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Communication

Economic effects of peak oil

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HIGHLIGHTS

- National and sectoral economic effects of peak oil until 2020 are modelled.
- The price elasticity of oil demand is low resulting in high price fluctuations.
- Oil shortage strongly affects transport and indirectly all other sectors.
- Global macroeconomic effects are comparable to the 2008/2009 crisis.
- Country effects depend on oil imports and productivity, and economic structures.

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ABSTRACT

Assuming that global oil production peaked, this paper uses scenario analysis to show the economic effects of a possible supply shortage and corresponding rise in oil prices in the next decade on different sectors in Germany and other major economies such as the US, Japan, China, the OPEC or Russia. Due to the price-inelasticity of oil demand the supply shortage leads to a sharp increase in oil prices in the second scenario, with high effects on GDP comparable to the magnitude of the global financial crises in 2008/09. Oil exporting countries benefit from high oil prices, whereas oil importing countries are negatively affected. Generally, the effects in the third scenario are significantly smaller than in the second, showing that energy efficiency measures and the switch to renewable energy sources decreases the countries' dependence on oil imports and hence reduces their vulnerability to oil price shocks on the world market.

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1. Introduction

The recent crisis in Libya, sanctions against Iran and the imminent oil supply shortage as well as high energy price fluctuations in the past years elucidate that energy security is becoming just as important as efficiency and sustainability of energy production. This was already stressed in a study by the Bundeswehr Transformation Centre of the German Federal Ministry of Defence (ZTB, 2010), which recognised that fossil fuels, especially oil, are not only necessary for a functioning of the global economy, but also for strategic issues. While the World Energy Outlook (IEA, 2011) as well as many others expects world oil production paths that are able to meet world oil demand in the coming decade, the discussion about peak oil today shows that these projections might be too optimistic. Comparing projections of world-wide oil supply of LBST (2010), which assumes that oil production has recently peaked, to projections of oil demand from e.g. WEO 2010 (IEA, 2010), shows that it might well be possible that oil supply shortages arise and grow over the next decade. That is, given the IEA oil prices, oil supply will not match oil demand, which obviously implies oil price increases until demand equals constrained supply.

There is an on-going vivid debate about whether peak oil is real and now (e.g. Aleklett et al., 2010) or just a myth for the next decades (Radetzki, 2010). Recent pessimistic contributions include Murray and King (2012), who argue that "oil's tipping point has passed". Kerr (2012) is quite optimistic for growing US oil production due to unconventional oil, but he still expects growing dependency on OPEC oil and limited supply on a global level. Tverberg (2012) points at the link between oil supply limits and the financial crisis. On the other hand, Mill (2012) sees no oil supply shortage, but argues that "oil demand will peak long before oil supply". According to Owen et al. (2010) part of the dissent can be resolved by clear definitions. Irrespective to the actual oil supply in the next decades, there can be a risk of short- or even long-term oil supply shortages (Fantazzini et al., 2011) or price shocks to balance inflexible supply and inflexible demand, which are worth-while to be evaluated in the economic dimension.

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Given this, the paper at hand presents results of a model-based scenario analysis on the economic implications in the next decade of an oil peak today and significantly decreasing oil production in the coming years. For that the extraction paths of oil and other fossil fuels given in LBST (2010) are implemented in the global macro-economic model GINFORS. Additionally, the scenarios incorporate different technological potentials for energy efficiency and renewable energy, which cannot be forecast using econometric methods. GINFORS then endogenously determines world-wide energy demand and energy prices. In modelling terms this means, that the oil price is increased until global oil demand equals global oil supply. The resulting oil price is by no means to be understood as the most likely oil price development; rather this exercise should be understood as an if-then-analysis in a research area that still needs extensive explorations. Given the assumption of a fixed medium term oil supply, the effects described here might be too strong.

2. Model and scenario setup

Modelling the macroeconomic effects of decreasing oil supply in GINFORS is done via matching global oil demand to global supply by adjusting the oil price. As there exists very little literature on macroeconomic effects of oil shortages directly and the oil shortage is modelled via increasing oil prices, the effects we will see in this exercise correspond to macroeconomic oil price effects. For an extensive literature review the interested reader is referred to Hamilton (2005) and Kilian (2008). According to Jones et al. (2004) the effects of oil price shocks are difficult to model at the aggregated macroeconomic level, i.e. GDP. Best suitable are sectorally disaggregated econometric models, as for example vector-autoregressive (VAR) or vector-error-correction (VEC) models, or models such as the MULTIMOD model of the IMF or the INTERLINK model of the OECD. They also give a short overview over these types of models.

To model the macroeconomic effects of this oil shortage we use the sectorally disaggregated global energy-environment-economy model GINFORS. It combines econometric-statistical analysis with input–output analysis embedded in a complete macroeconomic framework ensuring the accounting identities of the system of national accounts. GINFORS has recently been applied to various economic questions, ranging from an European environmental tax reform (Lutz and Meyer, 2010; Ekins and Speck, 2011) and environmental and economic effects of Post-Kyoto regimes (Lutz and Meyer, 2009b) to the impact of higher energy prices through international trade (Lutz and Meyer, 2009a). A detailed description of GINFORS can be found in Lutz et al. (2010) or Lutz and Meyer (2009a,b, 2010).

Fig. 1 displays the basic model structure of GINFORS. The countries' economies are either modelled with input–output models or aggregate macro models (if no OECD input–output table exist). Import demand and export prices are determined within the country models. The bilateral trade model then combines the information and gives export demand and import prices to the countries' economies. The model iterates until the convergence property of the solution is reached, which has to be fulfilled on a yearly basis.

Behavioural parameters of the model are estimated econometrically, and different specifications of the functions are tested against each other, which gives the model an empirical validation. The econometric estimations are based on times series from OECD, IMF and IEA for 1980 to 2006.

The approach is different from Kerschner and Hubacek (2009), who apply static input–output country models to assess the impact of oil supply reductions of 10%. There is no technological or behavioural change. Their supply-constrained model looks into the quantity dimension of peak oil. In contrast, our approach focuses on the price and overall macroeconomic impacts, if oil demand has to be reduced to equal the reduced oil supply applying econometrically estimated price elasticities of energy demand. These price elasticities are country, sector and fuel specific and range from 0 to -0.3 with a few outliers up to -0.5. A price elasticity of -0.3 means, that demand will be reduced by 30%, if the end-user price doubles.

The baseline scenario is comparable to the "new policy" scenario of IEA World Energy Outlook (WEO 2010). The second scenario assumes that world oil production has peaked and hence the gap between oil demand as projected in WEO (2010) and oil supply widens until 2020. Additionally to peak oil, the third scenario introduces energy efficiency and renewable energy measures according to the WEO 450 ppm scenario.

Energy demand in scenario "Peak Oil" is equivalent to energy demand in the baseline. For the supply side though it is assumed that world oil production has peaked and will significantly decline over the next decade until 2020. This shortage cannot only occur due to shrinking oil production but also due to political disruptions or military disputes as started in early 2011 in the MENA (Middle-East North-African) countries.

For the model we assume that world oil production is price independent in the medium run and decreasing after 2010. The assumption of a fixed oil supply in the short to medium run is feasible because of limited production expansion possibilities due to time and capital consuming necessary investments. In the long run oil production is less price inelastic, which should then be considered. Oil demand price elasticities are estimated in the model, as described above. Using these results, it is possible to increase the oil price until global oil demand has dropped such that it equals global oil supply. The implication of the price inelastic demand is a strong increase of the price for crude oil after 2015.

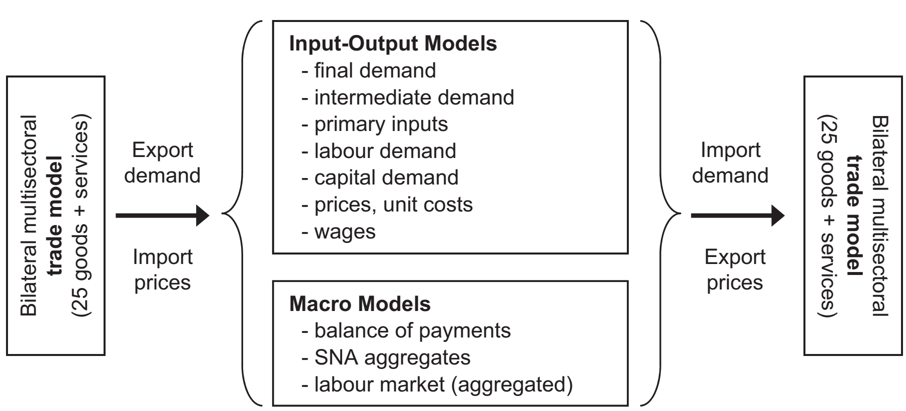

Fig. 1. GINFORS structure.

The third scenario "Peak Oil Eff/RE" also assumes peak oil, but uses the 450 ppm-scenario of the IEA WEO (2009) as a guideline for demand side development. The assumptions are increased energy efficiency and extended use of renewables.

3. Results

All scenarios have been implemented in GINFORS. They differ only with respect to the assumptions made above, so that the differences in the results must be due to the different assumptions concerning oil supply and demand. The development as projected in this analysis should be interpreted using if-then-statements and should be seen relative to each other and not in absolute terms. The three central questions that can be answered with this analysis are

What are the effects of an oil supply shortage, when demand is developing as in the business-as-usual case? (Comparison of "Peak Oil" scenario with baseline)

- What are the effects of a shrinking global oil production with a contemporaneous global climate protection action, i.e. improved energy efficiency and expansion of renewable energy? (Comparison of scenarios "Peak Oil Eff/RE" and "Peak Oil")
- What are the advantages of a global climate protection action in the case of declining oil supply compared to a continuing business-as-usual development? (Comparison of "Peak Oil Eff/RE" with baseline)

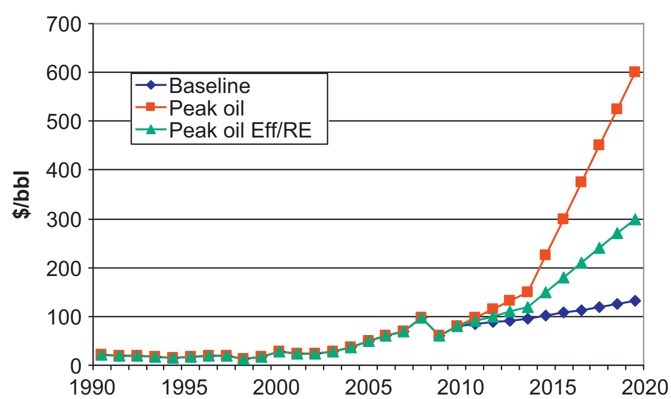

Fig. 2. Oil price development for the 3 scenarios.

- The main results are the change in oil price, which is endogenously determined within the demand-supply-system, the change in global energy consumption and macroeconomic effects at country level.

3.1. Oil price

A declining oil supply in the next decade combined with an increased demand for oil until 2020 as expected in the baseline scenario leads to a strong increase in the oil price that adjusts oil demand until it equals oil supply. In scenario "Peak Oil" without any efficiency improvements or increased use of renewables, the supply shortage will become apparent as from 2015 on, when the oil price starts to strongly increase up to 600 USD per barrel in 2020, see Fig. 2. This is about 420 USD in constant prices using the German price index; less in other countries due to higher inflation expectations. The IEA (2011) expects the oil price in 2020 to be somewhere between 85 and 120 USD per barrel in constant prices.

The oil price necessary to equalise demand and supply in 2020 in scenario "Peak Oil Eff/RE" is only half of the price in the "Peak Oil" scenario, i.e. 300 USD in current or about 210 USD per barrel in constant prices, which is still substantially higher than the all-time high of 150 USD per barrel in 2008.

The increase in the price of crude oil also has effects on the prices of other goods depending on their direct and indirect oil content. GINFORS is able to capture these effects with input–output and bilateral trade models. Results for sectoral effects are available from the authors upon request.

3.2. Energy supply and demand

Fig. 3 shows that energy demand for all energy carriers strongly increases until 2020 in the baseline. In the two alternative scenarios though demand for fossil fuels is significantly lower in 2020. The increase in the demand for gas in "Peak Oil" partly absorbs the decrease in oil demand. The lower use of coal though is due to lower global economic activity, especially in China. Biomass, other renewables as well as nuclear energy only play a minor role in the "Peak Oil" scenario until 2020. The efficiency effect and the expanded use of renewables are clearly visible in the energy mix in "Peak Oil Eff/RE" in 2020. Global demand for fossil fuels is significantly lower than in the other two scenarios. Global oil production for scenarios "Peak Oil" and

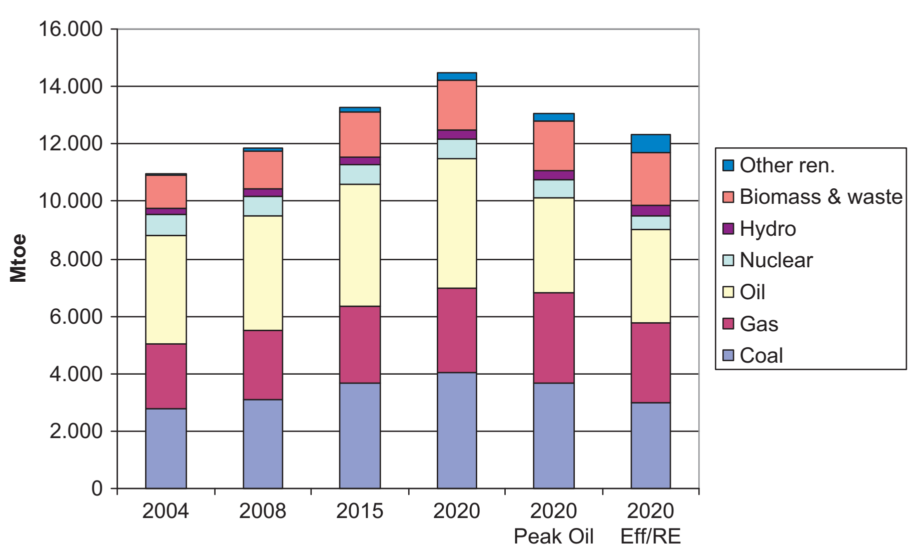

Fig. 3. Global energy demand for scenarios Baseline, Peak oil and Peak oil Eff/RE.

"Peak Oil Eff/RE" is displayed in Fig. 4. Production declines in all regions, while relative production shares hardly any change.

3.3. Macroeconomic effects

For the OECD countries GINFORS models production, prices and employment for 41 economic sectors. Macroeconomic aggregates such as GDP, private and government consumption, investments, imports, exports, total employment, price index or hourly wages are available for all countries and regions.

The substantial increase in the oil price in "Peak Oil" has a strong influence on the economic development of individual countries. The global effect is even comparable to the effect of the financial and economic crises of 2008/2009. Oil exporting countries though strongly benefit from the increased oil price: the GDP of both Russia and the OPEC is by about 35% higher in "Peak Oil" than in the baseline, see Fig. 5, even though physical oil exports shrink. However, this decrease is more than levelled by the price increase. Even though the UK and the US will be net importers of oil in 2020, due to their domestic oil production their GDP loss in "Peak Oil" compared to the baseline is substantially lower than the GDP loss in countries such as France, Japan or India that, if at all, have only little domestic oil production. China though, which is ranked among the top 15 countries according to oil reserves (IEA, 2010), is also highly negatively affected, which is due to the strong increase in energy demand, which exceeds by far possible domestic production increases. Still, GDP growth rates remain positive in all countries but Japan. Efficiency measures and increased use of renewables as modelled in "Peak Oil Eff/RE" could significantly lower the oil price increase and hence also the negative economic impacts. Overall, the economic influence of the oil exporting countries grows whereas the other countries influence' on the world market shrinks.

The relatively small effects in Germany can be explained by a number of factors. Germany has very high oil productivity; it needs about half as much oil per unit of production as the US and only one quarter the amount of China, compare Fig. 6. Germany shares the problem with France, Japan, Korea and India that they have no domestic oil reserves and therefore completely rely on imports of this good which is traded at very volatile prices. The US, UK, and China on the other hand do have some domestic oil production and hence do not depend that heavily on oil imports. Still, reducing oil consumption is easier for industrialised countries such as Germany than for the newly emerging economies India and China.

The economic structure itself and trade linkages also determine the macroeconomic effects. Germany as a producer of high quality goods, for which transport costs are only a minor factor for international competitiveness, and energy efficient investment goods has a good position in case of "Peak Oil". Additionally, the oil producing countries have a high share in German exports so that the indirect effects for Germany are positive.

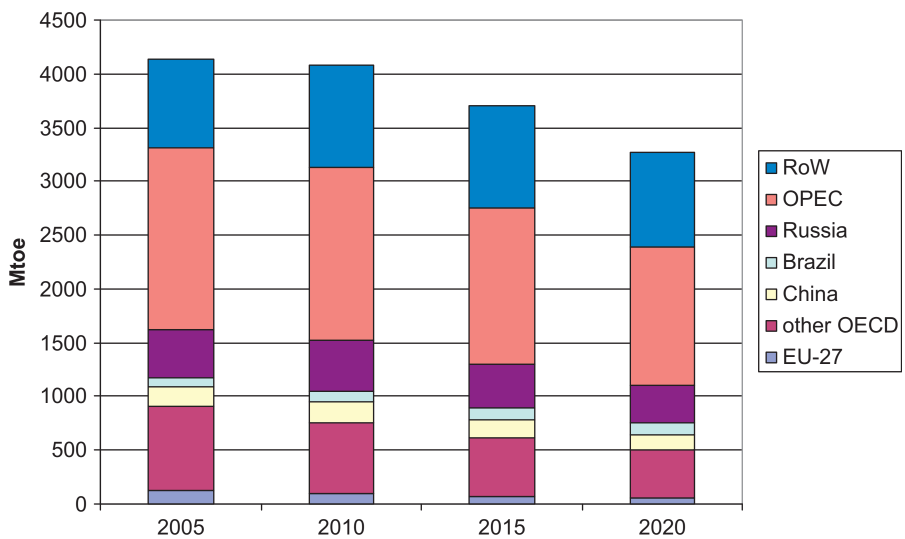

Fig. 4. Global (conventional) oil production for scenarios Peak oil and Peak oil Eff/RE.

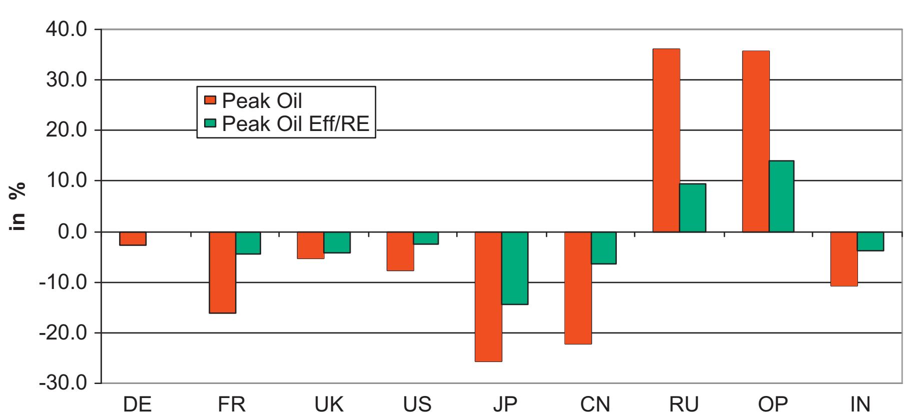

Fig. 5. GDP in 2020—differences between "Peak Oil"/"Peak Oil Eff/RE" and Baseline.

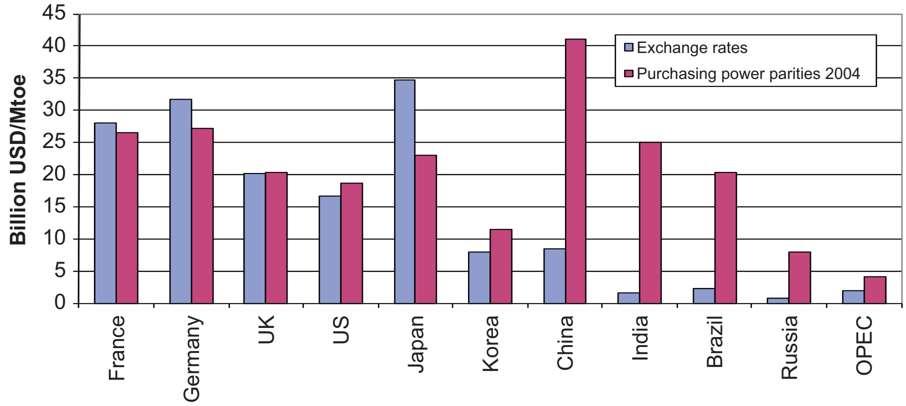

Fig. 6. Oil productivity (GDP in billion USD2000/Oil usage in Mtoe) in the baseline scenario in 2020.

Additional to economic factors, geographic factors also have an influence on the magnitude of the effects of the oil price increase. Generally, countries that are densely populated, with a high domestic demand, and close proximity to export markets, are better protected against a strong increase in the oil price. This explains why Japan is more negatively affected than the European countries despite its rather high oil productivity.

It is important to note that GINFORS is only able to display effects in monetary terms and that the results depend on a variety of model assumptions. Important factors that are not modelled in GINFORS are possible alternative transportation means, e.g. powerful electricity based train networks, or a switch from petroleum-based cars to biofuel, electricity or LPG driven cars. An inclusion would reduce the oil price effects in the long-term, but has to be related to the time and investment needs. The model only captures part of the oil price effects as described in the literature. Kilian (2008) analyses possible transmission channels of higher oil prices distinguishing between supply-side and demand-side channels. Three out of five of his demand-side channels are not captured in GINFORS. They include the ‘‘precautionary savings’’ channel and the ‘‘uncertainty effect’’, which will reduce consumption in the short run. The third effect is the ‘‘operating cost effect’’ which describes the decrease in purchases of energy intensive durable goods such as cars. The oscillating link between business cycle and oil price development that is described by Tverberg (2012) is a short-term phenomenon, which cannot be captured by the model GINFORS, which looks into the medium term. When interpreting the results one should additionally consider that there are high uncertainties with regard to the future behaviour of economic agents, not only on the oil market, so that one possible extension of the research at hand will be a variety of sensitivity analyses. Note that the results need to be interpreted with care as an oil price increase of this size has never been experienced before and reaction parameters that are estimated based on historical relations might no longer be valid. Small changes in the model parameters might substantially alter the results.

4. Conclusions

This analysis shows possible medium-term economic effects of a significant drop in world oil production over the next decade. Assuming that global demand for oil and petroleum products remains increasing, the price of oil will increase sharply due to the price inelastic nature of the oil market in the short to medium run. Large fluctuations in the oil price occur for only small changes in supply and demand. This is also supported by findings in the literature, and shows that strong price fluctuations as experienced in the past years are easily possible. The oil shortage firstly and strongly affects the transport sector but then has indirect impacts on all other sectors through global supply chains. The medium run reactions to the oil shortage and corresponding substantial increase in the oil price of the global energy system and the individual sectors are energy saving and substitution, lowering global energy demand. The global macroeconomic effects of an increase of the oil price as high as modelled here are comparable to the effects of the financial and economic crises of 2008/2009. Country specific effects are very different as the oil exporting countries gain importance in the global economy while the influence of the strong oil-importing economies of today decreases.

Comparing scenarios ‘‘Peak Oil’’ and ‘‘Peak Oil Eff/RE’’ shows that global climate mitigation actions can well reduce the negative economic impacts of oil supply shortages and associated with strong increases in the oil price.

The reasons for the oil shortage, which in this paper is assumed to be peak oil, could as well be political disruptions, military conflicts, or terror attacks in the oil producing countries. For the analysis of the macroeconomic effects though the actual source of the oil shortage and corresponding oil price increase does not matter. This analysis shows that not only the reduction in emissions, but also fossil fuel shortage, especially oil shortage, and energy security are good reasons for global climate action programmes regarding increase in energy efficiency and further development of renewable energy sources.

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