and Productivity in Belgium. Working paper nr. 15

BIO, SERI (2013). Sectoral Resource Maps Report, prepared in response to an Information Hub request, European Commission, DG Environment.

Bio et al. (2011). Analysis of the key contributions to resource efficiency. Final report. http://ec.europa.eu/environment/natres/pdf/Resource_Efficiency_Final.pdf

Bio Intelligence Service (2011). Estimating the economic value of the benefits provided by the tourism/recreation and employment supported by Natura 2000.

Bio Intelligence Service (2012). Implementing EU waste legislation for green growth.

Bleischwitz, R. (2001). Rethinking productivity: why has productivity focussed on labour instead of natural resources? http://epub.wupperinst.org/files/1212/1212_Bleischwitz.pdf

Bleischwitz et al., (2007). The relation between resource productivity and competitiveness http://ec.europa.eu/environment/enveco/economics_policy/pdf/part2_report_comp.pdf

Bleischwitz, R. (2009). Strukturwandel und Ressourcenpolitik. Wuppertal Institut für Klima, Umwelt, Energie GmbH

Bleischwitz, R. (2010). International economics of resource productivity – Relevance, measurement, empirical trends, innovation, resource policies. International Economics and Economic Policy 08/2010; 7(2):227-244.

Bleischwitz, R. et al. (2010). Resource Policy to Design Framework Requirements. Executive Summary. MaRess Project. Wuppertal. http://ressourcen.wupperinst.org/downloads/MaRess_AP3_12_ExecSummary.pdf

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) (ed.) (2007) GreenTech made in Germany. Umwelttechnologie-Atlas für Deutschland. München. (Studie von Roland Berger Strategy Consultants im Auftrag des BMU).

Boitier, B., Lancesseur, N., Paul, Z. (2015). Modelling the European policy response to the challenges arising from the socio-ecological transition. NEUJOBS Working Paper No. D.9.3.

Botta, E. and T. Koźluk (2014). Measuring Environmental Policy Stringency in OECD Countries: A Composite Index Approach, OECD Economics Department Working Papers, No. 1177, OECD Publishing. http://dx.doi.org/10.1787/5jxrjnc45gvg-en

Bovenberg, A.L. (1999). Green Tax Reforms and the Double Dividend: an Updated Reader's Guide, International Tax and Public Finance 6, 421-443.

Bowen, A., Kuralbayeva, K. (2015). Looking for green jobs: the impact of green growth on employment. Policy Brief, The Grantham Research Institute on Climate Change and the Environment and the Global Green Growth Institute.

Brahmbhatt, M. (2014). New Climate Economy Report: Background Note on Climate Mitigation and Jobs. London: New Climate Economy.

Brandt, N., P. Schreyer and V. Zipperer (2013). Productivity Measurement with Natural Capital, OECD Economics Department Working Papers, No. 1092, OECD Publishing. http://dx.doi.org/10.1787/5k3xnhsz0vtg-en

Brandt, N., P. Schreyer and V. Zipperer (2014). Productivity Measurement with Natural Capital and Bad Outputs, OECD Economics Department Working Papers, No. 1154, OECD Publishing. http://dx.doi.org/10.1787/5jz0wh5t0ztd-en

Bringezu S., Schutz H., Steger S., Baudisch J. (2004). International comparison of resource use and its relation to economic growth. The development of total material requirement, direct material inputs and hidden flows and the structure of TMR. Ecological Economics 51: 97– 124

Bruckner M, Giljum S, Lutz C, Wiebe KS (2012). Materials embodied in international trade—Global material extraction and consumption between 1995 and 2005. Glob Environ Change 22(3):568–576.

Buera, F.J., Kaboski, J.P., Rogerson, R. (2015). Skill-Biased Structural Change. NBER Working Paper Series, No. 21165. National Bureau of Economic Research.

Cainelli, G., Mazzanti, M., Zoboli, R. (2009). The Relationship Between Environmental Efficiency and Manufacturing Firm's Growth. http://ageconsearch.umn.edu/bitstream/46656/2/99-08.pdf.

Calel, R. and Dechezleprêtre, A. (forthcoming). Profit or Perish? Estimating the economic effects of cap-and-trade.

Calzadilla, A., K. Rehdanz, R. Betts, P. Falloon, A. Wiltshire, and R. S. Tol (2010). Climate change impacts on global agriculture. Working Papers FNU-185, Research unit Sustainability and Global Change, Hamburg University.

Cambridge Econometrics (2009). E3ME Manual – Version 4.6, online manual, www. camecon-e3memanual.com and from www.e3me.com

Cambridge Econometrics and Ecorys (2011). Assessing the Implementation and Impact of Green Elements of Member State's National Recovery

Plans, Final report for European Commission, Directorate-General Environment, Brussels. http://ec.europa.eu/environment/enveco/memberstate_policy/pdf/green_recovery_plans.pdf

Cambridge Econometrics, GHK and IER (2011). Studies on sustainability issues— green jobs; trade and labour; Final Report, Research Project for the European Commission, DG Employment, Social Affairs and Inclusion.

Cambridge Econometrics et al. (2014). Study on modelling of the economic and environmental impacts of raw material consumption. http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/RMC.pdf

Capros, P., Van Regemorter, D.,. Paroussos, L., . Karkatsoulis, P. et al. (2013). GEM-E3 Model Documentation. JRC Technical Reports. http://ftp.jrc.es/EURdoc/JRC83177.pdf

Cascadia Consulting Group (2009). Recycling and Economic Development: a review of existing literature on job creation, capital investment and tax revenues, for King County Solid Waste Division, WA http://your.kingcounty.gov/solidwaste/linkup/documents/recycling-economic-development-review.pdf

CEPS (2013). Assessment of cumulative cost impact for the steel and aluminium sectors. Study for DG Enterprise and Industry.

Chan, H. S. R., Li, S., and Zhang, F. (2013). Firm competitiveness and the European Union emissions trading scheme. Energy Policy, 63:1056-1064.

Chen, M. (2008). Rule of Law and Environmental Policy Stringency ISIAC Working Paper 10-3.

Chitnis, M., Sorell, S., Druckman, A. Firth, S.K., Jackson, T. (2014). Who rebounds most? Estimating direct and indirect rebound effects for different UK socioeconomic groups. Ecological Economics 106, 12-34.

Commins, N., Lyons, S., Schiffbauer, M., and Tol, R. (2011). Climate policy and corporate behaviour. The Energy Journal, 32(4):51-68.

Daly, H.E. (1992). Allocation, distribution, and scale: towards an economics that is efficient, just, and sustainable. Ecological Economics, 6 (1992), 185-193

Daly, H.E. (2008). A Steady-State Economy. Thinkpiece for the UK Sustainable De-velopment Commission, Workshop on 24 April 2008, London.

Daly, H.E (2010). From a Failed-Growth Economy to a Steady-State Economy. The Solutions Journal, www.thesolutionsjournal.com

Dasgupta, P., Heal, G.M. (1979). Economic Theory and Exhaustible Resources. Cambridge University Press, Cambridge.

De Bruyn et. al. (2009). Resource productivity, competitiveness and environmental policies. http://www.ce.nl/?go=home.downloadPub&id=1008&file=7915_defreportSdBMKA_1264767384.pdf.

Dechezleprêtre, A., Sato, M. (2014). The impacts of environmental regulations on competitiveness. Policy Brief. http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/11/Impacts_of_Environmental_Regulations.pdf

DEFRA (2015). Digest of Waste and Resource Statistics – 2015 Edition, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/422618/Digest_of_waste_England_-_finalv2.pdf

Dellink, R.B. (2005) Modelling the costs of environmental policy: a dynamic applied general equilibrium assessment, Cheltenham: Edward Elgar.

Devetter, F.-X., Rousseau, S. (2011). Working Hours and Sustainable Development. Review of Social Economy, 69:3, 333-355, DOI: 10.1080/00346764.2011.563507.

Distelkamp, M., Meyer, B. (2013). D3.2 Report about the modeling of water demand and land use in GINFORS. WP 3 - Scenarios and modeling of policy implementation for resource efficiency. https://www.ucl.ac.uk/polfree/publications/publications-2014/D3_2_POLFREE_final_version_FormatMay2014.pdf

Distelkamp, M., Meyer, M. (2014). Report about resource reduction cost curves for material consumption in different MS. Deliverable of the POLFREE project. http://www.polfree.eu/publications/publications-2014/d-1-final

Di Vita, G. (2007). Exhaustible resources and secondary materials: a macroeconomic analysis. Ecological Economics 63, 138e148.

Duchin, F., 1998. Structural Economics: Measuring Change in Technology, Lifestyles and the Environment, Island Press, Washington, D.C.

Elshkaki, A., van der Voet, E. et al. (2004). Development of a dynamic model for Substance Flow Analysis: Part 1. General stock model. 2004/IMS/R/292, CML and VITO.

EBI - Environmental Business International (2012). Environmental Business Journal: Strategic Information for a Changing Industry. Volume XXV, 6/7.

EC - European Commission (2001). COM(2001) 581 final – 2001/0245 (COD), Proposal for a Directive of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, Impact Assessment Form. EUR-Lex.

EC - European Commission (2005). Commission staff working document on the links between employment policies and environment policies, 17, SEC(2005) 1530. http://ec.europa.eu/environment/integration/pdf/sec_2005_1530_en.pdf

EC - European Commission (2008). Commission staff working paper accompanying the proposal for a directive of the european parliament and of the coundil on waste electrical and electronic equipment (WEEE), COM(2008) 810 final, http://www.europarl.europa.eu/registre/docs_autres_institutions/commission_europeenne/sec/2008/2931/COM_SEC%282008%292931_EN.pdf

EC - European Commission (2012). Towards a job-rich recovery. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions

EC - European Commission (2013a). Promoting green jobs throughout the crisis: a handbook of best practices in Europe, EEO Review. http://ec.europa.eu/social/BlobServlet?docId=10295&langId=en

EC - European Commission (2013b). Employment, Social Affairs & Inclusion “Pathways to green jobs: strategies and policy options for a sustainable job-rich recovery”.

EC - European Commission (2014). Green Employment Initiative: Tapping into the job creation potential of the green economy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2014) 446 final. http://ec.europa.eu/transparency/regdoc/rep/1/2014/EN/1-2014-446-EN-F1-1.Pdf

EC - European Commission (2014a). Study on economic and social benefits of environmental protection and resource efficiency related to the European semester http://bookshop.europa.eu/en/study-on-economic-and-social-benefits-of-environmental-protection-and-resource-efficiency-related-to-the-european-semester-pbKH0414261/downloads/KH-04-14-261-EN-N/KH0414261ENN_002.pdf?FileName=KH0414261ENN_002.pdf&SKU=KH0414261ENN_PDF&CatalogueNumber=KH-04-14-261-EN-N

EC - European Commission (2014b). Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains http://bookshop.europa.eu/en/scoping-study-to-identify-potential-circular-economy-actions-priority-sectors-material-flows-and-value-chains-pbKH0114775/downloads/KH-01-14-775-EN-N/KH0114775ENN_002.pdf;pgid=Iq1Ekni0.1lSR0OOK4MycO9B0000KELpYeA5;sid=4JyS2rk_qr6Siuw0y3AMfdsaQl_uihv8nMw=?FileName=KH0114775ENN_002.pdf&SKU=KH0114775ENN_PDF&CatalogueNumber=KH-01-14-775-EN-N

EC - European Commission (2014c). COMMISSION STAFF WORKING DOCUMENT. Impact Assessment. Accompanying the document ‘Proposal for reviewing the European waste management targets’ DRAFT x/x/2014.

EC - European Commission (2014d). Green Employment Initiative: Tapping into the job creation potential of the green economy. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions

EC-ILO (2011). Towards a greener economy: the social dimensions, European Commission, DG Employment, Social Affairs and Inclusion and the International Institute for Labour Studies of the International Labour Organisation (ILO).

ECOFYS (2014). Assessing the EU 2030 Climate and Energy targets A Briefing Paper. By order of: Greens/EFA group in the European Parliament http://www.ecofys.com/files/files/ecofys-2014-assessing-the-eu-2030-targets.pdf

Ecorys and IDEA (2009). Study on the Competitiveness of the EU eco-industry, Final Report – Part 1. http://ec.europa.eu/environment/enveco/eco_industry/pdf/report%20_2009_competitiveness_part1.pdf

Ecorys, Cambridge Econometrics and COWI (2011). The role of market-based instruments in achieving a resource efficient economy, Study for European Commission, DG Environment. http://bookshop.europa.eu/en/the-role-of-market-based-instruments-in-achieving-a-resourceefficient-economy-pbKH3013423/

Ecorys (2012). The number of Jobs dependent on the Environment and Resource Efficiency improvements. Final report. http://ec.europa.eu/environment/enveco/jobs/pdf/jobs.pdf

Ecorys, Acteon (2014). Potential for sustainable growth in the water industry sector in the EU and the marine sector – Input to the European Semester. Water Industry Final Report. http://www.eureau.org/images/img/Water_Industry_Tasks1to5_Definitive_Version_2014.pdf

Ecorys (2009). Study on the competitiveness of the EU-eco industry. Within the Framework Contract of Sectoral Competitiveness Studies.

EEA (2011). Earnings, jobs and innovation: the role of recycling in a green economy. EEA Report No8/2011. http://www.eea.europa.eu/publications/earnings-jobs-and-innovation-the/download

EEA (2014). Progress on resource efficiency and decoupling in the EU‑27. http://www.eea.europa.eu/publications/progress-on-resource-efficiency-and

EEA - European Environment Agency (2014a). Resource-efficient green economy and EU polices. EEA Report No 2/2014, Luxembourg. http://www.eea.europa.eu/publications/resourceefficient-green-economy-and-eu/download

EEB - European Environmental Bureau (2014). Advancing Resource Efficiency In Europe. http://www.eeb.org/EEB/?LinkServID=4E9BB68D-5056-B741-DBCCE36ABD15F02F

EIO (2012). The Eco-Innovation Gap. An economic opportunity for business. In: ECO-INNOVATION-OBSERVATORY (ed.). Brussels: Funded by the European Commission, DG Environment.

Ekins, P. (2009). Resource Productivity, Environmental Tax Reform and Sustainable Growth in Europe. http://petre.org.uk/pdf/FinRepFin.pdf

Ekins, P., Spangenberg, J. (2013). Resource efficiency indicators and targets in relation to the Resource Efficiency Roadmap.

EMF - Ellen MacArthur Foundation (Report Vol 3) (2014). Towards the Circular Economy vol.3: accelerating the scale-up across global supply chains. http://www.ellenmacarthurfoundation.org/business/reports/ce2014

EMF - Ellen MacArthur Foundation, McKinsey Center for Business and Environment, and Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (2015). Growth Within: A circular economy vision for a competitive Europe. http://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/sustainability/2015%20circular%20growth%20report/growth_within-a_circular_economy_vision_for_a_competitive_europe%20(1).ashx

EEA (2012). SOER 2010. Thematic assessment, Material resources and waste — update 2012. http://www.eea.europa.eu/publications/material-resources-and-waste-2014/at_download/file.

ENWORKS (2012). Making an impact. 2001 to 2012 http://www.enworksinabox.com/sites/default/files/Making_an_Impact_NW.pdf.

ESA. (2013). Going for Growth: A practical route to a Circular Economy. Environmental Services Association UK.

http://www.esauk.org/esa_reports/Circular_Economy_Report_FINAL_High_Res_For_Release.pdf

Estrada, Á., Hernández de Cos, P. (2009). Oil prices and their effect on potential output. http://www.bde.es/f/webbde/SES/Secciones/Publicaciones/PublicacionesSeriadas/DocumentosOcasionales/09/do0902e.pdf.

EUKLEMS (2008). see Marcel Timmer, Mary O'Mahony and Bart van Ark, The EU KLEMS Growth and Productivity Accounts: An Overview, University of Groningen and University of Birmingham; downloadable at http://www.euklems.net/project_site.html.

Eurostat (2001): Economy-wide material flow accounts and derived indicators' a Eurostat methodological guide:

Eurostat (2015). Resource productivity Statistics. http://ec.europa.eu/eurostat/statistics-explained/index.php/Resource_productivity_statistic

European Commission (2012) 'Green Jobs: Employments and Challenges'. http://ec.europa.eu/europe2020/pdf/themes/19_green_jobs.pdf

Falk, M., Koebel, B. (2002). Imports and Labour Demand. The Scandinavian Journal of Economics Volume 104, Issue 4, pages 567–586, December 2002. http://onlinelibrary.wiley.com/doi/10.1111/1467-9442.00302/abstract.

Fankhauser, S., Sehlleier, F., Stern, N. (2008). Climate change, innovation and jobs. Climate Policy. http://www.cccep.ac.uk/Publications/research-articles/Docs/climate-change-innovation-jobs.pdf

Fischer, H., Lichtblau, K., Meyer, B., Scheelhaase, J. (2004). Impulses for Growth and Employment through Profitable Savings in Material Resources. Paper commissioned by Aachener Foundation Kathy Beys.

Fischer-Kowalski, M., Wiedenhofer, D. (2014). An optimal policy mix for resource use. European Policy Brief No. 5, WWW for Europe. http://www.foreurope.eu/fileadmin/documents/pdf/Policybriefs/WWWforEurope_PB_no05_D204.1.pdf

Friends of the Earth Europe (2010). More jobs, less waste – potential for job creation through higher rates of recycling in the UK and EU, Brussels: FoEE https://www.foeeurope.org/sites/default/files/publications/FoEE_More_Jobs_Less_Waste_0910.pdf

Forfàs (2012). Ireland's Productivity Performance, 1980-2011. (http://www.forfas.ie/media/040512-Ireland's_Productivity_Performance_1980-2011-Publication.pdf)

Freeman, R. (2008). Labour Productivity Indicators: Comparison of two OECD databases, productivity differentials & the Balassa-Samuelson Effect. OECD Statistics Directorate

GHK(2007). Links between the environment, economy and jobs. (http://ec.europa.eu/environment/enveco/industry_employment/pdf/ghk_study_wider_links_report.pdf)

Georgescu-Roegen, N. (1971). The Entropy Law and the Economic Process, Cambridge MA, USA: Harvard University Press.

GHK, Cambridge Econometrics, and Institute for European Environmental Policy (2007). Links between the environment, economy and jobs.

http://ec.europa.eu/environment/enveco/industry_employment/pdf/ghk_study_wider_links_report.pdf

Giljum, St., Behrens, A., Hinterberger, F., Lutz, Ch., Meyer, B. (2008). Modelling scenarios towards a sustainable use of natural resources in Europe. Environmental Science & Policy 11, 204-216.

Giljum, St., Ditttrich, M., Lieber, M., Lutter, St. (2014). Global Patterns of Material Flows and their Socio-Economic and Environmental Implications: A MFA Study on All Countries World-Wide from 1980 to 2009. Resources 2014, 3, 319-339; doi:10.3390/resources3010319 resources ISSN 2079-9276 www.mdpi.com/journal/resources

Giljum St., Lutter, St., Bruckner, M., Aparcana, S. (2013). State-of-play of national consumption based indicators. A review and evaluation of available methods and data to calculate footprint-type (consumption-based) indicators for materials, water, land and carbon Negotiated Procedure ENV Fl/2013/env.fl(2013) 296596.

Giljum, S., Lutz, C., Jungnitz, A., Bruckner, M. and Hinterberger, F. (2011). European Resource Use and Resource Productivity in a Global Context. In: Ekins, P., Speck S. (Eds): “Environmental Tax Reform (ETR). A Policy for Green Growth.” Oxford University Press. Oxford.

Gjoksi, N., Sedlacko, M. (2011). Resource policies in the context of sustainable development: Current trends and challenges ahead. ESDN Quarterly Report.

Goodwin, N. (2003). Five Kinds of Capital: Useful Concepts for Sustainable Development.. Global Development and Environment Institute.

Gordon, R.J. (1995). Is there a tradeoff between unemployment and productivity growth? NBER Working Paper Series. Working Paper No. 5081.

Greenovate! Europe (2012). Guide to resource efficiency in manufacturing. Experiences from improving resource efficiency in manufacturing companies.
http://www.greenovate-europe.eu/sites/default/files/publications/REMake_Greenovate!Europe%20-%20Guide%20to%20resource%20efficient%20manufacturing%20%282012%29.pdf

Grimaud, A. (1999). Pollution permits and sustainable growth in a Schumpeterian model, Journal of Environmental Economics and Management, 38(3), 249– 266.

Grubb, M.J. (1990). Energy efficiency and economic fallacies, Energy Policy 18, 783–785.

Haas, W., Krausmann, F., Wiedenhofer, D., Heinz, M., (2014). How circular is the global economy? An assessment of material flows, waste production and recycling in the EU and the world in 2005. Journal of Industrial Ecology.

Haller, St., Hyland, M. (2014). Capital–energy substitution: Evidence from a panel of Irish manufacturing firms, Energy Economics, Volume 45, September 2014, Pages 501–510.
https://ideas.repec.org/a/eee/eneeco/v45y2014icp501-510.html

Harasztosi P. (2011). Growth in Hungary 1994-2008: The role of capital, labour, productivity and reallocation. MNB WORKING PAPERS 12

Harring, N. (2008). An explanation to the relationship between institutional quality and stringent environmental policy. 2nd ECPR Graduate Conference, Universitat Autonoma Barcelona 25-27. Panel: Environmental and Green Politics, 2008.

Hayden, A. and J. M. Shandra (2009). Hours of Work and the Ecological Footprint of Nations: An Explaratory Analysis. Local Environment 14(6): 575-600. http://dx.doi.org/10.1080/13549830902904185

Hausman J, Taylor W (1981). Panel data and unobservable individual effects. Econometrica 49:1377–1398

Hennicke P., Sewerin, S. (2009). Decoupling GDP Growth (‘Quality of Life’) from Resource Use: Achievements and Shortcomings for ‘Strategic Governance’ in Germany (On behalf of the International Panel for Sustainable Resource Management), 13 pp. Accessible from: http://wupperinst.org/uploads/tx_wupperinst/Decoupling_GDP.pdf.

Hepburn, C. and Bowen, A. (2013), ‘Prosperity with growth: Economic growth, climate change and environmental limits’ in Fouquet, R. (ed.), Handbook of Energy and Climate Change, Edward Elgar.

Herfindahl, O.C., Kneese, A.V. (1974). Economic theory of natural resources. Merrill, Columbus, Ohio.

Hinterberger, F., Renn, S., Schütz, H. (1999). Arbeit, Wirtschaft, Umwelt: Einige Indikatoren sozialer, wirtschaftlicher und ökologischer Entwicklung im Zeitablauf. Wuppertal Paper No. 89. Wuppertal Institute, Wuppertal.

Hinterberger, F., Giljum, S., Oman, I., Polsterer, N., Stocker, A., Burrell, L., Campregher, C., Fuchs, D. und Hartwig, F. (2013). Green growth. From Labour to Resource Productivity. Best Practice Examples, Initiatives and Policy Options.

Hinterberger, F., Pirgmaier, E., Stocker, A., Ax, Ch. (2012). Wachstum und Arbeit. Welche Spielräume hat Beschäftigungspolitik unter den Bedingungen unsicherer Wachstumsprognosen und wie kann Beschäftigungspolitik zu mehr Nachhaltigkeit in Wirtschaft und Gesellschaft beitragen? Policy-Paper-Serie Wachstum im Wandel, im Auftrag des Lebensministerium, Wien.

Hinterberger, F., Pirgmaier, E., Freytag, E. & Schuster, M. (eds.) 2011. Growth in transition: Earthscan.

Ho, M.S., Morgenstern, R., Shih, J-S., 2008. Impact of carbon price policies on U.S. industry, DP 08-37. Washington DC: Resources for the Future.

Hoekstra, A.Y., Wiedmann, T.O. (2014). Humanity’s unsustainable environmental footprint. Science, 344, 1114.

Horbach, J. (2010): The Impact of Innovation Activities on Employment in the Environmental Sector – Empirical Results for Germany at the Firm Level, Journal of Economics and Statistics, Vol. 230/4, 403-419

Horbach, J., Rennings, K., Sommerfeld, K. (2015). Circular Economy and Employment. https://sunstiftungsfonds.files.wordpress.com/2015/06/ce_employment_13052015.pdf

Horbach, J., Rennings, K. (2013). Environmental innovation and employment dynamics in different technology fields – an analysis based on the German Community Innovation Survey 2009. Journal of Cleaner Production 57, 158-165.

Houser, T., Mohan, S. & Heilmayr, R. (2009). A Green Global Recovery? Assessing US Economic Stimulus and the Prospects for International Coordination. Washington, DC: Peterson Institute for International Economics and World Resources Institute.

Hsiao C (1986). Chapter 3: Simple regression with variable intercepts. Analysis of panel data. University of Cambridge Press, Cambridge UK

ICF GHK (2013). Evaluation of the ENWORKS Project: "Embedding Resource Efficiency in Key Sectors" 2009-2013 Final Report. http://www.enworksinabox.com/sites/default/files/EREiKS%20Evaluation%20FR.pdf

IDEA et al. (2014). Cases of implementing resource efficient policies by the EU industry. Final report. http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/REPC%20final%20%20report%20IDEA%20Consult.pdf.

IEA - International Energy Agency (2012). World Energy Outlook 2012.

ILO (2013). Sustainable development, decent work and green jobs. International Labour Conference, 102nd Session, 2013 Report V. http://www.ilo.org/wcmsp5/groups/public/@ed_norm/@relconf/documents/meetingdocument/wcms_207370.pdf

Innovas (2009) Low Carbon and Environmental Goods and Services: An Industry Analysis, commissioned by BERR. (www.berr.gov.uk/files/file50254.pdf)

Jackson, T. (2009). Prosperity without Growth. (New York: Routledge).

Jackson, T., Drake, B., Victor, P., Kratena, K. Sommer, M. (2014). Foundations for an Ecological Macroeconomics: literature review and model development. Literature review and model development. Issue 65, Number of Pages: 39.

Jackson, T., Victor, P. (2011). Productivity and Work in the New Economy – Some Theoretical Reflections and Empirical Tests. Environmental Innovation and Societal Transitions,Vol.1, No.1,101-108.

Jackson, T., Victor, P. (2015). Credit creation and the 'growth imperative' - a quasi- stationary economy with debt-based money. PASSAGE Working Paper 15/01.

Jäger J, Rothman d, Anastasi C, Kartha S, van Notten P (2008) Training Module 6—Scenario development and analysis, in Pintér L, Chenje J and Swanson D (eds) IEA training manual: A training manual on integrated environmental assessment and reporting. United Nations Environment Programme and the International Institute for Sustainable Development.

Jaraite, J. and Maria, C. D. (2014). Did the EU ETS Make a Difference? An empirical assessment using Lithuanian firm-level data. CERE Working Paper, 2014(2).

Jarvis,A., Varma A., Ram, J. (2011). Assessing green jobs potential in developing countries: A practitioner's guide Geneva, International Labour Office. (http://www.uncsd2012.org/content/documents/230assessing%20green%20jobs%20potential%20ILO.pdf)

Kammen, D, Kapadia, K, and Fripp, M (2004). Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?. RAEL Report, University of California, Berkeley

Kallis et al., (2013). "Friday off": Reducing Working Hours in Europe. Sustainability 2013, 5. http://www.mdpi.com/2071-1050/5/4/1545/pdf

Knight, K.W., Rosa, E.A., Schor, J.B. (2013). Could working less reduce pressures on the environment? A cross-national panel analysis of OECD countries, 1970-2007. Global Environmental Change, 23, 691-700.

Koca, S. and Sverdrup, H. (2014). A Progress Report of the Two SimRess Group Modelling Workshops. http://simress.de/sites/default/files/Progress%20Report%20of%20Two%20SimRess%20Group%20Modelling%20Workshops.pdf#overlay-context=en/events

Koeniger W, Leonardi M (2006). Capital Deepening and Wage Differentials: Germany vs. US) IZA Discussion Series, No. 2065

Kohlhaas, M. (2005). Gesamtwirtschaftliche Effekte der ökologischen Steuerreform. Band II des Endberichts für das Vorhaben: „Quantifizierung der Effekte der Ökologischen Steuerreform auf Umwelt, Beschäftigung und Innovation". Forschungsprojekt im Auftrag des Umweltbundesamts. FuE-Vorhaben Förderkennzeichen 204 41 194. Available at http://www.umweltdaten.de/publikationen/fpdf-l/2961.pdf.

Kovandaa,J., Sandb I., Schützc, H., Bringezu S.,(2012). Economy-wide material flow indicators: Overall framework, purposes and uses and comparison of material use and resource intensity of the Czech Republic, Germany and the EU-15. Ecological Indicators 17 :88–98

Koźluk, T. and V. Zipperer (2013). Environmental Policies and Productivity Growth: A Critical Review of Empirical Findings, OECD Economics Department Working Papers, No. 1096, OECD Publishing. http://dx.doi.org/10.1787/5k3w725lhgf6-en

Kratena, K., Sommer M., (2014). Model Simulations of Resource Use Scenarios for Europe. WWWforEurope Deliverable No. 5

Krautzberger L., Wetzel H.(2012).Transport and CO2: Productivity Growth and Carbon Dioxide Emissions in the European Commercial Transport Industry. Environmental and Resource Economics : 53(3).

Kristof K., and Hennicke P.(2010). Material Efficiency and Resource Conservation. MaRess project Wuppertal. ISSN 1867-0237

Lee, B., Preston, F., Kooroshy, J., Bailey, R., Lahn, G., (2012). Resources Future: A Chatham House Report. http://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/1212r_resourcesfutures.pdf

Lenzen, M., K. Kanemoto, D. Moran and A. Geschke (2012). Mapping the Structure of the World Economy. Environmental Science and Technology, 46, 8374–8381.

Lenzen, M.,D. Moran, K. Kanemoto and A. Geschke (2013). Building EORA: A Global Multi-region Input–Output Database at High Country and Sector Resolution. Economic Systems Research, 25, 20–49.Lettenmeier, M., Rohn, H., Liedtke, Ch., Schmidt-Bleek, F. (2010). Resource Productivity in 7 Steps. How to Develop Eco-Innovative Products and Services and Improve their Material Footprint. Wuppertal Spezial no. 41).

Lettenmeier, M., Rohn, H., Liedtke, Ch., Schmidt-Bleek, F. (2010). Resource Productivity in 7 Steps. How to Develop Eco-Innovative Products and

Services and Improve their Material Footprint. Wuppertal Spezial no. 41).

Licht, G., Peters, B. (2013). The Impact of Green Innovation on Employment Growth in Europe, Working Paper of the WWW for Europe Working Paper 50, Wien

Licht, G., Peters, B. (2014). Do green innovations stimulate employment? – firm-level evidence from Germany. WWW for Europe Working Paper 53, Wien

Lu, Y., Stern, D. (2014). Substitutability and the Cost of Climate Mitigation Policy https://cama.crawford.anu.edu.au/sites/default/files/publication/cama_crawford_anu_edu_au/2014-03/28_2014_lu_stern.pdf

Luintel, K, Khan, M., Theodoridis, K. (2010). How Robust is the R&D-Productivity relationship? Evidence from OECD Countries, Cardiff Economics Working Papers E2010/7, Cardiff University, Cardiff Business School, Economics Section.

Luptacik, M., Stocker, A., 2005. Eco-efficiency and sustainability of the Austrian Economy, project final report to the Österreichischen Jubiläumsfonds, Wien.

Mahadevan, R. (2003). To measure or not to measure Total Factor Productivity Growth?, Oxford Development Studies, 31(3): 365-78.

Marin, G. and Mazzanti, M. (2009). Emissions Trends, Labour Productivity Dynamics and Time-Related Events - Sector Heterogeneous Analyses of Decoupling/Recoupling on a 1990-2006 NAMEA. http://mpra.ub.uni-muenchen.de/17903/1/MPRA_paper_17903.pdf

Martin, R., Muuls, M., and Wagner, U. (2011). Climate change, investment and carbon markets and prices – evidence from manager interviews. Climate Strategies, Carbon Pricing for Low-Carbon Investment Project.

Martin-Retortillo M. and Pinilla V. (2012). Why did agricultural labour productivity not converge in Europe from 1950 to 2005? EHES Working Paper | No. 25 | (http://www.ehes.org/EHES_No25.pdf).

Mazzanti, M., Zoboli, R. (2009). Environmental efficiency and labour productivity: Trade-off or joint dynamics? A theoretical investigation and empiricalevidence from Italy using NAMEA. In: Ecological Economics 68.

McKinsey Global Institute (2013). Resource Revolution: Tracking Global Commodity Markets. Trends Survey 2013. McKinsey Global Institute.

McDougall, R.A., A. Elbehri, and T.P. Truong (1998). Global Trade Assistance and Protection: The GTAP 4 Data Base, Center for Global Trade Analysis, Purdue University"

Meadows, D. and D., Randers,J., Behrens III, W. (1972). The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind.

Meyer, B., Bleischwitz, R,. Giljum, S., Pollitt, H. (2011). Macroeconomic modelling of sustainable development and the links between the economy and the environment. Study for the European Commission (DG Environment)

Meyer, B., Distelkamp, M., Beringer, T. (2015). WP 3 – Report about integrated scenario interpretation. GINFORS results. Delilverable of the project POLFREE.

Meyer, I., Sommer, M. W. (2014): Employment Effects of Renewable Energy Supply. A Meta Analysis, WWW for Europe Policy Paper no 12, Vienna, http://www.wifo.ac.at/jart/prj3/wifo/resources/person_dokument/person_dokument.jart?publi kationsid=47225&mime_type=application/pdf

Meyer, B., Lutz, C., Schnur, P. and Zika, G. (2007) 'National Economic Policy Simulations with Global Interdependencies. A Sensitivity Analysis for Germany', Economic Systems Research 19(1), pp. 37–55.

Moll, S., Pepescu, C. & Nickel, R. (2012). EU's Resource Productivity on the increase. Eurostat Statistics in focus. http://ec.europa.eu/eurostat/documents/3433488/5584760/KS-SF-12-022-EN.PDF/0fcda682-ebc6-448e-9a25-f46b1aeb15b9?version=1.0

Morgenstern, R. D., W. A. Pizer and J.-S. Shih (2002). Jobs Versus the Environment: An Industry-level Perspective, Journal of Environmental Economics and Management, Vol. 43, pp. 412-436.

Mulder, P., de Groot (2007). Sectoral Energy- and Labour-Productivity Convergence. Environmental and Resource Economics. January 2007, Volume 36, Issue 1, pp 85-112.

Mulder, P., Reschke, C. H., Kemp, R. (1999). Evolutionary Theorising on Technological Change and Sustainable Development, Communication to European Meeting on Applied Evolutionary Economics 7 - 9 June 1999, Grenoble, France

Muñoz P, Giljum S, Roca J (2009) The raw material equivalents of international trade. J Ind Ecol 13(6):881–897.

Narayanan B.G. and Walmsley TL, (2008). Global Trade, Assistance, and Production: The GTAP 7 Data Base, Center for Global Trade Analysis, Purdue University.

Nordhaus, W. (1992). Lethal Model 2: The Limits to Growth Revisited, Brookings Papers on Economic Activity, 23(2), 1–60.

Nordhaus, W. (2005). The Sources of the Productivity Rebound and the Manufacturing Employment Puzzle. NBER Working Paper Series, Working Paper No. 11354.

OECD (2010). Policy principles for sustainable materials management, Policy Report 1. Outcome of the Global Conference on Environment: Sustainable Material Management. http://www.oecd.org/dataoecd/3/60/46111789.pdf.

OECD (2011). Towards Green Growth summary. http://www.oecd.org/greengrowth/47984000.pdf on 20/01/2014

OECD (2015). Long-term productivity growth and the environment. ENV/EPOC/WPIEEP(2015).

OECD (2015a). Firm surveys relating environmental policies, environmental performance and innovation : design challenges and insights from empirical applications.

Ovidiu et al. (2011). Utilisation of benchmarking techniques for fundamenting development strategies in the manufacturing industry in Romania.

Pauliuk, S., R. Wood, and E.G. Hertwich. 2014. Dynamic Models of Fixed Capital Stocks and Their Application in Industrial Ecology. Journal of Industrial Ecology: n/a–n/a.

Peters, G.P., R. Andrew and J. Lennox (2011). Constructing aMulti-regional Input–Output Table using the GTAP Database. Economic Systems Research, 23, 131–152.Petrick, S. and Wagner, U. J. (2014). The Impacts of Cap-and-Trade on Industry: Evidence from the European Carbon Market and German Manufacturing Plants. Kiel Working Papers, (1912).

Pew Charitable Trusts (2009). The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America. Washington, DC: Pew Charitable Trusts.

Pirgmaier, E., Stocker, A., Hinterberger, F. (2010). Implications of a persistent low growth path. A Scenario Analysis. WP 1: Literature Review and Expert Interviews, Version 31 July 2010.

Pollitt, H., Barker, A. Barton, J., Pirgmaier, E., Polzin, C. Lutter, S., Hinterberger, F. and Stocker, A. (2010). A Scoping Study on the Macroeconomic View of Sustainability. Final report for the European Commission, DG Environment.

Preston, F. (2012). A Global Redesign? Shaping the Circular Economy. London.

Rayment, M., Pirgmaier, E., De Ceuster, G., Hinterberger, F., Kuik, O., Leveson Gower, H., Polzin, C., Varma, A. (2009). The economic benefits of environmental policy. Report for the European Commission under the Framework contract for economic analysis ENV.G.1/FRA/2006/0073.

Renner, M., Sweeney, S., and Kubit, J. (2008). “Green Jobs: Towards a Decent Work in a Sustainable, Low-Carbon World” (Geneva: UNEP/ILO/IOE/ITUC)

Rezai, A, Taylor, L., Mechler. R. (2013). Ecological Macroeconomics: An application to climate change. Ecological Economics (85): 69-76.

Ritthoff M., Rohn, H., Liedtke C. (2002). MIPS berechnen: Ressourcenproduktivität von Produkten und Dienstleistungen, Wuppertal, Wuppertal Inst. for Climate, Environment, Energy.

Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley (2009) Planetary boundaries:exploring the safe operating space for humanity. Ecology and Society 14(2): 32.

Romer, P. (1990). Endogenous Technical Change, Journal of Political Economy, 98, 71–102.

Røpke, I. (2011). Ecological macroeconomics – calling for a shift from consumption to investment. Paper for the SCORAI Workshop “Socio-technical transitions, social practices, and the new economics: Meeting the challenges of a constrained world”, Princeton, New Jersey, April 15-16, 2011.

Rosnick, D., Weisbrot, M. (2006). Are shorter hours good for the environment? A comparison of U.S. and European energy consumption. Center for Economic and Policy Research, Washington D.C. http://www.cepr.net/documents/publications/energy_2006_12.pdfRPA (2014). Study on Economic and Social Benefits of Environmental Protection and Resource Efficiency Related to the European Semester. Final Report prepared for DG Environment. http://ec.europa.eu/environment/integration/green_semester/pdf/RPA%20Final%20Report-main%20report.pdf

RPA (2015). Assessing the Potential Cost Savings and Resource Savings of Investments in 4 SME sectors. http://ec.europa.eu/environment/integration/green_semester/pdf/SME%20Investments%20in%20Resource%20Efficiency.pdf

Schmidt-Bleek, F. (1999). The Factor 10/MIPS-Concept: Bridging Ecological, Economic, and Social Dimensions with Sustainability Indicators. ZEF Publication Series, Tokyo/Berlin.

Slingenberg, A. et al. (2009). Environment and labour force skills, in Future Skill Needs of the Green Economy. Study by Ecorys. Cedefop, Thessaloniki.

Smulders, S., Toman, M., Withagen C. (2014). Growth theory and 'green growth'. Oxford Review of Economic Policy Volume 30 Number 3 Autumn 2014.

Solow, R. M (1956). A Contribution to the Theory of Economic Growth. Quarterly Journal of Economics (The MIT Press) 70 (1): 65–94.

Solow, R.M. (1974). Intergenerational Equity and Exhaustible Resources. Review of Economic Studies 41, 29-46. Springer Gabler Verlag (Eds) (2015). Gabler Wirtschaftslexikon, Stichwort: Beschäftigungspolitik, online: http://wirtschaftslexikon.gabler.de/Archiv/3917/beschaeftigungspolitik-v11.html.

Steffen et. al. (2015). Planetary Boundaries: Guiding human development on a changing planet. Science, 16 January 2015.

Steger S., Bleischwitz R., (2011). Drivers for the use of materials across countries. Journal of Cleaner Production, 19: 816-826.

Stiglitz, J. (1974). Growth with exhaustible natural resources: efficient and optimal growth paths, Review of Economic Studies, 41(1), 123–137.

Stock, JH, Watson MW 2003 Introduction to econometrics. Addison Wesley

Stocker, A., Hinterberger, F., Großmann, A. and M. I. Wolter. (2007). Wachstums-, Beschäftigungs- und Umweltwirkungen von Ressourceneinsparungen in Österreich (RESA). Study on behalf of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, Vienna. SERI Study No. 7. Sustainable Europe Research Institute, Vienna.

Scasny, M., Kovanda, J., Hak, Th..(2003). Material flow accounts, balances and derived indicators for the Czech Republic during the 1990s: results and recommendations for methodological improvements. Ecological Economics 45 : 41-57

Schaffartzik, A., Eisenmenger, N., Krausmann, F., Weisz, H. (2013). Consumption-based Material Flow Accounting. Austrian Trade and Consumption in Raw Material Equivalents 1995–2007. Journal of Industrial Ecology.

Schmidt-Bleek, F. (1999). The Factor 10/MIPS-Concept: Bridging Ecological, Economic, and Social Dimensions with Sustainability Indicators. ZEF Publication Series, Tokyo/Berlin.

Schreyer, Paul (2004) "Capital Stocks, capital services, and multifactor productivity measures" OECD http://www.oecd.org/std/productivity-stats/29877839.pdf

Schoer K. ,Wood R. , Weinzettel I. (2013). Estimating Raw Material Equivalents on a Macro-Level: Comparison of Multi-Regional Input–Output

Analysis and Hybrid LCI-IO. Environ. Sci. Technol.,47 (24), pp 14282–14289

Schoer K, Weinzettel J, Kovanda J, Giegrich J, Lauwigi C (2012) Raw material consumption of the European Union—Concept, calculation method, and results. Environ Sci Technol 46(16):8903–8909.

Schor, J.B. (2005). Sustainable Consumption and Worktime Reduction. In: Journal of Industrial Ecology 9(1-2), 37-50.

Stocker, A., Großmann, A., Madlener, R., Wolter, MI.(2008). Renewable energy in Austria: Modeling possible development trends until 2020. IIOMME, Spain.

Strand, J. and Toman, M. (2010). Green Stimulus, Economic Recovery, and Long-Term Sustainable Development. World Bank Policy Research. http://elibrary.worldbank.org/doi/book/10.1596/1813-9450-5163

Stricks, V., Hinterberger, F., Moussa, J. (2014). Developing targets for global material use. IntRESS Working Paper 2.3, Sustainable Europe Research Institute (SERI).

Sustain Labour (2013). Green Jobs and related policy frameworks: An overview of the European Union, February 2013.

United Nations 1990 Internationla Standard Industrial Classification of All Economic Activities. Third Version. Statistical Papers, Series/M, No 4, Rev.3 , sales No E.91.XVII.7. New York: United Nations Publishing Division.

United Nations 1991 Provisional Central Product Classification. Statistical Papers, Series/M, No 77, sales No E.91.XVII.7. New York: United Nations Publishing Division.

TNO (2014). Report on the linking of EXIOMOD and LPJmL Deliverable D3.3 of the POLFREE project. WP 3 - Scenarios and modelling of policy implementation for resource efficiency. https://www.ucl.ac.uk/polfree/publications/publications-2014/D3.3_Report_20on_20Linking_20EXIOMOD_20and_20LPJmL_02.pdf

TNO (2013). Opportunities for a Circular Economy in the Netherlands, The Netherlands Organisation for Applied Scientific Research. http://www.government.nl/files/documents-and-publications/reports/2013/10/04/opportunities-for-a-circular-economy-in-the-netherlands/tno-circular-economy-for-ienm.pdf

Tukker, A., A. de Koning, R. Wood, T. Hawkins, S. Lutter, J. Acosta, J.M. Rueda Cantuche, M. Bouwmeester, J. Oosterhaven, T. Drosdowski and J. Kuenen (2013). EXIOPOL – Development and Illustrative Analyses of a Detailed Global MR EE SUT/IOT. Economic Systems Research, 25, 50–70.

Tukker, A., E. Poliakov, R. Heijungs, T. Hawkins, F. Neuwahl, J.M. Rueda-Cantuche, S. Giljum, S. Moll, J. Oosterhaven and M. Bouwmeester (2009). Towards a Global Multi-regional Environmentally Extended Input–Output Database. Ecological Economics, 68, 1929–1937.Victor, P 2008. Managing without Growth. Cheltenham: Edward Elgar. UNEP (2009). Why Clean Energy Public Investment Makes Economic Sense - The Evidence Base, Paris.

UNEP (2010). Driving a Green Economy Through Public Finance and Fiscal Policy Reform. Working paper v. 1.0.

UNEP (2011). Decoupling Natural Resource Use and Environmental Impacts from Economic Growth http://www.unep.org/resourcepanel/decoupling/files/pdf/Decoupling_Report_English.pdf

UNEP (2011a). Towards a green economy. Chapter 7: Manufacturing. http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_7_Manufacturing.pdf

UNEP (2012). Environment for the Future we want. GEO5 (E-Book) http://www.unep.org/geo/GEO5_ebook/pdf/GEO5FULLEN.pdf

UNEP (2014). Decoupling2: technologies, opportunities and policy options. A report of the Working group on Decoupling to the International Resource Panel. Von Weizsäcker, E.U., de Larderal, J., Hargrover, K;, Hudson, C., Smith, M;, Rodriguez, M.

UNEP. (2014a). Using Models for Green Economy Policymaking. http://www.unep.org/greeneconomy/Portals/88/documents/GEI%20Highlights/UNEP%20Models%20GE_for%20web.pdf

UNEP, CSIRO (2011). Resource Efficiency: Economics and Outlook for Asia and the Pacific, United Nations Environment Programme, Bangkok. Published October 2011.

Uppenberg, K., Strauss, H. (2010). Innovation and productivity growth in the EU services sector.

Wackernagel, M.; Rees, W. (1996). Our Ecological Footprint: Reducing Human Impact on the Earth. New Society Publishers, Gabriola Island, British Columbia.

Wackernagel, M., Rees, W. (1997). Perceptual and structural barriers to investing in natural capital: economics from an ecological footprint perspective. Ecological Economics 20 (3), 3–24.

Walz, R. (2011). Employment and structural impacts of material efficiency strategies: results from five case studies. Journal of Cleaner Production 19, 805-815.

Weisz H., Krausmann F., Amann C., Eisenmenger N., Karl-Heinz Erb K-H, Hubacek K., Fischer-Kowalski M., (2006) The physical economy of the European Union: Cross-country comparison and determinants of material consumption Ecological Economics 58 : 676–698

Weizsäcker, E.U., Ayres, R.U., (2013). Boosting resource productivity: Creating pingpong dynamics between resource productivity and resource prices. Environmental Innovation and Scoietal Transitions, 9, 48-55

Wiedenhofer, D., Fischer-Kowalski, M. (2015). Achieving absolute decoupling? Comparing biophysical scenarios and macro-economic modelling results. WWW for Europe Working Paper no 86.

Wiedmann et al. (2013). The material footprint of nations.

Wijkman, A. Skånberg, K. (2015). The Circular Economy and Benefits for Society, Interim Report, Club of Rome with support from MAVA Foundation and Swedish Association of Recycling Industries, 2015.

Winship C, Morgan SL (1999). The estimation of causal effects from observational data. Annual Review of Sociology, 25:659–706Wooldridge JM (2002). Econometric analysis of cross section and panel data. MIT, Cambridge

World Economic Forum (2013). The Green Investment Report The ways and means to unlock private finance for green growth. A Report of the

Green Growth Action Alliance, Geneva. http://www3.weforum.org/docs/WEF_GreenInvestment_Report_2013.pdf

WRAP (2010). Securing the future – The role of resource efficiency http://www.wrap.org.uk/sites/files/wrap/Securing%20the%20future%20The%20role%20of%20resource%20efficiency.pdf

WRAP (2013). Economic Impacts of Resource Efficient Business Models. http://www.wrap.org.uk/sites/files/wrap/Economic%20impacts%20of%20resource%20efficient%20business%20models%20final%20report.pdf

Zachmann, G., Ndoye, A., and Abrell, J. (2011). Assessing the impact of the EU ETS using firm level data. Bruegel Working Papers.

ANNEX

Annex 1: Development of labour productivity in the service sectors

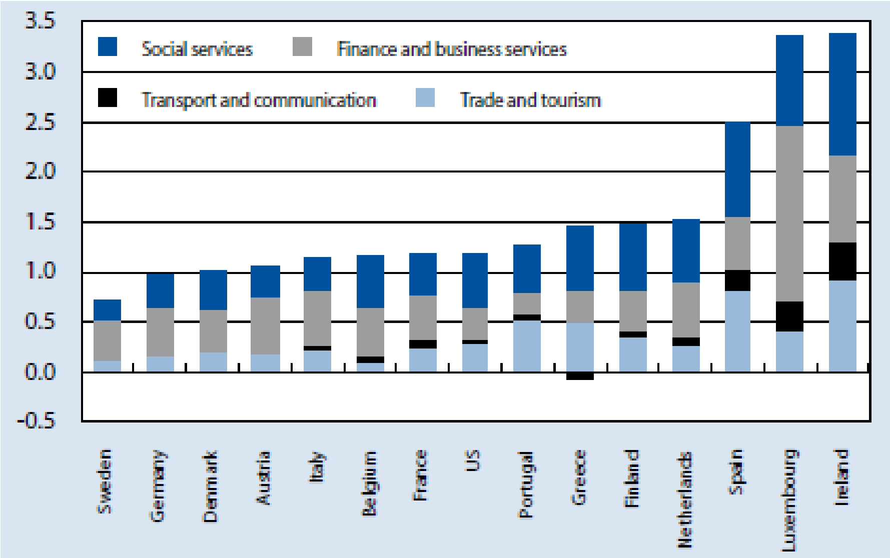
Many service sectors are quite resource efficient and contribute to a large degree to employment and economic output. Reductions in environmental pressures can in part be achieved by shifting consumption expenditure from material goods to services where possible (EEA 2014).

Although productivity growth is generally lower in the services sector than in manufacturing, it is responsible for a huge portion of aggregate growth in output per employee in the EU. This is due to its large size. Labour productivity in the EU services sector raised by about 1 percent per year from 1995 to 2005 (Uppenberg/Strauss 2010).

The services sector entails different subsectors, with varying productivity performance and mechanisms for improving output per employee. Figure A1.1 shows the respective contributions to employment growth of four major service subsectors (trade and tourism, transport and communication, finance and business services, and social services) between 1995 and 2005 for a selection of OECD countries. Finance and business services are the main contributors to the positive development of the services sector in many countries, being responsible for around half of total growth in output, with a slightly smaller share to employment growth. This sector is particularly important in Luxembourg, France, Belgium, and in the US.

In terms of productivity growth in services (measured as the ratio of real output over employment by sub-sector), remarkable deviations both across sub-sectors and across countries can be observed. Productivity growth has been mostly negative in social services, while it has typically been higher in trade and tourism and in transport and communication. The Netherlands, Sweden and Greece are among European leaders in aggregate services sector productivity growth, which in these cases has been driven mainly by trade and tourism, and to a smaller degree by transport and communication (Uppenberg/Strauss, 2010).

Figure A1.1 Growth in service sector employment (sub-sectoral contributions to average annual growth, 1995-2005, percent)



Source: Uppenberg/Strauss 2010 based on OECD data.

Depending on the branch considered, the potential to increase labour productivity varies. In the labour-intensive care economy, for example, productivity cannot be raised continuously, neither by technology, nor by standardisation. Personal services (especially in the field of care economy) cannot be rationalised to the same extent as it is possible for the production of goods or ICT intensive service industries (banks, insurance companies, communication service providers) (Hinterberger et al. 2013).

As already said, the service sector is in general more labour intensive than manufacturing and processing industries. Also due to demographic trends, i.e. an aging population, services (especially the care sector) will bind an increasing number of people. Today, qualified personnel is already scarce, in particular in sectors such as education and care. Therefore, especially in these sectors, a further increase of labour productivity is counterproductive (Hinterberger et al. 2013).

Additionally, it becomes increasingly obvious that the intention to increase labour productivity in the service sector has resulted in an intensification of work. In the meantime, this development has very negatively affected the costs of the social security system (health insurance contributions, early retirement, etc.) and burdened the production factor labour in terms of ancillary wage costs. The same holds for sectors with a high share of unqualified or personal services or for the retailing sector, which is characterised by low increases in production and whose relatively low productivity will be compensated by falling wages (Hinterberger et al. 2012).

Annex 2: Additional material and results from empirical analysis

Table A2.1 : Variables description

Variables	Description
VA	Gross value added at current basic prices (in millions of local currency)
VA_QI	Gross value added, volume indices (1995 = 100)
LP_I	Labour productivity. Measured as gross value added per hour worked, volume indices (1995 = 100)
RMI	Raw material input in kt. Direct input of raw material for use into the economy
CAP_QI	Capital services, volume indices (1995 = 100)
RP	Resource productivity. Measured as gross value added* per raw material input (1000 EUR per tonne)
CP	Capital productivity. Measured as gross value added per capital services, volume indices (1995 = 100)
Notes: *Gross value added data as Euro in annual average exchange rates	

Source: own calculation.

Table A2.2: Average value in productivity measures in agriculture sector (1995-2007)

Country	Labour Productivity			Capital Productivity		
	Mean	Min	Max	Mean	Min	Max
Czech Republic	146,937	92,717	226,464	0,862	0,697	1,000
Spain	120,796	100,000	133,770	1,110	0,999	1,186
Finland	135,303	100,000	179,032	1,130	1,000	1,337
France	125,943	100,000	145,321	0,922	0,783	1,010
Germany	138,194	100,000	180,389	1,795	1,000	2,946
Hungary	151,739	100,000	247,102	1,478	1,000	2,117
Ireland	139,220	100,000	169,153	1,025	0,947	1,124
Italy	120,453	100,000	134,284	0,955	0,845	1,065
Netherlands	103,728	94,675	115,252	0,924	0,832	1,006
UK	125,580	97,279	155,314	1,034	0,959	1,092
Notes: The units of measures of the variables are as defined on table A2.1						

Source: own calculation.

Table A2. 3 : Average value in productivity measures in construction sector (1995-2007)

Country	Labour Productivity			Capital Productivity		
	Mean	Min	Max	Mean	Min	Max
Czech Republic	96,356	89,315	116,653	0,572	0,375	1,073
Spain	85,914	80,441	100,000	0,925	0,820	1,000
Finland	105,718	100,000	116,974	0,779	0,541	1,184
France	99,570	96,086	103,850	0,896	0,822	1,000
Germany	101,069	97,782	105,897	0,906	0,867	1,000
Hungary	105,425	93,568	123,790	1,425	1,000	1,788
Ireland	91,724	79,293	107,968	0,728	0,614	0,922
Italy	97,414	91,107	100,917	0,801	0,667	1,000
Netherlands	95,310	92,318	100,000	0,762	0,655	1,000
UK	110,888	100,000	117,746	0,707	0,500	1,000
Notes: The units of measures of the variables are as defined on table A2.1						

Source: own calculation.

Table A2.4 : Average value in productivity measures in the energy sector (1995-2007)

Country	Labour Productivity			Capital Productivity		
	Mean	Min	Max	Mean	Min	Max
Czech Republic	97,645	72,380	127,634	0,715	0,582	1,064
Spain	142,769	100,000	171,517	1,123	1,000	1,216
Finland	141,759	100,000	184,718	1,139	1,000	1,243
France	134,732	100,000	160,744	1,260	0,941	1,531
Germany	148,318	100,000	184,087	1,070	0,995	1,220
Hungary	108,128	95,890	123,225	0,995	0,820	1,175
Ireland	115,395	89,471	168,672	0,899	0,774	1,072
Italy	116,439	97,475	134,178	0,918	0,880	1,000
Netherlands	132,868	100,000	176,412	1,032	0,861	1,254
UK	141,382	100,000	171,688	1,024	0,993	1,048
Notes: The units of measures of the variables are as defined on table A2.1						

Source: own calculation.

Table A2.5 : Average value in productivity measures in mining sector (1995-2007)

Country	Labour Productivity			Capital Productivity		
	Mean	Min	Max	Mean	Min	Max
Czech Republic	117,607	91,993	158,631	0,681	0,539	1,000
Spain	108,885	100,000	121,755	0,828	0,721	1,000
Finland	98,041	78,465	115,908	0,845	0,676	1,148
France	81,132	56,084	108,967	0,527	0,380	1,000
Germany	102,531	84,535	117,858	0,532	0,279	1,000
Hungary	139,667	90,697	196,959	1,234	0,985	1,823
Ireland	95,827	81,056	113,955	0,521	0,235	1,229
Italy	106,412	100,000	115,590	0,897	0,650	1,065
Netherlands	104,122	91,353	117,148	0,904	0,738	1,075
UK	101,242	87,549	114,595	0,959	0,734	1,085
Notes: The units of measures of the variables are as defined on table A2.1						

Table A2.6 : Average value in productivity measures in manufacturing sector (1995-2007)

Country	Labour Productivity			Capital Productivity		
	Mean	Min	Max	Mean	Min	Max
Czech Republic	135,471	100,000	201,746	0,930	0,798	1,034
Spain	101,334	96,475	111,187	0,923	0,858	1,000
Finland	142,717	100,000	205,380	1,174	0,962	1,539
France	125,853	100,000	151,284	1,026	0,989	1,050
Germany	119,136	100,000	145,004	0,972	0,926	1,045
Hungary	140,352	100,000	200,735	1,137	1,000	1,222
Ireland	171,414	100,000	249,099	1,047	0,879	1,162
Italy	102,479	99,732	106,635	0,854	0,767	1,000
Netherlands	120,080	100,000	146,715	1,018	0,971	1,115
UK	117,329	99,462	150,777	0,917	0,855	1,000
Notes: The units of measures of the variables are as defined on table A2.1						

Table A2.7 : Average value in productivity measures in transport sector (1995-2007)

Country	Labour Productivity			Capital Productivity		
	Mean	Min	Max	Mean	Min	Max
Czech Republic	101,436	82,994	125,554	0,816	0,707	1,006
Spain	102,263	97,433	105,814	0,808	0,631	1,000
Finland	113,502	100,000	123,503	1,117	1,000	1,174
France	118,810	100,000	135,125	1,070	1,000	1,166
Germany	121,404	100,000	145,968	0,894	0,807	1,007
Hungary	123,239	98,081	149,707	1,436	1,000	1,582
Ireland	87,079	68,320	106,328	0,681	0,481	1,067
Italy	102,049	97,379	106,656	0,909	0,839	1,000
Netherlands	115,879	100,000	134,150	1,044	0,987	1,096
UK	119,242	100,000	135,725	0,870	0,743	1,000

Notes: The units of measures of the variables are as defined on table A2.1

Source: own calculation.

Table A2.8 : Country, Period and Variable Coverage in EU KLEMS Database

			Growth accounting variables			
Country and regions	Abbrevia-tion	Labour productivity variables	MFP	Labour com-position	Capital Composition	Intermediate input composi-tion
Australia	Aus	1970	1982	1982	1970	-
Austria	Aut	1970	1980	1980	1976	1970
Belgium	Bel	1970	1980	1980	1970	1980
Cyprus	Cyp	1995	-	-	-	-
Czech Republic	Cze	1995	1995	1995	1995	1995
Denmark	Dnk	1970	1980	1980	1970	1970
Estonia	Est	1995	-	-	-	-
Finland	Fin	1970	1970	1970	1970	1970
France	Fra	1970	1980	1980	1970	1978
Germany	Ger	1970	1970	1970	1970	1978
Greece	Grc	1970	-	1992	-	1995
Hungary	Hun	1992	1995	1995	1995	1995
Ireland	Irl	1970	1995	1988	1970	-
Italy	Ita	1970	1970	1970	1970	1970
Japan	Jpn	1973	1973	1973	1970	1973
Latvia	Lva	1995	-	-	-	-

Lithuania	Ltu	1995	-	-	-	-
Luxembourg	Lux	1970	1992	1992	1970	1995
Malta	Mlt	1995	-	-	-	-
Netherlands	Nld	1970	1979	1979	1970	1987
Poland	Pol	1995	–	1995	–	1995
Portugal	Prt	1970	1995	1992	1970	1977
Slovak Republic	Svk	1995	-	1995	-	1995
Slovenia	Svn	1995	1995	1995	1995	1995
Spain	Esp	1970	1980	1980	1970	1980
Sweden	Swe	1970	1993	1981	1993	1993
United Kingdom	Uk	1970	1970	1970	1970	1970
United States (NAICS based)	Usa-naics	1977	1977	-	1970	-
United States(SIC based)	Usa-sic	1970	1970	1970	1970	1970
West Germany	Dew	1970	1970	1970	1970	1978
EU-25	EU-25	1995	-	-	-	-
EU-15	EU-15	1970	-	-	-	-
EU-10	EU-10	1995	-	-	-	-
EU-15ex	EU-15ex	1970	1980	1980	1980	1980
Eurozone	Euro	1970	-	-	-	-
Eurozone ex	Euro-ex	1970	1980	1980	1980	1980

Notes: This Table indicates for each country and variable the first year for which data is available in the EU KLEMS database, March 2008. (–) indicates not available.

Source : Mahony and Timmer (2009)

Table A2.9 : Mapping between GTAP (GSC) sectors, ISIC-Rev.3 and CPC

GTAP (GSC) Sectors Description	GTAP Code	ISIC (REV3 codes) Correspondance to GTAP* (n.a. data)	CPC Codes Correspondance to GTAP* (n.a data)
Paddy rice, Wheat, Cereal grains, Vegetables, fruit, nuts, Oil seeds, Sugar cane, sugar beet, Plant-based fibers ,Crops, Bovine cattle, sheep and goats, horses, Animal products, Raw milk, Wool, silk-worm cocoons, Fishing, Forestry	PDR, WHT, GRO, V_F, OSD, C_B, PFB, OCR, CTL, OAP, RMK, WOL, FRS, FSH	01111, 01301, 01401, 01112, 01302, 01402, 01113, 01303, 01403, 01121, 01204, 01404, 01114, 01305, 01405 01115, 01306, 01406, 01116,01307, 01407, 01117, 01122, 1132, 01308, 01408, 01211, 01309, 01409, 01220, 01212, 013010, 013011, 014010, 014011, 01213, 013012, 014012, 200, 0150, 0500	0113, 0114 , 0111, 0112, 0115, 0116 0119, 012, 013, 014, 018, 0192, 015, 016, 017, 0191, 0193, 0194, 0199, 0211 ,0299, 0212 0292, 0293, 0294 0295, 0297, 0298 0291, 0296 , 03,
textiles and man-made fibres	tex	17, 243(n.a.)	-
Chemical, rubber, plastic products	crp	24 [excluding 243 code (n.a.) and 244], 25	-
Dwelling: imputed rents. These are calculated based on ownership of dwellings.	dwe	n.a	n.a.
Notes: n.a Not available data for Labour and Growth * source: McDougall et. Al (1998).			

Table A2.10 : GTAP Sectors Defined by reference to the CPC

Number	Code gtap	Code CPC	Description
1	pdr	0113	Rice, not husked
		0114	Husked rice
2	wht	0111	Wheat and meslin
3	gro	0112	Maize (corn)
		0115	Barley
		0116	Rye, oats
		0119	Other cereals
4	v_f	012	Vegetables
		013	Fruit and nuts
5	osd	014	Oil seeds and oleaginous fruit
6	c_b	018	Plants used for sugar manufacturing
7	pfb	0192	Raw vegetable materials used in textiles

8	ocr	015	Live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds
		016	Beverage and spice crops
		017	Unmanufactured tobacco
		0191	Cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets
		0193	Plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes
		0194	Sugar beet seed and seeds of forage plants
		0199	Other raw vegetable materials
9	ctl	0211	Bovine cattle, sheep and goats, horses, asses, mules, and hinnies, live
		0299	Bovine semen
10	oap	0212	Swine, poultry and other animals, live
		0292	Eggs, in shell, fresh, preserved or cooked
		0293	Natural honey
		0294	Snails, live, fresh, chilled, frozen, dried, salted or in brine, except sea snails; frogs' legs, fresh, chilled or frozen
		0295	Edible products of animal origin n.e.c.
		0297	Hides, skins and furskins, raw
		0298	Insect waxes and spermaceti, whether or not refined or coloured
11	rmk	0291	Raw milk
12	wol	0296	Raw animal materials used in textile
13	for	03	Forestry, logging and related service activities
19	cmt	21111	Meat of bovine animals, fresh or chilled
		21112	Meat of bovine animals, frozen
		21115	Meat of sheep, fresh or chilled
		21116	Meat of sheep, frozen
		21117	Meat of goats, fresh, chilled or frozen
		21118	Meat of horses, asses, mules or hinnies, fresh, chilled or frozen
		21119	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen
		2161	Fats of bovine animals, sheep, goats, pigs and poultry, raw or rendered; wool grease
20	omt	21113	Meat of swine, fresh or chilled
		21114	Meat of swine, frozen
		2112	Meat and edible offal, fresh, chilled or frozen, n.e.c.
		2113	Preserves and preparations of meat, meat offal or blood

		2114	Flours, meals and pellets of meat or meat offal, inedible; greaves
		2162	Animal oils and fats, crude and refined, except fats of bovine animals, sheep, goats, pigs and poultry
21	vol	2163	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed rape, colza and mustard oil, crude
		2164	Palm, coconut, palm kernel, babassu and linseed oil, crude
		2165	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and mustard oil and their fractions, refined but not chemically modified; other oils obtained solely from olives and sesame oil, and their fractions, whether or not refined, but not chemically modified
		2166	Maize (corn) oil and its fractions, not chemically modified
		2167	Palm, coconut, palm kernel, babassu and linseed oil and their fractions, refined but not chemically modified; castor, tung and jojoba oil and fixed vegetable fats and oils (except maize oil) and their fractions n.e.c., whether or not refined, but not chemically modified
		2168	Margarine and similar preparations
		2169	Animal or vegetable fats and oils and their fractions, partly or wholly hydrogenated, inter-esterified, re-esterified or elaidinised, whether or not refined, but not further prepared
		217	Cotton linters
		218	Oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes
22	mil	22	Dairy products
23	pcr	2316	Rice, semi- or wholly milled
24	sgr	235	Sugar
25	ofd	212	Prepared and preserved fish
		213	Prepared and preserved vegetables
		214	Fruit juices and vegetable juices
		215	Prepared and preserved fruit and nuts
		2311	Wheat or meslin flour
		2312	Cereal flours other than of wheat or meslin
		2313	Groats, meal and pellets of wheat
		2314	Cereal groats, meal and pellets n.e.c.
		2315	Other cereal grain products (including corn flakes)
		2317	Other vegetable flours and meals
		2318	Mixes and doughs for the preparation of bakers' wares
		232	Starches and starch products; sugars and sugar syrups n.e.c.
		233	Preparations used in animal feeding
		234	Bakery products
		236	Cocoa, chocolate and sugar confectionery

		237	Macaroni, noodles, couscous and similar farinaceous products
		239	Food products n.e.c.
26	b_t	24	Beverages
		25	Tobacco products

Table A2.11 : GTAP Sectors defined by reference to the ISIC-Rev.3

Number	Code GTAP	Code ISIC Rev. 3	Description
14	fsh	015	Hunting, trapping and game propagation including related service activities
		05	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
15	col	101	Mining and agglomeration of hard coal
		102	Mining and agglomeration of lignite
		103	Mining and agglomeration of peat
16	oil	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	12	Mining of uranium and thorium ores
		13	Mining of metal ores
		14	Other mining and quarrying
27	tex	17	Manufacture of textiles
		243	Manufacture of man-made fibres
28	wap	18	Manufacture of wearing apparel; dressing and dyeing of fur
29	lea	19	Tan and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
30	lum	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
31	ppp	21	Manufacture of paper and paper products
		22	Publishing, printing and reproduction of record media
32	p_c	231	Manufacture of coke oven products
		232	Manufacture of refined petroleum products
		233	Processing of nuclear fuel
33	crp	241	Manufacture of basic chemicals
		242	Manufacture of other chemical products
		25	Manufacture of rubber and plastics products

34	nmm	26	Manufacture of other non-metallic mineral products
35	i_s	271	Manufacture of basic iron and steel
		2731	Casting of iron and steel
36	nfm	272	Manufacture of basic precious and non-ferrous metals
		2732	Casting of non-ferrous metals
37	fmp	28	Manufacture of fabricated metal products, except machinery and equipment
38	mvh	34	Manufacture of motor vehicles, trailers and semi-trailers
39	otn	35	Manufacture of other transport equipment
40	ele	30	Manufacture of office, accounting and computing machinery
		32	Manufacture of radio, television and communication equipment and apparatus
41	ome	29	Manufacture of machinery and equipment n.e.c.
		31	Manufacture of electrical machinery and apparatus n.e.c.
		33	Manufacture of medical, precision and optical instruments, watches and clocks
42	omf	36	Manufacturing n.e.c.
		37	Recycling
43	ely	401	Production, collection and distribution of electricity
44	gdt	402	Manufacture of gas; distribution of gaseous fuels through mains
		403	Steam and hot water supply
45	wtr	41	Collection, purification and distribution of water
46	cns	45	Construction
47	trd	50	Sales, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
		51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
		521	Non-specialized retail trade in stores
		522	Retail sale of food, beverages and tobacco in specialized stores
		523	Other retail trade of new goods in specialized stores
		524	Retail sale of second-hand goods in stores
		525	Retail trade not in stores
		526	Repair of personal and household goods
		55	Hotels and restaurants
48	otp	60	Land transport; transport via pipelines
		63	Supporting and auxiliary transport activities; activities of travel agencies
49	wtp	61	Water transport
50	atp	62	Air transport
51	cmn	64	Post and telecommunications

52	ofi	65	Financial intermediation, except insurance and pension funding
		67	Activities auxiliary to financial intermediation
53	isr	66	Insurance and pension funding, except compulsory social security
54	obs	K	Real estate, renting and business activities
55	ros	92	Recreational, cultural and sporting activities
		93	Other service activities
		95	Private households with employed persons
56	osg	75	Public administration and defense; compulsory social security
		80	Education
		85	Health and social work
		90	Sewage and refuse disposal, sanitation and similar activities
		91	Activities of membership organizations n.e.c.
		99	Extra-territorial organizations and bodies
57	dwe	n.a.	n.a.

Table A2.12 : Correspondence OF GTAP (GSC) sectors with EU KLEMS sectors (ISIC Rev 3) used in this study

Sectors description by EU KLEMS, ISIC Rev 3	Code ISIC Rev3	GTAP (GSC) sectors-Code
Agriculture	1	pdr,wht,gro,v_f,osd,c_b ,pfb,ocr,ctl,oap,rmk,wol,
Forestry	2	frs
Fishing	B	fsh
Mining of coal and lignite; extraction of peat	10	Col
Mining and quarrying of energy producing materials	10t12	Col+omn
Extraction of crude petroleum and natural gas and services	11	oil
Mining of uranium and thorium ores	12	omn
Mining and quarrying except energy producing materials	13t14	omn
Food , beverages and tobacco	15t16	cmt,omt,vol,mil,pcr,sgr
Textiles	17	tex
Wearing apparel, dressing and dying of fur	18	wap
Leather, leather and footwear	19	lea
Wood and of wood and cork	20	lum
Pulp, paper and paper	21	ppp

Printing, publishing and reproduction	22	ppp
Coke, refined petroleum and nuclear fuel	23	p_c
Chemicals and chemical products	24	crp
Rubber and plastics	25	crp
Other non-metallic mineral	26	nmm
Basic metals	27	i_s, nfm
Fabricated metal	28	fmp
Machinery	29	ome
Office, accounting and computing machinery	30	ele
Electrical machinery and apparatus, nec	31	ome
Radio, television and communication equipment	32	ele
Medical, precision and optical instruments	33	ome
Motor vehicles, trailers and semi-trailers	34	mvh
Other transport equipment	35	otn
Manufacturing nec	36	omf
Recycling	37	omf
Electricity and gas	40	ely, jdt
Water supply	41	wtr
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	50	trd
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	trd
Retail trade, except of motor vehicles and motorcycles; repair of household good	52	trd
Inland transport	60	otp
Water transport	61	wtp
Air transport	62	atp
Supporting and auxiliary transport activities; activities of travel agencies	63	otp
Post and telecommunications	64	cmn
Financial intermediation, except insurance and pension funding	65	ofi
Insurance and pension funding, except compulsory social security	66	isr
Activities related to financial intermediation	67	ofi

Sewage and refuse disposal, sanitation and similar activities	90	osg
Activities of membership organizations ne	91	osg
Recreational, cultural and sporting activities	92	ros
Other service activities	93	ros
Construction	F	cns
Hotels and restaurants	H	trd
Real estate, renting and business activities	K	obs
Public admin and defence; compulsory social security	L	osg
Education	M	osg
Health and social work	N	osg
Private households with employed persons	P	ros
Extra-territorial organizations and bodies	Q	osg

Table A2.13 Top ten countries with the Great Greatest Resource Input

Sector	Countries
Construction	Spain, Germany, France, Italy, United Kingdom, Poland, Belgium, Portugal, Ireland, Finland.
Agriculture	France, Germany, United Kingdom , Poland, Spain, Italy, Greece, Romania, Netherlands, Denmark
Food manufacture	France Germany United Kingdom Italy Spain Poland Greece Netherlands Belgium Ireland
Petroleum and coal products	Germany Italy France United Kingdom Spain, Netherlands, Poland, Belgium, Romania, Greece
Energy supply	Germany Poland United Kingdom Italy Spain Greece Romania Czech Republic France Bulgaria
Business services	Germany, France, United Kingdom, Spain, Italy, Poland, Sweden, Belgium, Finland, Netherlands
Transport	Germany, France, Italy, United Kingdom, Spain, Greece, Poland, Belgium, Netherlands, Sweden
Note: The sequence of the countries is sorted from greatest input to lowest	

Table A2.14 Percentage change in resource productivity between 1997 and 2007

Sector / Country	Agriculture	Constru-ction	Electricity, gas and water sup-ply	Mining and quarrying	Manufactu-ring	Transport
Spain	22,9	51,6	12,0	63,8	11,2	-10,0
Finland	23,1	28,9	108,5	186,3	45,1	-16,0
France	6,36	29,60	42,16	86,32	6,43	-43,93
Germany	-10,5	-4,1	35,8	-1,5	30,1	-33,3
Hungary	144,6	37,8	273,3	96,7	91,5	17,0
Ireland	39,6	114,5	94,7	104,4	171,8	-11,8
Italy	16,0	97,0	37,8	-25,5	8,4	-22,9
Netherlands	9,7	86,2	326,2	113,3	70,4	-7,4
UK	39,6	106,9	56,8	178,9	23,8	-29,3
Czech Repub-lic	n.a	n.a	n.a	n.a	n.a	n.a
Notes: n.a not available						

Table A2.15 List of European Member States (section 4.4.2)

Country
Belgium
Bulgaria
Czech Republic
Denmark
Germany
Estonia
Ireland
Greece
Spain
France
Croatia
Italy
Cyprus
Latvia
Lithuania
Luxembourg
Hungary

Malta
Netherlands
Austria
Poland
Portugal
Romania
Slovenia
Slovakia
Finland
Sweden
United Kingdom

Table A2.16 Variables description (section 4.4.2)

Variables	Description
DE	Domestic Extraction
Employment	Employment (1000 persons) covers all persons engaged in some productive activity (within the production boundary of the national accounts). Employed persons are either employees (working by agreement for another resident unit and receiving remuneration) or self-employed (owners of unincorporated enterprises).
Energy Consumption	This indicator expresses the sum of the energy supplied to the final consumer's door for all energy uses. It is the sum of final energy consumption in industry, transport, households, services, agriculture, etc expressed as 1000 tonnes of oil equivalent.
GDP	Gross Domestic Product at current prices figures expressed in (millions of) Euros
Population density	Population density measured as the ratio between the annual average population and the land area (person per km^2)
RME	Raw Material Equivalent
RMI	Raw material input in 1000 tonnes. Direct input of raw material for use into the economy.
RP	Resource productivity. Measured as GDP per raw material input (1000 EUR per tonne)
R&D expenditure	Intramural R&D expenditures (millions Euros) are all expenditures for R&D performed within a statistical unit or sector of the economy during a specific period, whatever the source of funds
Notes: All variables extracted from EUROSTAT database	

Labour and capital productivity across Member States

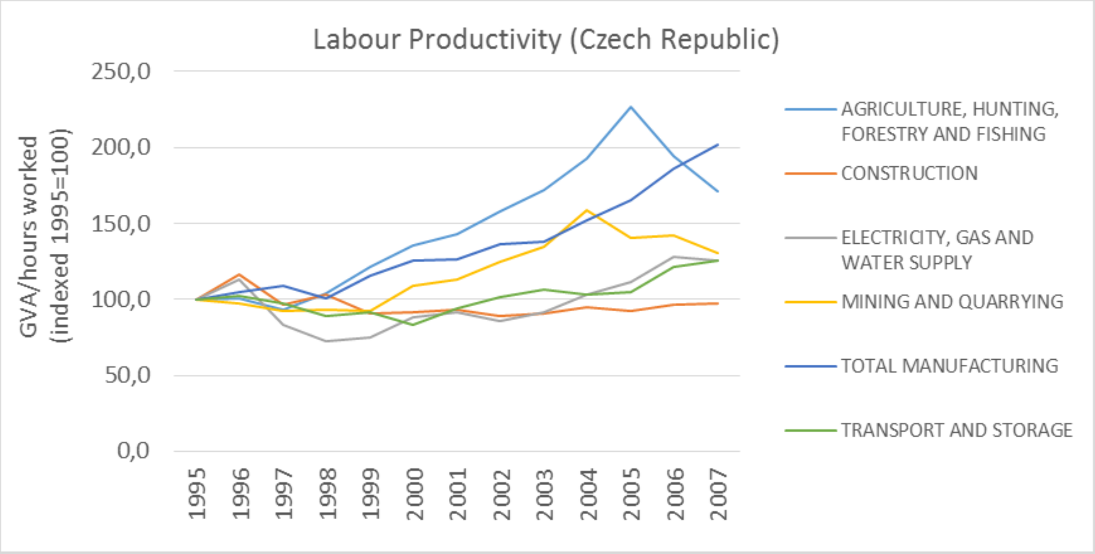
This section corresponds to Task A and C of the tender, and provides a descriptive analysis of how labour, capital and resource productivity change over time in ten Member States. We examine aspects of labour and capital productivity in six sectors for ten countries for the period from 1995 to 2007 and changes in resource productivity between 1997 and 2007. International comparisons of productivity growth can give useful insights in economic performance and identify common trends across countries that can be interesting for further investigation.

In this we examine individual Member States and their labour and capital productivity trends in different sectors. The aim is to give a comprehensive picture of labour and capital productivity of the different economies between 1995 and 2007.

Czech Republic and Hungary

Labour Productivity

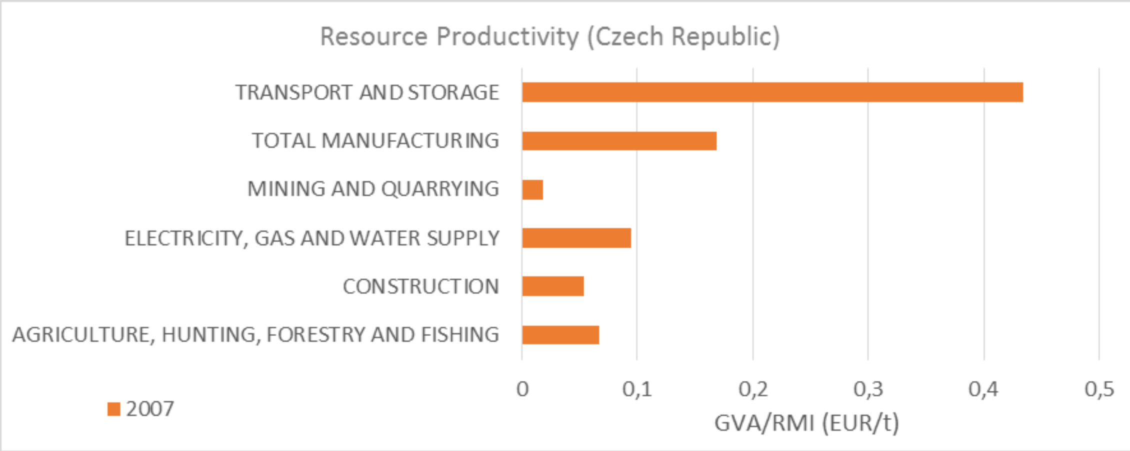
The Czech Republic and Hungary are more labour productive in agriculture, manufacturing and mining, than other sectors, although all sectors experienced either growth or remained unchanged. The agricultural sector reached a peak in 2005, more than doubling productivity in both countries, before dropping off until 2007. The manufacturing sector became consistently more productive in both countries, doubling its productivity levels in 2007 compared to 1995. The mining and construction sectors stagnated in both countries.



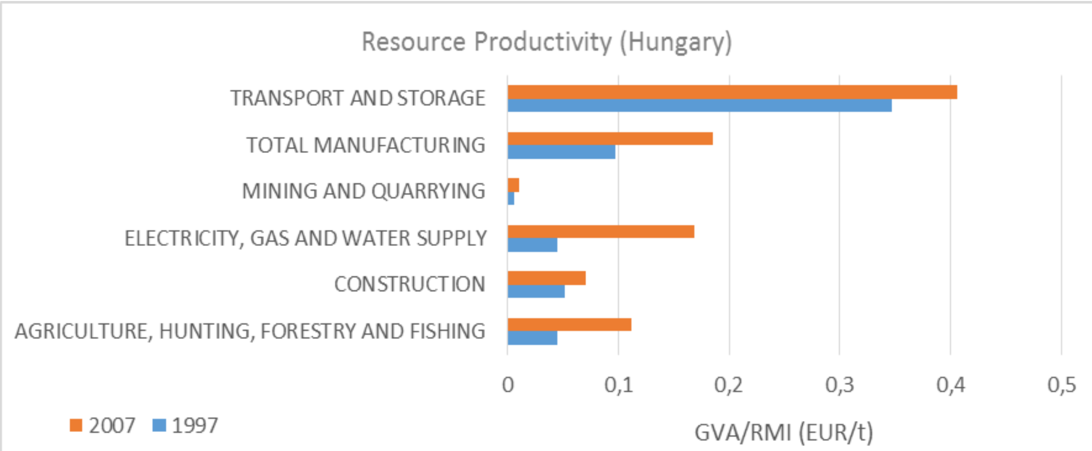
Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Resource Productivity



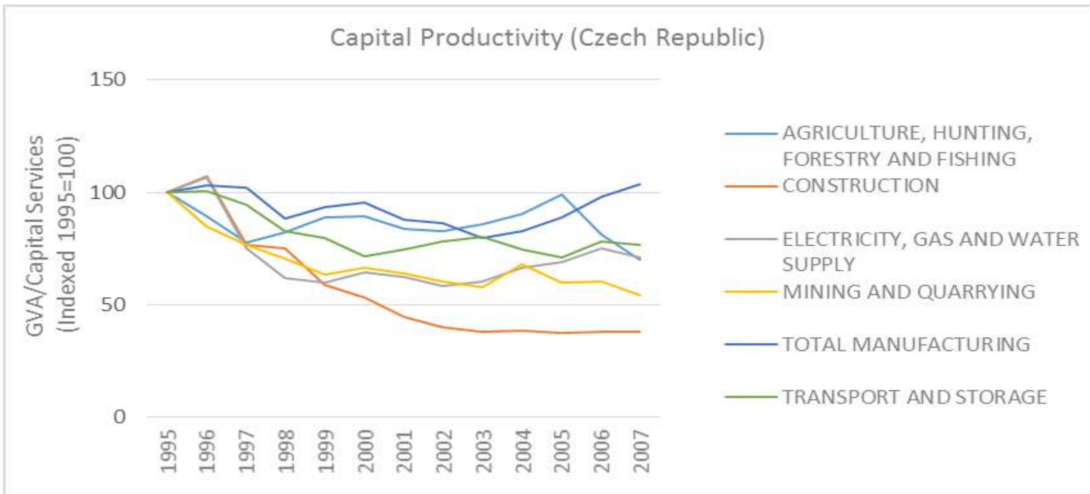
Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.



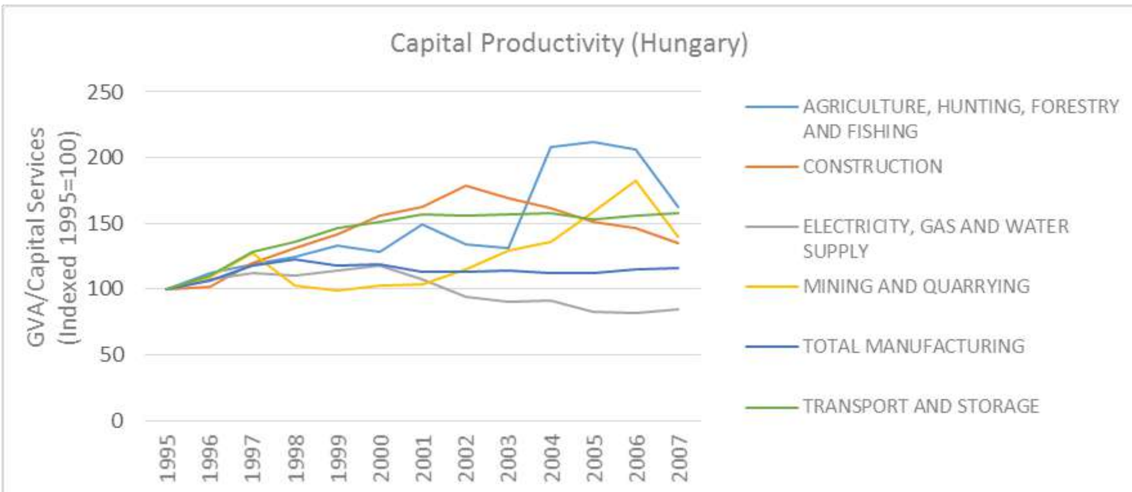
Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

Capital productivity in the Czech Republic experienced on overall decline as compared to 1995 levels, apart from manufacturing and energy that made a partial recovery over the time period. Hungary, on the other hand, had an overall increase in capital productivity, although with fluctuations for all sectors except energy, which decreased 15% in productivity when compared to 1995 levels. Agriculture in Hungary more than doubled its productivity in capital between 2004 and 2006 after decreasing again after 2006.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

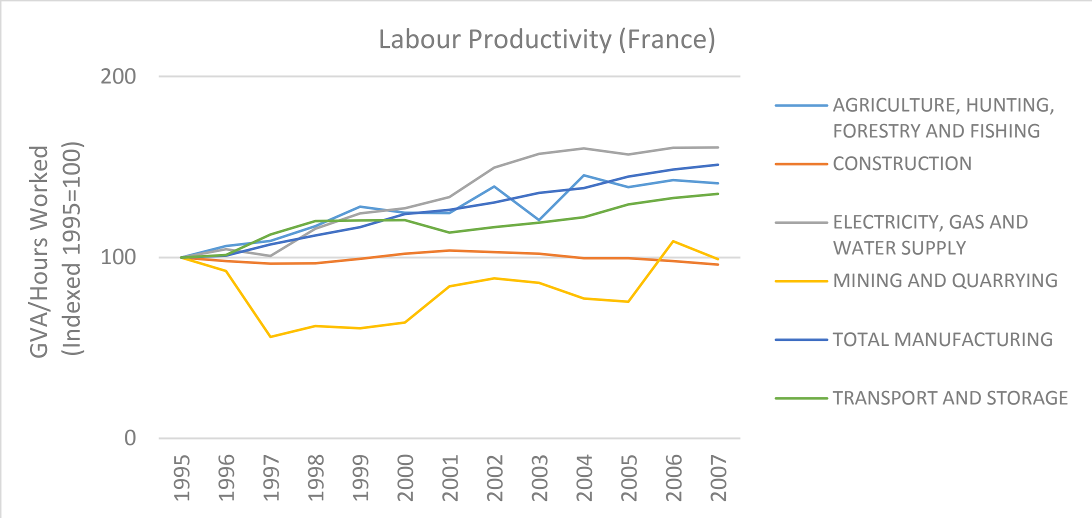


Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

France

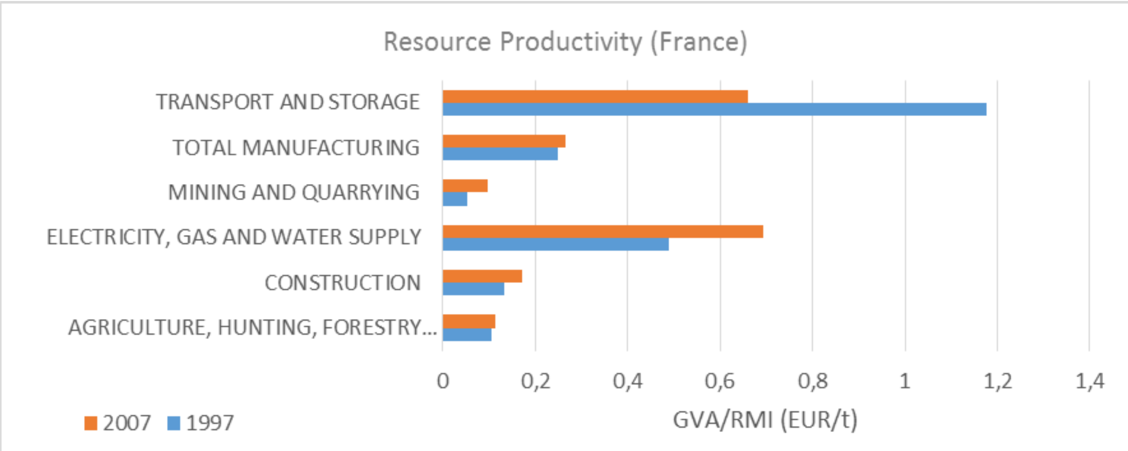
<u>Labour Productivity</u>

Manufacturing, energy and agriculture, followed by transport, were the most labour productive sectors in France, all four sectors experiencing growth throughout the period. The mining sector on the other hand was subject to a fluctuations with a significant fall in 1996, slowly recovering afterwards. Labour productivity in the construction sector stagnated over the entire period.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

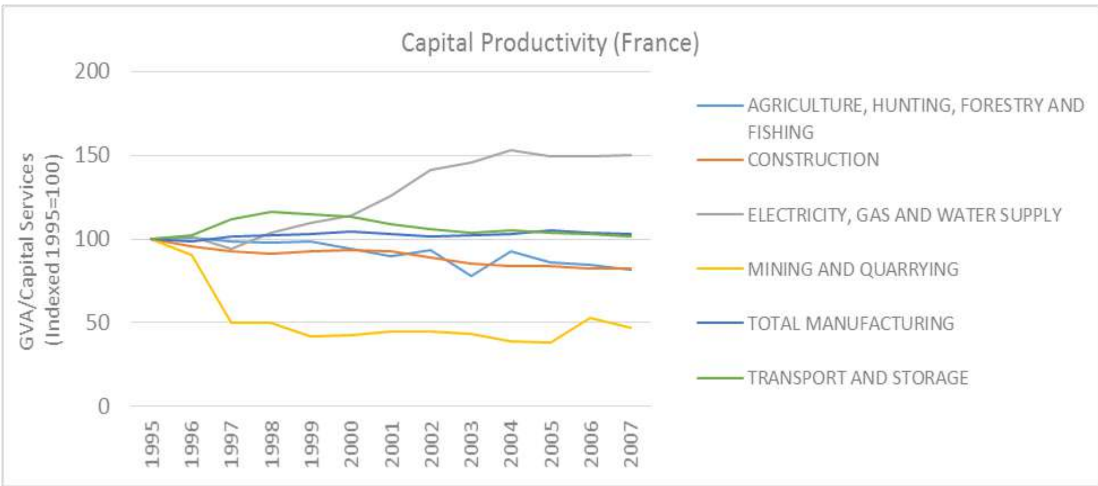
Resource Productivity



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

In France, capital services are used more productively in the energy sector reaching a peak in 2004, then levelling off. The other sectors remained at the same levels or were slightly decreasing over the period. The construction and agriculture sector slightly decreased to levels of productivity 80 percent of those in 1995. Just like labour productivity, mining and quarrying experienced a sharp decline in capital productivity after 1996 only to stagnate thereafter. Agriculture on the other hand experienced an increase in labour productivity while capital productivity stagnated over the same period.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

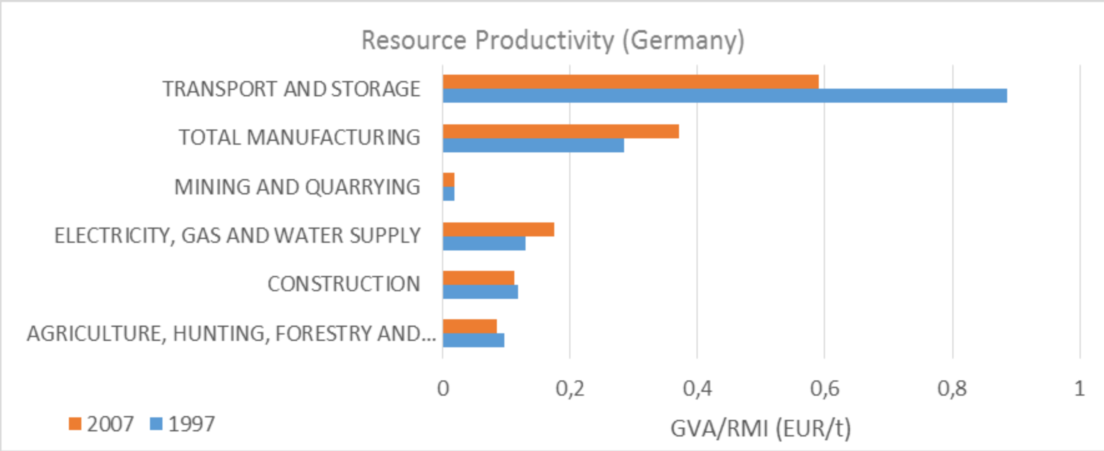
Germany

Labour Productivity

Like France, manufacturing, energy and agriculture, followed by transport, were the most labour productive sectors in Germany during the period under consideration. However, unlike France, all of the sectors either stagnated or increased in their productivity (construction was at a productivity level of 98 percent compared to 1995 levels). The mining sector fluctuated around the level of 1995 between the years.

Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

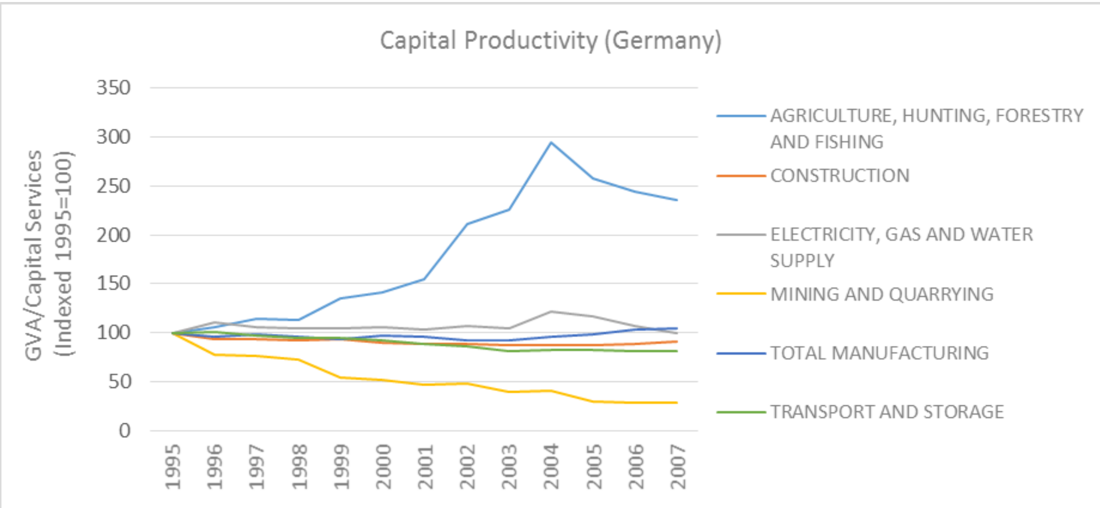
Resource Productivity



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

Almost all of Germany's sectors experienced negative or no change in capital productivity. The only sector that showed a different pattern was agriculture, which experienced a significant increase in capital productivity starting in 1998 and peaking in 2004.

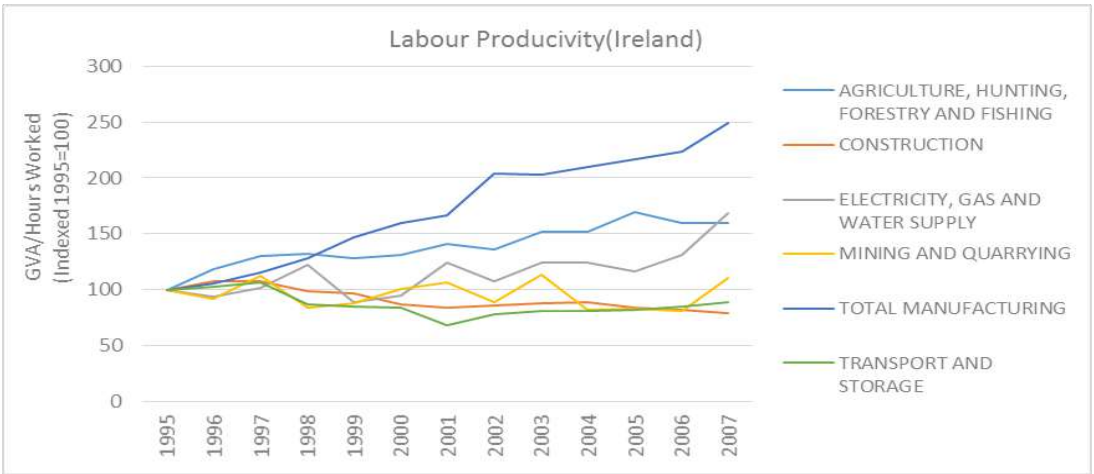


Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Ireland

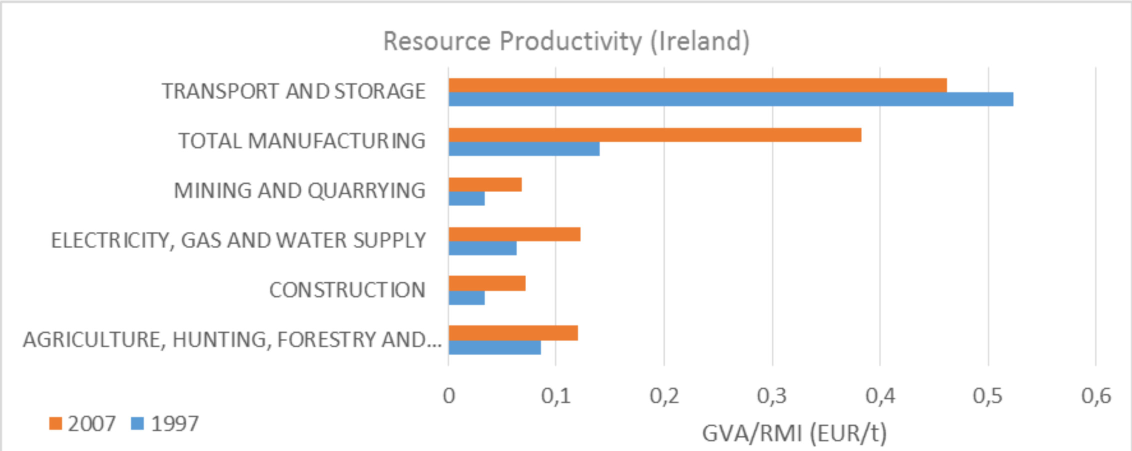
Labour Productivity

Ireland experienced considerable growth in labour productivity in the manufacturing sector over the observed period, with agriculture and energy also increasing considerably. Meanwhile, the construction and transport sectors decreased slightly, while mining fluctuated but around 1995 levels.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

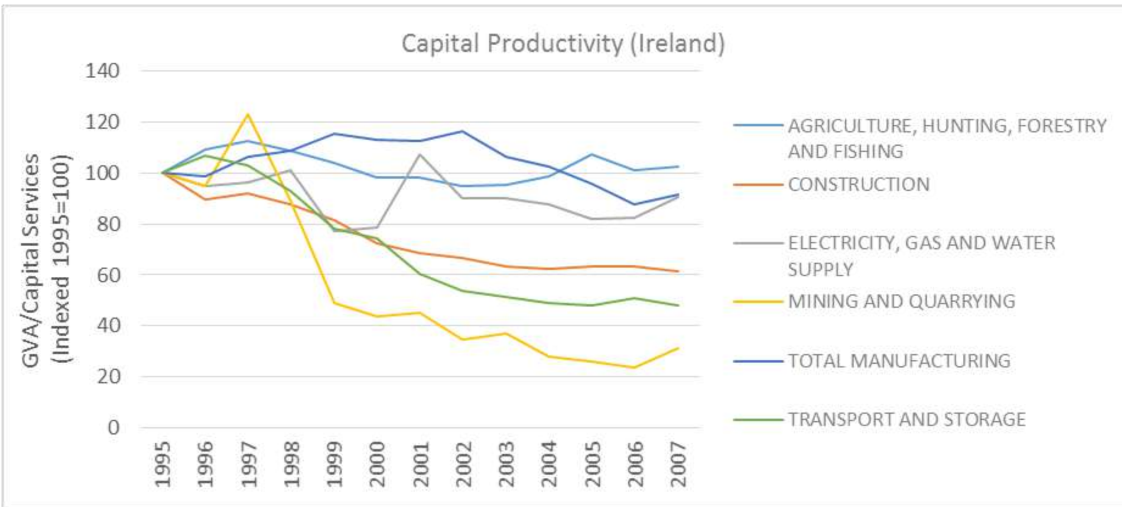
Resource Productivity



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

Capital productivity decreased in all sectors over the observed time period apart from agriculture, which stagnated around 1995 levels of capital productivity. Mining experienced the most significant decline in capital efficiency, ending up at levels 30% of 1995 levels of productivity, with transport and construction at 48% and 62%, respectively.

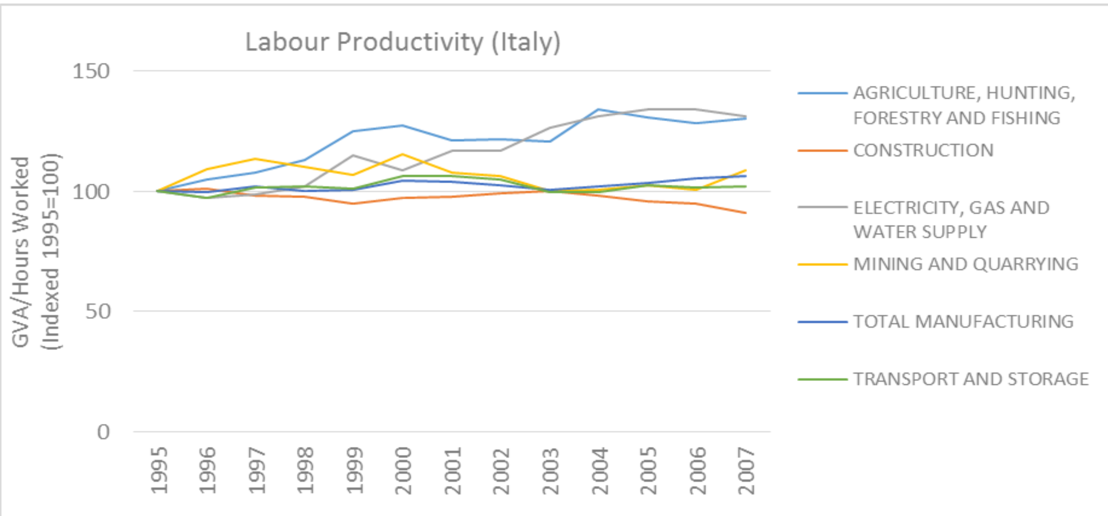


Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Italy

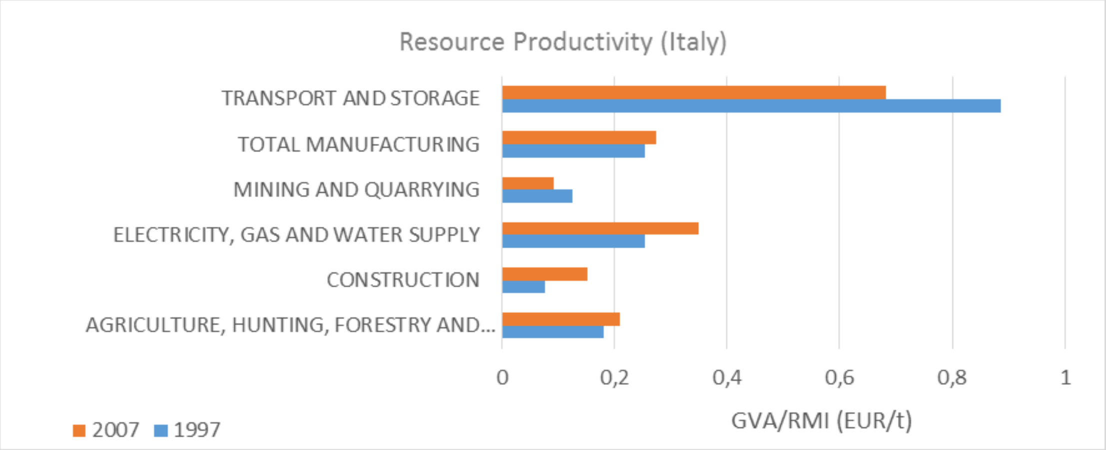
Labour Productivity

Italy's labour productivity followed more or less the same pattern as Spain. The biggest evolution occurred in the agriculture and energy sector with an increase of 30% over the observed period in both sectors. The other sectors increased mildly, with only construction declining to levels 90% of those in 1995.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

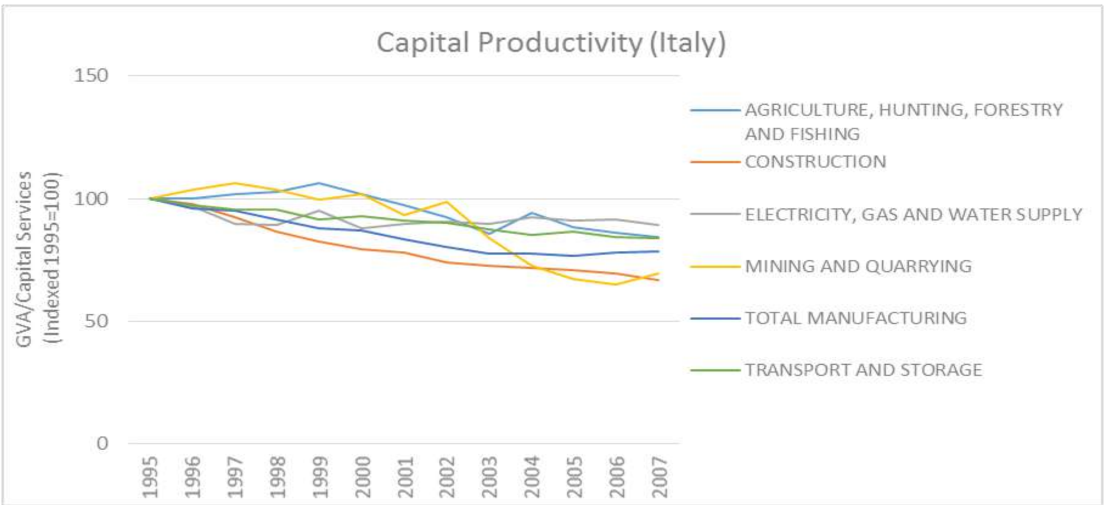
Resource Productivity



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

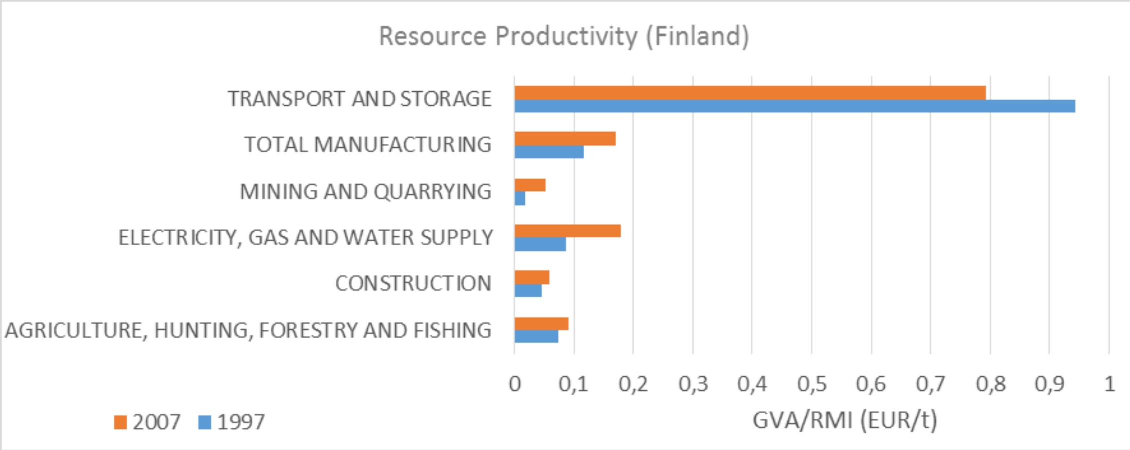
Capital Productivity

Capital productivity for Italy decreased in all sectors after 2000, where only electricity, gas, and water supply come out as the most capital productive sector in 2007. But even as the most capital efficient sector, it was only 90 percent as effective in terms of capital services input relative to output (GVA) when compared to 1995. Mining and quarrying was the most capital efficient sector in 2002 only to experience a sharp decline, becoming one of the least productive sectors in 2007. Construction experienced a consistent decline in capital efficiency throughout the observed period.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Finland



Labour Productivity

Finland overall experienced an increase in labour and capital productivity with more productive sectors being manufacturing, energy and agriculture. Construction remained stagnant throughout the period, whereas transportation experienced slow but consistent growth, ending up at a productivity level 23% higher than in 1995. Labour productivity in the mining sectors remained almost at the same level throughout the years, after experiencing a significant downward trend only between the years 1995-2000, but recovering thereafter, ending up 9 percent less productive than in 1995.

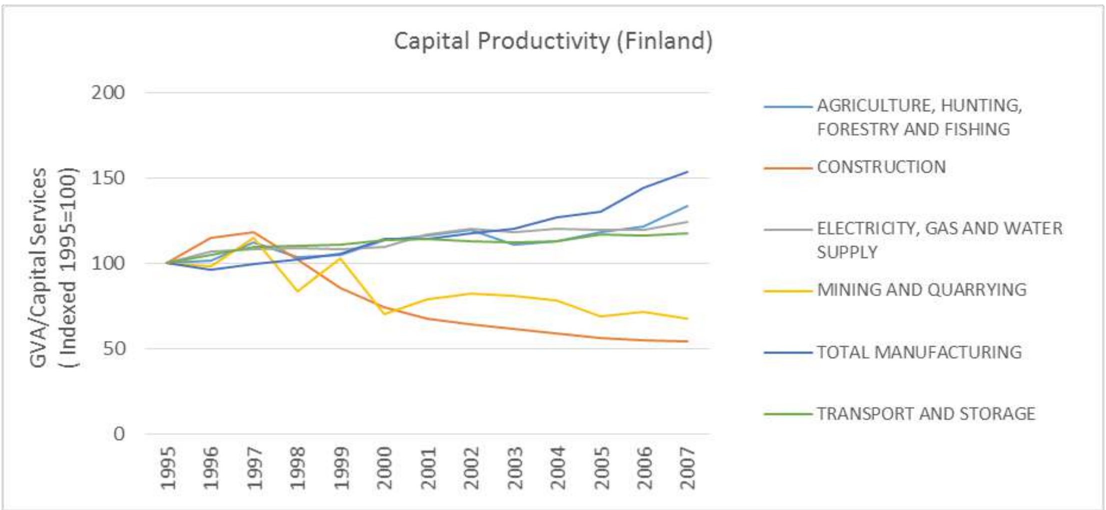
Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Resource Productivity

Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

Capital productivity in Finland experienced opposite trends in certain sectors. Manufacturing, agriculture, electricity, gas and water supply, and transportation all experiencing growth has decreased by more than half for these sectors over the same time period, increasing their productivity by 53%, 33%, 24% and 17%, respectively. On the other hand, mining and construction experienced dramatic decreases, being only 67% and 54% as productive when compared to 1995 levels.

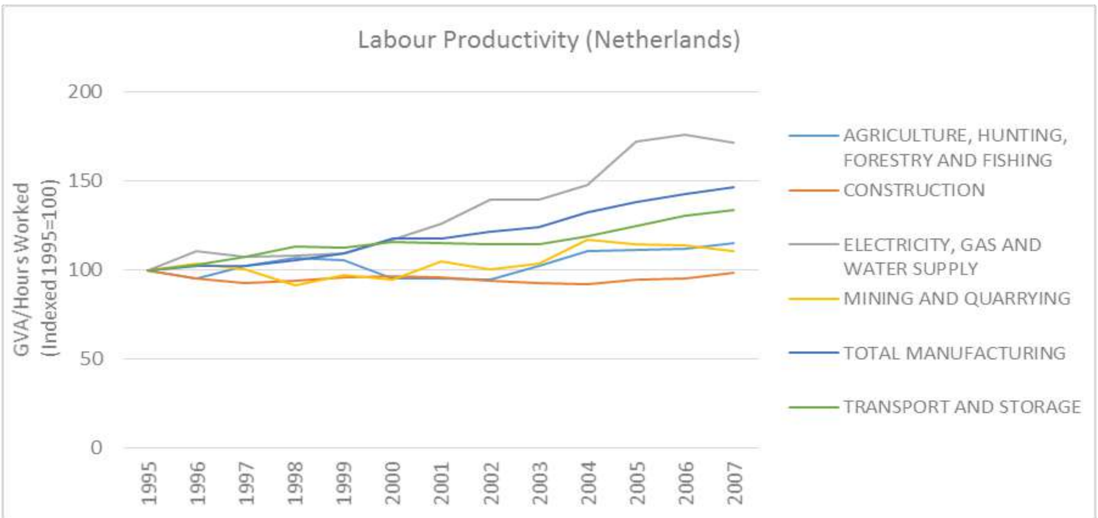


Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Netherlands

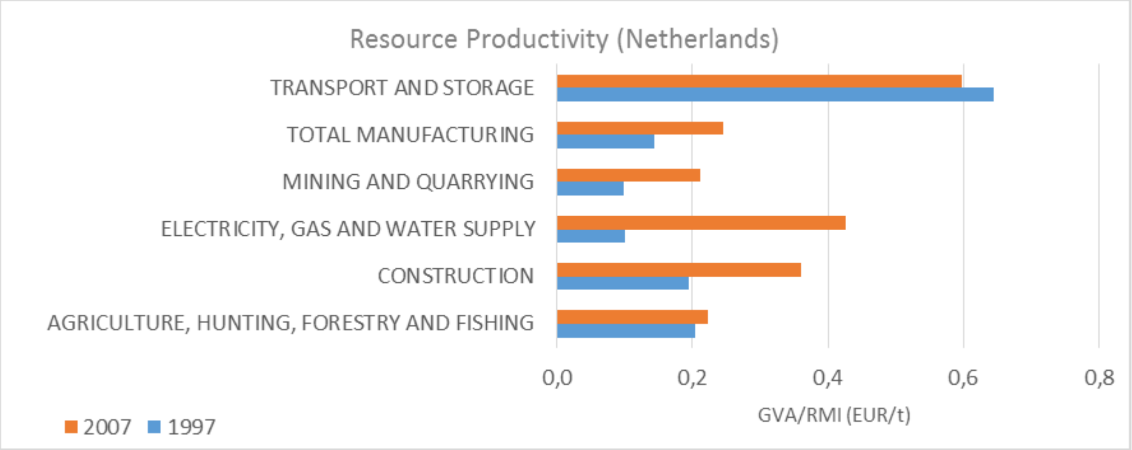
Labour Productivity

Energy, manufacturing and transport are the most labour productive sectors in Netherlands. Energy was 71% more productive in 2007 than in the base year 1995, manufacturing 46% and transport 34%. Almost every sector experienced growth, except construction, which was at 98 percent of the level of 1995.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

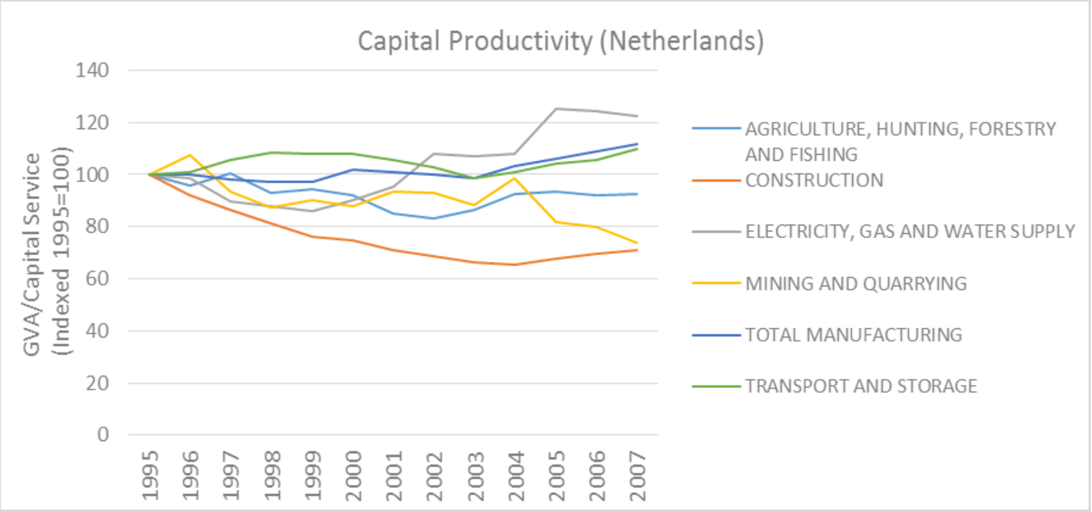
Resource Productivity



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

Capital productivity in the Netherlands has no general trend with each sector experiencing fluctuations between the years. Capital in construction, mining and agriculture ended up being less productive as compared to energy, transport and manufacturing that were more productive than 1995 levels.

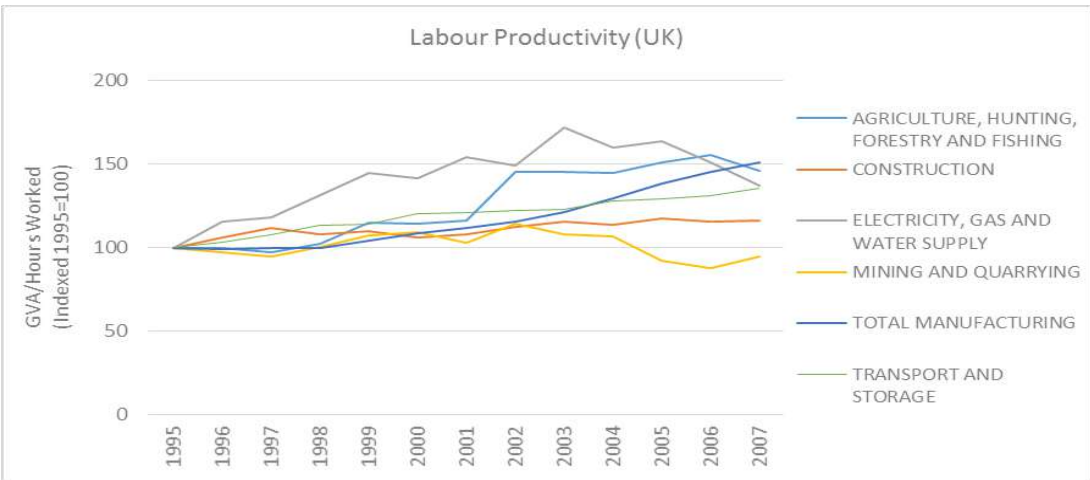


Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

United Kingdom

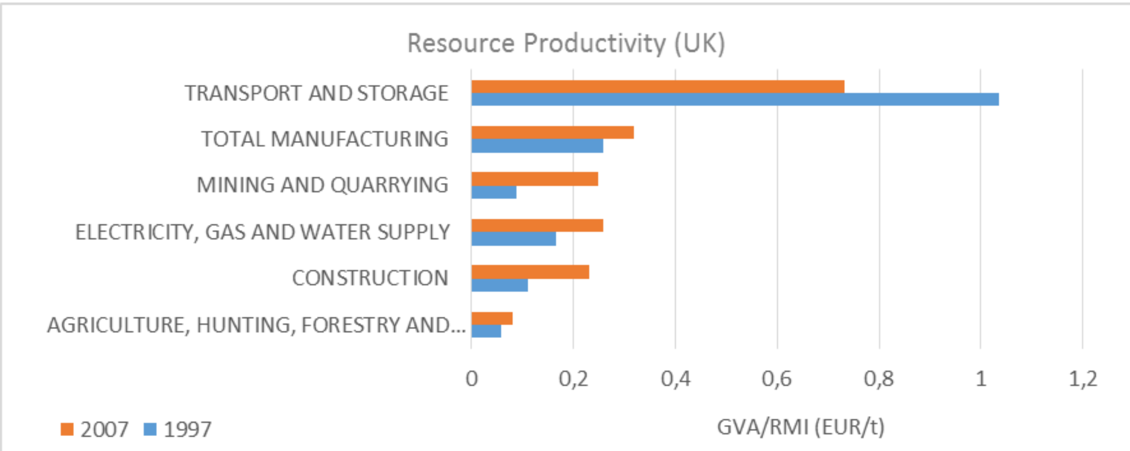
Labour Productivity

In general, apart from mining and quarrying, UK's labour productivity increased over the observed period. The UK's labour productivity in the energy sector showed a considerable increase throughout the whole period, reaching a peak in 2003.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

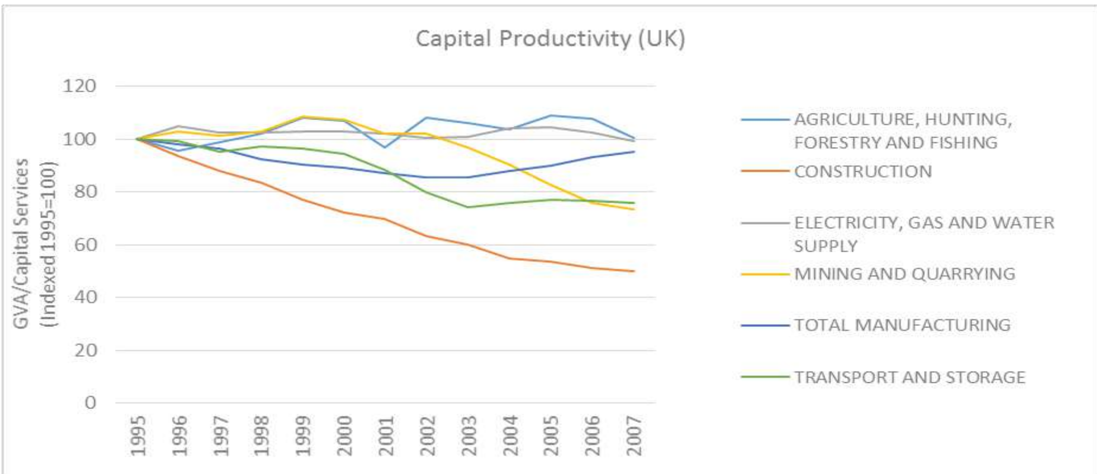
Resource Productivity



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

Capital productivity in construction cut in half over 12 years while transport and mining started having a significant fall after 2001.The UK experienced either a stagnant or downward trend in capital productivity in all sectors where only agriculture, manufacturing and electricity, gas and water supply managed to stay within 10% of productivity levels of 1995. An interesting observation here is that the UK is experiencing opposite trends in construction when looking at labour and capital productivity. Labour productivity increased about 20 percent when compared to 1995 levels, whereas capital productivity in construction is cut in half.



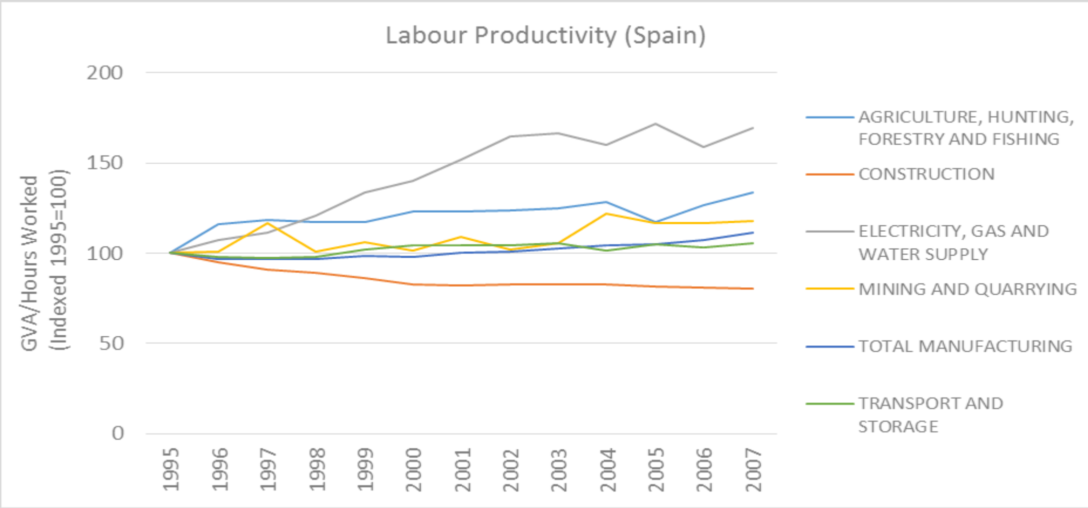
Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Spain

<u>*Labour Productivity*</u>

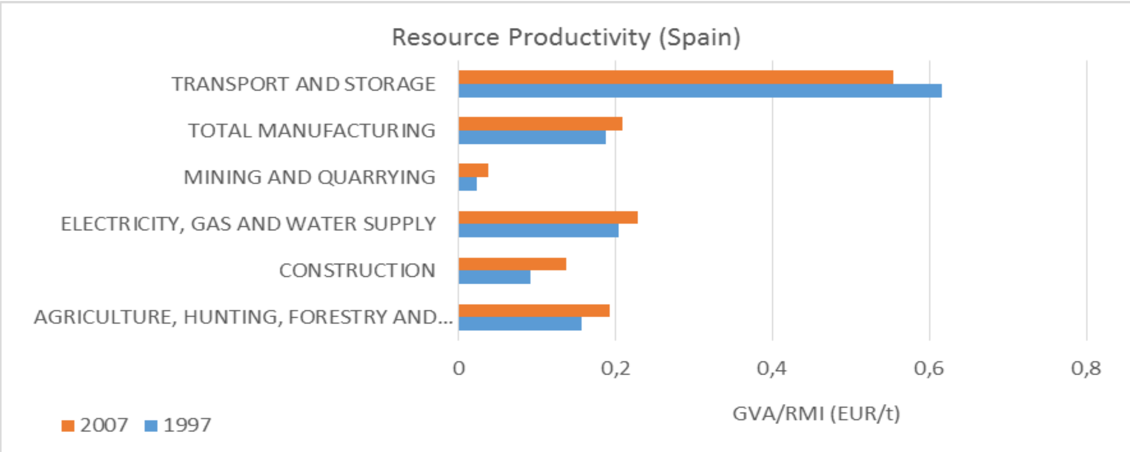
Labour productivity in electricity gas and water supply sector for Spain rose significantly faster than in the other sectors, with a 69 percent increase in productivity as compared to 1995 levels. Construction on the other hand, decreased until the end of the observed period, where it was 20 percent less productive in 2007 compared to 1995. Initially, the agricultural sector was the most labour productive sector, when in 1997 electricity, gas and water surpassed the sector.

Still, agriculture is the second most labour productive sector in Spain, steadily increasing to 34% with minor fluctuations as compared to its value in 1995. After 1997, a rapid downward movement occurred in the mining sector for labour productivity, which then stagnated for about five years, before increasing again in 2003 and ending at 18% more productive levels than the beginning of the period. Manufacturing and transportation, on the other hand, stagnated and show no remarkable improvement in labour productivity.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

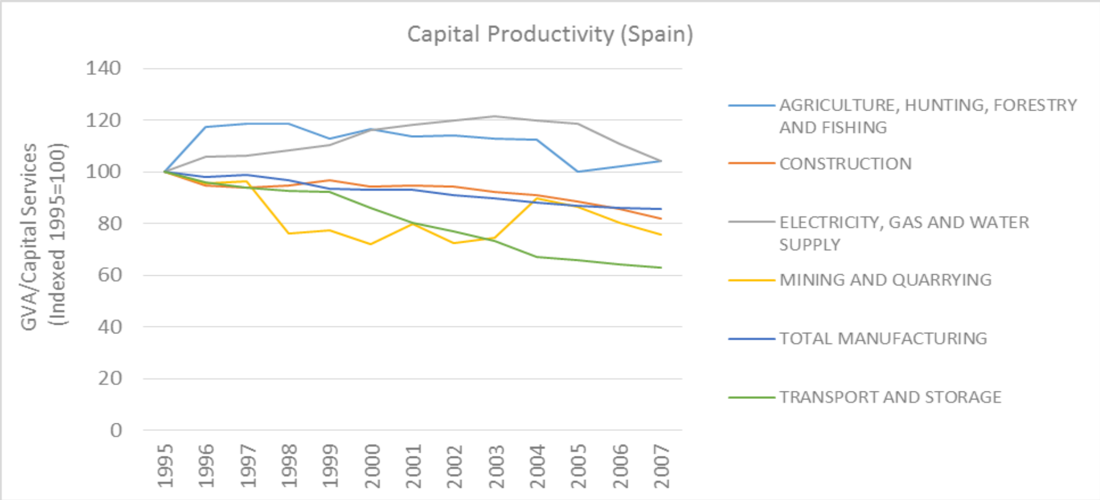
Resource Productivity



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation.

Capital Productivity

Spain presented an overall downward trend and with variation between sectors. Mining and quarrying experienced a similar pattern as labour productivity where a decline after 1997 could be observed. Transport and storage experienced the largest productivity decline, with capital being only 63% as productive as compared to 1995 levels. Electricity, gas and water supply experienced growth in capital productivity, but declined from 2005 on.



Data Source: Resource Sectoral Maps Study (2013) and EUKLEMS Growth and Productivity Accounts, own calculation