Resource productivity, competitiveness and environmental policies

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Summary

Human wealth is ultimately dependent on the use and consumption of natural resources like materials, energy and land. But the use of these resources puts an increasing burden on the environment. For some time now, the EU therefore emphasizes the sustainable use and management of resources as part of their environmental programs. Resource productivity is a catchword that recently gained significant interest in scientific and political discussions. Resource productivity can be defined as a measure of resource use divided by GDP. It is believed to be indicative of the amount of resources we need to obtain our current level of GDP.

Over the last 50 years, resource productivity has increased, albeit much slower than labour productivity. Investigation in the long-term price developments between wages, energy and materials showed that also the price of labour has been risen much faster than the price of energy and materials which –with exception of the period 2003-2008- remained more or less constant over the last 30 years. The increase in resource productivity of the EU is therefore most likely partly a natural phenomenon inherently in the process of economic development and partly a statistical phenomenon due to the displacement of resource intensive industries to other less developed economies.

It is often said that policies aimed at improvements of resource productivity are a win-win situation: they could both enhance the environment and the economy. The environmental improvements occur because saving on resources in the end implies less emissions and waste. The economic improvements occur because saving on resources simply would save money. Business normally tends to overlook profitable saving options, in this view, and resource productivity policies could help business in internalizing them.

In this research we have investigated the claim that resource productivity could entail a win-win situation. Instead of investigating individual case studies (where this can be true) we have focussed here as much as possible at the macro-economic validity of this claim.

Resource productivity improvements always have environmental improvements due to the law of mass balance. The question is whether these environmental improvements are desirable from a welfare perspective. Resource productivity could enhance welfare if it is correcting market failures that are at present not effectively addressed by environmental policies. We identified two possible market failures where resource productivity policies could be useful:

a The overexploitation of renewable resources.
b The degradation of the environment in regions outside the EU and specifically the degradation of the global commons such as the climatic system and biodiversity.

Other market failures due to resource consumption exist (such as waste management problems or scarcity of non-renewable resources) but these tend to be better regulated by tight-knitted environmental policies instead of a general resource productivity policy. With respect to environmental aspects, resource productivity policies should not focus too much on the input of materials, but rather on the environmental impacts from these materials, as kilogram input of materials in an economy proved to be a poor indicator of the environmental impacts from these materials.

Resource productivity policies could result in cost savings are resources are cost to companies. The cost-saving component has attracted attention of politicians and scientists, who have claimed that policies oriented on improving resource productivity could, actually, lead to enhanced competitiveness. Such claims have most successfully claimed in what is now known as the ‘Porter hypothesis’ claiming that savings on resource and energy inputs are actually contributing to a growth-enhancing impact from environmental policies. The Porter hypothesis was severely scrutinized in theoretical and empirical research since the mid-1990s. Evidence for the Porter hypothesis has always been mixed and if there is any effect to be observed it is likely to be small.

In our own empirical investigation we first elaborated on the relationship between energy productivity (as a proxy for resource productivity) and an indicator of competitiveness. As observed by others, energy productivity and competitiveness are correlated suggesting that resource productivity can enhance competitiveness. However, we show that both competitiveness and energy productivity themselves are better explained by reference to income levels. Richer countries tend to be more competitive and at the same tend to be more resource productive. If we correct for the level of income, there seems to be no relationship at all between competitiveness and energy productivity. Hence the popular claim that policies oriented on resource productivity can enhance welfare because it is good for the economy could not be justified in this research.

In providing an explanation, an input-output factorisation has been used in order to determine the amount of energy and material costs in the costs of all inputs to satisfy final consumer demands. The share of costs of raw energy and materials (e.g. fossil fuels, ores, mineral extraction, etc) proved to be fairly low, below the 5%. About 95% of costs should be attribute to other factors of production (labour, capital).

If governments want to stimulate resource productivity policies they should focus on environmental impacts instead of kilograms consumed material as there is not a general relationship between weight and environmental impacts. Economic instruments can be used, especially if they impact on consumer decisions. As the post 2012-EU ETS will not affect consumer decisions in a large scale, additional policies aiming to reduce environmental impacts at the level of consumers may be desirable, especially when taking into account the environmental impacts of their consumption on environmental problems in less developed countries. Global commons, like biodiversity or the climatic system, are currently not well enough protected by environmental policies tackling the individual consumer.

Increasing resource productivity is nowadays an important catchword for economic and environmental policy plans aiming to decouple resource use from economic growth. Clearly, reducing (unnecessary) resource use saves costs, reduces transport costs and is good for the environment. As resources are costs to companies and societies, this partly an autonomous process. The question is now whether governmental policies should speed this autonomous process up and which additional welfare gains can be expected from a policy steering at improved resource productivity.

1 Introduction

1.1 Resource productivity and EU policies

Human wealth is dependent on the use and consumption of natural resources like materials, energy and land. But the use of these resources puts an increasing burden on the environment. For some time now, the EU therefore emphasizes the sustainable use and management of resources as part of their environmental programs. The sixth environment action programme (6EAP) calls therefore for 'breaking the linkages between economic growth and resource use'. As a consequence, the European Commission launched in 2003 their Communication 'Towards a Thematic Strategy on the Sustainable Use of Natural Resources' which culminated in 2005 in the Thematic Strategy on the Sustainable Use of Natural Resources.

The Thematic Strategy on the Sustainable Use of Natural Resources aims to decouple the relationship between natural resource use and environmental impacts in a growing economy. According to the Thematic Strategy, two intertwined strategies should be followed:
1. Improving resource productivity, so that higher value is generated with less resources.
2. Reducing the environmental impact of the use of resources.

The concept of resource productivity, central in this study, is hence an important target of the Thematic Strategy. This target is often connected with economic benefits that would be associated with increased resource productivity. The EU Strategy for Growth and Jobs (also known as the Lisbon agenda), endorsed by the Spring Summit of 2005, gave high priority to more sustainable use of natural resources[1]. It is expected that a focus on resource productivity will have economic gains as well, such as cost savings and enhanced competitiveness for companies (see, e.g. von Weiszäcker *et al.,* 1997; Porter and Van der Linde, 1995).

The ministry of the environment, spatial planning and housing (VROM) wants to investigate the claim that enhanced resource productivity would yield wider economic benefits and link this to possible environmental policy instruments. This is an important topic for environmental policy making. If we want to enhance resource productivity, it is important to know from what setting we should do so.

1.2 Aims of this research

The main aim of this research is to elaborate the economic and environmental consequences from using the concept of resource productivity and to link this to environmental policy instruments. The following research questions will be addressed in this paper:

[1] Over time the Lisbon Agenda has evolved in more economic directions. At present, resource efficiency, as the inverse of resource productivity, is mentioned in the ninth objective of the Lisbon Agenda. The ninth objective states that: 'The Community will promote an industrial policy geared towards more sustainable production and consumption, focusing on renewable energies and low carbon and resource-efficient products, services and technologies'.

- What is the policy rationale for improved resource productivity?
- How can resource productivity be measured and how can improved resource productivity enhance environmental quality?
- What are the driving forces behind changes in resource productivity
- Does improved resource productivity result in improvements of competitiveness and hence serve as an input to the Lisbon Strategy?
- What role can market-based environmental policies and other policy initiatives play in enhancing resource productivity?

We will investigate these questions through literature review and present two pieces of new empirical work where we felt the literature was incomplete or indecisive.

1.3 Outline of this report

In Chapter 2 we will introduce the concept of resource productivity, discuss the measurement of resource productivity and identify potential driving forces of the changes in resource productivity over time. Chapter 3 contains an analysis of the impact of increased resource productivity on economic growth in general and competitiveness in particular. In Chapter 4 we will conduct an analysis into environmental policies where we will investigate, from an economic perspective, whether additional policies on resource productivity are needed and what the influence of existing environmental policies on resource productivity will be. Chapter 5, finally, concludes.

1.4 Links of this research with other on-going research

Research questions addressed in this paper will be rather similar to the first work package of research undertaken in the framework project 'Resource productivity, environmental tax reform and sustainable growth in Europe' undertaken by the Policy Studies Institute (Paul Ekins), Cambridge Econometrics (Terry Barker), Gessellschaft für Wirtschaftliche Structurforschung (Bernd Meyer), Freie Universität Berlin (Martin Jänicke), Sustainable Europe Research Institute (Stefan Giljum) and the University of Economics in Prague (Petr Sauer). This research project, funded by the Anglo-German Foundation, will last from 2006 till the end of 2009. Some intermediate results from this research initiative are included in the present report. Once this framework project is finished it would be wise to compare the results obtained in the present report with the findings from this research group and to organize discussions in order to better understand the role resource productivity can play for economic and environmental policies.

This research has also similar questions that were addressed in research for DG Environment undertaken by the Wupperthal Institute (Bleischwitz *et al.*, 2009) which also investigated links between resource productivity and competitiveness. Although the present research is much smaller in time and coverage of the research for DG-Environment, conclusions are however different.

1.5 Links of this research with other concepts

Resource productivity is, from an environmental perspective, central in the Thematic Strategy on the Sustainable Use of Natural Resources. However, in recent years, a myriad of initiatives have been undertaken addressing more or less the same issues. Such initiatives share the common feature that the aim is to reduce the environmental impacts throughout the life-cycle of product, materials, or activities. They have been labelled differently in the literature, depending on the focus of the initiatives in the life cycle:

- 'Sustainable production and consumption' is a term for initiatives that aim to integrate chain analysis in decisions relating to production and consumption.
- 'Integrated product policy' seeks to minimize environmental degradation by looking at all phases of a products' life-cycle (and taking action where it is most effective).
- 'Sustainable natural resource use' investigates minimizing environmental impacts from the use of natural resources throughout the lifecycle.
- 'Sustainable materials management' aims to minimize environmental impacts from the use of materials throughout the lifecycle.
- Eco-efficiency, finally, is a catch-all term intended to minimize environmental impacts of economic activities throughout the lifecycle.

In addition there are initiatives like *Corporate Social Responsibility*, or *Ecodesign* that share many of the views of the initiatives mentioned above. In the Netherlands, policy initiatives on biodiversity (LNV, 2008) also correlate with these initiatives.

As all these initiatives take a life cycle perspective they are more or less similar. After all, the life cycle implies that natural resources feed into materials which feed into products that are consumed and recycled or wasted. The similar characteristics of these initiatives can be summarized as follows:

- They take a life-cycle perspective.
- They often point at the greater effectiveness of environmental policies when taking a life-cycle perspective.
- They often point at the lower costs (greater efficiency) that can be achieved when taking a lifecycle perspective that could enhance competitiveness (see also Box 1).
- They often hint at the responsibility of the North for environmental damages occurring at the South due to the shifting of the environmental burden. All of these policy areas aim to 'correct' for the embodied environmental degradation in trade.
- They often point at the advantage of an integrated approach to environmental problems in creating a greater coherence between existing environmental policies (the so-called umbrella function of these initiatives).

However, these initiatives differ with respect to what is taken as a starting point. This makes the results of these initiatives not always comparable. A lifecycle analysis of waste flows may therefore deliver other results than a lifecycle analysis of consumption or resource inputs in the economy – simply because the flows themselves depend on the perspective chosen. Links between these fields of research have not yet been established fully. It is recommended that governments start to streamline these research initiatives. Otherwise, formulation of environmental policies may not be fully effective.

Box 1 Eco-efficiency and competitiveness

Debates about the alleged relationship between competitiveness and environmental aspects has been made in other areas as well, such as in the field of eco-efficiency. Two initiatives are worth mentioning here:

1. Clean Clever Competitive
The Dutch EU presidency launched the Clean, Clever, Competitive initiative in July 2004 during their Informal Environment Council in Maastricht to move eco-efficiency and eco-innovation higher up the political agenda in Europe. Creating more value with less impact is the simple idea behind the concept of eco- efficiency which was launched by the Word Business Council for Sustainable Development (WBCSD) in the 90s. "This initiative is the right thing at the right moment to convince European leaders that economy and ecology go hand in hand and that eco-efficiency can contribute to European competitiveness," said Dutch state secretary Pieter van Geel. See also http://www.wbcsd.org/plugins/DOCSEARCH/details.asp?DocTypeId=-1&ObjectId=MTEwNjk&URLBack=result.asp%3FDocTypeId%3D-1%26SortOrder%3Ddoctitle+asc%26CurPage%3D21#

2. A will to compete: a competitive, clever and clean Europe
During the Environmental Council of 20 December 2004 the Dutch Presidency of the EU launched a dialogue aimed at setting up a partnership among different stakeholders at EU level (EU Commission, Member States, business organizations, among which UEAPME, and environmentalists) in order to achieve a 'Clean, Clever and Competitive Europe'. The objective of this dialogue was to identify ways of improving the production and the dissemination of eco-efficient technologies in the EU and the export to third countries as an important way to achieve the Lisbon target. To this end an Eminent Persons Group was set up in the second half of 2005 with representatives of all the partners in order to send a clear message to the European Spring Council in March 2006. Their advice was published in January 2006.
http://www.ueapme.com/docs/various/2006/0601CCCEreport.pdf

As we will see in Chapter 3, the origins of the relationship between environmental efficiency and competitiveness lay in the Porter hypothesis.

2 Resource productivity, the economy and the environment

2.1 Introduction

Resource productivity is a relatively new concept, mainly developed in the sphere of environmental sciences. The book *Factor Four: Doubling Wealth, halving Resource Use* (von Weiszäcker *et al*., 1997) can be considered as the more popular starting point of a vast body of studies claiming that reducing resource use would result in a win-win situation: saving on economic costs while reducing the impacts to the environment of our consumption[2]. This idea can also be found in the much more modern concept of cradle-to-cradle (McDonough and Braungart, 2002). Such concepts have been influential in the sphere of environmental and economic policies as well. The EU, that has adopted the Thematic Strategy on the Sustainable Use of Natural Resources in 2005, has introduced the concept of resource efficiency in the Lisbon Agenda (EC, 2008). Eurostat has developed and implemented a system of material flow accounts (Eurostat, 2001) and the OECD has developed programs in the sphere of sustainable management of resources and material flow analysis. Saving natural resources can nowadays be seen as an important environmental policy theme.

In this chapter we will investigate how resource- and energy use have developed over time and investigate some of the driving forces that have influenced the consumption of materials and energy. First, in paragraph 2.2, a historic perspective is chosen by investigating the long-run relationship between resource use and economic development. Then in paragraph 2.3, the main driving forces of changes in resource productivity over time will be discussed. Paragraph 2.4 draws some conclusions.

2.2 Historic developments

Materials and energy are in essence costs in the process of economic growth. The process of economic growth itself is often described by the influence of only two factors of production: labour and capital. The idea behind this is that the production of energy and materials themselves can be described (to a large extent) by the input of labour and capital[3].

Economic growth consists of augmenting the inputs to production (e.g. capital and labour supply) and by making the inputs to production more productive (e.g. that a given set of labour and capital yields more output, such as services or products). Labour productivity, for example, can be measured as the total output of a country (in monetary terms this is GDP) divided by the labour input (the population that has a paid job, or better, the total hours worked). GDP

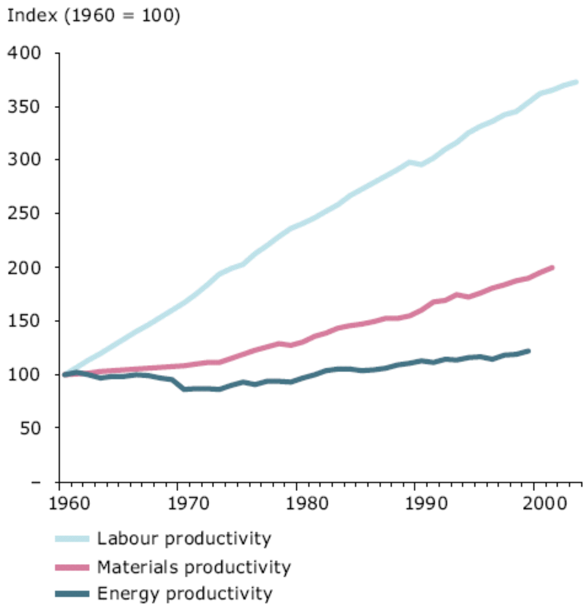
[2] However, the concepts introduced by von Weiszäcker *et al*. (1997) expand on earlier work by Herman Daly (1977) and Ayres (1978) see also paragraph 2.3.

[3] There may be a part in the prices of materials and energy (e.g. the resource rents) that can be labelled as the intrinsic value of materials and energy and that could enter the production function in economics.

over the aggregated energy and materials inputs can in a similar fashion be labelled as the energy productivity and materials productivity respectively.

As both labour, materials and energy constitute costs to production, it is interesting to investigate how their productivity indices have developed over time. EEA (2005) has investigated the trends in labour, materials and energy productivity within the EU-15 over the last 40 years. Figure 2 shows that during this period, labour productivity has grown much faster than materials or energy productivity. While labour productivity has grown by a factor 4 almost, materials productivity has increased by a factor 2 only and energy productivity has risen by 20% only. See also Figure 1.

Figure 1 Labour productivity, material productivity and energy productivity, EU-15, 1960-2002



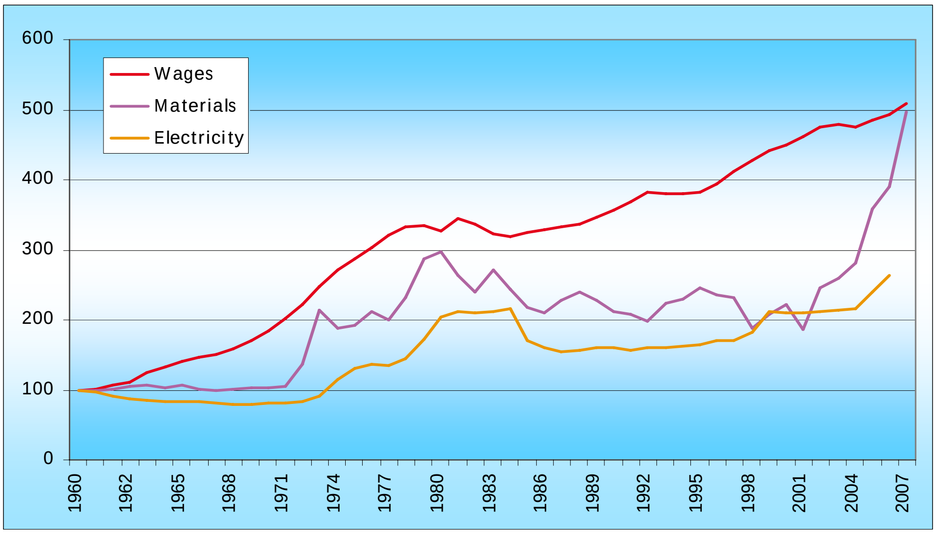
Note: Labour productivity in GDP per annual working hours; material productivity in GDP per domestic material consumption (DMC) and energy productivity in GDP per total primary energy supply (TPES).

Source: EEA, 2005.

An interesting question is why labour productivity has grown so much faster than materials and energy productivity[4]. One of the prepositions would be that this could be explained by the developments in the costs (in real terms) of these three inputs. Using various data sources, Figure 2 shows indeed that the prices of labour inputs have increased more steadily than the price of energy or material inputs. In the year 2000 prices of wages were a factor 4 higher, while materials and energy prices only increased by a factor 2. The recent hike in the price of materials is related to the tension on resource markets mainly. However, for reasons outlined in Annex D, one can expect that in the future this may be reversed and prices will revert to much lower levels.

[4] Although over the last 40 years (1960-2001), labour productivity growth is much higher than materials productivity growth, they are not so different when we compare them for the last 30 years (1970-2001). In the last 30 years, labour productivity has increased by a factor 2.2 and materials productivity, measured as DMC, by a factor 1.8. However, the differences may be more pronounced if the DMC was corrected for the displacement of dirty industries to developing countries (and if the TMC was used as a measure). See also paragraph 2.3.

Figure 2 **Price developments of labour, materials and energy (1960-2007)**



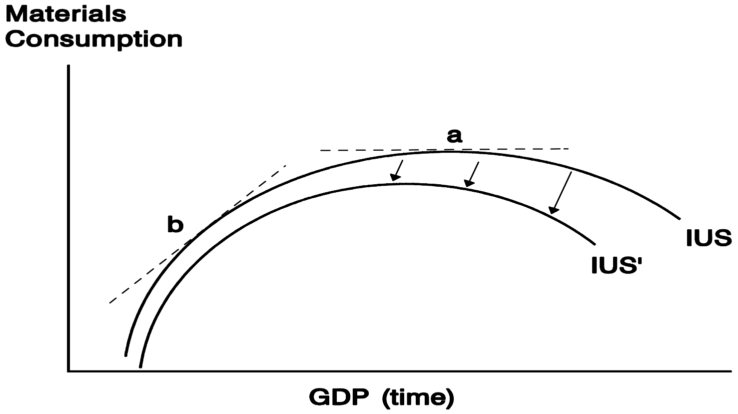
Note: All series are in real prices without direct taxes. Wages are based on collectively agreed wages (CAO) in the Netherlands (source CBS). Materials are from the CRB Commodity Price Index (CCI) reflecting world-wide prices. Electricity prices are from CBS and Eurostat. Own calculations in the wages series and electricity series in order to standardize different series on each other (multiplicative standardization).

Concluding: labour productivity rose much more than materials productivity but this might (partly) be explained by the fact that for a long time the cost of labour inputs grew faster than the costs of materials inputs. Only the recent hike in resource prices has made the final price developments in absolute terms similar. As rational resource markets tend to stabilize prices at a relatively low level (see Annex D), one may expect that this is only a temporarily phenomenon. Finally, one should notice here that the mere coincidence in the developments of prices and productivity of labour, materials and energy does not necessarily imply that price is the main explanatory variable for changes in productivity. Other driving forces could have played an important role as well (see also Chapter 3).

2.3 Driving forces in materials demand

Forecasting materials demand has been an important area of study for resource economists. Until the 1970s it was believed that materials demand would grow almost at the same rate as the growth of the economy (see e.g. the forecasts in the report to the Club of Rome by Meadows, *et al.*, 1972). However, Malenbaum (1978) was the first to doubt this. He developed a theoretical sketch which later became known as the 'intensity-of-use hypothesis'. According to Malenbaum, the demand for materials is derived from the demand for final goods: consumer durables such as automobiles and disposables such as beer cans. Because material costs form only a small fraction of the total costs of these products the demand for materials, according to Malenbaum, is hardly influenced by price changes. Instead, income is the dominating factor for materials consumption. Malenbaum predicted non-uniform income elasticities over time and across countries because of the different characteristics of the composition of final demand associated with different stages of economic development. Developing countries with an economic structure relying on subsistence farming typically have a low level of materials and energy consumption. But when industrialisation takes off, countries specialise first in heavy industries to satisfy the material-intensive demand for consumer durables (houses, infrastructure, cars), and the consumption of materials and energy, and associated pollution, increases at a higher rate than income growth. The growth in materials demand will level off as countries start to specialize in light consumer product industries. A subsequent shift towards service sectors may finally result in a decline in the demand of materials and associated pollution (Malenbaum, 1978; Baldwin, 1995). Technological change would, according to Malenbaum, accelerate this process of reduction in materials demand and diffusion of technology would guarantee that developing countries would not have to follow the same resource intensive trajectory as developed countries have followed in the past. Malenbaum expected that at a certain point in time materials consumption would fall in absolute terms (point a in Figure 3).

Figure 3 Intensity of use hypothesis according to Malenbaum (1978)



Explanation: IUS = Intensity of Use as the relation between consumption and income. IUS' gives the demand curve for materials including technological change. Point (b) refers to the point that materials intensities are falling, point (a) to the point that consumption starts to decline.

Source: De Bruyn, 2000.

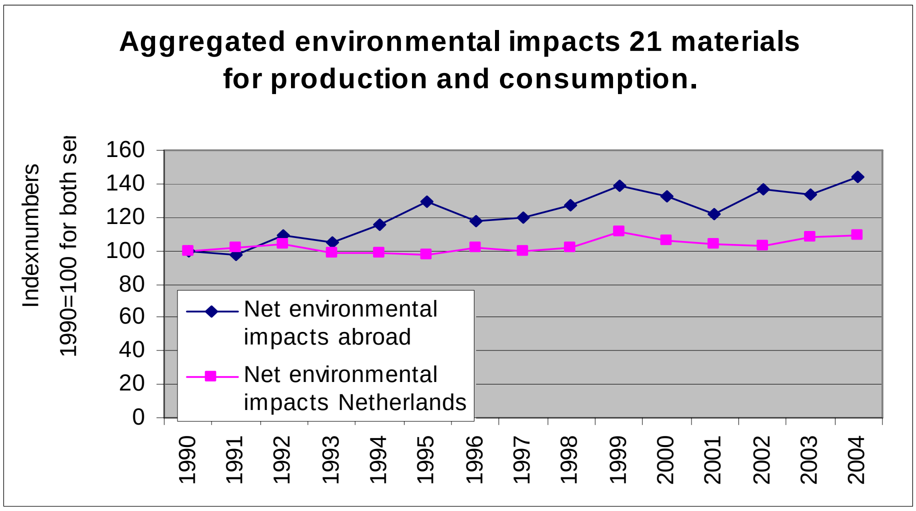
The ‘intensity of use’ hypothesis has found support in a number of case studies on the consumption of some specific materials and energy (e.g. Williams et al., 1986; Tilton, 1990; Nilsson, 1993). These show that considerable improvements in the productivity of energy and materials have been achieved in a wide range of developed countries after the mid-1970s.

However, others have questioned whether this can be perceived as a general trend. First, Labys and Wadell (1989), have emphasized that conclusions about dematerialisation based on studies that take only a few materials into account may be misleading. Comparing the trends in consumption of some thirty materials in the US economy, they conclude that the phenomenon of dematerialisation may more adequately be described as ‘transmaterialisation’. Whereas the intensities of copper and iron ore in the US economy peaked during the 1940s, new peaks are currently recorded for polyethylene, platinum and ceramics. Because the collection of statistics for the consumption of new materials lags behind the introduction and growth stages, studies using statistical data often observe saturation and declining stages of materials demand, which may not reflect overall dematerialisation but rather substitution between materials, or transmaterialisation.

Second, several authors have pointed at the fact that the reductions in materials demand may be the result of relocation of resource intensive industries. Most of the empirical work investigates, for example, the consumption of steel of a country. However, this consumption is largely determined by the steel demanding sectors, such as the manufacturing of cars and machineries. If changes in the structure of production in developed economies are not accompanied by equivalent changes in the structure of consumption, the intensity of use hypothesis may simply record displacement of dirty industries to less developed economies.[5] An attractive feature of this 'displacement hypothesis' is that the reallocation of dirty industries can effectively explain the inverted-U curve: decreases of consumption in developed and increases in developing countries.[6]

Empirical evidence on the displacement hypothesis has been rather convincing. Schutz *et al*. (2004) present empirical evidence on various indicators of resource use in a wide range of countries and conclude that the process of economic development in industrial countries was accompanied by a shift from domestic to foreign resource extraction. CE (2006) investigated the developments in origins of consumption of 21 polluting materials in the Netherlands. They conclude that while production in the Netherlands of these materials remained more or less constant, the growing demand for these materials was served from outside the Dutch territories.

Figure 4 Development of environmental impacts due to the consumption of 21 materials, differentiated to country of origin. Indexnumbers, 1990=100



Source: Adapted from data used in CE, 2006.

Concluding: there has been a vast body of literature elaborating on the driving forces of materials demand. Resource use is mainly dependent on the stage of economic development. In early stages of economic development, both the

5 Although displacement is generally not regarded as a solution to environmental problems, there can be a rationale for displacement when it results in a more even spatial distribution of environmental pollution with local impacts. For pollutants with global impacts, however, total environmental impacts remain the same (or even increase if production is less efficient in the recipient countries or the emissions are being capped in the developed economies like in emission trading systems).

6 See also Herman et al. (1989) who remarked that the dematerialisation of production and increased efficiency of production processes most likely is accompanied with a rematerialisation of consumption.

structure of final demand and the structure of production are more resource intensive implying that resource use grows at a rate above or near the rate of growth of the economy. This growth will level off if countries are specializing in services. However, the subsequent observed decline (or declining growth) in resource use for developed economies may more be the result of inadequate measurement of the concept of resource use (covering 'old' materials and relating to production instead of consumption). There is ample evidence that many of the gains in resource productivity actually imply a translocation of production to other parts of the world, causing there environmental stress and overexploitation of renewable resources. The policy implications of this phenomenon will be discussed in Chapter 4.

2.4 Conclusion

Resource productivity is a topic that recently gained significant interest in societal and political documents. Over time, resource productivity has been improved but not as much as labour productivity. This can partly be explained by reference to the price developments: over the last 50 years labour has become much more expensive than resources in most developed economies. Furthermore, improvements in resource productivity are partly an inherent phenomenon for any economic development trajectory which firstly specializes in buildings, infrastructure and heavy industry and only in later stages of economic development tend to revert to a more service oriented economy. There exists evidence that part of the improvements in resource productivity are actually achieved by shifting away the environmental burden of consumption to other countries and regions in the world. This can also be explained from an economic perspective by reference to the positive income elasticities people have for environmental quality. Once people become richer, resource intensive and dirty production become more like an annoyance one is willing to relocate to other poorer countries with less regard for environmental protection.

3 Impacts of resource productivity on competitiveness

3.1 Introduction

Reducing (unnecessary) resource use saves costs, reduces transport costs and is good for the environment. The cost-saving component has attracted attention of politicians and scientists, who have claimed that policies oriented on improving resource productivity could, actually, lead to enhanced competitiveness. This is a specification of the general believe that environmental, resource and energy productivity policies could have additional gains for companies and hence result, in addition to environmental improvements, in improvements of competitiveness as well. his is called the 'Porter hypothesis' in economics.

Competitiveness is a concept that is poorly defined and is being applied to firms or nations (see Annex A for a detailed elaboration including indices to measure competitiveness). For a firm, competitiveness may refer to the ability of the firm to maintain its operations in a given market. For a country it may refer to the ability of future productivity growth and wealth creation.

The claim that enhanced resource productivity would enhance the competitiveness of firms and nations is investigated in this chapter. First, in paragraph 3.2 the Porter hypothesis will be discussed for the relationship between environmental policies, resource productivity and competitiveness. Then, in paragraph 3.3 we will investigate whether a relationship between resource productivity and competitiveness exists at the level of individual countries and find explanations for the empirical findings. Finally, paragraph 3.6 concludes.

3.2 Theoretical observations: resource productivity and competitiveness at the firm level

A whole bunch of literature has estimated the impacts of environmental policies, resource productivity and competitiveness at the firm level. This is known as the Porter hypothesis. We will elaborate this literature here in this paragraph.

3.2.1 The Porter hypothesis

Environmental regulation often aims at promoting more efficient use of natural resources. Could it be the case then that environmental policy is beneficial for competitiveness by providing right signals to the market players to make more efficient use of natural resources?

The hypothesis that environmental regulations, through providing right signals on how to use natural resources more efficiently, increases profitability and competitiveness, has been formulated by Harvard professor Michael Porter (Porter, 1991). According to conventional wisdom, environmental regulation imposes costs on companies, which affects their competitiveness and in the end may have negative socio-economic effects such as lower employment and welfare. However according to Porter, more stringent environmental policies, if they are implemented correctly, can in fact lead to the opposite outcome: higher productivity, or a new comparative advantage, which can lead to improved competitiveness. In other words, environmental policy can lead to a win-win situation, or an extra profit of environmental regulation (in addition to net benefits related to less pollution).

Two variants of the Porter hypothesis exist. The 'weak' version says that environmental regulation stimulates environmental innovations. The 'strong' version of the hypothesis asserts that properly designed regulation may induce cost-saving innovation which more than compensates for the costs of compliance to the regulations (Lanoie et al., 2009)[7].

Porter points out two main reasons why environmental policies can lead to improved competitiveness: (1) more stringent environmental regulations can reveal inefficiencies within firms that were previously hidden and in this way put pressure on a company to become more efficient and (2) more stringent regulations induce innovation in companies. These effects may lead not only to neutralizing the regulation's initial costs but also to improving the company's competitive position (Porter and Van der Linde, 1995).

The Porter's hypothesis is built on an assumption that a company itself is somehow unable to take economically beneficial measures on their own. This may occur because companies are unable to find the most efficient way to produce or because they do not have the ability or capacity to make investment decisions that benefit the company in the long term. Although the hypothesis is controversial, there is a general consensus in literature that it can be supported in cases where there is a systematic lack of information or limited or bounded rationality (e.g. Brannlund and Lundgren, 2009).

Central to Porter's argument is that governments design and implement the 'right type of policy instruments, i.e. the instruments that lead to new technical solutions and innovation, which in turn leads to improved resource allocation. Well-designed regulations, according to Porter, serve several purposes. First, regulations can give a signal that efficiency gains and technological improvements are possible. Such a signal may be given in a price form (as with introducing taxes or tradable permits) or for example as a reference to the outcomes achieved with best available techniques. Second, regulations can contribute toward a company's increased environmental awareness. Environmental regulations are often implemented in conjunction with regular reporting requirements – this transparency is meant according to Porter not only for the public but also for the company itself. The third characteristic of a well-designed regulation is that it reduces the uncertainty that is associated with some investments. This argument assumes that environmental policies will be consistently implemented over a long time period. The fourth purpose of good regulation, as pointed out by Porter, is that regulations contribute to an improved environmental awareness in general, which affects consumers' preferences. Thus, regulations force companies to transform themselves and their products in the direction that is in accordance with the demand trends of society (Porter, 1991).

Porter and Van der Linde (1995) provide several examples of cases where regulation-driven innovation led not only to better environmental performance

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7 There is also a 'narrow' version of the Porter hypothesis that states that flexible environmental policies (such as market-based instruments) give firms greater incentive to innovate than prescriptive regulations. See also Chapter 4.

but also to increased efficiency and/or product quality[8]. Porter and van der Linde point out that environmental improvement efforts have traditionally overlooked resource inefficiency. They write: "(…) although pollution prevention is an important step in the right direction, ultimately companies and regulators must learn to frame environmental improvement in terms of resource productivity, or the efficiency and effectiveness with which companies and their customers use resources. Improving resource productivity within companies goes beyond eliminating pollution (and the cost of dealing with it) to lowering true economic cost and raising the true economic value of products. At the level of resource productivity, environmental improvement and competitiveness come together."

3.2.2 An assessment of the Porter hypothesis from the literature

Porter hypothesis has been scrutinized thoroughly in the scientific literature. It has been criticized both on theoretical and empirical grounds. Critics related to the theory focus mostly on assumptions that have been adopted by Porter, especially (1) that the private sector systematically fails to capitalize on all profitable opportunities, and (2) that the state (or other regulatory authority) is not only in a position to observe the inefficiencies of the private sector, but can even correct for such inefficiencies. Porter in essence assumed that the regulator is a more informed actor at the market and that he is in a position to implement measures to encourage companies to lower these inefficiencies. According to some critics, this assumption goes too far (Palmer et al., 1995). An additional question that arises from critiques is whether or not Porter's hypothesis about government regulations applies in general, or if there is something unique about environmental policy.

Several theoretical models have been developed to test how the Porter effect could work in theory[9]. It has been found that the Porter hypothesis can be proved only in special conditions. A general finding is that in order for the Porter hypothesis to work, there has to be an additional market imperfection (other than pollution) that can be neutralized or alleviated through the environmental regulation (Brannlund and Lundgren, 2009). One of the examples of such a market imperfection is asymmetric information, where the companies do not possess all the information needed for implementing efficiency improvements. If environmental policies force companies to collect information on, e.g., energy use, additional benefits may be reaped from this information alone. In the Netherlands this is called the 'attention benefits' from environmental policies.

A number of empirical studies exists that are directly related to testing the Porter hypothesis. Based on a review of a broad empirical literature, Brannlund and Lundgren (2009) conclude that there is lack of strong evidence for the existence of a strong Porter effect, however the literature does not provide strong evidence against the hypothesis either. Lanoie et al. (2009) distinguish two broad sets of empirical studies related to the Porter

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8 For instance in 1990, in Reytheon, a company specializing in cleaning printed electronic circuit boards, replacing CFCs (as required under the Montreal Protocol and Clean Air Act) with another cleaning agent that could be reused resulted in increasing average product quality and in lower operating costs. Another example is 3M company which developed a new technique to run quality tests on their products, resulting in reducing hazardous wastes by 10 tonnes per year at almost no cost, yielding annual savings of over 200,000 USD.

9 The explanatory models can be roughly categorized as either (1) models that focus on the diffusion of technological innovations and positive externalities associated with R&D in the environmental arena (see e.g. Mohr (2002)), (2) models based on imperfect markets and strategic interaction (see e.g. Simpson and Bradford, 1996), and (3) models based on the idea that companies may not act rationally due to problems of coordination associated with internal decision-making (see e.g. Gabel and Sinclair-Desgagne, 1998).

hypothesis. A first set assesses the impact of environmental regulations on firm's innovation strategy and technological choice, as measured by investment in R&D and successful patent applications. These studies test the weak version of the Porter hypothesis that more stringent environmental regulation enhance innovation (e.g. Jaffe and Palmer (1997), Brunnermeier and Cohen (2003)). The studies suggest a weak but positive link between a more stringent environmental policy regimes and the firm's innovation policy.

The second set of studies reported in the same paper focuses on the effects of regulation on productivity. Most papers reviewed in Jaffe et al. (1995) highlight a negative impact of environmental regulation on productivity. More recent papers find some evidence for positive relationship between more stringent environmental regulation and productivity, which would be in line with the strong version of the Porter hypothesis. For example, Berman and Bui (2001) report that refineries located in the Los Angeles area enjoyed a significantly higher productivity than other US refineries despite more stringent air pollution regulation in this area. Alpay et al. (2002) estimated that the productivity of the Mexican food processing industry is increasing with more stringent environmental regulation. These are, however, unique examples which cannot be interpreted as evidence for existence of a general rule.

In spite of some positive examples that are in line with strong version of the Porter hypothesis, some studies find that the effect of environmental regulation on business performance is weak or ambiguous. For instance, Darnall et al. (2007) find that better environmental performance enhances business performance but that stringency of the environmental policy regime has a negative impact on business performance. Lanoie et al. (2009) report results of an empirical model applied on a dataset of 4,200 business facilities from seven OECD countries (Canada, France, Germany, Hungary, Japan, Norway and the US) collected in 2003[10]. This study found strong evidence for the weak version of the Porter hypothesis, i.e. according to the study results, more stringent environmental regulations implied more investment in environmental R&D. With respect to the strong version of the Porter hypothesis, evidence was found that the direct effect of stringency of environmental policy on business performance is negative. However, there is also a positive indirect effect of stringency of environmental regulation on business performance. Namely, environmental regulation induces environmental R&D investments, which in turn have a positive effect on business performance. This indirect positive effect was found to be weaker than the direct negative effect, which suggests that innovation only partially offsets the costs of complying with environmental policies.[11]

Brannlund and Lundgren (2009) investigated the case of Sweden. In their analysis, they did not find any significant relationship between environmental regulation and productivity. The results from studying the effects of the CO_2 tax on the Swedish industry between 1990 and 2004 show no support for the Porter hypothesis except for the rubber and plastic sector, where improved environmental performance was accompanied with improved productivity.

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10 Respondents of the survey included CEOs and environmental managers who answered questions related to environmental performance, environmental R&D and business performance.

11 The econometric estimates were not conclusive regarding the issue if market-based instruments give a better incentive for innovation than other instruments. The authors conclude that this may be due to the fact that in practice, such measures are frequently applied at too low a level to induce innovation.

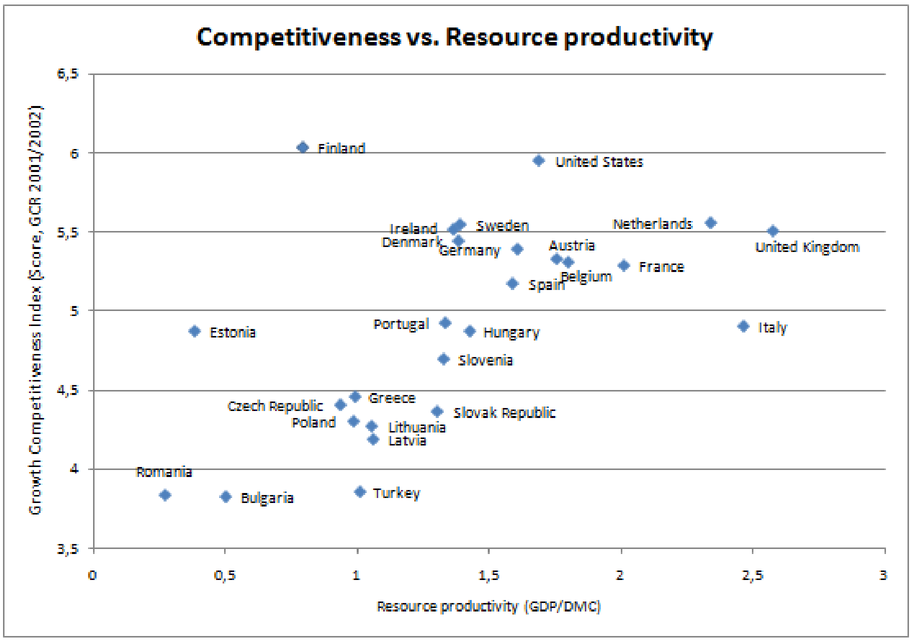
The overall policy conclusion that can be made on the basis of the theoretical and empirical review is that there is quite a lot of empirical evidence supporting the weak version of the Porter hypothesis, i.e. environmental regulation tends to enhance environmental innovation. With regard to the strong version, it is impossible to show that the Porter effect is generally valid, i.e. that more stringent environmental regulation will lead to a general improvement in competitiveness. It can be shown that under some circumstances, a company may experience improved competitiveness following implementation of an environmental policy instrument. These unique cases however cannot serve as a basis for formulating environmental policy because they are observed *ex post* and they may arise for reasons other than environmental regulation. Theoretical studies indicate that such a situation is more likely when in addition to pollution another market imperfection (such as asymmetric information) exists which can be fixed simultaneously by applying environmental regulation.

3.3 Empirical observations: resource productivity and competitiveness at the level of nations

Most studies focusing on the Porter hypothesis investigated the impact of environmental regulations on individual companies or sectors. However it is also possible to look at the relationship between environmental regulation and competitiveness in entire countries.

According to a recent investigation by the Wuppertal Institut, there exists a clear correlation between resource productivity and an indicator of competitiveness (see Figure 5).

Figure 5 **Assumed positive relationship between competitiveness and resource productivity according to Bleischwitz et al. (2009)**



They interpret this as a sign that resource productivity does enhance competitiveness. However, the mere correlation between competitiveness and an indicator of resource productivity does not mean that there exists a causal link between both variables. There is a risk here of a spurious correlation.

Spurious correlations, for example, may occur because of an omitting variable. As an example: the number of pigs living in the Netherlands is highly correlated with the number of cars but that does not imply that pigs drive cars, or cars are fuelled by pigs. As both pigs and cars are highly influenced by GDP – GDP should be included here in order to explain the influence of the number of pigs on the number of cars.

In this section we will conduct an empirical estimation if enhanced resource productivity can be associated with a higher degree of competitiveness at the level of individual nations where we explicitly test the influence of an omitted variable (GDP in this case).

3.3.1 Indicators for competitiveness and resource productivity

For our empirical estimation we will use data for competitiveness and resource productivity. Together with information on GDP (Gross Domestic Product, at nominal exchange rates), these will provide the background of our empirical estimation whether increased resource productivity can be associated with a higher degree of competitiveness.

Resource productivity

As stated in Annex C, resource productivity is a concept that is difficult to measure. Although time-series have been developed for the often used indicator DMC (Direct Material Consumption), the DMC itself may be regarded as a too narrow concept of resource use because displacement of production is not corrected for appropriately (CE, 2004). Moreover, DMC series between countries differ considerably due to the lack of primary data.

Therefore we decided in this study to use energy productivity as a proxy of resource productivity. Energy use is taken here as the Total Primary Energy Supply (TPES). The ratio GDP/TPES is then an indicator of energy productivity.

Competitiveness

The World Economic Forum is one of the leading institutes developing and maintaining indices for the competitiveness of a country. The methodology for calculating the index of global competitiveness published yearly by the World Economic Forum has evolved over the years in an effort to introduce the best available technology. An important milestone was reached in 2000, when Professor Jeffrey Sachs introduced the Growth Competitiveness Index, based on academic foundations in economic growth theory. The Growth Competitiveness Index was reported during the period 2001-2005, and since 2006, a Global Competitiveness Index has been reported as the main competitiveness index of the Global Economic Forum. In Annex A, a description of both the Growth Competitiveness Index and the Global Competitiveness Index is given.

3.3.2 Empirical estimation

In the empirical estimation we will test the hypothesis that, on a country level, competitive nations can be associated with a higher resource productivity. Although we could investigate this over time, we lack long reliable time-series on competitiveness. Therefore we decided to use a cross-country analysis[12].

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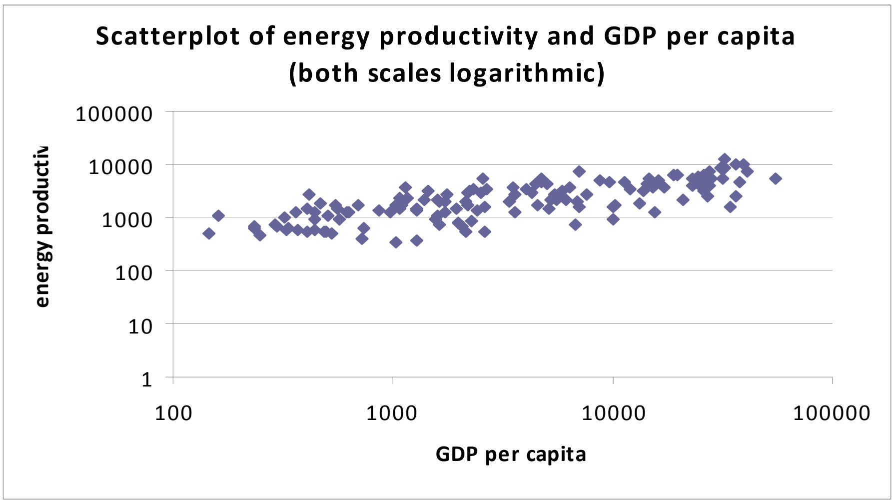
[12] There is a technical reason as well. One of the problems in econometrically estimating this long-run relationship is that we must assume that all other variables influencing resource use and competitiveness have remained stable over time (or otherwise spurious results may occur). Labson and Crompton (1993) have shown that stochastic shocks in technology and structure tend not to evaporate over time but introduce a permanent drift in the relationship between materials demand and income. Hence, time-series analysis cannot be conducted.

For this we will be using an extensive set of statistics covering total primary energy supply (TPES) and GDP data in nominal terms for 137 countries published by the International Energy Agency for the year 2006. In addition, we will use GCI scores obtained from WEF (2008), published for 109 countries.

Energy productivity is related both to the level of GDP per capita and to the Growth Competitiveness Index. Simple regression analysis shows that the model describing the relationship between energy productivity and GDP per capita has a better fit than the model describing the relationship between energy productivity and Growth Competitiveness Index. The best fit for both relationship has been achieved in the log-log model (where natural logarithms of both variables: energy productivity and GDP per capita are entered in the regression).

Figure 6 shows the relationship between energy productivity and GDP per capita for the year 2006. Every dot indicates one single country.

Figure 6 Energy productivity vs. GDP per capita in 2006



The regression analysis showed that every 1% higher GDP is associated with 0.4% improvement in energy productivity[13]. This result makes sense from an economic perspective. GDP per capita is the flow of returns from a given stock of (natural and man-made) capital. As energy consumption is a cost (which are deducted from the returns), economizing on energy use will be a component of economic growth. However, as outlined in Paragraph 2.2, other explanations exist that are being based on the intensity of use hypothesis (e.g. the transformation of resource intensive production economies towards service based economies and the associated translocation of dirty industries to lower income countries).

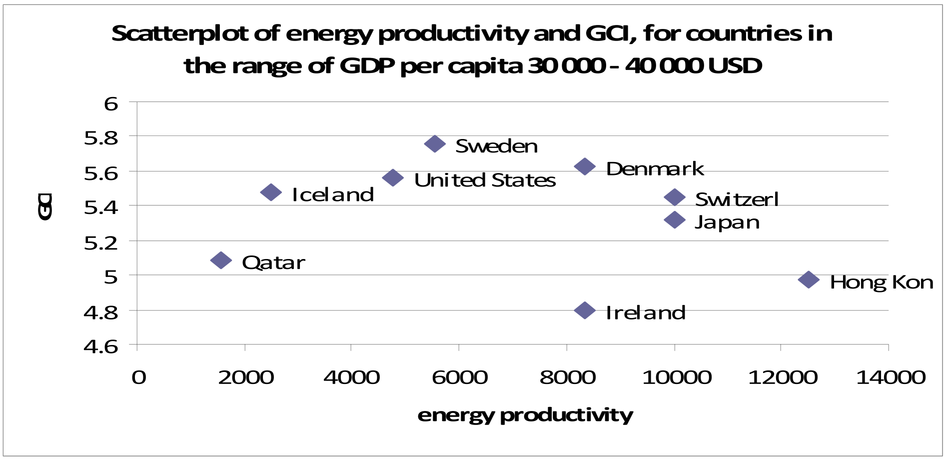
From Figure 6 we see that countries with the same level of income differ widely in their energy productivity. For example, United States and Switzerland have a similar level of GDP per capita (in USD of 2000) but while the US has an energy productivity of 4760 GDP/toe, Switzerland has an energy

[13] It should be noted that these coefficients in a strict sense have been derived in a cross-section analysis and not a time-series analysis so the effect of economic growth on resource productivity is not directly captured.

productivity of 10,000 GDP per toe. Could the difference in GCI between the US and Switzerland explain the differences in energy productivity?

First we can take a slice of the countries listed in Figure 6 with similar income range and investigate whether the differences in energy productivity can be attributed to the difference in the competitiveness index. Figure 7 gives the result for the countries ranging in income between the USD 30-40.000. We see here that there appears no relationship whatsoever between the GCI and energy productivity for these countries.

Figure 7 **Relationship between energy productivity and the Global Competitiveness Index for a selected set of countries in the income range of USD 30.000-40.000**



Of course, this lack of correlation can be just accidentally the case for countries in this income range. For the formal test whether the GCI would add explanatory power explaining the differences in energy productivity between countries we used a simple model where:

EP = a+ bGDP +cGCI +e

The model was estimated in double logarithmic form. Table 1 gives the results.

Table 1 **Regression analysis of energy productivity on income (GDP) and competitiveness (GCI)**

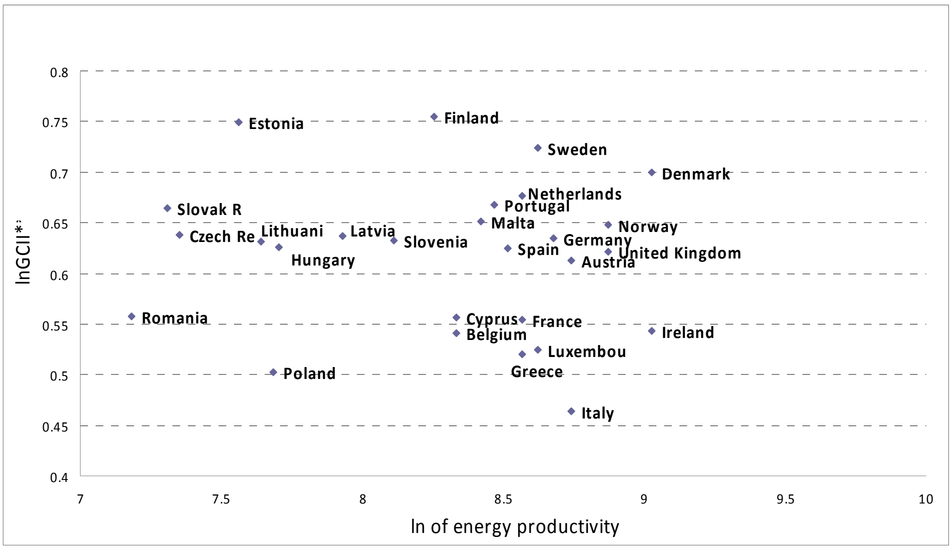
Variable	Coefficient	Prob.	Interpretation
Constant	(a) 4.551269	0.0000	Highly significant
GDP	(b) 0.480129	0.0000	Highly significant
GCI	(c) -0.575331	0.3019	Not significant
Adjusted R-squared	0.606345		

Note: all variables were transformed in natural logarithms.

We see here that the variable expressing the influence of GDP on energy productivity is highly significant. However, the impact of the Global Competitiveness Index is not significant under normal significance levels. This indicates that the GCI does not add additional explanation to the variation in energy productivity between countries. Clearly: countries that are less competitive can be as energy productive as countries that are more competitive when corrected for the level of income[14]. The level of competitiveness has no influence on the degree of energy productivity.

If we redo this analysis for the EU-27 we obtain a similar conclusion: insignificant influence of the variable explaining the GCI.[15] Removing the influence of the GDP on the relationship between GCI and energy productivity we now can see that there is virtually no correlation between the GCI and energy productivity (see Figure 8). This implies that the variation in energy productivity is well explained by reference to the variation in income levels but not to the variation in competitiveness.

Figure 8 Relationship between the for the influence of GDP corrected GCI and the energy productivity



Concluding we find here that there is no relationship between energy productivity and competitiveness. Although these results are not with the same variables as used in Bleischwitz *et al*. (2009), these conclusions are likely to hold for material productivity as well. The relationship between resource productivity and competitiveness most likely is the result of a spurious regression caused by 'forgetting' an omitted variable (GDP).

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14 Although the variables could express here a certain amount of multicollinearity we have no reason to suggest that OLS would not yield efficient estimators here. Also some of the standard solutions towards multicollinearity (such as inclusion of interaction variables or the construction of a variable that corrected the GCI for the influence of GDP) did not yield significant results for the influence of competitiveness. We also conducted a White-test showing that the equation is free of heteroskedasticity and the estimated relationship can be classified as efficient. The White test can be seen also as a general test for model specification and if the model would be plagued by multicollinearity, the White test may show this as well. Since the White test showed no evidence of model misspecification, our conclusion remains that energy productivity is only determined by the level of income and not by the degree of competitiveness of an economy.

15 For the EU-27 the relationship would be (between brackets significance levels): EP=2.855 (0.001)+ 0.69 (0.000) lnGDP – 0.759 (0.266) lnGCI.

3.4 Explanations

Both the extensive empirical literature following the Porter hypothesis in paragraph 3.2 and our own empirical treatment in paragraph 3.3 come to the conclusion that it is unlikely that policies aiming to increase resource productivity will have additional gains for competitiveness as well. The question is how these things should be interpreted. What can be explanations for the lack of causal relations between resource productivity and competitiveness?

A first explanation would be that companies at present are simply operating efficiently with their resource inputs. This would imply that they cannot enhance their competitive position by further economizing on resource inputs as the costs would outweigh the benefits. The variation in energy productivity, as shown in Figure 8 would then be more related to differences in production structure and lifestyles than to the state of technology.

Although this is intuitively an appealing explanation, empirical evidence points exactly at the opposite direction. Studies show large potentials for energy savings that can be made at no cost for society (Blok *et al*., 2004). Obviously firms are not perfectly informed agents and may overlook certain potentially profitable investments. Hence, it could be entirely true that competitiveness would be partly explained by the degree to which these inefficiencies are tackled, e.g., through institutional arrangements (see for a more detailed elaboration of this point paragraph 4.2.3).[16] Therefore this may not provide an explanation for the missing link between resource productivity and competitiveness.

The second explanation would be that the costs of resources are simply too small for companies to have any impact on their competitive position. Instead, companies who want to be competitive can better look at alternative costs, like costs of capital and labour or finding market niches.

In the literature, it is sometimes stated that resources form a very important part of the total costs of companies. Estimates have been given of around 40% (EEA, 2005). However, such estimates have been arrived by adding up all costs that are, statistically, known as 'intermediate use' of economic sectors. Intermediate use is the costs that companies make by buying goods from other companies. For a steel company, the intermediate uses will be iron ore. But for the manufacturer of car parts, the intermediate use will be the steel. However, in the costs for steel, already a part of labour costs are included as well as costs for the reward on invested capital. Finally, the car manufacturer will buy car parts from the other manufacturer and these will be labelled as 'intermediate use', but these contain again labour and capital costs. Hence, the material costs which appear in this figure of 40% do not only include the

[16] From a purely subjective economic perspective (e.g. Chicago school), one should even say that negative costs cannot exist. There is no free lunch, is a popular saying underlying this statement However, this outcome is, in the end, entirely dependent on the allocation of the property rights with respect to energy saving. If, for example, energy saving would not be the responsibility of individual firms, but of society in general, discount rates would drop and more measures would be profitable. In other words: national wealth could be enhanced by a different allocation of property rights through environmental and fiscal policies and therefore the resource productivity of a country may depend on the *average* discount rate that is being used for investments in energy saving measures. Countries that have diverted part of the risks from firms to the government may therefore be more resource efficient, *ceteris paribus*. See also paragraph 4.2.3.

costs for raw materials, but also the labour and energy costs embodied in these materials.

To establish a pure figure of the share of materials and energy in the total costs of our economy, we used input-output tables. An input-output table is a description of the flows of goods and services through an economy in financial terms. Each column and row in such a table represents an economic sector. A row shows the intermediate deliveries of that sector to other production sectors and the deliveries to final demand. A column contains all purchases of intermediate deliveries and primary inputs of the corresponding economic sector (see Annex B). The input-output table in essence gives the amount of inputs that is needed to generate the GDP.

Given the input-output table of an economy, one can check the pathway of inputs of material and energy in the economy until it finally reaches the consumers (final demand). Output from agriculture and mining (energy and non-energy) enter the economy and then subsequently move through all economic sectors into final products. Using the input-output tables we can estimate the total amount of costs from the products of the raw materials sectors into all further transactions in the economy. By doing this, one may come with an estimate of the total costs of materials and energy in the end-products. This is representative of the share of costs from the mining and agricultural sectors with respect to the total transactions that are required to satisfy final demand. Results from this analysis, for the input-output tables in Netherlands and Germany are given in Table 2. It appears that materials and energy costs, in essence, only constitute a very small proportion of the total costs borne by an economy: between the 3 and 6%[17].

Table 2 **Costs of raw materials (from the mining and agricultural sectors) in relation to total costs to obtain one unit of final demand (GDP) in the year 2005**

Country	Percentage of costs in total costs
Germany	2.8%
The Netherlands	5.3%

The here calculated figure is much lower than the 40% estimated by others (see e.g. EEA, 2005). The figure of 40% is clearly based on the concept of 'intermediate use', which, in itself, already includes large shares of labour costs. When these labour costs are excluded from the analysis, the corresponding figure drops to 3-6% of the total transactions in the economy.

This finding could explain the conclusion that competitiveness and resource productivity are actually not related to each other. As the costs of raw material inputs are very small compared to all other costs of input in the economy (mainly capital and labour), rationalizing on resources and energy may not be the most fruitful strategy to become more competitive. Variation in competitiveness may hence be better explained by reference to other factors, such as labour productivity, than resource productivity alone. Although such findings are widely acknowledged by economists and politicians dealing with competitiveness.[18]

17 For this analysis we use the use tables from the Eurostat (including imports). Therefore these results are not influenced by the small share of the mining sectors in Germany and the Netherlands.

18 In the annual European Competitiveness Reports labour productivity is identified as the most important issue when dealing with competitiveness.

3.5 Conclusions

Resource productivity has frequently been lined up with improvements in competitiveness. The idea is relatively simple: resources are costs to society and saving on these costs will enhance welfare. However, this is a normal economic phenomenon. If the benefits of saving resources outweigh the costs, one would expect that the market would take for this process. In normal neoclassical economics there is hence no strong case for governmental intervention.

The Porter hypothesis, however, takes a different stance in this field. According to this hypothesis, many market imperfections exist that can be corrected with environmental and resource productivity policies. More stringent environmental policies, if implemented correctly, may result in a higher level of productivity, or a new comparative advantage, which can lead to improved competitiveness. In other words, environmental policy can, according to Porter, lead to a win-win situation: in addition to the environmental benefits there may be economic gains as well.

Two variants of the Porter hypothesis exist. The ‘weak’ version says simply that environmental regulation stimulates environmental innovations that, in the end, can bring down costs of complying to environmental policy goals. The ‘strong’ version of the hypothesis states that environmental and resource productivity enhancing policies may result in cost-saving innovations that more than compensate for the costs of compliance to the regulations. Hence in the strong version environmental and resource productivity enhancing policies may have a positive effect on competitiveness resulting in a win-win situation.

There is a vast body of empirical and theoretical literature addressing the Porter hypothesis. This literature finds, in general, support for the weak variant: environmental policies do stimulate innovations in environmental techniques. However, evidence for the strong version (environmental policies enhance competitiveness) is mixed.

In our own empirical work we find that at first glance it seems that competitiveness and energy productivity are positively correlated to each other for a dataset of 140 countries. However, this correlation seems to be spurious. As higher GDP is both related to higher energy productivity and higher scores on the competitiveness index, the correlation is caused as both variables are highly correlated with GDP. For countries with comparable levels of GDP, no relationship at all between competitiveness and energy productivity can be found. This is evidenced by our econometric estimate that shows that competitiveness does not influence energy productivity when corrected for the level of income. Hence, there exists no clear evidence that policies aiming to improve energy productivity (as a proxy for resource productivity) do enhance competitiveness.

One explanation for this finding is that the costs of materials and energy in the total final demand are small. Our estimates show here that only 3-6% of the total costs that are made to arrive at a certain level of income (GDP) are made up by costs of raw materials and energy. This figure is certainly much lower than found in other studies that have applied the concept intermediate use. However, in the intermediate use already a large share of labour costs are included.

4 Policy analysis

4.1 Introduction

If governments aim to improve resource productivity, the question is which policy instruments should be used. In this Chapter we will give an analysis into the policy options for improving resource productivity. First, in paragraph 4.2 we will try to identify the main policy rationales for a policy aiming to improve resource productivity. We will identify here elements in consumption and information as the main market failures that could be corrected using a resource productivity policy. Then, in paragraph 4.3 various economic instruments will be identified that can play a role in enhancing resource productivity. Paragraph 4.4 concludes.

The orientation on economic instruments in this Chapter does not imply that we only see a role for economic instruments in stimulating resource productivity. However, as resources are used as inputs in the economy, economic instruments surely are a logical starting point for a discovery into policy instruments.

4.2 Policy rationale for resource productivity

Ever since the concept of resource productivity was introduced in the Factor 4 handbook (von Weiszäcker *et al*., 1997) various studies have listed the advantages of a policy oriented on increasing resource productivity. The general notion is that improved resource productivity enhances both welfare and the environment – e.g. that it is a crucial element in sustainable development. The idea of future generations impacted by our current wasteful use of resources is also dominant in this: policies for resource productivity typically set aims in the long-run.

In this paragraph, an alternative view will be taken on the question whether resource productivity is a policy theme. Economic theory tells us that there exists a cause for governmental intervention if the market fails to attain the social optimal outcome. Market failures, such as external effects (e.g. pollution), can be corrected by imposing adequate governmental policies. However, the government is also not perfect and hence the social costs of market failures should be weighted against the social costs of governmental failures. We will apply this theoretical economic framework on three areas where policies for resource productivity may enhance welfare: scarcity, environment and competitiveness.[19]

4.2.1 Scarcity

For elaboration of the topic of scarcity, one should differentiate between scarcity of abiotic (non-renewable) resources and biotic (renewable) resources, as the underlying mechanisms are quite different.

19 In addition to these areas one may identify security of supply as a separate argument.

Abiotic non-renewable resources

With respect to non-renewable resources (e.g. metal ores, fossil fuels, minerals), the basic question is whether the market price is a good indicator of future expected scarcity (see Annex D). If scarcity and long-term availability of resources is reflected in the price, these considerations are taken into account in economic decision making and hence no external effects can be identified. Simon (1981) seems to take this point of view when he states that the price is a good indicator for scarcity.

Opponents of this view put forward the burden of current resource use to future generations. Some ecological economists consider over-consumption of non-renewable resources unfair to future generations. They argue that putting prices on irreplaceable natural resources is like auctioning the Mona Lisa to a very small group: the price would be too low, since other parties, including people living in the future, cannot bid. Another argument is made by ExternE (2005). Under the assumption that the current interest rates are higher than the social preference rate that should be used for social issues, external costs could indeed be attached to the depletion of abiotic resources. Traditional economics tend to marginalize impacts on future generation using discount rates. However, this discount rate may not reflect the 'true' societal preferences for future generations (see also paragraph 4.2.2). A third argument, provided by Cleveland (1991) is that the extraction of non-renewable resources involves external effects, e.g., pollution of rivers and ground. Moreover, due to the lower grades of mining ores (Meadows *et al.*, 1991), these are expected to increase in the future. Hence, extraction of resources now (and thus consuming part of the limited stocks) would result in higher external costs in the future.

These views all depend on the idea that the stocks themselves are limiting future human welfare and wealth creation is limited to resource markets only. However, both prepositions can be questioned. If resource rents are invested in, e.g., technology of extraction, also future generations may benefit through technological development. Investigations into historical unit mineral prices show declining trends instead of increasing trends evidencing that scarcity is less and less putting a constraint on economic activities (Barnett and Morse, 1963; Simon, 1981). Simon (1981, p. 46) has remarked that 'as economists or as consumers, we are interested in the particular services that resources yield, not in the resources themselves'. The value of these services may be represented by the price of the resources and these show declining long-term trends, both in extraction costs and in price. Hence, future generations may well be better off by our rate of resource extraction.

In sum, it is rather unclear if scarcity of abiotic resources would form an argument for governmental intervention. It is clear that future generations are entitled to their 'fair share' of welfare. However, it is not clear if that would imply that we preserve abiotic resources or deplete them even faster. From the perspective of intergenerational efficiency, there is not a strong argument to intervene in markets. In most cases, markets function normally and issues related to scarcity are already reflected in the price. However, environmental impacts from resource extraction should be internalized so that the price does reflect the social marginal costs.

Biotic renewable resources

The case of renewable resources (wood, fish, agricultural products) may require governmental intervention – especially if the biological processes of renewal is difficult to manipulate by humans (fish) or is taking a long time-span (wood). In that case, policies are needed in order to prevent the tragedy of the commons' phenomena. In his famous essay, Hardin (1968) illustrated the mechanism by showing how sharing of a pasture by local herders may lead to overgrazing. Adding an additional animal to the pasture will provide the individual herder an extra income (= individual benefit) while with every additional sheep the pasture gets more and more degraded (= a commonly shared cost). Since all herders are interested in their own utility, they continue to add animals to the field as long as their private benefits outweigh their share of the costs. In the end the pasture is totally degraded. Overfishing, or more generally, overharvesting is an example of this phenomena. Optimal renewable resource harvesting from the perspective of the individual fisher will lead to the biological exhaustion of stocks or even extinction of species.[20] This is called a negative external effect: the collective consequences are not taking into account by the individual fisherman who aims to optimalize his decision making.

There are several reasons why privately rational resource exploitation decisions are not socially optimal. These include poorly defined or unenforceable property rights and a divergence between private and social discount rates. Overharvesting is more likely to occur where the stock is exploited under conditions of open access than where access can be regulated and enforceable property rights exist.

While scarcity of abiotic resources would best be tackled with specific regulatory policy instruments (such as quota), policies aiming to improve resource productivity may be of additional help, especially when targeted on reducing the (over)consumption of biotic resources.

4.2.2 Environmental effects

The question whether environmental effects would yield a cause for governmental intervention can be discussed from two sides:

a What is exactly the relation between resources and environmental effects?
b Are the environmental effects not already (or more efficiently) regulated through environmental policy instruments?

Both aspects will be discussed below.

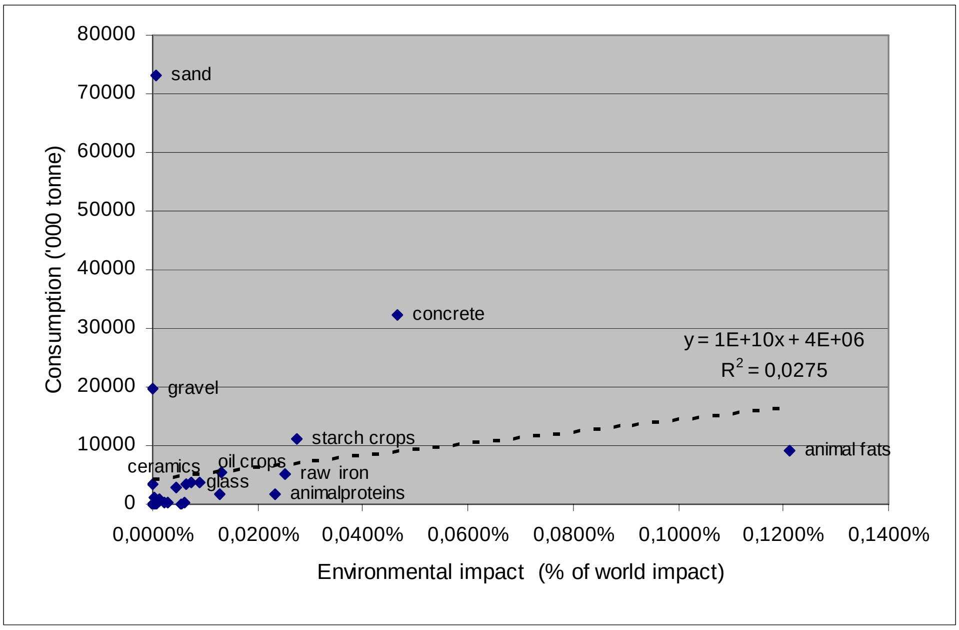
Ad 1) Relation resources and environmental effects
It is clear that by the law of mass-balance (see Annex C), an improvement in resource productivity should ultimately imply a reduction in environmental pressure relative to the level of income. However, the question is whether we should strive at an *aggregate* improvement of resource productivity, or whether we should aim for reduction of *specific* resources.

This question was addressed in a policy paper for the Netherlands in 2004 (CE, 2004). In this research, an estimation was given for the relationship between weight and environmental impacts for 34 materials. In figure 3 the Dutch consumption (in mass) in 2000 is shown on the y-axis and the environmental impact from this volume of consumption (determined through LCA) on the x-axis. As can be seen in the figure, sand and animal fats occupy the two most extreme positions on the spectrum: sand is extremely bulky but has little environmental impact over the chain, while animal fats are associated with substantial environmental impacts but relatively light-weight. Simple

20 Biological growth properties of renewable resources can be described with mathematical models such as logistic growth equation. Based on such models, the rate of sustainable yield for a given resource can be established. However, for some species, there is some positive level of population size below which the stock cannot be sustained (and so will eventually collapse to zero).

regression analysis showed that there is no correlation between weight and environmental impact at all.

Figure 9 Relationship between kilogram consumption and cradle-to-grave environmental impact for 34 materials; Dutch data for the year 2000



Source: CE, 2004.

Hence this implies that the environmental impacts from reducing material input largely depend on *which* flows are to be reduced. If only sand is to be reduced, not much environmental impacts can be expected. Based on this finding one could argue that policies aiming to improve resource productivity should aim for reducing impacts and consumption of specific resources. Only if the aggregated indicator of resource use would weight mass with environmental impacts (as has been done in the EMC – see Van der Voet *et al.*, 2004), policies aiming to reduce the aggregated weighted resource use would be equivalent to the policies oriented on specific resources. As these schemes are not widely applicable yet, we thereby take the guideline that policies improving resource productivity should differentiate between the type of resources in such a way that the more polluting resources should have a more pronounced policy treatment and vice versa.

Ad 2) Relation to traditional environmental policies
A second question relates to the effectiveness of policies aiming to improve resource productivity vice-versa the traditional environmental policy instruments. It should be clear that many environmental impacts are more efficiently and more effectively regulated by traditional environmental policies. Everybody would agree that it has no use to, e.g., skip the IPPC guidelines in the EU and replace them by a policy aiming to reduce resource use. Clearly, for environmental problems that are not too far away in space or time, traditional environmental policies based on a mix of economic instruments and traditional command and control simply are more effective and more efficient. However, for environmental problems that are far away in space and time, resource productivity policies may have an advantage over traditional environmental policies.

Long time horizons are a characteristic of some environmental problems, like climate change. As GHG stays in the atmosphere over centuries, actions now impact on future generations for a considerable time span. Traditional economics, on which impacts on future generations are marginalized away using discount rates, may not properly reflect our long-time moral objective towards future generations. In that case, policies aiming to improve resource productivity could yield a co-benefit in tackling climate change and other environmental impacts that are distanced far away in time.[21]

However, we would in this case not claim that resource productivity policies are an alternative for sound climate change policies. Clearly, climate change policies are more directly targeted to the underlying environmental problem than resource productivity policies and therefore probably more effective and efficient than resource productivity policies in combating climatic change.

Many environmental problems clearly have a *spatial* component. Economic activities relating to production and consumption here have often worldwide consequences. One of these consequences is environmental decay in other regions due to activities undertaken within the EU27. In paragraph 2.4 we presented evidence that these impacts are growing over time.

These impacts are currently not included in most environmental policies. Apart from 'communicative' actions like quality certificates (FSC for wood and wood products, MSC for fish and fish products, for example) and codes of conduct and similar voluntary agreements, there are currently few if any policies addressing the upstream negative impacts of materials use on nature and the environment, at the back end of production chains, beyond national or European borders. For this category of impacts, then, a resource productivity policy might well serve a useful purpose. The philosophy here is that resource-consuming countries have a certain responsibility for impacts occurring upstream in the producer countries if environmental policies are less well developed there.

4.2.3 Other considerations

Besides scarcity and environmental impacts a couple of other rationales for resource productivity have been identified in the literature. Of this *competitiveness* has been the most important. In Chapter 3 we investigated the relationship between resource productivity and competitiveness. There it was concluded that, contrary to common belief, there is not a clear relationship between resource productivity and competitiveness in the sense that countries that utilize resources more efficiently are characterized by a more competitive economy. One of the explanations offered was that resources (including energy) form only a small fraction of the total costs that are borne in an economy.

The fact that there is no evidence that resource productivity enhances competitiveness does not imply that policies that would stimulate resource productivity would *harm* competitiveness. As a matter of fact, resource productivity policies could result in *cost-savings* at the firm level if specifically targeted at providing information, lowering transaction costs or lowering the financial risks for the firm of investing in resource saving technologies. DeCanio (1993) showed that firms typically establish internal hurdle rates for energy efficiency investments that are higher than the cost of capital to the firm. If resource productivity policies are specifically targeted at

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21 Notice that this is valid here because there are non-pecuniary externalities involved in climate change. There is direct damage to future generations. In the case of resource scarcity, externalities are in essence pecuniary externalities

the market failures that are associated with investments in resource saving technologies, companies may experience cost savings from such policies.

Another argument for resource productivity policies may be **security of supply**. The argument is that resources form vital inputs to EU industries and that saving on resource use would be beneficial for security of supply. This argument is largely depending on the context. While it may be true that dependency on resources that are traded by only a few suppliers can be troublesome, the question is whether the international resource markets are characterized by monopolic or monophonic market power. We will not elaborate this topic here further as this may yield a very detailed mapping of market structure on each commodity.

4.2.4 Conclusions
In this long paragraph we have identified two main areas of 'market failure' which can be corrected using resource productivity policies:
1. Overexploitation of scarce renewable (biotic) resources.
2. Environmental consequences of consumption and production outside the EU (e.g. shifting the environmental burden to other countries).

In addition to these, there may be cost-savings that are not capitalized as firms use discount rates and risk premiums that are above the social optimal discount rate.

As these market failures have typically different characteristics, it is unlikely that one policy instrument (e.g. a resource tax) is likely to cover all aspects equally. In the next paragraph we will do a first investigation in the possibility of economic instruments to play a role in improving resource productivity.

4.3 Economic instruments

In this paragraph we will discuss whether the current taxation can be altered so that resource productivity will be enhanced, environmental pollution will be lowered and cost-savings can be capitalized.

First, we will give a general introduction in environmentally motivated charges and taxes (4.3.1), then we will discuss whether resources can be taxed additional to the current taxes on energy use and pollution (4.3.2). In paragraph 4.3.3 we will discuss consumption based taxation schemes and introduce a variant (the Carbon Added Tax) here. In paragraph 4.3.4 will discuss whether Green Fiscal Tax Reforms may play a role in enhancing employment while lowering the environmental burden from resource use and in paragraph 4.3.5 we will discuss whether some of the proposals here can be additional to EU ETS. In our treatment of EU ETS we will make clear that the instrument, although efficient in economic terms, may not give the right stimuli to higher resource productivity.

4.3.1 General treatment environmental charges and taxes
Environmentally motivated taxes cover a rather broad range of taxes. Some of the taxes may have various purposes. Raising revenues and generating environmental incentives are the most important motives. Environmental taxes cover taxes which are explicitly recognized as having an environmental purpose (reduce environmental damage). But it also covers a number of areas of the tax system where the structure of existing taxes may be seen as having significant effect on the environment, although their purpose originated in revenue considerations (OECD, 1995).

Apart from the purpose of the taxes (revenue raising or environmental target), taxes can be divided between emission charges and product/input charges. We distinguish here two ends of the spectrum:

- Input or output taxes (raw material, energy or product tax).
- Environmental taxation (emission tax).

From an economic theoretical framework, emissions form the externality which can be corrected by applying a so-called Pigouvian tax. A pure environmental charge is referred to as a Pigouvian tax if it is set equal to the marginal social damage cost[22]. Under (neo-) classical conditions (including fully informed consumers and producers) they can correct the externality. An emission tax *directly* corrects the externality. On the other hand of the spectrum, product or input charges include charges on specific goods as being introduced to *indirectly* correct externalities.

From the perspective of effectiveness of taxes emission charges are considered as being more efficient. Input and output taxes are considered as two possible policy alternatives for controlling externalities when the standard Pigouvian emission tax for correcting the externality in question is assumed to be unfeasible. This externality can be unfeasible because of difficulties (or high costs) involved in measuring the marginal social damage caused by the efficient level of waste emission, cost of compliance and/or in constructing an adequate tax base. Substantial costs of monitoring and compliance can offset the initial efficiency gains of taxation.

When emissions monitoring is impossible, difficult or costly, taxes may be levied on some input or output that is more easily monitored and a good proxy for the pollution to be regulated. They sometimes are referred as 'presumptive taxes', because in the absence of direct monitoring the agent that uses a certain input or produces a certain output is presumed to be polluting. A polluter that demonstrates abatement of clean technology can be exempted or refunded, but the burden of proof is moved from the regulator to the firm. Excise taxes on cars, cigarettes, and fuel already make up a large share of taxation in western countries. Although environmental concerns have played some role in introducing these excises, the main reason is probably the ease of tax administration. Another factor may be the relative attractiveness in taxing these goods as luxury goods or for moral or ethical goods (so-called demerit goods).

[22] Setting the level of tax is far from trivial; in fact it is one of the main difficulties with the tax or charge approach. In many real-world situations the charge is adjusted by trial and error.

Box 2 Do environmental taxes work?

One of the questions frequently being asked is whether environmental taxes would have any environmental effect at all. Research conducted by Ecologic and EFTEC for the European Environment Agency (2005) found that only a limited number of European countries have undertaken ex-post cost effectiveness studies of economic instrument and in particular charges and taxes. They conclude that ex-post evaluation of environmental policy is a relatively recent phenomenon and experience is limited. The complexity of these analyses is, however, that there are also other instruments used for controlling pollution. The question of isolating the effect of economic instruments from the effect of other instruments is discussed in an OECD report (OECD, 1997). The evidence on the functioning of taxes is mostly based on ex-post evaluations of energy and CO_2 taxes:

- Agnolucci (2004) surveys evaluation studies quantifying the effects of the CO_2-based taxes which have been introduced in six countries. Agnolucci (2004) concludes, that due to differences in the tax design, either as part of a package or as a change in design, makes it difficult to make an ex post evaluation and even more difficult to compare the evaluations across countries.
- An overview of ex-ante and ex-post evaluations of CO_2-taxes in the Nordic countries is presented in Andersen et al. (2000). The vast majority of studies are ex-ante studies, but a total of 20 ex-post studies have been made for the Nordic CO_2 taxes. All studies conclude that CO_2 taxes do limit the domestic emission of CO_2. The paper also discusses methodological considerations for ex-post evaluation.
- Norway — CO_2 tax: The carbon taxes contributed to only a 2 % reduction in CO_2 emissions because of the generous tax treatment of energy/carbon-intensive economic sectors. This relatively small effect relates to extensive tax exemptions and relatively inelastic demand in the sectors in which the tax is implemented (Bruvoll and Lasen, 2004).
- Germany — energy tax: Increased petrol and diesel prices resulting from the introduction of energy taxes led to a decrease in the sale of petrol and diesel between 1999 and 2003; consumption of petrol fell by around 15 % between 1998 and 2003 and diesel consumption increased between 1998 and 2001 but has fallen slightly since then. During this period, the energy tax levied increased by around 31 % for petrol and 48 % for
- Evidence on the efficiency of environmental taxes (their main textbook advantage) has proved difficult to obtain. However, it is clear that full pricing is the main determinant of efficient schemes. An often overlooked phenomenon is the relative high taxes on motor fuels in Europe. They have led to fuel prices which are roughly twice those in the United States, and the European passenger car fleet is about 25–50 % more fuel efficient than that in the United States (EEA, 2008).

4.3.2 Resource based taxation schemes

Without doubt, taxes on fossil energy resources and/or carbon dioxide are the most widespread form of environmental taxation in Europe. In 2001, energy taxes accounted for 76.8 percent of the total revenue from environmental taxes in the EU-15. In comparison, transport taxes accounted for 20.7%, and pollution and resource taxes for 2.6 percent (Johansson and Schmidt-Faber (2003). This latter part is, however, growing.

Can the tax base of environmental taxes be extended to certain resources? Resource use is in Europe currently taxed, mainly for surface minerals. Different kind of mineral (extraction) taxes has been designed throughout Europe. Taxing resources can have two purposes: (a) correcting externalities at the mining spot; (b) reduce use of this resource in later stages of economic processing.

Sand, gravel and rock, which are commonly known as aggregates, are relevant in terms of the impact they have on the environment. Not only does extraction of aggregates alter the landscape they also affect groundwater reserves and the cultural assets of a region, hence an important factor to consider in EU policies. A comprehensive study (EEA, 2008) of national aggregates taxes in the EU shows that a combination of policies was needed to stimulate a change in production methods and practices. The tax or charge had often formed an important component of a policy package. It was this integrated approach that created incentives to which the extraction industry could respond. The study concluded that the combination of taxes and other policy levers, introduced as a package of policy measures, is likely to be more effective in delivering environmental improvements for the extraction industries.[23]

Several member states like the Czech Republic are currently revising the basis for their mining charge to reflect the ecological impact. However, calculating the ecological score is complex, and concerns have been raised about whether the administrative costs will exceed the benefits. It is interesting to note that none of the other countries, included in the study (EEA, 2008), have attempted to vary the tax or charge across different locations to reflect the extent of environmental damage.

Aggregates taxation implies taxes at the level of production. However, resources could be taxed at the level of consumption as well. However, for public acceptability as well as economic efficiency, there should be a rather straightforward correlation between the environmental impact and the use of the resource. Several studies have been made with the aim of identifying material resources with the highest environmental impacts (see e.g. Van der Voet *et al*., 2004). One of the conclusions can be that with the exception of environmental impacts directly related to resource extraction, there are only few instances where the relationship between resource use and environmental impacts are straightforward. For the following resources a correlation with impact seems to exist, although further analysis is still needed:
- Use of specific metals, where there is a clear and linear relationship to environmental impacts from metal extraction and refining. A reduction in use of these metals will lead to a direct reduction in the associated impacts.
- Land use, where it is the land use itself that is of environmental concern. A reduction in area occupation will reduce the pressure on biodiversity.
- Construction materials, where the resource use drives the waste stream, albeit mostly with a significant delay corresponding to the lifetime of the constructions.

From these categories, probably land use would yield the greatest possibilities. Land is not trade so international competition will not be directly affected if the external costs of using land are included in a tax. The tax base, however, is far from simple as normally this should be differentiated across the various land-use types. Construction materials would yield a second candidate as these are used in buildings and buildings are not traded. Also here the tax base would yield problems: should this be on weight or on environmental impact? As construction materials differ widely in terms of environmental impacts (e.g. cement is much more polluting than sand), weight as a tax base may give even a wrong stimulus to the environmental problems. Metal taxes, finally, may be even more problematic to introduce as these materials are being used in internationally traded products. Fears of competitive disadvantages for EU producers may form an important practical and political obstacle to introduce taxes here.

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[23] For example, an Italian study highlighted the importance of the regional/provincial planning systems in controlling quarrying activities and extraction quantities. Such systems minimize external impacts and support the sustainable management of landscapes to provide environmental benefits to local areas.

4.3.3 Consumer based taxation schemes

Paragraph 4.2 showed that one of the rationales for a policy intervention is the growing shifting of environmental burden to countries outside the EU. This is partly due to a relocation of heavy industries that do not move out only because of environmental costs but also because of other cost considerations. However, the fact that capital is internationally mobile poses a border on the height of the fiscal tax regime for environmental policies. Obviously, fiscal instruments do raise costs for companies and therefore be adding to the problem of shifting the environmental burden instead of alleviating it.

Therefore, a reconsideration of the fiscal tax regime should be considered where it is investigated whether the current environmental tax base (pressing mostly on *production*) could not be altered towards *consumption*. Consumption based taxes have the advantage of giving the right incentives at the consumption level but at the same time not aggravating the relocation of dirty industries towards other countries. Consumption based taxes can add towards a better level playing field between EU and non-EU industries as their products fall equivalently under the tax regimes.

This is especially pressing in specific environmental problems like CO_2. At present the progress on CO_2 reduction policies is severely hampered by the fact that unilateral climate change policies may result in relocation of energy intensive industries and thereby resulting in carbon leakage. This undermines the effectiveness of these policies at the global scale. Moreover, it reduces the willingness of politicians in developed economies to accept more stringent reduction targets.

At present, the most successful policies for CO_2 reduction largely press on companies (like with the EU ETS). Ultimately, however, a transformation to a low carbon economy should also be achieved through consumption. Consumer decisions are based on relative prices and preferences on which they spend their income. It is therefore important that environmental policy that is aimed at producers will be translated into price changes at consumer level.

One way to achieve this would be to introduce an explicit tax on carbon consumed. This could be done with analogy to the value added tax and is proposed in a few papers (but not really developed): a tax on the Carbon Added (CAT) of products. The system of CAT works in essence similar to the tax system of a VAT. Under a CAT only the input of carbon is being taxed, while in a VAT in essence the input of labour and capital are being taxed.

How would this system of a CAT work? Under a system of a CAT each company would be required to keep carbon accounts. These accounts indicate how much fuel is used within a company. This information is already present in the current accounts of the company: the only thing that needs to happen is by adding information on the carbon content of fuels, verified by accountants. To give an example: a steel producer sells his products to the manufacturer of auto parts. The steel producer sells his steel including a CAT representing the value of the carbon used in steel making. If the CAT is designed in a similar way as the US sales tax, the steel maker can deduct this tax from his taxes so that the net cost increase for the steel producer is zero.[24] This manufacturer of car parts makes a door. He sells the car door to a car manufacturer and accounts the price of the door, the CAT of the steel maker plus added carbon from it's own account. The car parts manufacturer thus gets a revenue for the

[24] An alternative system would be where the steel maker can *not* deduct his taxes. In that case, the CAT would have to be accompanied with border tax adjustments in order to guarantee a level playing field with non-EU suppliers of steel.

CAT he paid to the steel producer. His own CAT he can deduct from his taxes so that he also has no cost price increase. The car manufacturer makes a car and sells this to the consumer. He adds his own CAT, the CAT from the part manufacture and the CAT from the steel producer to the price of the product. His own CAT he can deduct from taxes. In this way, none of business had any competitive disadvantage from this CAT and the consumer pays the full life-cycle carbon costs of the product.

This system of carbon based consumer taxes has several advantages. First, the cost of carbon is directly paid by the consumer. Consumers will find that certain products are relatively cheap (e.g. shoe repair) while others are expensive (like cars) and start to bring their lifestyle consumption more in accordance with the underlying price of carbon. Second, companies from the EU will no longer face competitive disadvantages from unilateral climate policies. However, this system implies that also for imported products a CAT can be established. This may be difficult as for companies exporting to the EU, there is no official rule to keep track of the carbon added. However, based on LCA studies and experience data on the carbon content of European products would be an average can be established for the thousands of products that enter Europe. The CAT, when introduced in this way, may be more easily accepted by the WTO than the unilaterally imposed border tax adjustments that are often suggested in the literature on unilateral climate policies (see e.g. CPB, 2008). In addition, it will lower eventual chances on trade wars.

Although the concept of a CO_2 added tax is probably best suited for CO_2 emissions as these are relatively easy to monitor, other resources could be included here as well. If this were to be done, the CAT would eventually transform itself to a RAT (Resources Added Tax). However, the discussion on how to measure the environmental consequences from resource use (see paragraph 4.2 and Annex C), would still exist.

4.3.4 Green tax reform as a stimulus to competitiveness and job growth

Environmental taxes have historically been applied on a one-by-one basis as a way of meeting particular environmental objectives. However, the early 1990s saw the beginning of a more general shift of the tax burden from labour and other economic activities (e.g. profit) to environmentally damaging activities such as resource use and pollution. Countries in the Nordic region were the first to launch such reforms, followed by the Netherlands and other countries in the EU. In most cases, the shifts were from labour taxes and social contributions to taxes on energy. Can this be a ‘magic bullet’ for resource productivity policies that aim to stimulate competitiveness and economic prosperity? Can we at the same time limit resource use and increase job opportunities in our economies?

There has been a debate in economics whether a double dividend from shifting the tax base away from labour to pollution would occur. Both environmental and employment benefits can be achieved by decreasing pollution and reducing labour costs so that unemployment can be reduced and output increased. This issue has mostly been solved theoretically, using various existing economic models. The findings of an analysis of macroeconomic studies examining the double dividend hypothesis are summarized in a recent OECD publication: 'that the results of many models converge, to indicate that a carbon-energy tax combined with cuts in labour taxation would yield some double employment-environment dividend. However, the employment effect is limited' (OECD, 2001, pp. 37–38). A more recent OECD report that studied the results of the different modelling approaches used to analyse the economy-wide employment impacts of environmental policy emphasizes: 'that an employment dividend is possible when the revenues raised when implementing economic instruments - such as taxes or auctioned tradable permits - are recycled in the form of a reduction in labour costs. The employment increase is likely to be greater when payroll tax reductions are concentrated on unskilled workers. However, these findings are conditional on the possibility of lowering labour costs and the elasticity of demand for labour. However, the OECD also concludes that the effects are likely to be very small. In addition, the employment dividend can be expected to be temporary since labour costs are likely to increase in the longer run, as a result of wage pressure. Finally, it should be noted that environmentally related taxes that succeed in changing behaviour will lead to lower revenues.' (OECD, 2004, p. 72).

This body of literature suggests that fiscal greening can only have relatively small and temporary effects on the extra demand for labour by reducing the distorting effect of labour taxes. This doest not mean that green fiscal tax reform is not relevant for material and energy recourse efficiency, but that the merits of fiscal greening should be first and foremost appraised from an ecological perspective. If in the future there might be extra employment effects, these should be considered as extra side-benefits but do not constitute the main rationale behind fiscal greening.

4.3.5 EU ETS as a driving force?

In 2005 the European Union introduced a market for tradable CO_2 emission rights. The first two phases of the ETS, running from 2005 to 2012 can be perceived as tests. The allowances are allocated largely free of charge to the participants. Ex-post analysis showed that particular industry had many more rights than their allotted emissions and electricity producers were the purchasers of the rights that the industry had in excess.[25]

The third phase of EU ETS will start in 2012 and last until 2020. Under the third Phase, emission credits will be allocated free of charge to industry (except a few very small industrial sectors) and auctioned for the electricity sector. One of the questions now is: to what extent can EU ETS play a role in enhancing resource productivity?

Resource productivity can be enhanced by decisions of producers and consumers. EU ETS alters the use of energy (as an important precursor of CO_2 emissions) by producers and consumers. In principle, an emission trading scheme like EU ETS gives incentives both to producers and consumers. Producers are obliged to meet emission reduction criteria. If they don't meet these, they have to buy additional allowances on the EU ETS market to cover their emissions. However, also consumers will obtain incentives as prices of CO_2 embodied in products are likely to rise. If firms pass through the costs of allowances onto the prices, prices of products with substantial carbon embodied will rise which will suppress demand.

However, this latter mechanism may not properly work in the current EU ETS. This is due to three reasons:

a The EU ETS only covers EU production. As a growing share of carbon embodied products is being imported from outside Europe, where no carbon prices exist for industry, the costs of carbon are not (fully) included in a growing share of products.[26]

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25 Sandbag, 2009.

26 This is also dependent on the question if importers are price makers. If they are price makers, they will include the price of carbon in their products.

b In order to maintain competitive position with respect to imports, EU industry may decide not to pass on the opportunity costs of EU-allowances into the prices. They can do this as the allowances are allocated free of costs to industry. Hence they have the possibility to sacrifice profitability for the sake of maintaining market shares.

c The current EU ETS gives an implicit subsidy on expanding production and penalizes closure down of facilities. As outlined in, amongst others CE (2008), this implies that companies have an incentive not to pass through the costs of freely obtained EU ETS allowances on to the prices (see also Box 3) because they will prefer expanding output.

We want to emphasize here that the question whether EU ETS industries pass on the costs of their freely obtained allowances is most likely sector-specific and depending on the business cycle. If all capacity is fully utilized, points (b) and (c) may not hold anymore (as capacity cannot be expanded easily for most energy-intensive production facilities) and industries may decide to pass through the costs of their freely obtained allowances into the price of products.

Box 3 Allocation rules, efficiency and price developments in EU ETS

According to economic theory selling by auction is no more efficient than the free issuance of rights. To safeguard the necessary efficiency of free issuance it is essential that the allocation formula is determined once only and maintained for many years to come. If the formula were to be adjusted periodically the system would show inefficiencies because extra production would be implicitly subsidized. A company realizing that in 2012, for example, rights will be re-allocated according to the production level of 2010 will start intensifying production in 2010 because the optimal production volume will also be determined on the basis of the benefits of more rights received for free in 2012.
Evaluations of the European emissions trading system show exactly this phenomenon. In 2005 Phase I was launched in which the rights were issued for free for the period of 2005-2007. In Phase II, launched this year for the period of 2008-2012, allocation rules were once again drawn up for the free issuance of rights. Reviewing the allocation rules in Phase II we learn that most countries have adjusted the allocation formula to the last available emissions or output data (Schleich *et al.*, 2007). The inefficiency of periodically adjusting the allocation formula has also been demonstrated by Demailly and Quirion (2008). According to their calculations, in case of annual adjustment of the formula the price to be paid for CO_2 rights would be almost twice that of rights sold by auction at a reduction goal of 20% lower CO_2 emissions. This effect is mainly the result of the implicit production subsidy based on annually adjusted issuance which results in the fact that companies no longer pass through the opportunity costs of their allowances in the price of the products. As the price of these products does not contain the carbon embodied, consumption is higher than socially optimal.

4.4 Conclusions and outlook

This Chapter has offered a perspective on the focus and direction of policies oriented on improving resource productivity. We took here as central starting point that resource productivity policies should enhance welfare: they should correct certain market failures that occur now in the way we use our resources. Here, we identified two main areas of market failures

– Overexploitation of biotic renewable resources (fish, wood, etc). The market has here a tendency to overuse these resources because of the well-known prisoner’s dilemma. Individual self-interest is here blocking the collective most desired outcome. Although such problems need to be regulated by specific policies (e.g. fishing policies), resource productivity

policies could help here by reducing demand for these resources and increasing price.
- Environmental impacts of production and consumption occurring outside the EU. Currently these are hardly regulated and yet have impact on, in additional to localized environmental problems, to the global commons, such as the climatic system and biodiversity. Regulation of these impacts does therefore add potentially to welfare but should, however, differentiate between type of materials as weight is not a good proxy for environmental impacts.

Resource productivity enhancing policies may not be very costly to society as there are cost savings involved that are not realized fully yet because of risk premiums and lack of information for, especially, producers. Clearly companies demand a higher rate of return on their investments than society as a whole. This has to do with the associated risk in their operations. Resource productivity policies could incorporate part of these risks and have even a slight positive impact on welfare.

Policies enhancing resource productivity could make use of economic instruments. The past decade has seen a growth in support for and implementation of environmental tax or fiscal reforms in European countries. Taxing activities that lead to environmental pressure and natural resource use would lead to a better functioning of markets and increased welfare, as it moves society towards a more sustainable development path. Current EU ETS gives an impetus to use resource more rational at the firm level but is –due to the specific design- unable to fully translate this onto the consumer level.

Hence, there is room for enlarging the tax base to the consumption of certain resources. Especially land use and construction materials are candidates here. However, the proper tax base is far from evident in these cases and more studies and analyzes may be required to determine the external effects of these inputs and determine a proper tax base. With increasing technologies for monitoring, taxation can be expected more and more to fully and precisely incorporate the externalities of production and consumption[27]. This will eventually increase efficiency and effectiveness of market-based instrument in reaching material and energy efficiency targets.

Another alternative would be to introduce taxes at the level of consumers. In this research we have proposed a carbon based equivalent of the Value Added Tax: The Carbon Added Tax. Although such a CAT would require alterations to the current tax system (and bookkeeping system of companies), it has various merits over other forms of fiscal instruments.

Finally, we addressed here the question whether a policy on resource productivity could be justified from the perspective of a shift of the tax burden from labour to the environment. Unfortunately, this does not seem to have substantial benefits for the economy or for employment, at least at a macro level. Such a shift should mainly be justified by reducing environmental pollution and natural resource use. There may be some temporary employment effects but these are certainly not being considered as substantial.

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27 Road charging reflecting the externalities of transport is a good example.

5 Conclusions and recommendations

5.1 General conclusion

Resource productivity is a topic that recently gained significant interest in scientific and political discussions. Resource productivity can be defined as a measure of resource use divided by GDP. It is believed to be indicative of the amount of resources we need to obtain our current level of GDP.

Over the last 50 years, resource productivity has increased, albeit slower than labour productivity. The increase in resource productivity is partly a natural phenomenon inherently in the process of economic development and partly a statistical phenomenon due to the displacement of resource intensive industries to other less developed economies.

Resource productivity policies are often presented as a win-win concept: they could both enhance the environment and the economy. This claim has been investigated in this research in more detail.

With respect to the environmental aspects, resource productivity could enhance welfare if it is oriented on two market failures
a The overexploitation of renewable resources.
b The degradation of the environment in regions outside the EU and specifically the degradation of the global commons such as the climatic system and biodiversity.
Other market failures due to resource consumption exist (such as waste management problems or scarcity of non-renewable resources) but these tend to be better regulated by tight-knitted environmental policies instead of a general resource productivity policy.

The more popular claim that policies oriented on resource productivity can enhance welfare because it is good for the economy could not be justified in this research. There is no relationship between resource productivity and competitiveness for countries with comparable levels of income. This is due to the fact the resources (agricultural, mining and energy) only form a very small fractions of the total costs that we make to construct our GDP. From the position of competitiveness it is hence much wiser to orient on labour and capital productivity instead of resource productivity.

If governments want to stimulate resource productivity policies they should focus on environmental impacts instead of kilograms consumed material as there is not a general relationship between weight and environmental impacts. Economic instruments can be used, especially if they impact on consumer decisions. As the post 2012-EU ETS will not affect consumer decisions in a large scale, additional policies aiming to reduce environmental impacts at the level of consumers may be desirable, especially when taking into account the environmental impacts of their consumption on environmental problems in less developed countries. Global commons, like biodiversity or the climatic system, are currently not well enough protected by environmental policies tackling the individual consumer.

5.2 Detailed conclusions

The detailed conclusions are largely based on the conclusions at the end of every chapter.

5.2.1 Development of resource productivity over time

Resource productivity is a topic that recently gained significant interest in scientific and political discussions. The main aim of a policy towards resource productivity is not entirely clear but should, in a broad sense, be related to a reduction of the throughput (concept of Herman Daly) and to bring the economic system within the boundaries the ecosystem poses.

Developments over time: improving resource productivity but slower than labour productivity.
Over time, resource productivity has been improved. This may be due to three reasons:

a Improvements in resource productivity are partly a natural phenomenon for the economic development trajectory of a country which firstly specializes in buildings, infrastructure and heavy industry and only in later stages of economic development tend to revert to a more service oriented economy.
b Improvements in resource productivity are caused because resources form costs to companies. Saving on these resources is hence economically rational. Environmental and natural resource based policies can add this by making resources more expensive.
c Improvements in resource productivity are partly achieved by shifting away the environmental burden of our consumption to other countries and regions in the world. More and more resource intensive production takes place outside the EU. Therefore the statistics may measure an improvement in resource productivity while in fact they only measure displacement of resource intensive dirty production. Such a displacement can be explained from an economic perspective by reference to the positive income elasticities people have for environmental quality. Once people become richer, resource intensive and dirty production become more like an annoyance one is willing to relocate to other poorer countries with less regard for environmental protection.

It is unclear to what extent each of these underlying reasons has contributed to the gradual improvement in resource productivity over time in the EU. If we compare the improvements in resource productivity with other productivity indices, it appears that resource productivity grew slower than labour productivity over the last 50 years in the EU. This can partly be explained by reference to the price developments: over the last 50 years labour has become much more expensive than resources in most developed economies.

5.2.2 Resource productivity and the Porter Hypothesis

Resource productivity is said to be beneficial to the competitive position of companies and nations. The idea is relatively simple: resources are costs to society and saving on these costs will enhance welfare. This is similar to the Porter hypothesis. According to this hypothesis, many market imperfections exist that can be corrected with environmental and resource productivity policies. More stringent environmental policies, if implemented correctly, may result in a higher level of productivity, or a new comparative advantage, which can lead to improved competitiveness. In other words, environmental policy can, according to Porter, lead to a win-win situation: in addition to the environmental benefits there may be economic gains as well.

Two variants of the Porter hypothesis exist. The 'weak' version says simply that environmental regulation stimulates environmental innovations that, in the end, can bring down costs of complying to environmental policy goals. The 'strong' version of the hypothesis states that environmental and resource productivity enhancing policies may result in cost-saving innovations that more than compensate for the costs of compliance to the regulations. Hence in the strong version environmental and resource productivity enhancing policies may have a positive effect on competitiveness resulting in the win-win situation that was expected from resource productivity policies.

There is a vast body of empirical and theoretical literature addressing the Porter hypothesis. This literature finds, in general, support for the weak variant: environmental policies do stimulate innovations in environmental techniques. However, evidence for the strong version (environmental policies enhance competitiveness) is mixed.

In our own empirical work we find that at first glance it seems that competitiveness and energy productivity are positively correlated to each other for a dataset of 140 countries. However, this correlation appears to be spurious. As higher GDP is both related to higher energy productivity and higher scores on the competitiveness index, the correlation is caused as both variables are highly correlated with GDP. For countries with comparable levels of GDP, no relationship at all between competitiveness and energy productivity can be found. This is evidenced by our econometric estimate that shows that competitiveness does not influence energy productivity when corrected for the level of income. Hence, there exists no clear evidence that policies aiming to improve energy productivity (as a proxy for resource productivity) do enhance competitiveness.

One explanation for this finding is that the costs of materials and energy in the total final demand are small. Our estimates show here that only 3-6% of the total costs that are made to arrive at a certain level of income (GDP) are made up by costs of raw materials and energy. This figure is certainly much lower than found in other studies that have applied the concept of intermediate use. However, in the intermediate use already a large share of labour costs is included.

5.2.3 Policy rationales for resource productivity policies

If governments want to establish policies to enhance resource productivity, which policies should they choose? This question depends on the role one takes with respect to the necessity of a resource productivity policy. Here a welfare perspective has been chosen: resource productivity policies need to enhance welfare (globally and across generations). Interpreted in this way, one should take a perspective that resource productivity policies need to correct certain market failures that occur now in the way we use our resources. Moreover, we should somehow assess that these market failures are not already addressed by other, more effective, policies.

Using this framework, two main areas of market failures:

– Overexploitation of biotic renewable resources (fish, wood, etc). The market has here a tendency to overuse these resources because of the well-known prisoner's dilemma. Individual self-interest is here blocking the collective most desired outcome. Although such problems need to be regulated by specific policies (e.g. fishing policies), resource productivity policies could help here by reducing demand for these resources and increasing price.

- Environmental impacts of production and consumption occurring outside the EU. Currently these are hardly regulated and yet have impact on, in additional to localized environmental problems, to the global commons, such as the climatic system and biodiversity. Regulation of these impacts does therefore add potentially to welfare but should, however, differentiate between type of materials as weight is not a good proxy for environmental impacts.

Resource productivity enhancing policies may not be very costly to society as there are cost savings involved that are not realized fully yet because of risk premiums and lack of information for, especially, producers. Clearly companies demand a higher rate of return on their investments than society as a whole. This has to do with the associated risk in their operations. Resource productivity policies could incorporate part of these risks and have even a slight positive impact on welfare.

Policies enhancing resource productivity could make use of economic instruments. The past decade has seen a growth in support for and implementation of environmental tax or fiscal reforms in European countries. Taxing activities that lead to environmental pressure and natural resource use would lead to a better functioning of markets and increased welfare, as it moves society towards a more sustainable development path. Current EU ETS gives an impetus to use resource more rational at the firm level but is –due to the specific design- unable to fully translate this onto the consumer level.

Hence, there is room for enlarging the tax base to the consumption of certain resources. Especially land use and construction materials are candidates here. However, the proper tax base is far from evident in these cases and more studies and analyzes may be required to determine the environmental effects of these inputs and determine a proper tax base. This research showed that kilograms do not offer a reliable tax bases as there exists hardly any relationship between kilograms and environmental impacts.

Another alternative would be to introduce taxes at the level of consumers. In this research we have proposed a carbon based equivalent of the Value Added Tax: The Carbon Added Tax. Although such a CAT would require alterations to the current tax system (and bookkeeping system of companies), it has various merits over other forms of fiscal instruments.

Finally, we addressed here the question whether a policy on resource productivity could be justified from the perspective of a shift of the tax burden from labour to the environment. Unfortunately, this does not seem to have substantial benefits for the economy or for employment, at least at a macro level. Such a shift should mainly be justified by reducing environmental pollution and natural resource use. There may be some temporary employment effects but these are certainly not being considered as substantial.

5.3 Recommendations for the Dutch Ministry of Environment

Based on this research we would have the following recommendations for future resource productivity policies:

- If advocating resource productivity policies, focus on the environmental gains instead of the (macro-) economic gains. This research showed that the conclusion that resource productivity policies can enhance competitiveness is flawed. This does not imply that resource productivity could not result in cost-savings. Cost-savings are possible but these are small when compared at the level of nation-wide economies.

- A general policy on reducing kilograms of material is not to be recommended. As the relationship between kilograms and environmental impacts is very different between the various materials, policies improving resource productivity should differentiate between the various materials.
- For policies aiming to use economic instruments, this implies that the basis of these economic instruments should be on the environmental impacts and not on the weight of resources to be consumed.
- The post 2012-EU ETS is likely to give not enough impetus for resource productivity as the prices at the consumer level will not be changed fully to reflect the costs of carbon. Additional policies aiming to reduce environmental impacts at the level of consumers may be desirable, especially when taking into account the environmental impacts of their consumption on environmental problems in less developed countries. Global commons, like biodiversity or the climatic system, are currently not well enough protected by environmental policies tackling the individual consumer.

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Annex A Competitiveness definition and indices

A.1 Concept of competitiveness

One important question is how one may define competitiveness. It is normal to distinguish micro/meso-economic concepts of competitiveness from macro-economic concepts. The first applies to firms or sectors, the latter, in general, to nations.

Competitiveness for sectors and firms
With respect to firms, competitiveness may be defined as the ability of the firm to maintain it's operations in a given market. This ability is difficult to measure beforehand but various cost-concepts (such as additional costs over net profits) have been developed (see OECD, 1993 for various concepts). Most literature investigating the competitiveness of firms uses a myriad of indicators, such as output measures of performance (i.e. profitability, productivity, return on investment, etc.) and input measures of performance (such as R&D spending, employment). There is no conceptual framework that has identified the 'ideal' indicator in this respect.

Competitiveness for a country
For a country, one may define competitiveness as the ability to maintain a certain level of (increase in) welfare in a country. The OECD (1993) defined a nation's competitiveness, for example, as:

"The degree to which it can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the incomes of its people over the longer term".

However, many economists have argued that competitiveness at the scale of individual nations is a poorly defined concept. While firms based in different countries sell products that compete with each other, at the country-level there are mutual benefits from trade[28]. For example, Noble Prize Laureat Paul Krugman (1994) argues that:

"the doctrine of 'competitiveness' is flatly wrong. The world's leading nations are not, to any important degree, in economic competition with each other."

As Krugman notes, national economic welfare is determined primarily by productivity in both traded and non-traded sectors of the economy and not by the amount of competitiveness of it's economic sectors. This boils down to a central fact in macro-economics: If all production factors are utilized to a certain degree, productivity gains are the driving force of economic growth, not increasing output. And, as Krugman notices, there is no difference between policies stimulating productivity in a closed autarchic economy and policies in an open economy. This leads Krugman to conclude that policy

[28] The mutual benefits from trade originate to the 18th century economist Ricardo who developed the theory of comparative advantage. Comparative advantage forms the basis of modern trade theory (e.g. the Heckscher-Ohlin theorem) which states that welfare of a single country will be enhanced if this country specializes in the production of a product made from inputs that are cheaply available in this country.

recommendations for stimulating competitiveness at firm levels often result in a misallocation of resources.

The Krugman critique has resulted in an adequate response from the institutes that collect data on competitiveness of countries. According to the World Economic Forum, who developed and maintain the Global Competitiveness Index (see paragraph 3.4.1), *competitiveness is a set of institutions, policies and factors that determine the level of productivity of a country*. The level of productivity sets the sustainable level of prosperity of an economy. The productivity level also determines the rates of return on investments. Because the rates of return are the fundamental drivers of the growth rates of the economy, a more competitive economy is one that is likely to grow faster over the medium to long run. The concept of competitiveness thus involves static and dynamic components: although the productivity clearly determines the ability of a country to sustain a high *level* of income, it is also one of the main determinants of the rates of return on investments, which is one of the key factors contributing to an economy's *growth potential* (WEF, 2008). Thus, their Global Competitiveness Index can to a certain extent be seen as a predictor of future economic growth.

Bringing this discussion back to the issue of resource productivity, it implies that at the macro-economic level the orientation should not be on the impact from resource productivity on competitiveness at the firm level, but on the impact from resource productivity on economic growth; i.e. the growth in national income or the potential of growth in national income in the future[29]. In addition to effects on income, politicians may be interested in the effects of resource productivity on employment. This is difficult to say beforehand. If measures to increase resource productivity do result in additional benefits for firms, employment may increase in the short run. However, in the long-run the higher level of employment will put an upward pressure on the wages which will result in a reduction to overall employment. Hence a gain in employment in one sector is, after a certain transition period, often translated in a loss in employment in other sectors. Only if there is already large scale unemployment and the wage increases due to productivity gains are fixed due to institutional constraints, one may conclude that employment effects may be permanent and have additional consequences on the national income as well.

A.2 Indices of global competitiveness

Two organisations publish annual competitiveness reports with country rankings. The most often cited are the rankings of the Global Competitiveness Reports published by the World Economic Forum (WEF) since 1979. The International Institute For Management Development (IMD), has published a similar report referred to as The World Competitiveness Yearbook since 1989. The Global Competitiveness Report was originally published jointly by the WEF and the IMD, but because of differences over how to define and measure competitiveness, these organisations split and produce separate reports. Main differences include factors that are taken into account in the competitiveness index and how to weight these factors (MAAW, 2007).

[29] Or welfare, of course. Income is a smaller concept than welfare. Many categories that are valuable to humans are not included in the income statistics but do matter for welfare. One can think of household labour or a clean environment. The welfare effects of a policy measure are normally included in Societal Cost-Benefit Analysis.

In our report, we will use the indexes reported in the Global Competitiveness Reports because of three main reasons: higher scientific recognition, stronger popularity and better availability (via Internet).

According to the World Economic Forum, *competitiveness is a set of institutions, policies and factors that determine the level of productivity of a country*. The level of productivity sets the sustainable level of prosperity of an economy. The productivity level also determines the rates of return on investments. Because the rates of return are the fundamental drivers of the growth rates of the economy, a more competitive economy is one that is likely to grow faster over the medium to long run. The concept of competitiveness thus involves static and dynamic components: although the productivity clearly determines the ability of a country to sustain a high *level* of income, it is also one of the main determinants of the rates of return on investments, which is one of the key factors contributing to an economy's *growth potential* (WEF, 2008). Thus, the Global Competitiveness Index can to a certain extent be seen as a predictor of future economic growth.

The methodology for calculating the index of global competitiveness published yearly by the World Economic Forum has evolved over the years in an effort to introduce the best available technology. An important milestone was reached in 2000, when Professor Jeffrey Sachs introduced the Growth Competitiveness Index, based on academic foundations in economic growth theory. The Growth Competitiveness Index was reported during the period 2001-2005, and since 2006, a Global Competitiveness Index has been reported as the main competitiveness index of the Global Economic Forum.

A.3 Global Competitiveness Index

Currently, the Global Competitiveness Index (GCI) is constructed as a weighted average of many different components. The components are grouped in 12 pillars of economic competitiveness:

1. Institutions.
2. Infrastructure.
3. Macroeconomic stability.
4. Health and primary education.
5. Higher education and training.
6. Goods market efficiency.
7. Labour market efficiency.
8. Financial market sophistication.
9. Technological readiness.
10. Market size.
11. Business sophistication.
12. Innovation.

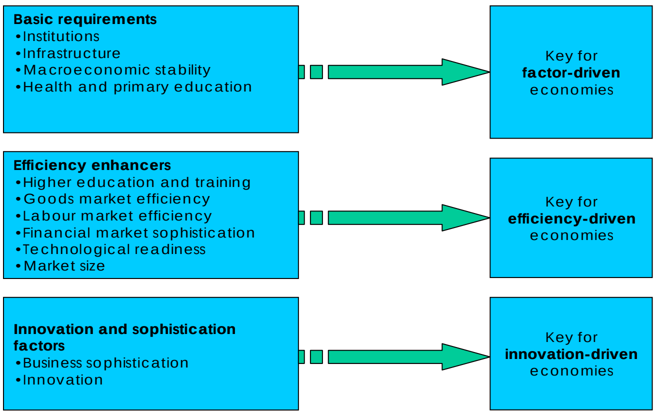
The pillars are not only related to each other but they reinforce each other. The pillars affect different countries differently, depending on a stage of development. According to GCI, in the first stage, the economy is *factor-driven*. In this stage, countries compete based on their factor endowments, primarily unskilled labour and natural resources. Companies sell basic products. Low productivity is reflected in low wages. Basic requirements for maintaining competitiveness at this stage of development are: well-functioning institutions, well-developed infrastructure, macroeconomic stability, and healthy and literate workforce.

The second, *efficiency-driven* stage of development begins when countries develop more efficient production processes, product quality and wages rise. At this point, competitiveness is driven by higher education and training, efficient goods markets, well-functioning labour markets, sophisticated financial markets, technological progress, and a large domestic or foreign market.

The last stage of development is *innovation-driven*. The countries are able to sustain higher wages and the associated standard of living only if their business sectors are able to compete with new and unique products. At this stage, the most important factors of competitiveness are business sophistication and innovation.

Figure 10 below depicts twelve pillars of competitiveness and their division into the groups of factors of primary importance for different development stages.

Figure 10 The 12 pillars of competitiveness divided in groups of factors related to stages of development



Source: WEF, 2008.

The three groups of factors that are the most important for the three different stages of development form a basis for calculating three sub-indexes: basic requirements sub-index, efficiency enhancer's sub-index, and innovation and sophistication factors sub-index. At every stage of development, different weights are attributed to each sub-index. To obtain the weights, a regression of GDP per capita was run against each sub-index for past years. Rounding these estimates led to the choice of the following weights (Table 3):

Table 3 Weights of the three main groups of pillars at each stage of development (in percent)

Pillar group	Factor-driven stage	Efficiency-driven stage	Innovation-driven stage
Basic requirements	60	40	20
Efficiency enhancers	35	50	50
Innovation and sophistication factors	5	10	30

Source: WEF, 2008.

Countries are classified to different development stages based on two criteria. The first is the level of GDP per capita at market exchange rates (as a proxy for wages). The thresholds are shown in Table 4.

Table 4 **Income thresholds for establishing stages of development**

Stage of development	GDP per capita (in USD)
Stage 1: Factor driven	< 2,000
Transition from stage 1 to stage 2	2,000 – 3,000
Stage 2: Efficiency driven	3,000 – 9,000
Transition from stage 2 to stage 3	9,000 – 17,000
Stage 3: Innovation driven	> 17,000

Source: WEF, 2008.

The second criterion measures the extent to which countries are factor-driven. This criterion is expressed with a proportion of exports of primary goods to total exports of goods and services; it is assumed that countries with a share of over 70% of primary products in total exports are to a large extent factor driven.

Countries falling in between two stages are considered to be in transition. For these countries, the weights are changing smoothly as the country develops.

A.4 Growth Competitiveness Index

The World Economic Forum has reported the Global Competitiveness Index annually since 2006. Earlier, since 2001, Growth Competitiveness Index was reported based on a slightly different methodology; in the transition year 2006 both indexes were published. In our assessment of the relationships among energy and material efficiency on one side and competitiveness on the other side, we will use the Growth Competitiveness Index because a longer time series is available (6 years as compared to only 3 years with the Global Competitiveness Index).

The Growth Competitiveness Index (GCI) shows scores on a scale of up to 7 points (with actual country scores being in the range between 2.5 and 6). GCI is built on the basis of 35 variables which are organised in three pillars: the quality of the macroeconomic environment, the state of the country's public institutions, and the level of its technological readiness. These pillars are evaluated using separate indexes. The GCI uses a combination of hard data such as university enrolment, inflation, access to Internet, with data from the WEF Executive Opinion Survey. The survey is carried out in each country featured in the report among a representative sample of business leaders (WEF, 2005).

The countries are divided in two groups called core innovators and non-core innovators, to account for the notion that technology matters in different ways for different countries, depending on their stage of development. Thus, innovation may be a key factor for example in Switzerland while in Chile, the adoption of foreign technologies may be more important. This division is based on a rate of patents, where countries with at least 15 patents per million population are classified as core innovators. According to this methodology, the factors which explain a nation's competitiveness vary in importance across these two sets of countries. For core-innovators, the GCI places a weight of ½ on the technology index against ¼ each on public institutions and macroeconomic environment. In the group of non-core innovators, GCI places a weight of 1/3 on each of the sub-indexes (WEF, 2005).

Annex B Input-output analysis

There could be several reasons for the lagging of materials efficiency behind labour productivity. We assume that material costs play an important part at the beginning of the chain of products, but constitute a smaller part of total costs at the end of the product chain. It is easier to pass on costs at the end of the product chain.
To check this proposition we make use of a Dutch input-output table. An input-output table is a description of the flows of goods and services through an economy in financial terms. Each column and row in such a table represents an economic sector. A row shows the intermediate deliveries of that sector to other production sectors and the deliveries to final demand. A column contains all purchases of intermediate deliveries and primary inputs of the corresponding economic sector.

Table 5 shows the structure of an input-output table. The rows of an input-output table show the revenues (in financial terms) for the corresponding sectors or the so-called intermediate deliveries to other production sectors (Z) and the deliveries to final demand (Y). The columns shows the inputs or purchases of intermediate deliveries and primary inputs (W). The value of total production (x) is the sum of intermediate and final deliveries.

Table 5 Schematic representation of an input-output table

	Economic sectors	Final demand	Total
Economic sectors	Z	Y	x
Primary inputs	W	V	u
Total	x^T	t^T	

The direct requirements matrix or technological matrix (A) reflects the direct inputs (in monetary terms) that are required to produce one financial unit of output: $A = Z(x^T)^{-1}$.
However, these are only the *direct* requirements of each sector. The sectors that deliver these inputs also require inputs. Therefore, to calculate the total requirements of each sector, we also need to include these *indirect* requirements. The second order requirements of the sectors is A^2 , the third order requirement is A^3 , etc. This means that the total requirements for one financial unit of total production are: $A + A^2 + A^3 + \ldots$.
In order that each sector produced one unit final demand, each sector not only has to produce its own final demand, but also the direct and indirect requirements for the other sectors. The total production that is needed so that each sector produces one financial unit of final demand (matrix B) is calculated by: $B = I + A + A^2 + A^3 + \ldots$.
If the conditions for convergence are met, this equals: $B = (I - A)^{-1}$.
Matrix B is also called the Leontief inverse matrix or the total requirements matrix. Each column in matrix B gives the production needed from every sector, so that the corresponding sector is able to produce one financial unit of final demand.

We use a Dutch Input-Output table with 104 sectors and apply the method described above to calculate the coefficients b_{ij} (the total financial input required from sector j to produce one financial unit of final demand of sector i). The assumption is that the sector ‘basic metals’ represents raw materials. In the next subsection we will determine how much raw materials (in €) are needed to produce one unit of final demand for different sectors.

Annex C Introduction

In this Annex we will first outline a discussion how resource use can be measured adequately (C.2) and then introduce a few concepts from the Material flow analysis framework.

C.1 Measuring resource use

Resource use has drawn attention for a long time in political and societal debates. Originally it was often considered that our wealth was originally dependent on the availability of resources. The limited availability of scarce resources on this planet has worried scientists and policy makers for the sustainability of our wealth creation for more than 20 decades (see Annex D).

If scarcity is our main concern, resource use can simply be measured by indices as the Statistical Life Index (number of years of consumption potential) of individual resources. This index divides the available stock over current consumption and then concludes then how much of the stock is left for future consumption. However, as indicated by Simon (1981), this index assumes fixed technology. Over time, the Statistical Life Index is remarkably constant despite increasing use of scarce resources (for an explanation, see Annex D).

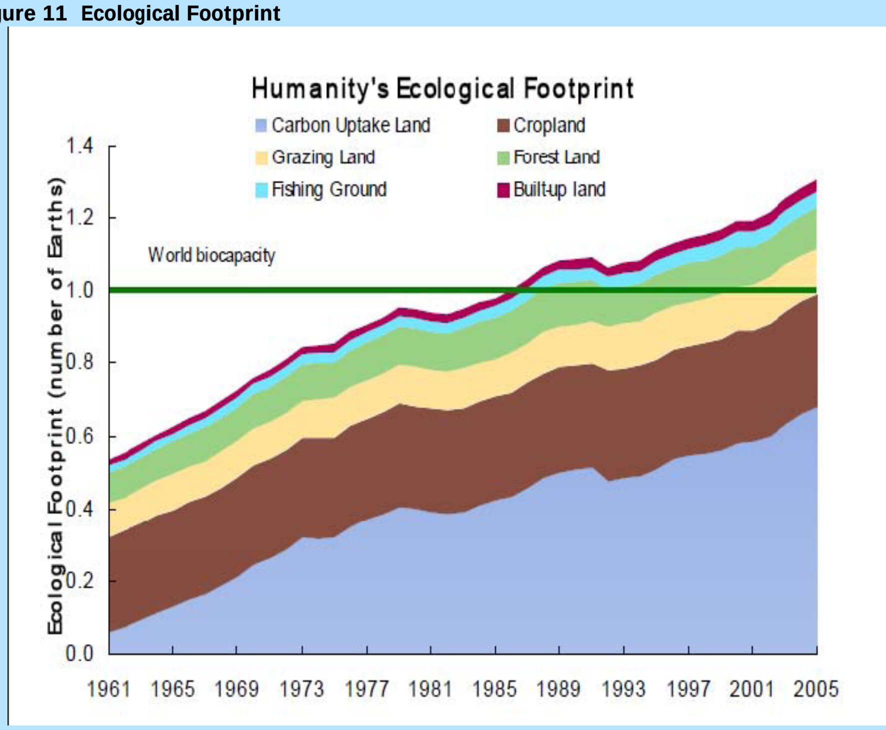
The topic of resource use also has environmental implications, as first pointed out by Ayres and Kneese (1969). The economy is connected to the environment through flows of materials and energy. Ayres and Kneese where among the first to understand that the size of resource input in the end also determines the amounts of waste and emissions due to the laws of thermodynamics. Inevitably any resource input sooner or later ends up as emissions and waste. This has led Herman Daly (1971, 1991, p62) to conclude that the only solution to our environmental problems is 'to get off the growth-path', defined as a reduction on the 'throughput'.

Throughput is defined by Daly (1991a, p. 36) as the entropic physical flow of matter-energy from the environment through the economy to nature's sinks. It can hence be approximated by the total resource extraction (including harvests) from nature, or the materials consumed by an economy. The total throughput is thus indicative of the pressure that mankind exerts on it's environment (both as a source and a skink) and can be regarded as an early approach towards something that later became known as the Ecological Footprint (see box).

Box 4 The Ecological Footprint

The Ecological Footprint is a resource accounting tool that measures how much biologically productive land and water area a population uses to produce the resources it consumes and the waste it generates, taken the prevailing technology and resource management into account (Kitzes et al. 2007). The Ecological Footprint is expressed in global hectares, which is a hectare with the world's average biological productivity. The ecological footprint can be determined at the level of countries or the globe (see Figure 11).

Figure 11 Ecological Footprint



When a country has an ecological deficit, it means that the Ecological Footprint of the population exceeds the available biocapacity of the country. This can be solved by trade. A global ecological deficit cannot be offset by trade and is equivalent to the annual global overshoot (Monfreda et al. 2004). From Figure 1 we see that the current global overshoot is largely explained by reference to the carbon uptake: the land that is required to compensate the CO_2 emissions to the atmosphere.

Although the Ecological Footprint may provide one type of indicator relating to the total throughput, attempts have been made to aggregate the matter-energy flows directly. However, in order to capture the thousands of materials that are being consumed in our economies into a single indicator, measuring the 'total throughput' is quite a challenge. This implies, somehow, that we should add different type of resources as only their aggregate defines whether we reduce throughput or not.

The numeration problem for a meaningful concept of resource productivity has intrigued the literature already at an early stage (see e.g. Moll, 1993; Ayres and Schmidt-Bleek, 1993). While this was in debate during the early 1990s, one concept has gained dominance: the numeration over weight.[30] Based on the aggregation over weight a relatively sophisticated approach has been developed in material flow accounting. Firstly introduced by the Wuppertal Institute as part of their ecological rucksacks (Bringezu et al., 1994), this approach has finally evolved in the field of material flow accounting (Eurostat, 2001; OECD, 2008) where -analogous to the macro-economic national accounts- a system of material flow accounts was developed that aggregates all material flows over mass. Like GDP is only one of the indicators from the system of national accounts, the system of material flow accounts has brought forward their own indicators. The most popular indicator in this field is the Direct Material Consumption (DMC) which measures the amount of materials and energy that remain in an economy or it's biosphere once corrected for import and export flows. The DMC is hence an indicator of the observed consumption of materials in a country (see Annex B) and is often regarded as an approximation of the throughput (Giljum et al., 2006).

However, one of the questions that has frequently popped up is whether the aggregation of all material flows in a country over weight provides a representative picture for the environmental impacts from these materials. Pearce (2001) states that aggregation over mass to represent the total material requirement does not make any sense from an economic and environmental perspective. It seems indeed strange as if sand, metals and fish could be added on the basis of weight. In Van der Voet *et al*. (2004) an alternative measure is introduced where materials are weighted with respect to their environmental impacts. This approach combines the MFA with LCA. However, as the LCA approach typically distinguished 10-15 environmental impact categories at the mid-point level, the weighting problem is not entirely resolved in this approach.
In short, if we aim to increase resource productivity for environmental reasons, the issue of how we need to measure aggregated resource use is still to be resolved. In this report we will not resolve this issue but frame some of our arguments around two indicators for resource productivity:

a The DMC because it is widely used.
b Energy use (measured as TPES) as energy use is associated with a large share of environmental problems and can be expected to approximate resource use because the extraction of materials requires large quantities of energy.

C.2 Indicators from the Material Flow Analysis Framework

There are several measures of material efficiency that can be divided into input, consumption and output indicators. Some examples of input and consumption indicators are described below (Eurostat, 2001).

Two examples of input indicators are the direct material input (DMI) and the total material requirement (TMR).

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30 Others, such as Wackernagel and Rees (1996) have attempted to employ hypothetical land use as the common conversion unit. Here all types of environmental pressure, including CO_2 emissions, are translated into occupied land that would be required to mitigate the harmful impact of these pressures. Other schemes that have been proposed include net energy or entropy (see Ayres and Schmidt-Bleek, 1993 for a review). It has often been proposed that energy stocks and flows are the key determinants of ecological systems. Formal analyses of such aggregation schemes have been provided by Chapman (1974) and Hannon (1975).

Direct material input (DMI) measures the input of materials that are directly used in the economy: domestic used extraction (fossil fuels, minerals, biomass) plus imports.

DMI = domestic raw materials + imports

Total material requirement (TMR) is equal to the DMI plus the unused domestic extraction (materials that are moved by economic activities but are not used as input for production or consumption) and plus the indirect material flows related to imports that take place in other countries. .

TMR = DMI + hidden flows

Two examples of consumption indicators are the domestic material consumption (DMC) and the total material consumption (TMC).
Direct material consumption (DMC) measures the total amount of material directly used in an economy or, in other words, DMI minus exports.

DMC = DMI - exports

Total material consumption (TMC) measures the total material use including indirect flows imported but less exports. It is equal to TMR minus exports and their indirect flows.

TMC = TMR – exports – hidden flows of exports

These indicators for material efficiency have some drawbacks. One is that the structure of the economy determines for a large part the level of material efficiency. Service-intensive economies tend to be less resource-demanding for example. Another drawback is the aggregation by a single unit of mass without regard to the differences in environmental pressure per unit of mass.

Annex D Scarcity of mineral resources

The availability of natural resources, land and minerals was a central theme in economics since Adam Smith founded the discipline. It was thought that the availability of natural resources was a crucial determinant for the possibility of economic growth in the long-run. Obviously, the planet earth is limited in a physical sense in terms of land and mineral availability. Malthus was the first to analyze the consequences of this limit on population growth and wealth creation. Subsequent contributions showed that the fixed availability of land and mineral resources would result in diminishing returns to agriculture (Ricardo) and mining (Jevons), which in turn would limit the possibility of continuous growth of production and population. The resulting outcome of the economic process of growth would ultimately be a 'steady state' (Mill) with a constant population and a constant level of production.

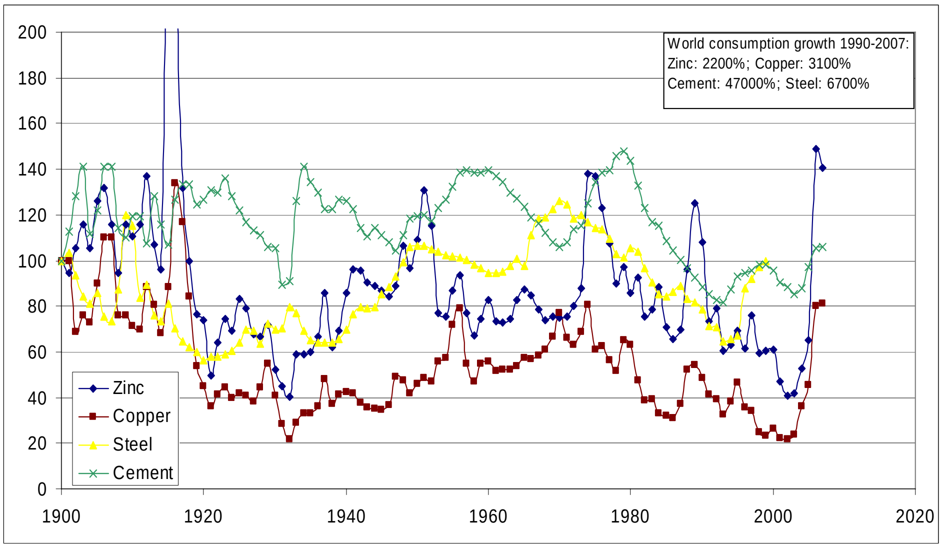
However, since the beginning of the 20th century the topic slowly lapsed into obscurity. Advances in economic thinking around 1900 resulted in the so-called 'marginal revolution' where economic growth was explained solely by reference to the payments for the factors of production: capital and labour. But after publication of the 'Limits to Growth' report to the Club of Rome (Meadows *et al.*, 1972), the topic of resource availability firmly came back on the research and political agendas. The alarming message of the model calculations presented in the report was that the limits would be reached within two generations: a collapse of mankind would be the result. Technological change would not escape the limits but would result only in higher levels of population and industrial production before the collapse. The limits themselves would be inevitable unless growth in both population and per capita income could be halted.

These 'limits to growth'-predictions, as conducted by Malthus and Meadows, have been tackled by several economists and most influentially by Barnett and Morse (1963) and Simon (1981). They argue that the scarcity concept in these predictions is related not to an economic but to a technical notion of scarcity. Technological scarcity deals with the total amount of land and mineral resources available, which is obviously limited on earth. But Simon (1981, p. 46) has remarked that 'as economists or as consumers, we are interested in the particular services that resources yield, not in the resources themselves'. The value of these services may be represented by the price of the resources. Growing scarcity would then be reflected in higher prices for natural resources. In investigating the development of prices as indicators of scarcity, Barnett and Morse (1963) and Simon (1981) found significant declining long-term trends in the extraction costs and prices of various metals. They concluded that there is no evidence of growing scarcity of natural resources at all.

In providing an explanation, Barnett and Morse (1963, p. 11) and Simon (1981) point at the role of technological progress. Their conclusion seem to be that progress in human knowledge opens up new possibilities for substitution and advances the technologies of extraction, use and recycling, which may prevent resource scarcity becoming a limiting constraint to economic growth. Simon (1981) has in this context referred to human knowledge as 'the ultimate resource'.

The trust in technological advancements for relieving the scarcity constraint is often accompanied by a firm belief in a proper working of price mechanisms on the resource markets. The price for (mineral) resources is determined by four intertwined factors: (i) demand for the mineral; (ii) supply through mining; (iii) supply through recycling; and (iv) supply and demand of substitute minerals. Even under conditions of fixed technology, price increases of a certain mineral tend to neutralize themselves because demand falls and supply rises as more reserves (both of virgin and recycled materials) become economically exploitable. When the development of technology is also made dependent on the prices of materials (high prices induce innovation), temporary price increases may even result in a long-term downward movement in the prices. Such trends can be observed for a number of important metals from 1800 until mid-1970s (Simon, 1981). Using data from the US Geological Survey we can see in Figure 1 that the deflated prices for a number of important materials have remained remarkably constant between 1900 and now. Temporary prices increases, such as mid 1970s or early 1950s, have been followed by price decreases in later years. Since 1900, worldwide consumption has far from remained stable but increased by a factor 22 (zinc) to 470 (cement).[31]

Figure 12 Price indices (1900=100) for zinc, copper, steel and cement 1990-2007



Source: US Geological Survey. Price data for steel before 1926 have been standardized on prices of pig iron.

[31] Quantity data for steel before 1926 and cement before 1943 have been standardized on US production developments.

These findings have important implications for the discussion on resource productivity. As prices of mineral resources remain relatively low over a longer time-span, scarcity will most likely not form a cost-driver resulting in enhanced resource productivity for non-renewable resources. Scarcity will be resolved by four developments on resource markets stimulating supply, recycling and technology and reducing demand if prices rise. Therefore, resource prices most likely remain low in the coming decades.[32]

Resource scarcity of non-renewable resources is probably not a very strong argument for policies oriented on resource productivity. Policy intervention on grounds of scarcity would be justified only if prices for resources do not reflect the true information on the scarcity or social costs. In that case there would be a market failure that would justify correction through governmental policies. Otherwise, resource scarcity would simply be. But the suggestion that resource markets do not reflect information on scarcity is not very convincing (Pearce, 2001). Some of the stronger arguments relate to external costs and rational expectations. Cleveland (1991), for example, has argued that the lack of price increases on resource markets may be due to the fact that external costs are not included in the price of the product. Pollution and other external costs of mining are growing (due to the lower metal content in ores) and are not included in the price. If all external costs were to be included in the price of the product, prices could be significantly higher and rising over time according to Cleveland (1991). In an interesting contribution, Victor (1991) has emphasized the role of rational expectations in price formation on resource markets. Victor states that price reflect the long-term *expected* scarcity of the resource. Now if the prices on resource markets are determined by optimistic economists, who believe that scarcity does not exist because they trust the working of the price mechanism, prices will stay low and there will be no incentives for technological development. Only if it is believed that scarcity will increase in the future will prices rise, creating incentives to invest in technological development.

The consequence of Victor's theorema is that the development of resource prices over time may be characterized by high variability and uncertainty as underlying expectations tend to be irrational, by definition. Indeed, from Figure 2 we see that longer period of rising prices are followed by longer periods of falling prices. This volatility has indeed economic costs as investments will be lower than in a situation of stable prices. Firms that will invest in resource-saving technologies may typically place a mark-up on their investments in order to insure themselves against unexpected losses due to falling resource prices. However, the magnitude of this market failure is probably low. Moreover, it can be questioned whether this is more than simply a normal process in *any* economic market. Evolutionary economics has suggested that the process of technological change does not follow a smooth process along a path of equilibrium, but is characterized by both disequilibrium *and* an evolutionary path of learning and selection (Dosi and Orsenigo, 1988). Innovations over time may typically come in certain clusters as the result of a process of creative destruction, first introduced by Schumpeter (1934) and later elaborated by Nelson and Winter (1982). Resource markets perfectly fit this explanation, as elaborated by Labson and Crompton (1993). So in that case the irrational expectations would not constitute a market failure as this process is inevitably linked to technological progress itself.

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[32] It should be noted here that this does not hold for slow-growing renewable resources, such as fish. Scarcity here originates in a dynamic ecosystem constraint on the availability of the resource that is characterized by a prisoners-dilemma. Depletion of the stock of fish is hence economically rational for every fisher but irrational for society as a whole.