THE IMPACT OF HIGH OIL PRICES ON TRANSPORT AND ENERGY SYSTEMS IN EUROPE

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Introduction

The continuous growth of oil price characterized the recent years until the first half of 2008, raising concerns at all levels of policy makers. At the end of 2008, oil price started to decline back to values well below 50 $/bbl (American Dollars per Barrel) mainly due to the global economic crises, becoming the primary emergency for citizens, enterprises and policy makers and depressing demand in all economic sectors.

At the end of the year 2006, when energy availability had started to climb up in the policy makers' agenda, the Research Directorate General of the European Commission launched the HOP! (High Oil Prices) research project, as part of the 6th Framework Research Programme, to analyse the direct and indirect impacts of high oil prices on the transport, energy and economic systems in the European Union (www.hop-project.eu). This paper reports the methodology of the project and its main findings; it is structured as follows: Chapter 1 presents the methodology of the project and underlines some key assumptions. Chapter 2 introduces the scenarios considered in HOP! Chapter 3 summarises the main impacts of high oil prices foreseen in different sectors at the EU level. Lastly, chapter 4 provides the main conclusions.

1. The HOP! methodology

There are numerous direct and indirect impacts of high oil prices on the various sectors of the economy, even if focus is to be put only on the most relevant effects. Furthermore, many of the issues are interlinked and some impacts may lead the system to even turn into opposite directions. For instance, the impact of higher costs of energy and transport are expected to be negative on economic growth, whereas investments in alternative energy sources are expected to provide a positive contribution. According to which of the two effects is stronger and faster, the economy can react more positively or negatively. Overall, the final result can hardly be predicted on a qualitative basis and is likely to change over time.

For this reason, an analytical toolbox consisting of the two interconnected models was applied in HOP! to simulate in a consistent way the effects of various scenarios assuming high oil prices, taking into account various feedback loops and the dynamics of impacts.

1.1 The HOP! modelling tools

The two models used are POLES (including the Biofuels model BioPOL) and ASTRA. The POLES (Prospective Outlook for the Long term Energy System) model is a global sectoral simulation model for the development of energy scenarios until 2050. ASTRA stands for Assessment of Transport Strategies. The model is developed since 1997 with the purpose of strategic assessment of policies in an integrated way i.e. by considering the feedback loops between the transport system and the economic system. More details on ASTRA and POLES can be found in Krail et al. (2007).

The POLES/BioPOL model

The POLES (Prospective Outlook for the Long term Energy System) model is a global sector simulation model for the development of energy scenarios until 2050. The dynamics of the model are based on a recursive (year by year) simulation process of energy demand and supply with lagged adjustments to prices and a feedback loop through international energy prices. The model is developed within the framework of a hierarchical structure of interconnected modules at the international, regional and national level. It contains technologically-detailed modules for energy-intensive sectors, including power generation, production of iron and steel, aluminium and cement, as well as modal transportation sectors.

In each sector, energy consumption is calculated both for substitutable fuels and for electricity. Each demand equation contains an income or activity variable elasticity, a price elasticity, captures technological trends and, when appropriate, saturation effects. Particular attention is paid to the treatment of price effects. The world is subdivided into 47 regions, for which the model delivers detailed energy balances. A single world oil market is assumed (the "one great pool" concept), while three regional markets (America, Europe and Asia) are identified for coal, in order to take into account different cost, market and technical structures. Natural gas production and trade flows are modelled on a bilateral trade basis, thus allowing for the identification of a large number of geographical specificities and the nature of different export routes.

Energy prices are determined endogenously in POLES. Oil prices in the long term depend primarily on the relative scarcity of oil reserves (i.e. the reserves-to-production ratio). In the short run, the oil price is mainly influenced by spare production capacities of large oil producing countries. Furthermore, in the HOP! version a 'market power' price add-on is simulated in dependence of the geographical distribution of oil reserves. It must be noted that the endogenous price forming mechanism cannot model the price volatility induced by short term market expectations.

The main exogenous variables are the population and GDP, for each country / region, the price of energy being endogenised in the international energy market modules. According to the principle of recursive simulation, the comparison of imports and exports capacities for each market allows for the determination of the variation of the price for the following period of the model. Combined with the different lag structure of demand and supply in the regional modules, this feature of the model allows for the simulation of under- or over-capacity situations, with the possibility of price shocks or counter-shocks similar to those that occurred on the oil market in the seventies and eighties.

The biofuels model (BioPOL), developed for previous projects, has improved the capability of POLES to deal with a potentially relevant alternative source of energy for the transport sector. The biofuels model is based on recursive year by year simulation of biofuels demand and supply in the EU-27 until 2050. For each set of exogenously given parameters an equilibrium point is calculated at which the costs of biofuels equal those of the fossil alternative they substitute, taking into account the feedback loops of the agricultural market and restrictions in the annual growth rates of capacity. This equilibrium point is envisaged by market participants but not necessarily reached in each year. Increasing production of biofuels and a subsequent rise in feedstock demand has an impact on the prices of biofuels feedstock, which in turn affects biofuels production through a feedback loop.

The ASTRA model

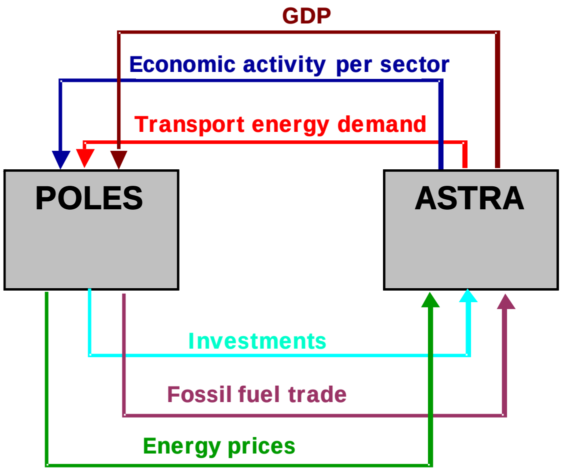
ASTRA stands for Assessment of Transport Strategies. The model is developed since 1997 with the purpose of strategic assessment of policies in an integrated way i.e. by considering the feedback loops between population, the transport and energy system and the economic system. The model is based on the System Dynamics methodology and follows system analytic concepts, which assume that the implemented real systems can be conceived as a number of feedback loops that are interacting with each other. These feedback loops are implemented in ASTRA and the model is calibrated for key variables for the period 1990 until 2003. The spatial coverage extends over the EU27 countries plus Norway and Switzerland. Each country is further disaggregated into at maximum four functional zones classified by their settlement characteristics.

The ASTRA model consists of nine modules, linked together in manifold ways. The modules are all implemented applying the Vensim system dynamics software. They can be run stand-alone and within one integrated model, which is the case for HOP!. Relevant features of ASTRA for the objectives of the study include:

- a representation of the inter-sector links between 25 economic sectors by means of input/output tables at the country level. In this way, the relationships between the energy sector and the other sectors can be simulated, analysing how changes of energy demand impact on the energy production sector as well as the effects of higher energy prices on value added and employment of other sectors;
- a detailed description of the transport sector, including transport cost calculations based on technologies and therefore the capability of describing manifold changes both on the supply and the demand side and the resulting impacts on transport energy consumption as well as the impacts of transport in the input-output table structure like for the energy sector;
- a detailed sector investment model that is driven by the sector consumption and exports. Since, both consumption and exports are affected by sector shifts due to higher energy prices also the endogenously calculated investments react to the energy prices. This is complemented by investment changes in the energy sector calculated by the POLES model;
- multiple linkages between the transport sector and the economy sector, which allow to take into account different economic impacts of changes of the amount and of the characteristics of transport demand and supply;
- a trade model that considers the changes of energy trade flows as provided by POLES and the changes of transport cost (e.g. induced by energy price changes) for trade within the EU;
- a detailed fleet module where innovative technologies can enter as result of the changes of relative prices of alternative energy sources as well as of alternative technologies.

In HOP! the two models were linked as shown in figure 1: ASTRA received from POLES: fuel prices, the value of investments for developing alternative energy sources and the trade of fossil fuels; POLES received GDP development, energy demand for the transport sector and the economic activity per sector from ASTRA. The simulation of scenarios was an iterative process: POLES started the simulation to provide initial input for ASTRA, whose interface results are transferred back to POLES. Scenario run was then replicated in POLES to produce updated outcomes for ASTRA and so on. At the end of each iteration, results were compared with those of the previous iteration and the process was stopped when in both models differences were sufficiently small.

Fig. 1.1 The interlinked ASTRA and POLES/BioPOL modelling process



1.2 Key assumptions in HOP!

It's worth to note that, as any other tool, also the HOP! models are a simplified description of the real world based on some theoretical approach and empirical findings. This means that not all impacts are covered at the same level of detail and that various assumptions are used in the structures of the model.

Some relevant aspects affecting the impact of high oil prices, especially on the economic side are not fully modelled in HOP!. One example is the role of the monetary policy. The mission of the European Central Bank is to control inflation, so when oil price growth puts pressure on prices, some intervention of the ECB can be expected (e.g. a raise of the discount rate) to contrast inflation. In turn, this intervention will impact on economic growth, employment, etc. However, monetary policy is not dealt with in the HOP! models. Another key issue is the economic development outside EU, which is assumed exogenously (some sensitivity simulations have been carried out to investigate how the picture could change if growth rates of non-EU economies decline).

Second, the reference scenario assumes a positive economic growth for the EU for the whole simulation period (the time horizon of the simulations ends in 2050). Recent economic downturn suggests that these assumptions can be too optimistic. On the other hand, however, it should be taken into account that the modelling exercise aim at forecasting up to the year 2050. In this long term horizon, it may well happen that economic growth is temporarily stopped due to specific circumstances. So the present crisis can be seen as one of these temporary breaks in the overall growth trend and the models used in HOP! are not built to reflect short-term economic cycles. It may be argued that the credit crunch emerged in late 2008 is a symptom of a structural crisis of the global economy and cannot be considered a mere accident that will be solved briefly. This is possible, but the HOP! models assume that economic growth will remain the normal condition (though at a more or less fast pace) in the future; a more 'revolutionary' perspective is beyond their scope.

Within this approach, some key assumptions have to be particularly emphasised because they are embedded in the modelling tools and play a major role in explaining their results. Such key assumptions are:

- All required investments in alternative energy sources/energy efficiency will be made available to develop and implement the required technological solutions for tackling high oil price;

- Therefore, alternative energies are installed as long as they are economically competitive (yet with some time constraints reflecting the time needed for permission, planning and construction of installations);

- All the energy demanded can be produced (using alternative sources if fossil fuels are unable to cater for the global need), such that no physical energy supply shortages occur.

- The changes of investments and different cost of feedstock to produce energy are reflected in changes of the energy prices such that the changes on the energy supply side (i.e. adapted investments) and the energy demand side (i.e. adapted energy prices) correspond to each other. In other words, market forces are able to peacefully adjust supply and demand of energy. This also means that no conflicts for controlling energy sources will be fought.

As a whole, such assumptions describe a world where economic growth can continue without structural problems, the market forces are able to generate a peaceful development and where investments are available to promote economic growth and ensure energy supply. This is the perspective assumed in the HOP! models and the results of the project can be considered an appraisal of what could happen under this ‘ideal world’.

2. The HOP! scenarios

Table 2.1 provides an overview on the HOP! scenarios. It should be noted that in all scenarios, oil prices are expressed in Euros$_{2000}$ (i.e. Euros at the value of the year 2000) per barrel rather than in Dollars per barrel. This choice does not imply any assumption concerning the use of Euro as intentional oil trade currency. It is just the simplest way to focus the attention on the key aspect to be investigated in HOP!: how much oil will cost for the EU. Given the difficulty about making assumptions on the exchange rate, a reasonable value was selected and kept fixed throughout the simulations. It should also be noted that oil price development in the HOP! project scenarios is not an input of the modelling tools, but it is endogenously calculated by POLES/BioPOL on the basis of the exogenous assumption on oil reserves availability and competitiveness of alternative energy sources.

Tab. 2.1 HOP! scenarios

Scenario	Oil price in year 2020 (€$_{2000}$/bbl)	Fuel taxes	Price growth path
Reference 70	70	EU directives	Stable
150 smooth	150	EU directives	Smooth rise
150 smooth no invest	150	EU directives	Smooth rise
150 smooth reduced tax	150	**Reduced Tax**	Smooth rise
150 smooth Carbon tax	150	**Carbon Tax**	Smooth rise
150 early	150	EU directives	**Early Step**
150 late	150	EU directives	**Late Step**
220 smooth	**220**	EU directives	Smooth rise

Source: HOP! Deliverable D3

In the table, "smooth rise" means a regular smoothly rising from nowadays price to the defined price in the year 2020. "Early step" stays for a steep rise in the next couple of years until the price of 150 $€_{2000}$/bbl then kept stable until year 2020. "Late step" means that oil price is unchanged until about 2017 and than suddenly grows to the value of $€_{2000}$/bbl.

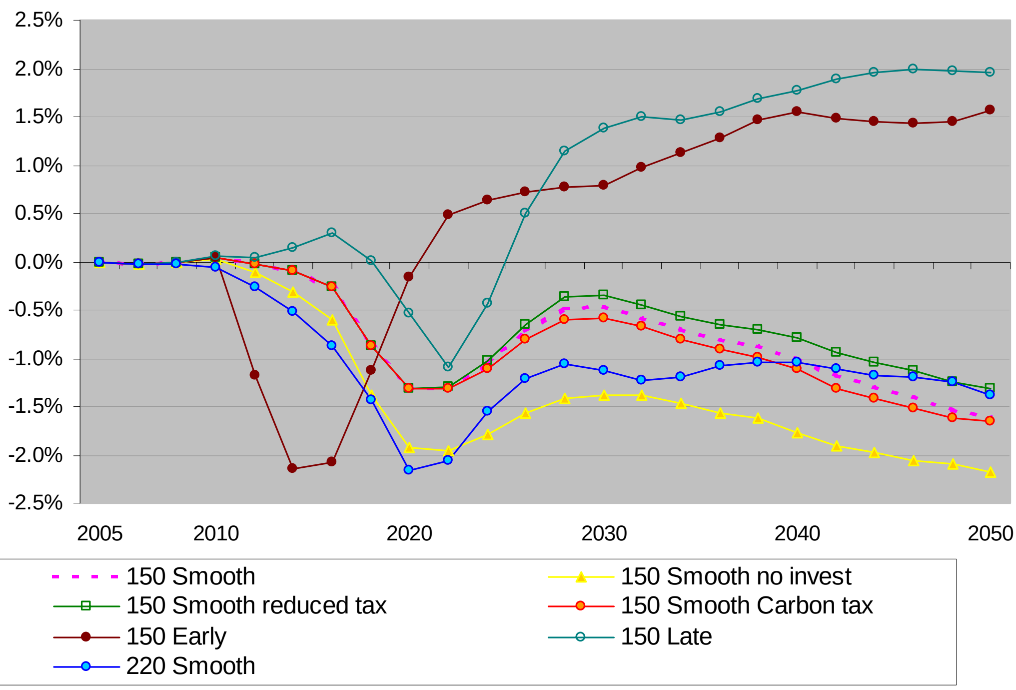
In the "150 smooth reduced tax" scenario a tax reduction by 20% with the purpose to limit the increase of transport costs is assumed. In the "150 smooth carbon tax" scenario carbon taxation is raised to 30 €/tCO_2 aiming at higher tax revenues to compensate higher governmental investments.

3. The HOP! results

3.1 The impact of high oil price on the economy

GDP development is significantly affected by the high oil prices, though a number of compensating mechanisms like investments into alternative energies, modal-shift to public transport dampen the negative impacts of the high oil prices on the economy. Figure 2 shows the difference between the GDP level in the various scenarios compared to the level of the reference scenario.

Fig. 3.1 Change of EU27 GDP compared with Reference 70 scenario



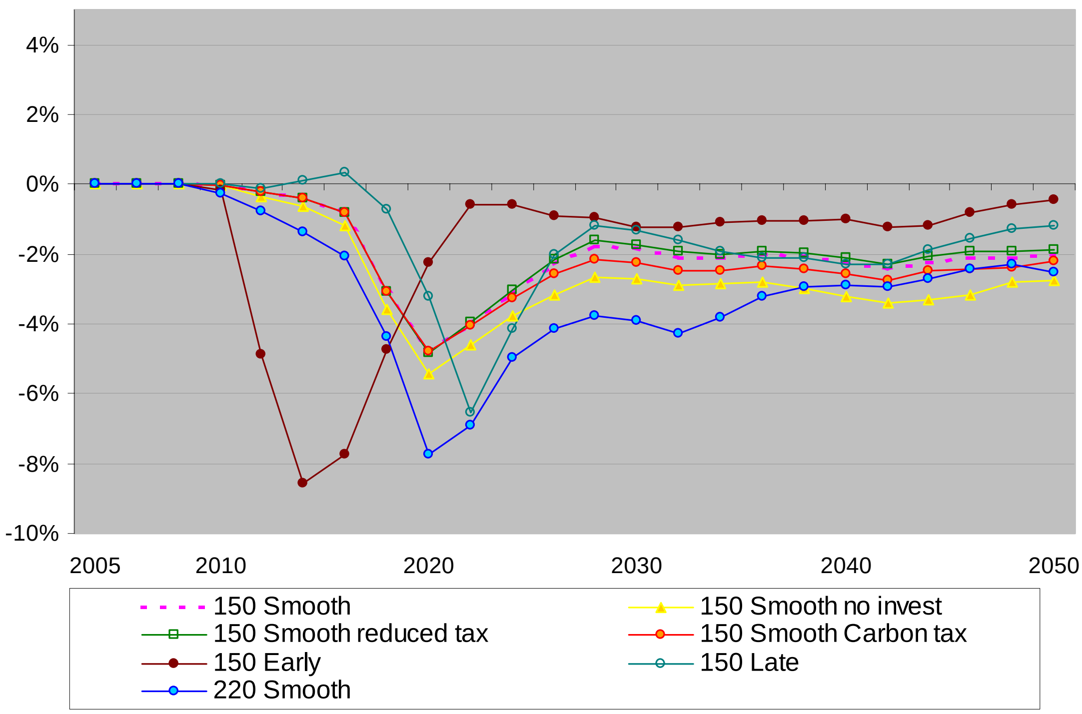
Source: HOP! Deliverable D3

One can observe that for the scenarios increasing oil price to 150-220 €/bbl, growth rates are reduced by up to 0.5% over about a decade leading to about losses of 1-2% of GDP over the whole period. Specifics can be observed for the scenario in which the bottom-up investments from POLES and the investments into the adaptations of the vehicle fleet are limited to the reference scenario (scenario 150 Smooth no invest), which reveals in the long run the worst development of all scenarios. This provides the first indication of the utmost importance of investments to tackle high oil prices.

Further specifics can be seen for the time variations of the price increase, the early increase to 150 €/bbl (scenario *150 Early*), which means that the 150 €/bbl are reached in 2014 instead of 2020, and the late increase (scenario *150 Late*), which means that until 2017 oil price follows the reference scenario and only until 2023 the 150 €/bbl will finally be reached. These two scenarios in 2050 end with a higher GDP than the reference scenario, though because of different reasons. The *150 Early* scenario seems to stimulate investments in a most productive way and is less negatively affected by the increase of oil imports and oil prices than the *220 smooth* scenario, while the *150 Late* scenario the fact that the lead time to adapt the energy and transport system is longer makes it happen that the negative impacts are more limited, while higher investment and sector shift generate positive stimuli.

A common feature to all scenarios is that when the decade of fast oil price growth ends around 2020 a kind of rebound effect occurs that over a period of 3 to 5 years leads to higher growth rates of GDP than in the reference scenario. Partially, this should be because of POLES providing reduction of fuel prices in response to the investments in the energy system reducing the demand for oil and because of lagged effects of the economic system in response to the increased investments e.g. growth effects of productivity. Overall, the response of GDP to these scenarios is small. It seems that the boom in investment can mostly compensate for the shock.

Fig. 3.2 Change of EU27 employment compared with Reference 70 scenario

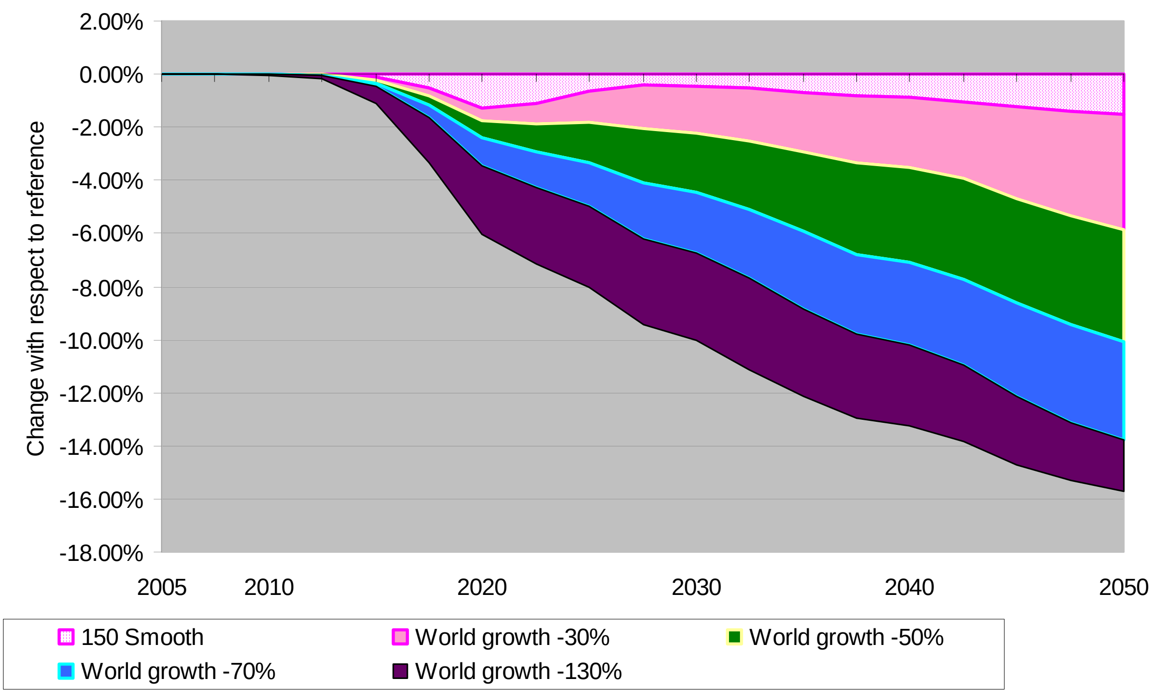


Source: HOP! Deliverable D3

A strongest impact of the scenarios is observed for employment (Figure 3.2). All scenarios expect a reduction of employment with respect to the reference scenario, which is caused by several interacting impact chains. First, there is the reduction of private consumption due to inflation and the reduced GDP in the scenarios. Second, more money is spent for the energy sector, which means less for the other sectors (budget effect). In particular, these impacts negatively affect the service sectors that reveal a comparatively high labour intensity. Third, the structural changes of consumption, investment and exports tend to favour less labour intense sectors, which would even with the same level of GDP imply a reduction of employment (substitution effect). Fourth, the energy price increase affects the input cost of intermediate products to all good and services, thus reducing value-added and employment. Even though in most scenarios differences are minor, in some scenarios and for some periods, the potential impact of high oil price on employment is significant (and in any case even one percentage point of less employment would mean 2 million more jobless people in EU27).

Despite the effect of employment cannot be undervalued, the simulations of the HOP! scenarios suggest that oil prices could not lead to an economic crisis but just give rise to (temporary) slowdown of the growth. Indeed, while oil prices grew significantly and steadily between 2003 and mid-2008, the European economy continued to show positive growth rates. The symptoms of the crisis emerged in late 2008 had a different origin in the financial market. This does not demonstrate that the HOP! simulations are right but corroborate that they might be so.

Fig. 3.3 Impact on GDP of alternative scenarios of world recession coupled to high oil prices



Source: HOP! Deliverable D3

The recent economic crisis contributed to reduce oil prices, but one might wonder what could happen if higher oil prices coupled with a slowdown of the global economy. In HOP! some sensitivity tests were made where the growth rate of the economy outside the EU is reduced at various extent. World GDP growth constitutes an exogenous input to ASTRA driving the trade model and contributing to the EU economic growth. Figure 3.3 shows that already a 30% reduction of the global growth (compared to the reference case) would have stronger impacts than the impacts caused by a oil price of 150 €/bbl.

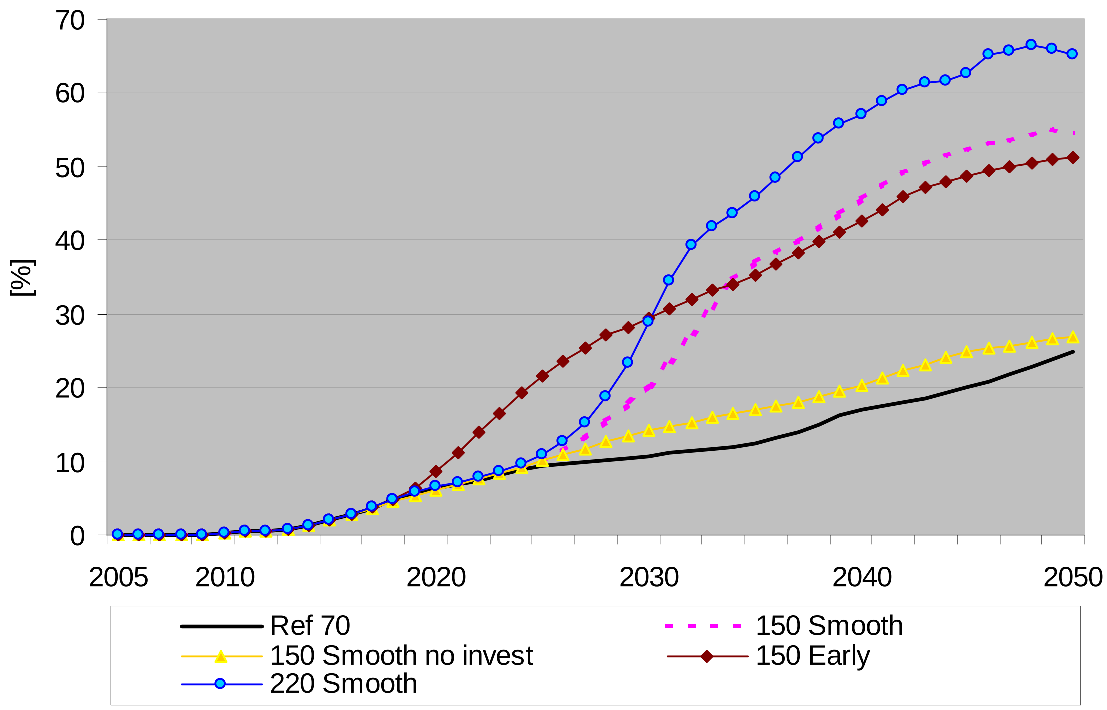
3.2 The impact of high oil price on the energy sector

In the scenarios the reduction of total energy demand reaches levels of about -10%. The picture differs if only transport energy demand is considered. The growth in oil prices enables to break the growth in energy consumption of transport around 2015 even in the Reference Scenario.

A co-benefit of the oil-price induced changes in the energy supply and demand is that a larger part of the EU's energy consumption can be derived from domestic energy production. By 2030 (2050), the share of domestic energy production in the EU's gross inland energy consumption would increase from 47 % in the reference to 54 % in the scenario "150 Smooth", and may even rise further to exceed 65% in "Smooth 220". This implies a reduced rate of imports and may thus be beneficial for energy security.

Changes in the fuel mix of primary energy consumption are one of the most direct impacts of high oil prices, due to the altered relative competitiveness of the various energy carriers. Both compared to "Ref 70" and to today's levels, renewable energy carriers, coal and nuclear power would benefit most from the oil-price induced changes in the fuel mix in the order mentioned. Renewables would provide more than one third of the overall energy consumption, partly due to biofuels but also to renewable energy sources in electricity production. If we look more specifically at the fuel mix for transport, the fast deployment of biofuels become apparent (see Figure 3.4).

Fig. 3.4 Share of biofuels in EU27 transport fuel demand for some HOP! scenarios



Source: HOP! Deliverable D3

A share of 50% or more for biofuels in transport energy demand, as predicted in some HOP! scenarios, is a very high value. It may be interpreted of an upper boundary of their pure market-based penetration, assuming the availability of investments and of 2nd generation production technologies as well as of imports. The outcomes illustrate the importance of discussing biofuels in the wider context of food and fodder production, of international trade and of technological innovation. Ultimately, a biofuels policy would not primarily look into how to increase their market shares, but rather on how to restrain biofuels feedstock production to a level that restricts its impact on food/fodder production and environmental pressures to an acceptable limit. Yet, the definition of these 'acceptable levels' is a societal choice and as such beyond the limits of a modelling analysis.

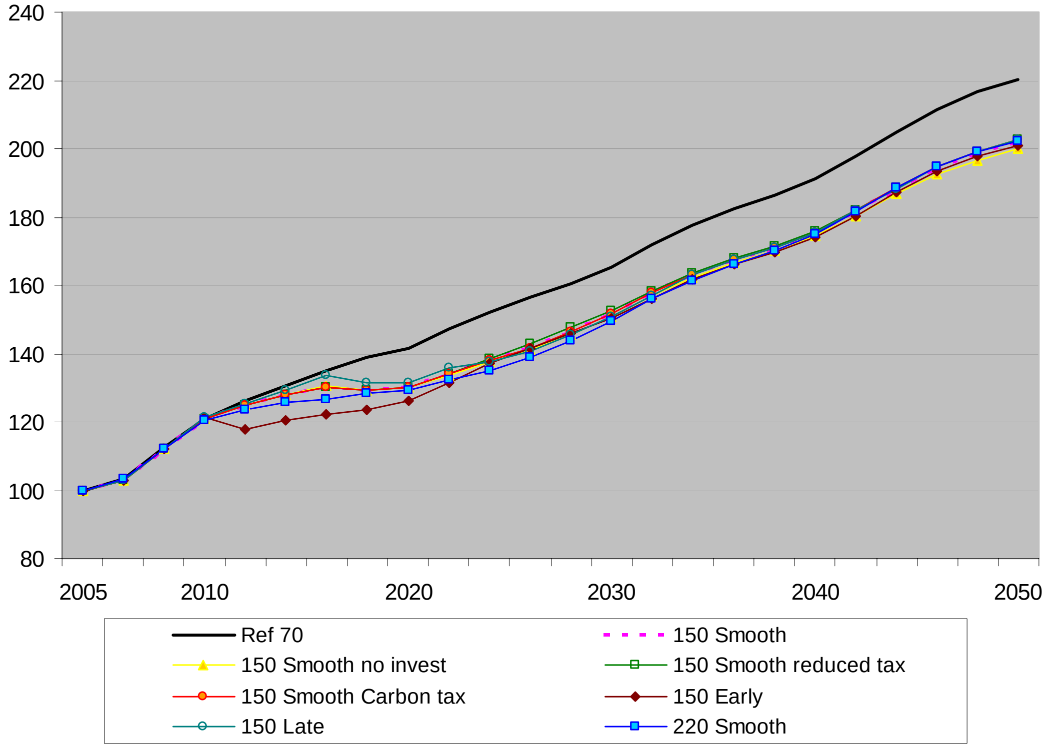
3.3 The impact of high oil price on the transport sector

The transport sector is very energy intensive and therefore the impact of higher oil prices – translated into higher fuels prices – can be readily seen. It is generally believed that transport demand is very rigid and therefore only minor adjustments should be expected. However, when fuel prices climb to unusual high values and remain high, people behaviour can change. Figure 3.5 and 3.6 present the reactions of passenger and freight transport demand. Both are reduced by between -10 and -20%, which is the consequence of manifold reaction patterns like mode-shift, change of destinations and reduced distances as well as lower economic activity. In general, inherent transport system reactions are stronger for passenger transport, while freight transport is reacting stronger to changes in economic activity (e.g. reduced trade flows) than passenger transport.

Fig. 3.5 Trend of passenger demand in the HOP! scenarios

Source: HOP! Deliverable D3

Fig. 3.6 Trend of freight demand in the HOP! scenarios



Source: HOP! Deliverable D3

The passenger mobility reduction is associated to a different mode split with car and air losing mode share whereas public transport and slow modes gain demand. Car share could be reduced to 67%-68% (so car would remain the dominant mode anyway) at the year 2020, to recover some share lately but staying below the current level. Air demand growth would be significantly stopped: air market could lose about 20% of its demand between 2014 and 2020.

Including within the innovative cars: biofuels, hybrid, electric and fuel cells vehicles, their share is expected to be about 15% in the year 2050 in the reference case, while in case of high and very high oil price the share grows up to 21% and, respectively 30%. At the same time, also the size of the vehicle fleet is a bit lower in the high oil price scenarios.

4. Conclusions and policy implications

The HOP! research project estimated the direct and indirect effects of a long term future oil price escalation on the EU's economy, energy and transport systems based on a combined systems dynamics modelling approach and under a set of assumptions concerning the sustainability of economic growth in the longer terms, the availability of investments and the capability of technology and market forces to avoid energy shortages. Different high oil price scenarios have been tested using the ASTRA transport and macroeconomic model and the POLES partial equilibrium global energy model in an iterative modelling process until the year 2050. The key messages derived from the HOP! scenarios analyses can be summarized as:

- GDP and employment are negatively affected during the peak period of the oil price increase with employment being reduced significantly stronger. The impact after the peak period of oil price increase strongly depends on the mechanisms kicked-off by the price increase. Mitigating the impacts by investing into energy efficiency and alternatives could even lead to a positive economic impact in the medium to long-term, while a world economic slowdown could multiply the negative impacts by factors of 5 to 10.

- A rapid price increase over a few years would be advantageous compared with a smooth price increase since the shock most effectively triggers the compensating mechanisms in particular the investments into energy efficiency and alternatives. This presupposes that investors expect a sustained oil price increase and not a temporary one, and that governments do not take actions to lower the fossil fuel prices artificially distorting the price signal.

- The most relevant impact to counterbalance the negative impact of high oil prices are investments into energy efficiency and alternatives, as first they directly provide a positive stimulus for the economy as part of final demand and as second they indirectly help to reduce the vulnerability of the economy to oil price increases by reducing energy demand, energy cost and imports of fossil energy. If investments were either not available or too late, the macroeconomic impacts of high oil prices in the EU-27 would be significantly greater.

Overall, the conclusion is that oil scarcity and oil price shocks can have significant negative impacts on the EU – but they need not, if the EU prepares itself adequately. A first policy issue is therefore how to promote investments in the required size either directly through public budgets or by creating incentives that encourage investments of the private sector. Looking at the fast decreasing mid-term oil production forecast, the EU should have enough reasons to prepare. Furthermore, in a time where the intervention of the governments is loudly advocated to alleviate the consequences of the economic crises, promoting investments in the direction of the energy efficiency and of alternative energy sources would a wiser strategy to sustain the economy and save jobs than just saving financial institutions.

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