The Policy Implications of Economy-Wide Rebound Effects: Insights from a Macroeconometric Model Simulation of Concurrent Climate Policy and Resource Efficiency Actions for Germany.

Abstract

Up to now research on rebound effects of resource efficiency improvements focused more or less exclusively on the use of energy. This might be easily understood as energy expenditures represent a significant share of private consumption expenditures and a necessary factor of production in most industrialised economies. However, these studies are very likely to underestimate the hazards of rebound effects arising from industrial resource efficiency improvements. Note for instance that in 2006 the energy share of total German manufacturing costs was below 2% whereas more than 40% of German manufacturing costs were allocated to material inputs. Thus, at least in case of Germany, rebound effects induced by an increase in industrial material inputs efficiency may be more important than those depending from industrial energy efficiency gains.

Our macroeconometric simulation results indicate that the economy-wide rebound effects of improvements in German material efficiency range around 55%. This estimate challenges previous policy attempts aiming at decoupling economic growth from resource consumption growth. Nevertheless, our findings also indicate that even an absolute decoupling of resource consumption from economic growth appears possible as far as an ambitious combination of climate - as well as material policy objectives is implemented.

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1. Introduction

Starting with Jevons (1865) numerous energy economists focused on the rebound effects of efficiency improvements (see. i.a., Schipper, 2000 or Sorrell, 2007*a,b*, 2009 for literature surveys). Yet, whereas Jevons' theoretical argument of technical improvements in resource efficiency inducing direct and indirect economic effects which curtail overall achievements in economy-wide resource demand reductions might indeed be labelled an "universally acknowledged phenomenon" (Alcott, 2005, p. 10), its actual policy implications are still subject of fundamental concerns. Our paper therefore intends to contribute novel empirical findings to the ongoing discussion whether technological progress might be understood as a valuable instrument of current policy approaches to environmental sustainability. As long as the economy-wide rebound effects do not (over-) compensate initial efficiency gains this would obviously be the case. And, accordingly, a decoupling strategy aiming at continuing economic growth in conjunction with sustained reductions in overall resource consumption might be appreciated a serious policy measure. – A supposition which is subjected to continuing criticism by proponents of a "need for resource rationing" hypothesis which seems to suggest that only "zero-growth" or even "de-growth" policies were able to achieve sustainability (see, i.a., Jackson 2009a, 2009b and Sorrell 2010 for recent contributions in this regard). Jackson (2009, pp67) describes the historic development of GDP and resource consumption in his chapter "the Myth of Decoupling" and comes to the result that growing economies may achieve relative decoupling of GDP and resource consumption but are not able to realise an absolute decoupling.

Improvements in resource efficiency increase consumer income and shift the macroeconomic production frontier. The induced price and income adjustments have the potential to stimulate widespread reallocations of final as well as intermediate demand which might only be depicted by means of a total analysis (Greening et al. 2000, Binswanger 2001, Guerra and Sancho 2010). From our point of view the task of evaluating economy-wide rebound effects therefore seems to constitute a natural application for economic-environmental models. As a matter of principle this methodology is basically capable of incorporating the different economy-wide effects associated with, e.g., the interdependencies of economic sectors, the circular flow of income, or international competition.

To be precise, two types of 3E-models (Energy-Environment-Economy) come into consideration: Computable General Equilibrium Models (CGE) and macroeconometric simulation models. CGE models are basically theoretical models rooted in neoclassical economic theory with calibrated parameters (see, e.g., Hanley et al. 2005 or Washida 2004 for CGE based rebound estimations). However, despite their apparent prominence (see, e.g., Sorrell 2007*a* who reflects the results of eight CGE studies in an overview on economy-wide rebound evaluations but only of a single macroeconometric model simulation), CGE models might be seriously criticised (see again Sorrell 2007*a*, Box 4.2: "CGE models are (...) poorly supported by empirical evidence. In particular, the possibility of 'win-win' policies, such as those aimed at encouraging energy efficiency, may be excluded if an economy is assumed to be at an optimal equilibrium"). In light of this criticism we generally favour the analysis of complex economic systems by means of macroeconometric simulation studies which are not restricted by theoretical equilibrium constraints but have been empirically evaluated by time series and input-output analyses.

Sorrel (2007*a*) acknowledges a general lack of literature in this regard but refers to Barker and Foxon (2006) whose macroeconometric model MDM-E3 produced an estimate of UK-wide rebound effects of only 26 %. However, most of the CGE studies reviewed by Sorrel (2007*a*) indicate the rebound effects to exceed 50 %. Furthermore, whereas the overall magnitude of the economy-wide effects seems to depend heavily upon the sector where the initial energy efficiency improvements took place, the potential for "backfire", i.e. higher overall energy consumption caused by an initial increase in energy efficiency cannot be ruled out generally. In the first instance, our estimate of German economy-wide rebound effects might therefore be understood as a supplemental contribution to overcome the aforementioned sparsity of empirically rooted publications which might hopefully be useful to curtail the apparent variation in previous reported economy-wide rebound estimates.

But beyond that we would like to point out that all of the above cited literature on economy wide rebound effects effectively only considers the use of *energy*. This might be easily understood as energy expenditures represent a significant share of private consumption expenditures in most industrialised economies. Thus, a rise in energy efficiency which reduces the costs of the use of energy services may also raise private households' energy demand in a significant amount. Furthermore, indirect effects may occur since the money saved in energy demand may be used for purchases of other goods whose additional production would then trigger energy demand. On the other side m*aterials* represent the dominant part of industrial resource consumption. However, until recently material prices – unlike energy prices – did not show continuous upward trending price dynamics in comparison to energy prices (see also Allwood et al. 2011 in this regard). Thus, material inputs – unlike energy inputs – have not been focused by the controlling systems of firms for a long time (Fischer et al. 2004).

Anyhow, it seems quite astonishing that rebound effects of improvements of *material* efficiency have not been explicitly analysed by now (see, e.g., the corresponding annotations in Allwood et al. 2011). Hence we would like to point out that an analysis of material-induced rebound effects suggests itself, at least, for the following two reasons: First, materials play a much bigger role in the cost structure of firms than energy. Bringezu and Bleischwitz (2009, p. 219) for instance assert that the energy share of German manufacturing costs did not exceed 2 % in the year 2006 whereas materials represented about 40 % of total costs. Apparently, at least with regard to this selected example, the potential to induce widespread indirect rebound effects appears much higher in case of materials than in case of energy. Second, materials are part of the product (Georgescu-Roegen 1990). This means that, apart from usual substitution effects where reductions in the utilisation of a selected input will always be accompanied by increasing demand for other inputs, we have to acknowledge that, at least in some cases, product re-design offers possibilities for a reduction in the amount of material required. As far as the previous services can still be derived from the innovative product, reductions of material inputs thus represent intrinsic increases in product quality (see also Allwood et al. 2011 in this regard). Referring to this, an isolated increase in resource efficiency which does not alter the utilisation of other production inputs appears more likely in case of materials than in case of energy where, e.g. investments in new technologies often prove as an inevitable necessity for demand reduction (Henly et al. 1988).

As far as we know, Meyer et al. (2007) represents the only publication which already tried to consider the economic and environmental effects of rising material efficiency for Germany by means of a macroeconometric model simulation. Whereas their study did not explicitly address the rebound discussion, their simulation setup might easily be incorporated to the aforementioned literature. Based on experience of consulting firms (Fischer et al. 2004), Meyer et al. simulated the overall economic effects of a 20% cut in German material costs. Assuming a time period of eleven years for the economy-wide implementation of this transformation process, they estimate the final achievements to equal a 13.5 % reduction of total material requirements. So their implicit estimate of the economy-wide rebound effects adds up to 32.5 %. However, Meyer et al. (2007) might have indeed underestimated the rebound effect as their model simulation was based on an estimation period ending in 2001. As already mentioned, material prices have not been suspect to induce serious cost pressures within this estimation period. Therefore, one may doubt whether Meyer et al. could have been able to observe any significant price and substitution elasticities with regard to material inputs.

As a matter of fact an explosion of material prices could have been observed since then and, admittedly, it appears quite likely that a structural break occurred as overall expectations seem to have adjusted to a more or less general agreement on upward trending price dynamics not only in case of fossil fuels but also in the cases of metals, non-metallic minerals, and biomass. Against this background we decided to derive an up-to-date estimate of the German rebound effect with regard to material efficiency improvements by means of the macroeconometric simulation model PANTA RHEI.

Based on an estimation period ranging from 1995 to 2007 our replication of the simulation exercised by Meyer et al. (2007) indicates the economy-wide rebound effect of an isolated rise in material efficiency to range at about 55 %. This figure is considerably higher than the implicit estimate of the original work by Meyer et al.

But what does this mean for the central policy question “is it possible to decouple economic growth from resource consumption growth”? Our model simulations point out that, as far as being considered as an isolated policy measure, even an ambitious climate policy will not be able to realise an absolute decoupling of GDP growth from total material requirements in Germany in the long run. Insofar the findings of Jackson (2009a, 2009b) and other critics of the “decoupling myth” are confirmed. Nevertheless, as long as the assumed climate policy is combined with additional policy measures to achieve improvements in material efficiency, absolute decoupling might be achieved.

Our paper is structured as follows: Chapter 2 provides a short introduction to our methodological framework. Chapter 3 outlines the central characteristics of our scenario assumptions and Chapter 4 summarises the main empirical findings. The discussion of our results with regard to the rebound literature follows in Chapter 5. Finally, Chapter 6 concludes with a discussion of the implied policy considerations and with some hints on further research.

2. The model PANTA RHEI

As already stated our analysis rests on the initial framework of Meyer at al. (2007). Therefore we restrict our methodological annotations to a brief summary. See the corresponding annotations in Meyer at al. (2007) as well as the following references for supplemental information.

PANTA RHEI, the applied macroeconometric model, represents a well acknowledged quantitative simulation environment which is regularly employed in environmental policy consulting projects. Those results have been repeatedly published in academic journals. Its areas of application cover the simulation of suggested policies (see, e.g., Lutz et al. 2005) as well as the evaluation of implemented policies (see, e.g. Bach et al. 2002 or Lehr et al. 2008). Furthermore, PANTA RHEI represents a central part of several studies seeking sustainability strategies for Germany (Spangenberg 2003, Coenen und Grunwald 2003, Bockermann et al. 2005, Distelkamp et al. 2010) and served as a central workhorse in the development of the energy concept of the German government (Lindenberger et al. 2010).

The name of the model is not an acronym. It rather cites Heraklit's note that "all things flow". This label has been chosen to stress that endogenisation of structural change represents the most important feature of the model. The central assumption is that all agents decide under conditions of bounded rationality on imperfect markets. All parameters of the model are estimated econometrically.

The economic heart of the system is given by the INFORGE model (INterindustry FORecasting GErmany). In a deep disaggregation of 59 branches all components of final as well as intermediate demand and all components of primary inputs as well as all sectoral wages, producer, and purchaser prices are endogenous variables. The input-output balance equations are all fulfilled, but the system should not be addressed as a Leontief model, because of its variable structures in final demand, primary inputs, and intermediate demand. For instance each of the 3481 model input-coefficients is treated as a variable that has to be tested regarding its dependency on relative prices. The model has a bottom-up structure: The macro variables are defined by definition as aggregates of the corresponding sectoral variables. The complete system of national accounts starts from sectoral value added and its components, aggregates them for firms, households, government, and rest of the world, transforms incomes for these institutions via distribution and redistribution by taxes and the social security system to disposable income and calculates the financial surplus/deficit of the mentioned institutions. The whole SNA system of Germany is depicted with all variables being endogenous.

The population module is based on official forecasts of the German Statistical Office. Based on these exogenous variables labour supply is calculated and given to

INFORGE, where labour demand based on the sectoral labour input is calculated. The implemented disaggregation of population into age clusters influences final consumption demand and the variables of the social security system in many ways.

The energy module models final energy demand in physical terms (TJ) for 30 energy carriers by production activities of individual branches, and by consumption purposes. The conversion of primary energy into secondary energy as well as the supply of primary energy for different carriers is calculated in the energy balance. Relative energy prices play an important role to explain structural change in the energy system. Energy demand for the individual carriers feeds back into INFORGE to explain the change in its sectoral energy rows. The consumption of fossil fuels (oil, gas, and coal) is multiplied by emission factors to give CO_2 emissions.

For a better estimation of the influences of stocks on resource demand a traffic module and a dwelling module have been developed. The traffic module takes prices and income figures from INFORGE and explains traffic demand in physical terms (person kilometres and ton kilometres) for private individual traffic, public street traffic, public rail traffic, air traffic and traffic on waterways. The INFORGE forecast of the number of new cars together with the energy consumption of new cars per kilometre and the corresponding depreciation rate enable PANTA RHEI to calculate the average consumption of the stock of cars per kilometre. The information about fuel consumption then feeds back in physical terms to the energy module and in monetary terms to INFORGE. The dwelling module allows deriving the housing space - which is an important determinant of energy demand for heating - from demographic data (number of households, persons per households) and income figures.

The material module is based on physical data measured in tons provided by the Wuppertal-Institute (Acosta- Fernandez 2007). The module simulates German "total material requirements" as used and unused extractions of biomass, metallic minerals, non-metallic minerals, and fossil fuels (oil, gas and coal) including imported materials. Used domestic extractions are linked to the production of the extracting sector. Unused extraction – like rubble – of a material in a specific extracting sector has a constant relation to its used extraction figure. The direct physical material imports are explained by their variables in monetary terms measured in constant prices. Hidden material inputs in physical terms are linked to the import values in constant prices of the imported goods. These indirect material inputs are often called "rucksacks", because they are extracted abroad, but are induced by the imports of goods to Germany.

3. Key scenario assumptions

Any simulation study needs a baseline, which reflects a "business-as-usual" scenario which can easily be interpreted as natural reference to the assumed alternative scenario. In our case, the baseline differs from the alternative scenario only with regard to the assumed improvements in material efficiency.

However, compared to usual policy impact simulations our application appears more sensitive with regard to underlying baseline assumptions. Usually, relative deviations from the baseline are most important for an interpretation of results. And these relative deviations are commonly independent from baseline levels. But whereas the estimation of the rebound also refers to an analysis of relative deviations the answer to the underlying question whether decoupling might be possible or not needs a very careful evaluation of the implemented baseline because the historical levels of resource consumption represent a central reference to its answer.

3.1 The baseline

The key assumptions of our baseline refer to climate policy, the development of world resource prices, and world economic growth until 2030. As the energy concept of the present conservative administration in Germany (Lindenberger et al. 2010) aims to reach an 85 % reduction in greenhouse gas emissions in 2050, compared to emissions in 1990, the general targets of German climate policy seem to be in agreement among all political parties. For 2020 a 40 % reduction is intended (Lindenberger et al. 2010) and for 2030 on a linear path a 55 % reduction of green house gas emissions is aimed at. Political controversies rather arise with respect to the choice of instruments. In this regard we follow the study Politikszenarien V (Umweltbundesamt 2009) where the Öko-Institut, the Forschungszentrum Jülich, the Deutsche Institut für Wirtschaftsforschung (DIW) and the Fraunhofer-Institut für System- und Innovationsforschung (ISI) developed a structural change scenario which reaches the afore mentioned targets until 2030. Most of its relevant instruments are already established in Germany but have been further developed within this scenario. Despite improved energy efficiency in industry and households (here especially in dwelling) a further expansion of renewable energies is assumed whereas the phase-out of nuclear energy has not been changed.

Due to the expectation of growing scarcity of resources their **real** prices (compared with the US-GDP deflator) will grow from 2009 to 2030 by 60 % (crude oil), 71 % (metals), 42 % (food). The exchange rate of the EURO to the US- Dollar remained fixed to a historical value of 0.68 within our simulations.

With regard to the world economy we assumed a rapid recovery from the 2008-2009 sub-prime crisis. From 2010 to 2030 German exports have been expected to equal an average growth rate of 3.4 % p. a. in constant prices. Thus, German exports are assumed to double within this twenty year horizon. This implies a light reduction with regard to historical average growth rates, but results with an export ratio (relative to GDP) of 63 % in 2030 which is even by far greater than the historic maximum of 46 % in 2007. The underlying assumption about world economic growth has been evaluated by simulations with the global model GINFORS (Lutz and Meyer 2009).

3.2 The material efficiency scenario

Following Meyer et al. (2007) it is assumed that all manufacturing firms achieve an improvement of their material costs of 20 %. This number is based on experience of consulting firms (Fischer et al. 2004), who assume this order of magnitude if market failures based on information deficits were eliminated by an information and consulting program. Necessary expenditures for consulting services and supplemental investments for the implementation of the achieved efficiency improvements should equal the savings generated within a one year horizon. Year by year 5 % of the existing firms might be reached by this information program. Thus, it needs 20 years till 2030 to see the full effect in the economy.

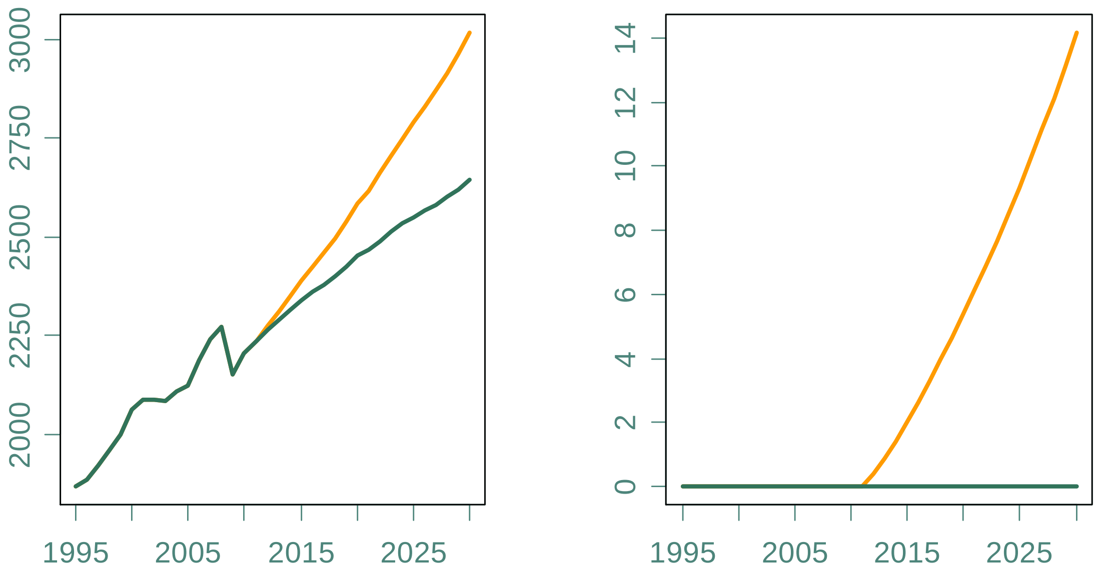
A more or less pure improvement of material efficiency is assumed, since the additional service and capital inputs are relatively low. This assumption may be criticised, but it is in line with all studies on rebound effects of energy efficiencies discussed by Sorrell (2007). It has to be mentioned that a pure reduction of material inputs is much more plausible in the case of materials than in the case of energy, because materials are an integrated part of the product. So less material input means a change in product design and not necessarily a change in technology.

4. Simulation results

4.1 Baseline results

According to the baseline average economic growth will equal about 1.1 % p.a. from 2009 to 2030 (dark line in figure 1). This is a bit less than in the period from 1995 to 2005 when average GDP growth was about 1.4 % p.a. Employment in 2030 will be about 8.5 % lower than in 2009 because labour supply will shrink even more due to demographic change. Hence, as the number of unemployed people will be about 300,000 persons less than today, GDP per capita will approximately follow its historical growth trend until 2030.

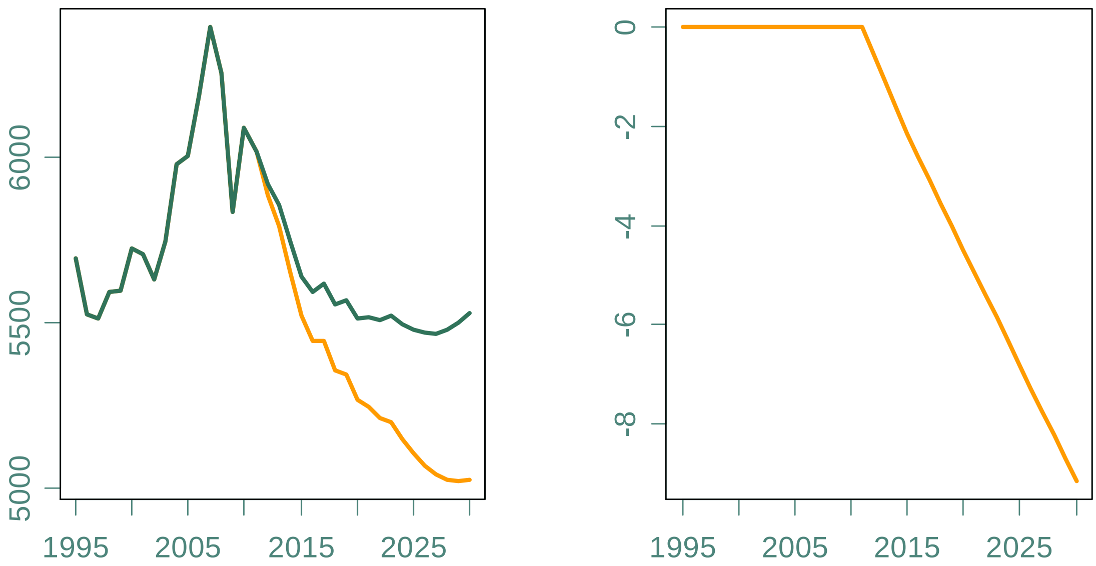
Figure 1: German real gross domestic product. Baseline (dark) and simulation (light). Left panel: Levels in bn €. Right panel: Percentage deviation of simulation from baseline values.



Total material requirement has had its peak in 2008. The crisis in 2009 produces a sharp fall which is initially compensated by the quick recovery from the crisis. Then the engaged climate policy reduces total material requirement. As a result the historical level of 1996 will be re-achieved in 2030 (dark line in figure 2). In absence of the assumed material efficiency “shock” the engaged climate policy is therefore able to reach an absolute decoupling.

The use of fossil fuels reduces by 60 % from 2010 to 2030 (-1.33 bill. tons), whereas driven by the production of exported investment goods the use of metals rises by 39 % (+0.58 bill. tons). The use of non-metallic minerals follows its long-term trend with a reduction of 35 % (-0.22 bill tons), the use of biomass will increase by 9 % (+0.12 bill tons), the use of other products rises by 95 % (+0.3 bill. tons).

Figure 2: German total material requirements (TMR). Baseline (dark) and simulation (light). Left panel: Levels in million tons. Right panel: Percentage deviation of simulation from baseline values.



4.2 The effects of an improved material efficiency shock

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

Cost reductions have a lot of indirect effects: Not assuming perfect markets, prices will fall less than costs which induces additional value added in those branches which dematerialise their production. Thus, in case of these firms productivity rises which will have a positive impact on wages. However, on the other side a coincidental negative impact applies on wages as prices tend to be lower in the alternative scenario than in the baseline scenario. The wage function of the model has been estimated over a period of rising productivity due to a rise of capital intensity of labour and not of a drastic dematerialisation. Further, the very low rates of inflation over a 20 year horizon of the alternative scenario do not have any correspondence with the historical model estimation period. Thus, we have to acknowledge the occurrence of a serious structural break which raises doubts whether positive or negative impacts might finally be effective for the simulated scenario under consideration. Therefore, in order to facilitate an interpretation of our results, we decided to abstract any wage rate variations from this simulation exercise. The wage vector of the alternative scenario thus equals the baseline vector over the whole simulation horizon.

Lower prices induce higher demand via rising exports, falling imports, and rising domestic consumption because of rising real income. Furthermore, domestic demand is positively affected by the push on value added of those firms who are dematerialising their production. Those firms will expand their material demand which represents the rebound effect. And of course employment will expand in these branches. The fall of sales in those branches that produce materials from resources will reduce employment.

The impact on the different branches of the economy is varying strongly. Table 1 shows the results for prices and gross production for some typical representatives. “Manufacture of furniture, jewellery, and other manufacture”, “manufacture of machinery and equipment”, “manufacture of electrical equipment” are typical branches that take part in international competition. These branches are winners of dematerialisation, because it reduces their costs and prices to a large extend which raises demand and production. The branches “manufacture of basic metals”, “manufacture of non-metallic mineral products” or “non-metallic mineral processing” are typical examples of producers processing mainly materials. They lose production. Service sectors have relative low price reductions and are winning from rising value added and income that pushes domestic demand.

Table 1: The effects of an improved material efficiency on selected branches. Deviations from the baseline in the year 2030.

Sector	Producer price	Gross output
Accommodation and food service activities	-9.1	24.4
Manufacture of furniture, jewelery and other manufacturing	-17.4	18.0
Manufacture of machinery and equipment	-14.8	11.3
Construction	-13.0	10.5
Insurance, reinsurance and pension funding	-3.3	9.8
Manufacture of electrical equipment	-17.9	9.2
Activities of households as employers	1.0	7.2
Arts, entertainment and recreation	-2.9	6.0
Activities auxiliary to financial services and insurance activities	-1.6	5.7
Manufacture of other transport equipment	-9.7	5.5
Manufacture of fabricated metal products	-8.5	-4.7
Manufacture of basic metals	-3.9	-7.6
Manufacture of other non-metallic mineral products	-6.5	-7.9
Nonmetallic mineral processing	-7.2	-11.3
Manufacture of coke and refined petroleum products	-8.5	-11.8
Mining of coal and lignite	-5.3	-14.5

For the understanding of the macroeconomic effects it is central to start from the rise of value added (+10.1 % in constant prices) compared to the baseline in the year 2030. All figures in the following argumentation have this reference. Since on the one side value added is not distributed completely to the households and since consumer prices fall less than producer prices, disposable income in constant prices of private households rises by 8.5 % which raises private consumption in constant prices by 7 %. Disposable income in constant prices of the government rises by 7.7 % because taxes rise in constant prices. Public consumption will expand in constant prices only by 3.1 % because the public services (internal security, external security, jurisdiction, administration, education) are less income elastic than private consumption. Consequently the government realises savings that reduce public debt till 2030 by 10.2 % or 226 billion EURO.

The other components of GDP (see table 2) are affected in a different way. Exports rise by 4.7 % due to the falling prices in manufactured goods. Imports fall much more (-10.7 %) because of two effects : On the one side improved competitiveness on international markets for manufactured goods, on the other side the imports of resources like metals, non metallic minerals, and biomass are reduced drastically.

Production in constant prices will be 2.2 % higher than in the baseline scenario because the positive effects in export intensive and consumer oriented branches over-compensate the negative effects coming from the material producing branches. The capital stocks rise by 1.5 % till 2030, employment will be 1.9 % higher, which means 700,000 new jobs. This is accompanied by a strong structural change: Manufacturing loses 120,000 jobs; the plus in services over-compensates this by far.

In spite of the drastic rise of GDP (14.2 % in constant prices) shown in the light line of figure 1, total material requirement falls by 9.2 % (light line in figure 2).

Figure 2 clearly shows that this means an absolute fall in total material requirement compared to historical values. Comparing this with the initially given efficiency improvement of 20 % a rebound effect of 55 % can be calculated.

The reduction of total material requirement is 12.2 %, for metals it is 13.7 %, and for biomass 8.5 % are calculated. Fossil fuels are not directly affected by the scenario installations. Endogenous effects on fossil fuels via final demand of energy are only very slightly positive, because the reduction of material consumption has a strong positive impact on energy productivity, which rises by 13.7 %.

Table 2: The impact of improved material efficiency on selected macro indicators. Deviations from the baseline in the year 2030.

Aggregate	Total	%
Gross domestic product (bn €)	374.7	14.2
Export (bn €)	93.1	4.7
Import (bn €)	-170.9	-10.7
Private consumption (bn €)	83.4	7.0
Government consumption (bn €)	14.2	3.1
Machinery and equipment investment (bn €)	13.0	3.4
Building investment (bn €)	2.2	1.1
Employees (1000)	696.0	1.9
Public debt (bn €)	-226.1	-10.2
Total material requirement (m t)	-506.5	-9.2
Total final energy consumption (T Joule)	33 147.5	0.5

5. Is absolute decoupling possible?

The effects of an improvement in resource efficiency could be demonstrated comparing the alternative scenario with the baseline. It could be shown that the rebound effect of remarkable 55 % is accompanied by a strong positive effect on GDP (+14.2 %) and employment (+ 1.9 %). The question about absolute decoupling can only be answered comparing the alternative scenario with historic values. Is it possible to reach a permanent absolute reduction of resource consumption?

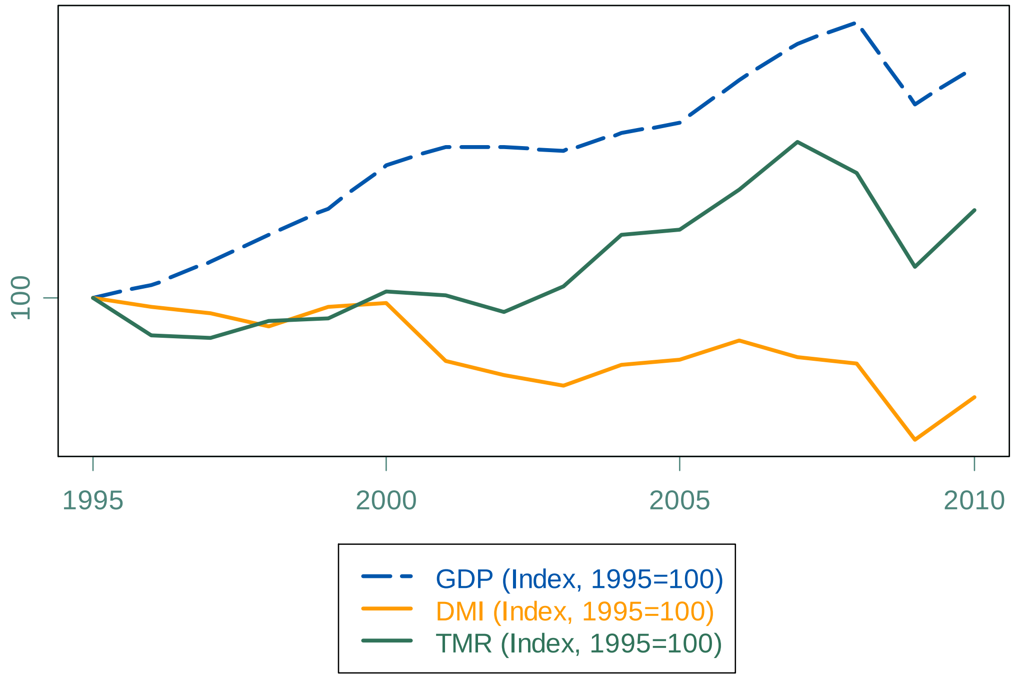
The discussion of the results for the baseline has already shown that an engaged climate policy following a strict reduction path is able to achieve an absolute decoupling. Total material requirement in 2030 is about 12 % lower than in the historic peak of the year 2008 (dark line in figure 2). But most of the reductions can be achieved during the first 10 years. After that period the engaged climate policy is only able to stabilise the level of total material requirement. The reason is that especially those materials with growing consumption that are linked to exports like metals and the group of other products have **rising** growth rates which compensate the further reductions of fossil fuels. These resources cannot be reached by climate policy no matter how engaged it ever may be.

Comparing the development in the alternative scenario with the historic peak of total material consumption we are facing the effect of an engaged climate target as well as the effect of an improved material efficiency. This means that the deviation from the historic peak is now 21 % and the reductions of material consumption are developing continuously (light line in figure 2). Now those resources that cannot be reached by climate policy are additionally reduced by improved material efficiency.

As regards the Jackson (2009) hypothesis that growing economies may achieve relative decoupling of GDP and resource consumption but not an absolute decoupling we would like to refer to figure 3 which plots the historical available time series of

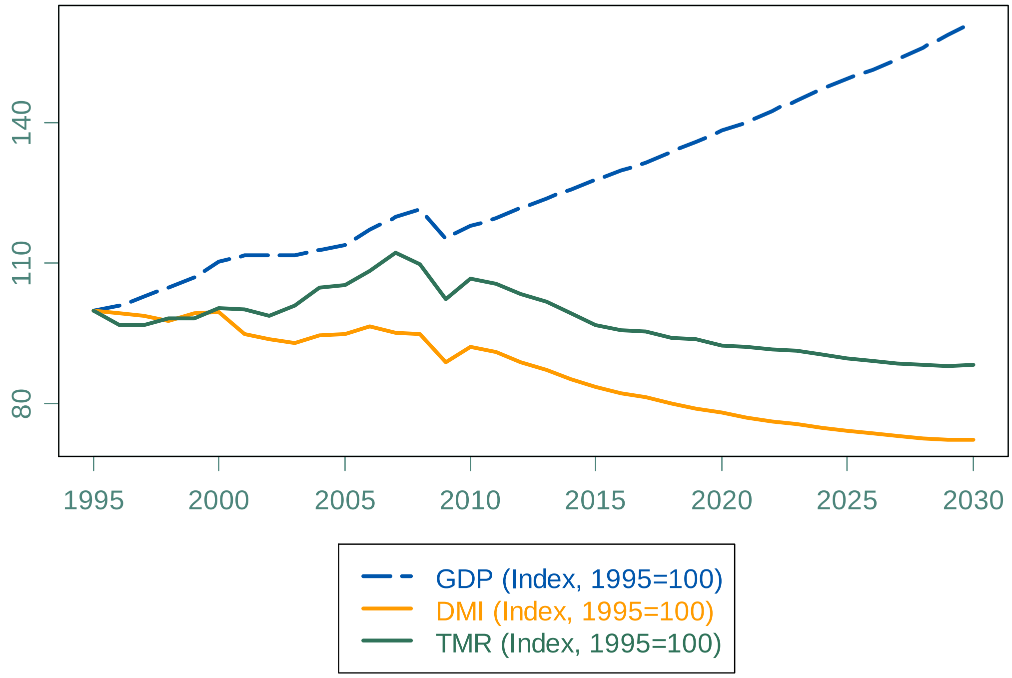
GDP in constant prices direct material inputs and total material requirement in tons as indices with base year 1995.

Figure 3: Real gross domestic product (GDP), direct material requirements (DMI) and total material requirements (TMR) in the historical baseline scenario.



Based on recent historical evidence Jackson's (2009, p. 73) hypothesis appears apparently evident: Relative decoupling of the direct resource use may happen in several countries, but direct material input (DMI) only measures domestic extraction plus the weight of imports, but it does not measure the resources that had to be extracted abroad to produce the imported finished and semi-finished products. The indicator total material requirement (TMR) used in the paper at hand includes this hidden resource consumption. Since the year 2000 even no relative decoupling of this indicator can be observed in Germany. This has happened in spite of the reduction of CO_2 emissions of about 12 % during that period. Total material requirement has the same growth rate as real GDP.

Figure 4: Decoupling of real gross domestic product (GDP), direct material requirements (DMI) and total material requirements (TMR) in the improved material efficiency scenario.



However, the assumed combination of an engaged climate policy with improvements of material efficiency satisfies an absolute decoupling from 2011 until the end of our simulation period. So the answer to Jackson and all other critics of decoupling is: Absolute decoupling is possible, but until now it has never been tried. Our simulations show even a really engaged climate policy alone is not able to reach a permanent absolute decoupling, because metals, biomass, and non metallic minerals do not react on these policies. On the contrary some instruments of climate policy like extension of the use of biofuels or hybrid cars (two motion systems instead of one) may even consume more resources. It's the combination of an engaged climate policy and a policy to improve material efficiency (Ekins et al. 2011 speak of a "dual" policy in this regard) that is able to reduce resource consumption absolutely combined with a rise in GDP. Such a policy would be conform to the Lisbon strategy of the EU.

6. Conclusions

An absolute decoupling of resource consumption and GDP growth can only be reached in the long run, if an engaged climate policy is combined with improvements in material efficiency. In this manner it will be possible to prevent a further destruction of nature without changing the constitution of the economy. The latter would be necessary, if a "zero growth" economy would be established, and one may doubt whether this could be prevailed. On the other side Ekins et al. (2011) and Meyer (2010) have shown that a structural change in policy is necessary following the concept presented in this paper: Environmental targets will have to dominate economic targets. Further, year by year it will be necessary to check whether the targets have been met, and immediate policy adjustments have to be implemented, if this is not the case yet. Policy has to follow a stringent target line. Of course this change will also not easily be achieved, but it is only a change in the preference structure of targets and not a change in the economic constitution.

One may criticise that the experience of the consulting firms about efficiency potentials that can be harvested only by better information of the management cannot be generalised on that broad scale. On the other side the simulation results have shown that the very strong positive effect on GDP would also allow for other cost intensive instruments like taxes or other economic instruments to induce improvements in material efficiency.

It may also be argued that the pure improvement of material efficiency is problematic. What ever the reason of the efficiency improvement is, how can we exclude the reaction of other input coefficients? Our ongoing research currently addresses this question econometrically. If substitutions are the reason for the efficiency gains, other inputs should rise. But also the opposite is possible: If changes in the product design are the reason for less material input, it may be that other inputs – especially those of labour and capital – are also reduced. A further critic might argue that the simulations have been done only for Germany – a country with a very special structure of production. Is it possible to generalise the result for other countries? Our ongoing research currently also addresses this question by means of a similar simulation for a number of member states of the EU. Both of these ongoing research efforts are part of the research project "Macroeconomic modelling of sustainable development and the links between the economy and the environment" financed by the European Commission.

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