

Peak oil, biofuels, and long-term food security

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Abstract

Recent oil prices escalations, current production of biofuels from food, and rising food prices have caused an awareness of a potential conflict between biofuel production and food availability. Biofuels could help countries reduce their dependence on imported oil and biofuels could lead to some reductions in CO₂ emissions. For such reasons governments have stimulated research and development and subsidized biofuel production. In this study we use a simulation model to study how markets for oil, biofuel, and food may interact and develop in the long run as world oil production peaks and starts to decline due to resource depletion. We hypothesize that a shortage of oil will make biofuels highly profitable, lead to a take-off for the biofuel industry, and lead to food shortages and starvation. We do not reject this hypothesis. A number of proposed policies turn out to delay rather than cure the problem. A better policy is to develop alternative energy sources that do not require agricultural land. In addition one should consider building support for a ban on biofuel production requiring such land.

1. Introduction

“Biofuel revolutionaries — like Silicon Valley venture capitalist Vinod Khosla — see plant power as a way to break America's dependence on foreign oil, and produce auto fuel that doesn't kill the climate. Opponents dismiss biofuels — most of which are currently distilled from crops like corn and sugar cane — as a blind alley, one that drives up food prices without saving the earth.” Walsh (2008).

“Demand for ethanol and other biofuels is a "significant contributor" to soaring food prices around the world, World Bank President Robert Zoellick says. Droughts, financial market speculators and increased demand for food have also helped - - - -The soaring costs of food and fuel led to riots in Haiti and Egypt and a general strike in Burkina Faso this week. Skyrocketing food prices are topping the agenda this weekend of the World Bank and International Monetary Fund annual spring meetings in Washington. - - "In Bangladesh a two-kilogram bag of rice ... now consumes about half of the daily income of a poor family," he said." NPR (2008).

The above quotes show growing concerns about a conflict between biofuel production and food availability. These concerns are to a large extent based on recent events. In this paper we take a longer term view and hypothesize that dwindling oil production will lead to radically different conditions for biofuel production. Lack of oil will lead to soaring prices for liquid fuels including biofuels. In turn, demand for feedstock for biofuel production will cause food prices to increase. If so, the consequence will be starvation among poor people who already depend on the staple food used as feedstock.

We develop a simulation model to explore the long-term consequences. The model is an aggregated representation of the markets for food and liquid fuels (oil and biofuels) and the couplings between these markets. At the outset we assume that there are no regulations in place to limit production of biofuels. Market development is driven by competition.

In this paper we reserve the term biofuel for biofuels produced from feedstock grown on land suitable for food production. For instance, while the value of sugarcane for human nutrition is limited, sugar plantation land could be used to produce food crops with higher nutritional value. Thus, we focus on biofuel production in direct competition with food production for nourishment. We do not include in our definition biofuels produced from forest products, products from aquacultures etc. (agricultural residues are included since they remove nutrients from land areas).

The simulations suggest that the hypothesis cannot be easily rejected. Oil depletion is likely to lead to considerably higher food prices than what has been observed thus far. This calls for a new look at policies. Simulations show that removing current subsidies to biofuel production is of only limited value, and so is a possible fee on biofuels. Improvements in fuel efficiency, which are likely to have the most beneficial effects on import dependence and CO₂-emissions, have limited effects on food prices. This means that one must explore new policies that work to separate food markets from the fuel markets. The challenges involved imply that time is short.

Section 2 presents the simulation model with reference behaviours for isolated markets. Section 3 shows the base case development when all three sectors interact. Section 4 presents policy tests and Section 5 concludes.

2. Model

The details of the model are documented in Sandvik (2008). Figure 1 shows an overview of the model structure. In the oil market price of oil (and easily substitutable fuels) is determined by oil demand and oil supply (production). In addition there is a loop to the left where oil production is dampened by production costs - which increase when oil reserves decline. On the right, indicated oil demand increases with economic activity.

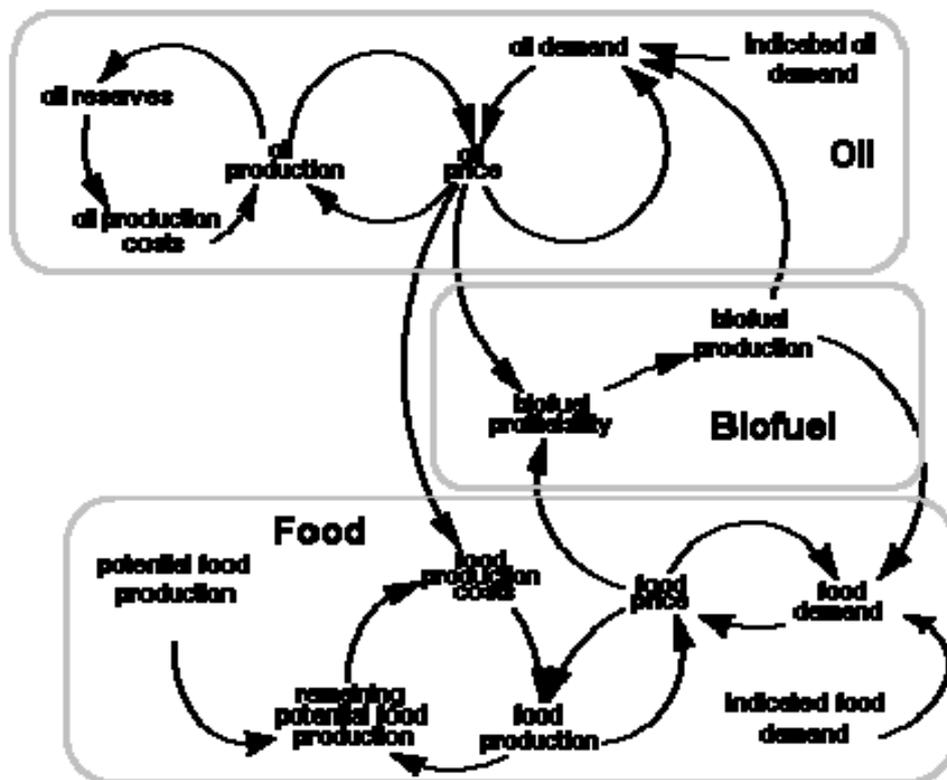


Figure 1: Causal loop diagram of model structure

In the food market, (staple) food price is determined by food demand and food supply (production). To the left is a loop where marginal food production costs increase as more and more of the remaining potential for food production is used. Potential production increases over time by exogenous technological progress. Production costs also increase with the oil price since food production requires use of tractors, fertilizer, and transportation. On the right, indicated food demand increases with population size and income.

Finally, the oil and food markets are coupled through the biofuel market. Production of biofuels depends on profitability. Profitability increases with oil (liquid fuel) price and is reduced by food price and thus the cost of feedstock.

As a starting point, our model builds on an assumption of free markets and competition between substitutes. Compared to regulations that may be needed in the future, current regulations and trade barriers are of minor importance for our model. To illustrate, about half of Brazil's sugarcane is currently used to produce ethanol, WorldBank (2008). Ethanol production has a long history in Brazil; the domestic market is large, well established and flexible. A growing share of Brazilian sugar mills can produce both sugar and ethanol, Schmidhuber (2006). When the oil price is high enough to make cane-based ethanol competitive, producers sell sugar at a price that reflects the oil price. As Brazil is the leading sugar exporter, these shifts between sugar and ethanol production determine the availability of sugar on the world market. The sugar price is therefore tightly linked to the oil price, Schmidhuber (2006). With sufficiently high oil prices one should also expect to see similar couplings between the oil price and prices for other feedstocks such as maize, potatoes, wheat, and cassava. Even for types of food that will not be used to produce biofuels, competition will be felt through the competition for arable land.

2.1 Oil sector

Figure 2 gives a detailed overview of the oil sector. We assume increasing costs with decreasing remaining oil resources, consistent with much literature on petroleum resources. It takes more drilling to find new resources, the fields become smaller and smaller, and activities move towards more remote places. Over time, these tendencies will dominate technological progress. Shortage of oil will eventually bring the oil price to high levels, which is the main underlying reason for our hypothesis. We assume limitless potential supplies of liquid fuels when oil prices exceed costs of alternative fuels coming from unspecified sources such as oil shale, tar sands, coal, and non-food biofuels. We assume that the break even price is 200 USD per barrel.

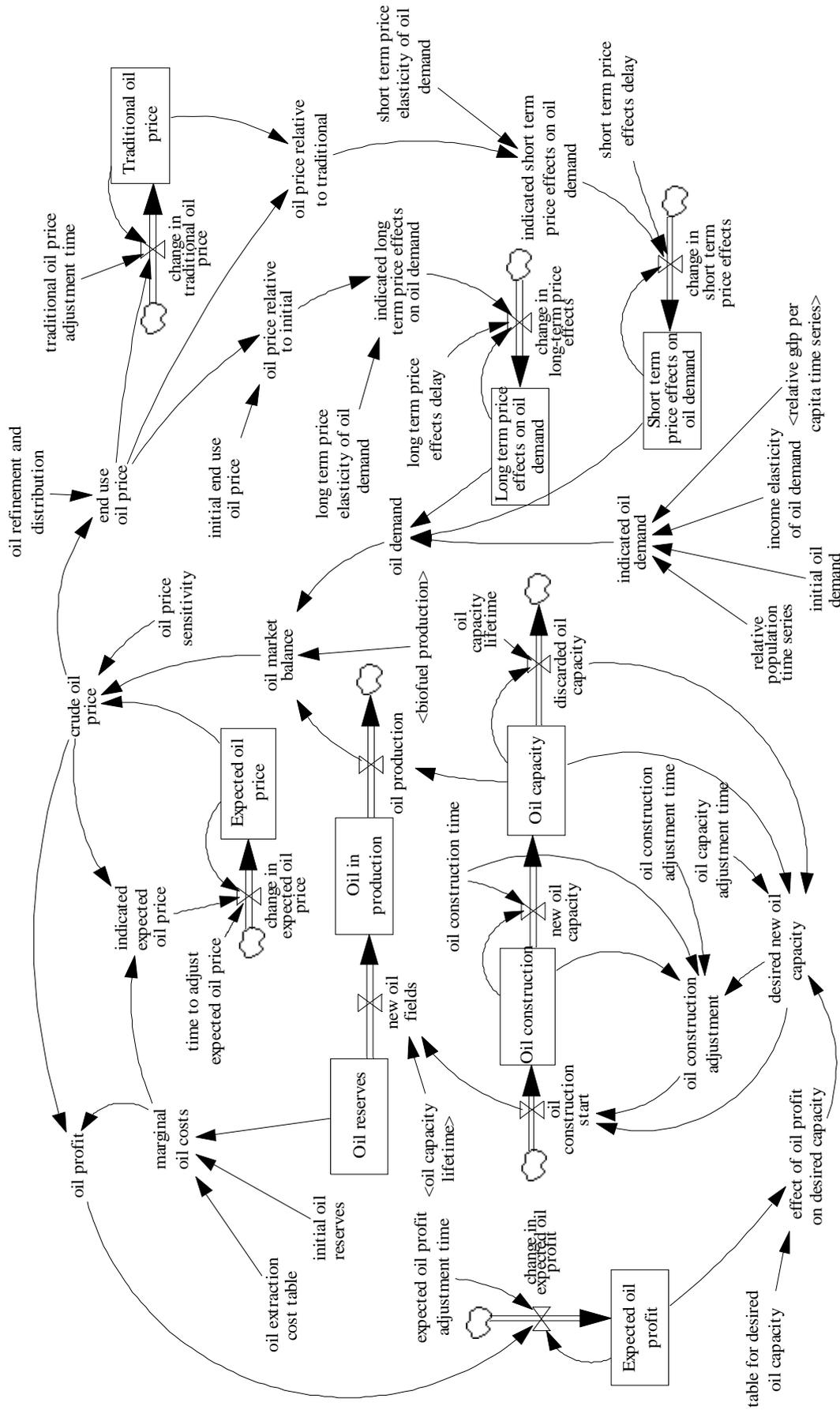


Figure 2: Oil market

Indicated oil demand grows in pace with exogenous world population and per capita income modified by an income elasticity. These effects create an additional pressure on the oil price. Actual oil demand is price sensitive. The expected oil price is influenced by the average of current oil price and current marginal oil costs. The crude oil price builds on the expected price and is modified by the current oil market balance between production and demand, Sterman (2000).

The dynamics of the oil market are dominated by a slow depletion of reserves and long times to explore and develop new fields, here combined in the construction time. On the demand side, we assume that long-term changes follow the oil price with a long delay for technological improvement and replacement of oil consuming capital. In the short run, there is always a limited potential for adjustments in the utilization of existing capital equipment.

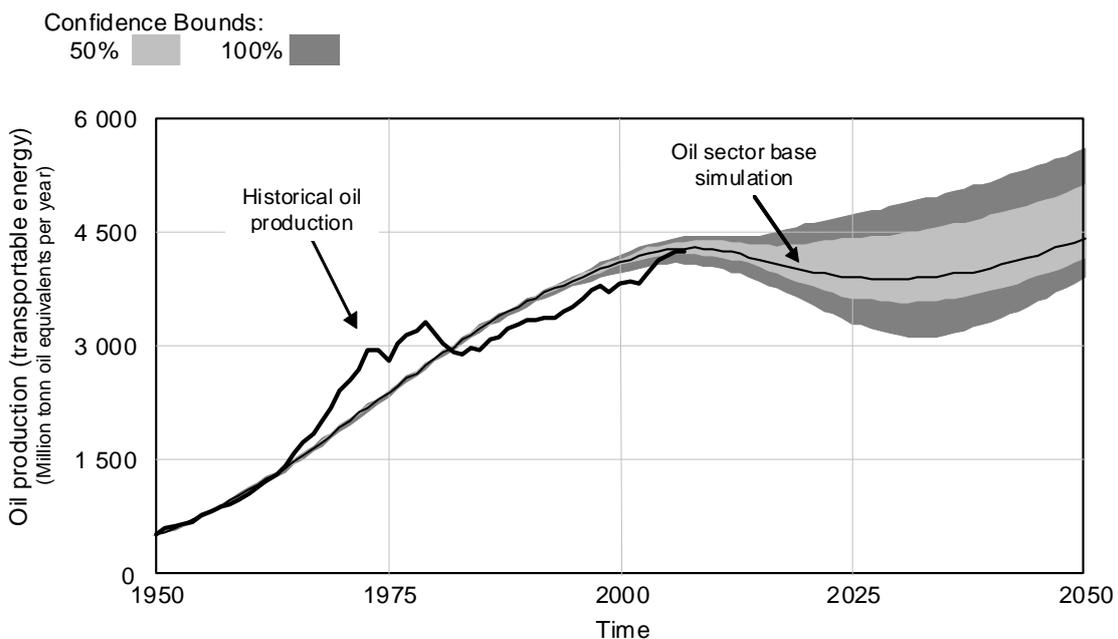


Figure 3 shows the behaviour of the oil sector when simulated in isolation from the biofuel sector. Uncertainty is introduced in a limited number of assumptions on the demand side; all model uncertainty is not captured. The model is consistent with the peak oil hypothesis. The decline in traditional crude oil production is counteracted by production of high cost liquid fuels. The oil price reaches the fixed cost level for alternative non-food fuels before 2025. Towards the end of the simulation, prices have reduced demand by more than 50 percent of indicated oil demand. We have not made efforts to make the model reproduce the commodity cycle behaviour seen in historical

time-series. The simulation produces the key driving force for the hypothesised take-off for biofuels.

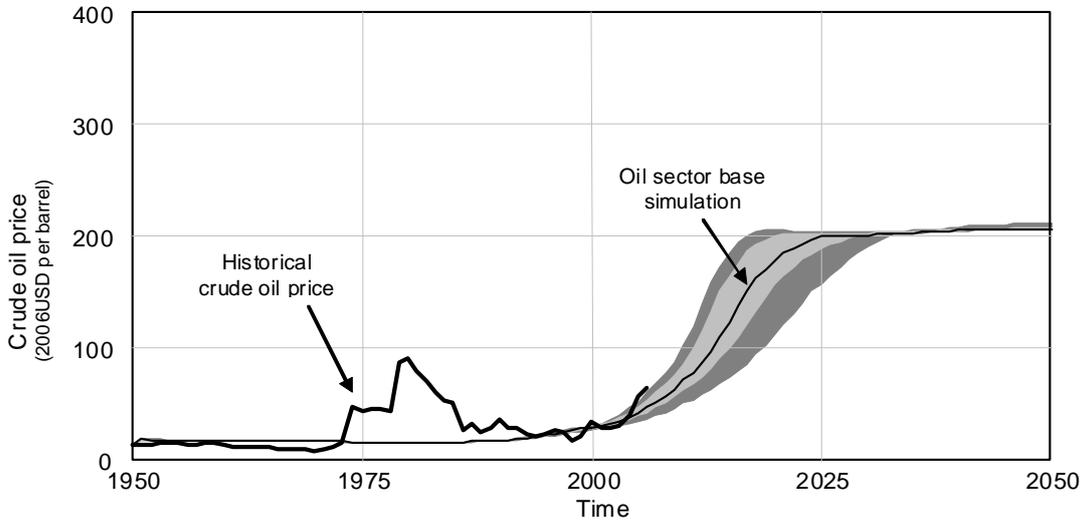


Figure 3: Sensitivity runs of the oil sector without biofuels.

2.2 Food sector

Figure 4 shows a stock and flow diagram for the food market. The exogenous influences on food demand come from world population and from per capita income modified by an income elasticity. This causes an upward pressure on food prices. Prices in turn lead to lower food demand either through substitution in the direction of staple foods or through malnutrition.

Food production also reacts to food prices. Utilization of arable lands around the world is assumed to increase with increasing profitability, after a time needed to finance and cultivate new land or to change to new crops. Potential production on world arable lands is assumed to increase exogenously over time due to technological improvement. Marginal production costs for food increase when more marginal lands are being utilized and costs increase with the oil price. The food price is determined in a similar fashion to the oil price.

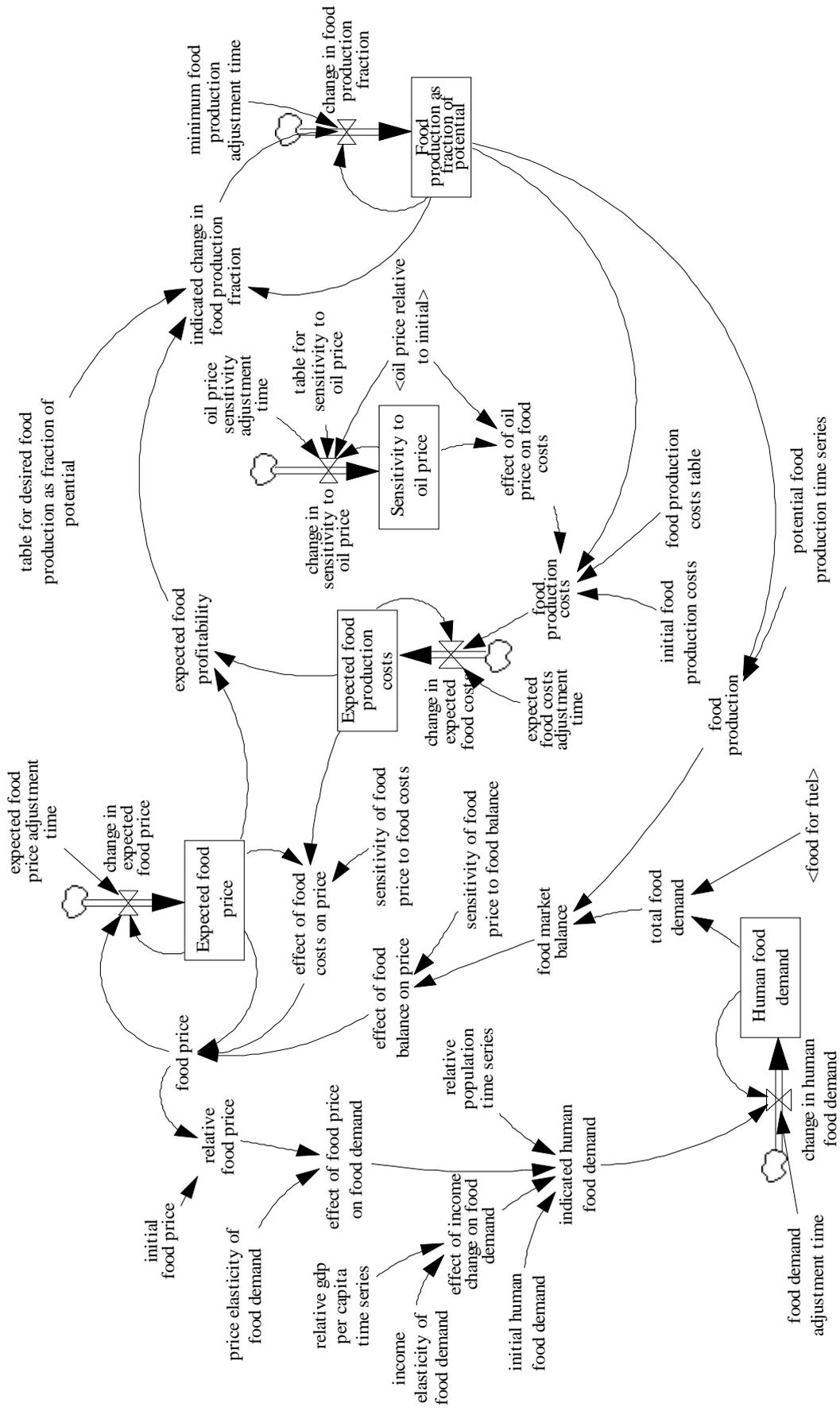


Figure 4: Food market

Figure 5 shows behaviour of the food market when there is no production of biofuels. The model is initialized such that it replicates historical food production. Potential food production is all the time well above actual production and increases over time. Food prices fall historically with rapidly increasing potential production. Over time, increasing prices are needed to bring production closer to the potential. In a separate simulation food production costs are influenced by the increasing oil price from Figure 3. Food price increases somewhat, while production drops only very little. The scenario in Figure 5 suggests that food prices are likely to increase even in the case with no biofuel production.

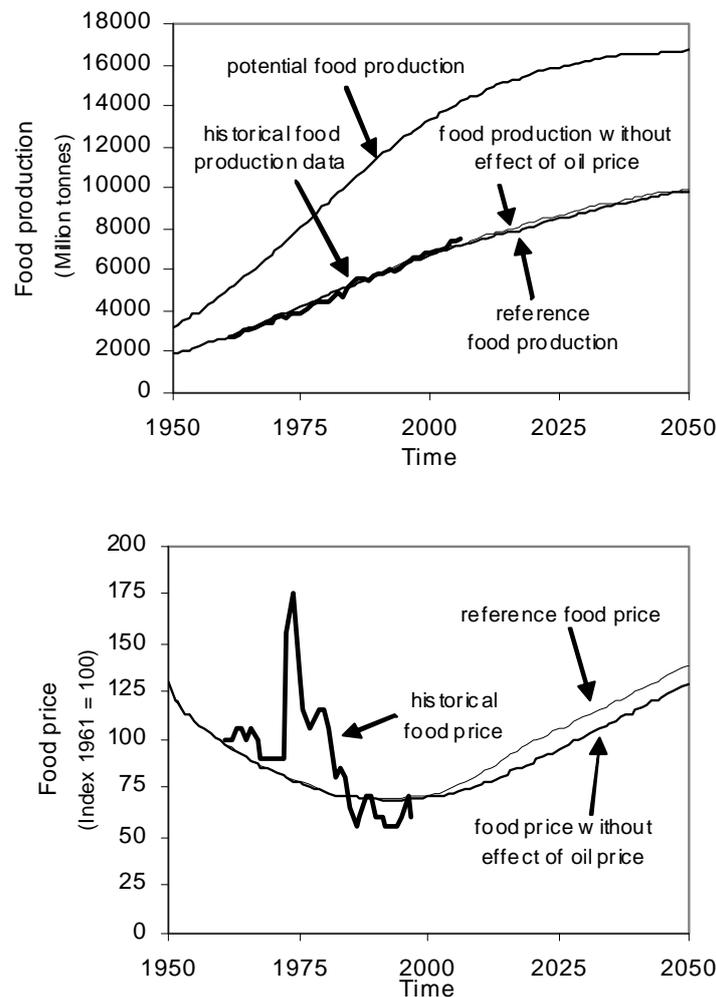


Figure 5: Development in food production and food price with and without increasing oil prices, no biofuel production.

2.3 Biofuel sector

Figure 6 shows a stock and flow diagram for the biofuel sector. Investments in biofuels are determined by profits, which in turn depend on the oil (liquid fuel) price. A take-off

of the industry depends on prices exceeding production costs. To take account of the fact that this is a new industry, early investments depend very much on external financing, which in turn depend on expected profits and existing capacity. Capacity is modelled similar to oil production capacity with a construction delay. Accumulated biofuel production influences efficiency improvements (learning curve effect), which in turn determine the amount of feedstock (food) needed per unit of biofuel. Currently feedstock makes up about 50 of biofuel production costs, IEA (2006). The use of feedstock means that biofuel costs dependent directly on food prices.

Figure 7 shows how biofuel production develops for the most likely oil price from Figure 3. In a scenario without governmental subsidies and other forms of support, there is hardly any biofuel production before 2010. In a simulation with support, production increases at about the same rate as historical production, I.E.P. (2008). The support variable is an aggregate of all public support measures. It steps up to 170 million USD per Mtoe in 1975 (the start of the Brazilian ethanol program). This support level corresponds to about 0.15 USD per litre gasoline; or 30 to 40 per cent of what the World Bank considers to be the cost of current support measures in the United States, WorldBank (2008).

Figure 8 shows profits for the cases with and without support. Clearly, support is needed for investments to take place before 2008.

2.4 Food security

While we do not make any attempt to model and quantify food security or starvation, we note here that it does not take large increases in food prices to cause severe problems for poor urban populations with no possibility of growing their own food. In low income countries about 47 per cent of household budgets are spent on food; first and foremost on low value staples, such as cereals, Regmi (2001). Ironically, with higher food prices, low income families have less potential for substitution than wealthy ones since they already depend on low value staples.

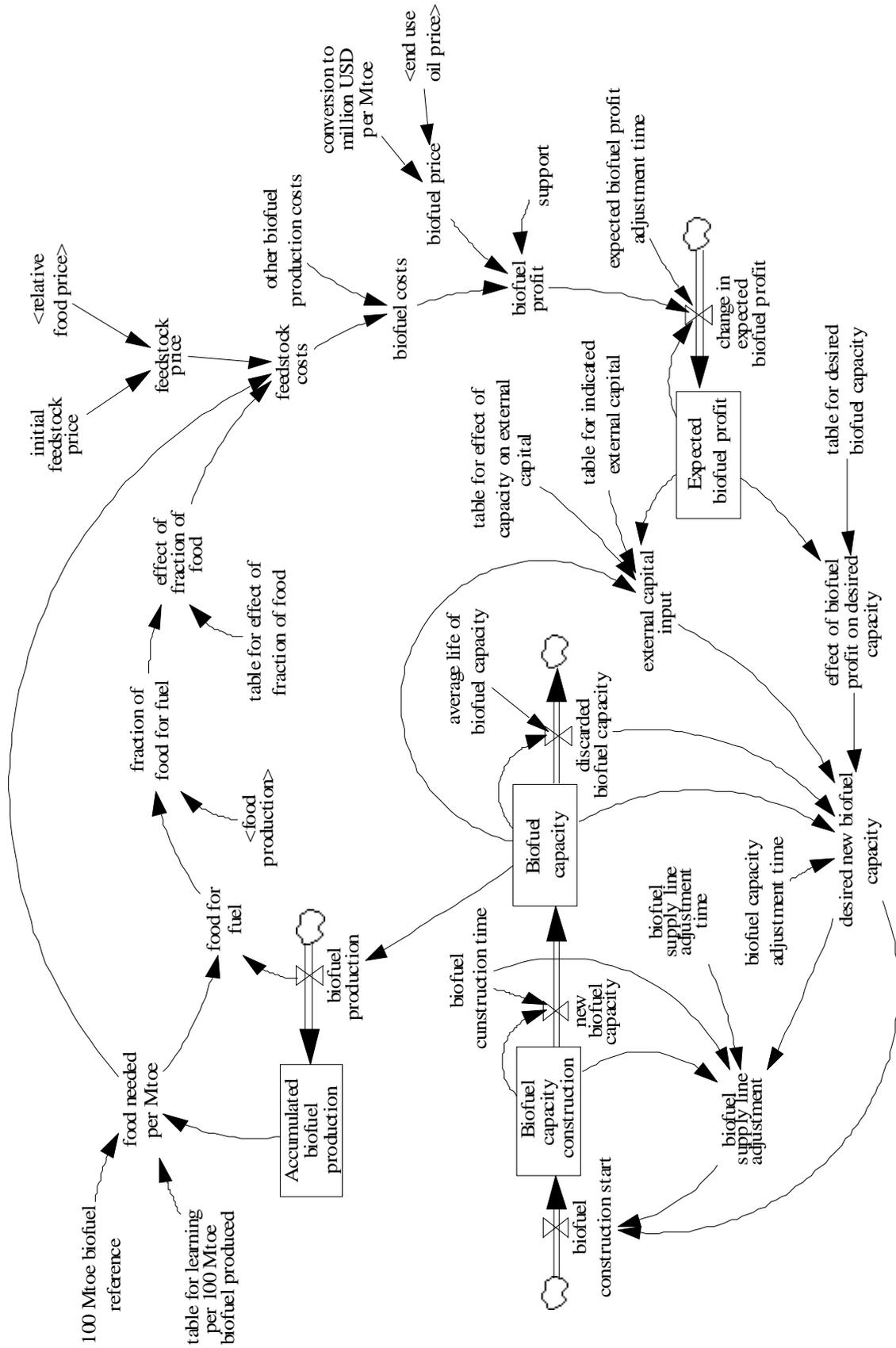


Figure 6: Biofuel sector

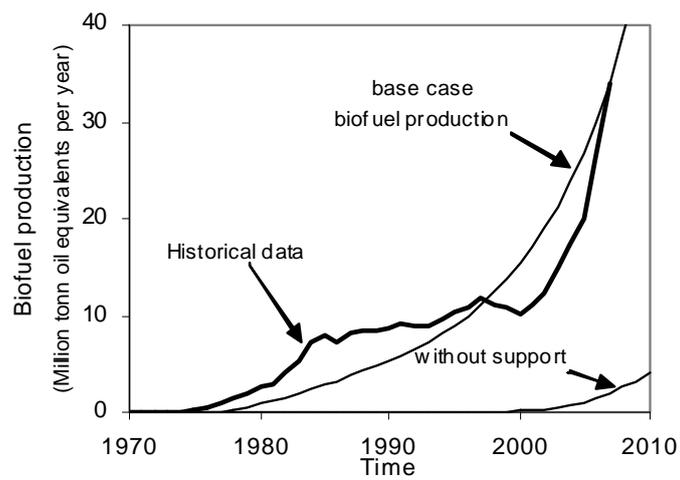


Figure 7: Biofuel production

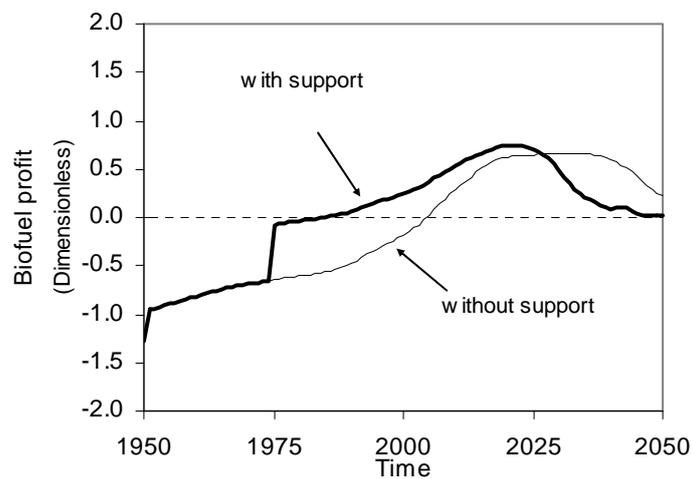


Figure 8: Biofuel profits with and without support

3. Base case

Then we connect all three sectors and keep the policy of supporting biofuel production for the entire period. Now biofuel production will influence both food and oil prices. Figure 9 shows sustained strong growth in biofuel production. Recall in 2008 production was less than 40 Mtoe per year. The main effect of the increased biofuel production is to substitute for expensive oil, while some of it allows for greater oil consumption.

The increase in biofuel production could be a valuable contribution to energy security for many countries. Oil import dependence would be reduced and time would be gained to adapt to a higher oil prices. Most likely, oil substitution would also lead to CO₂ reductions.

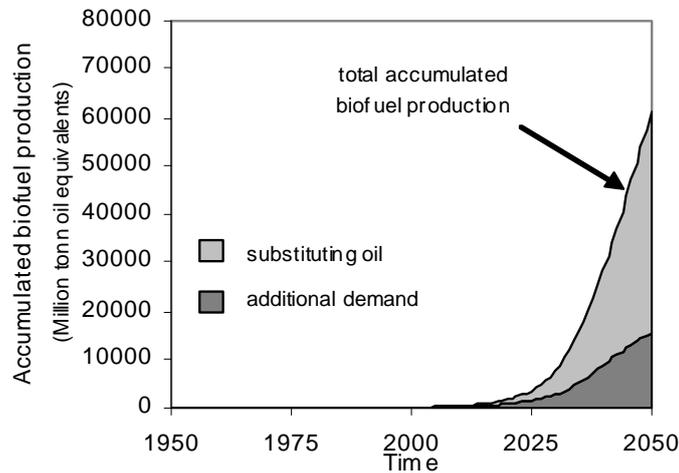


Figure 9: Biofuel production

Figure 10 shows how the oil price develops compared to the reference case without biofuels. A lower price than in the reference case explains why biofuel production led to additional consumption in Figure 9.

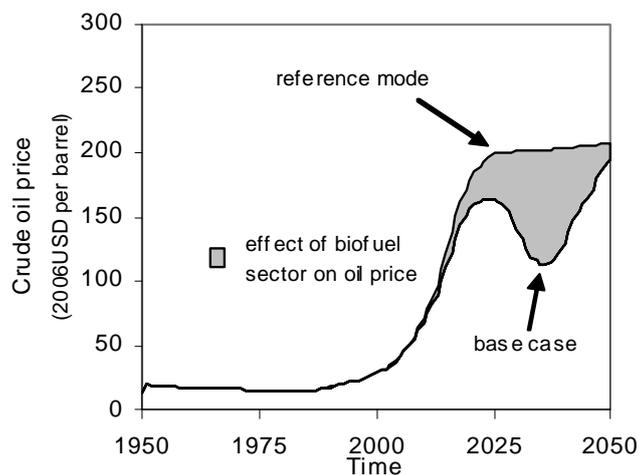


Figure 10: Oil price

Figure 11 shows that demand for feedstock for biofuel production leads to a boost in food production. In 2050 production is only 2000 Mt below the production potential, see Figure 5. However, much of the food used for human consumption in the reference

scenario is now used to produce biofuels. Total food consumption drops while the population is still assumed to increase.

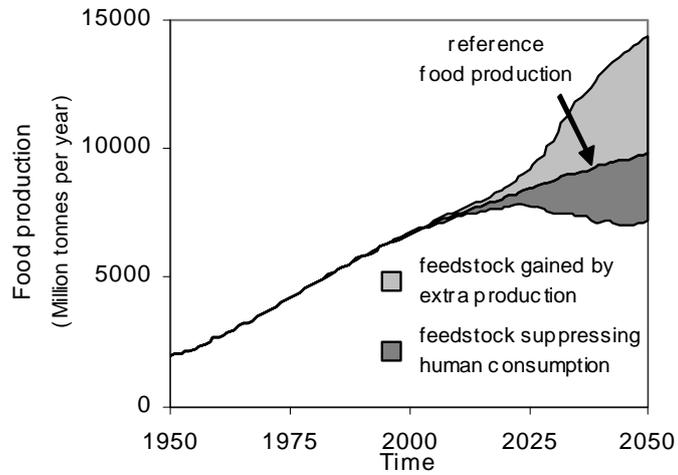


Figure 11: Food production

Finally, Figure 12 shows that food prices increase dramatically towards the end of the period. A first comment is that prices go so high that it is likely that several model assumptions will not hold. For instance, starvation is likely to reduce population growth and high oil and food prices are likely to dampen economic growth. A second comment is that even a much more modest development of food prices in the same direction is unacceptable and calls for new policies.

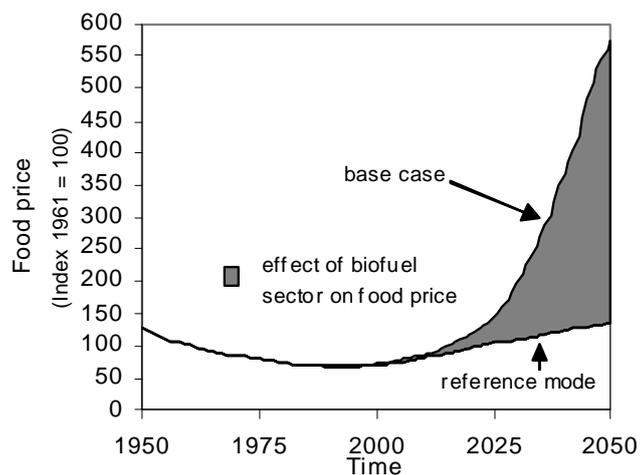


Figure 12: Food price

4. Policies

The base case calls for policy initiatives. Here we test three policies: Removal of current biofuel support, a fee on biofuel production, and improvements in energy efficiency.

In the base case scenario, biofuel production is subsidized with a constant amount per produced unit from 1975 and throughout the rest of the simulation, see Figure 8. Clearly, if problems in terms of increased food prices occur, and profits in the biofuel sector grow to high levels, it would be easy and natural for governments to remove the support. Figures 11 and 12 shows that food consumption stagnates around 2020 and prices start to soar. By this time it should be quite obvious that support is no longer needed, although concerns about oil dependence and CO₂ emissions could still be influential. Figure 13 shows that the effect on food prices is only marginal. The reason for this is that the biofuel sector has already taken off and production is profitable without support.

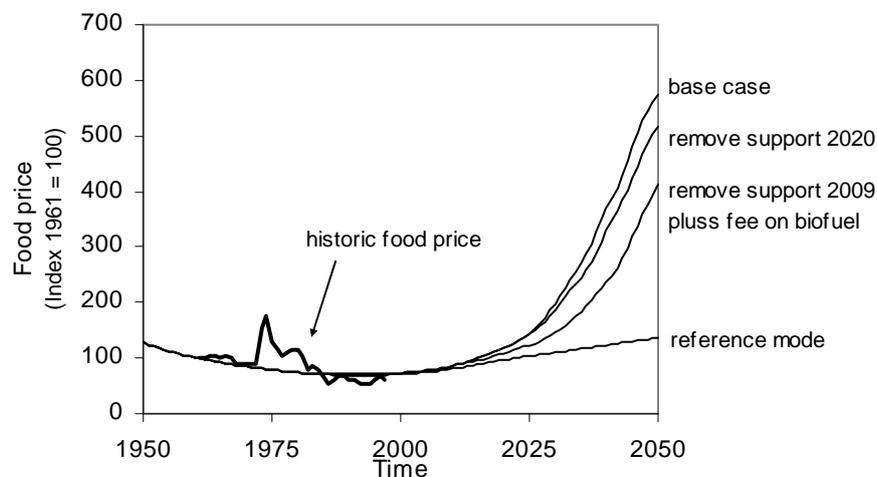


Figure 13: Base case, removal of support in 2020, and removal of support and introduction of fee in 2009

Knowing the limited effect of removing support in 2020, and assuming far-sighted policymakers, what would the effect be of removing support in 2009 and introducing a fee at the same time? The fee is 170 million USD per Mtoe; similar in size to the removed subsidy. Figure 13 shows a somewhat greater effect. However, food prices still rise to unacceptable levels; the sector still takes off.

Larger fees would be needed to counteract the rising pressure from soaring oil prices. Political aversion towards fees and taxes suggests that this is not an option, at least not in the near future. What about measures to keep the oil price down? Policies that reduce demand for oil have the potential to reap many benefits: import dependencies are reduced, CO₂ emissions are reduced, and the market effect will be to lower oil prices and expenditures for consumers. Lower oil prices in turn reduce the pressure on the food market. Efficiency improvements could be stimulated through other policies than taxes, for instance through R&D, standards and building codes, information campaigns, and subsidies, see e.g. Socolow and Pacala (2004).

We implement a conservation policy on top of the previous policy with no support and a fee for biofuels after 2009. The conservation policy is sufficiently effective to cut world oil demand by about 40 percent by 2050, compared to the base case. This means that it is quite successful with respect to reducing CO₂ emissions. However, Figure 14 shows that food prices still rise to unacceptable levels.

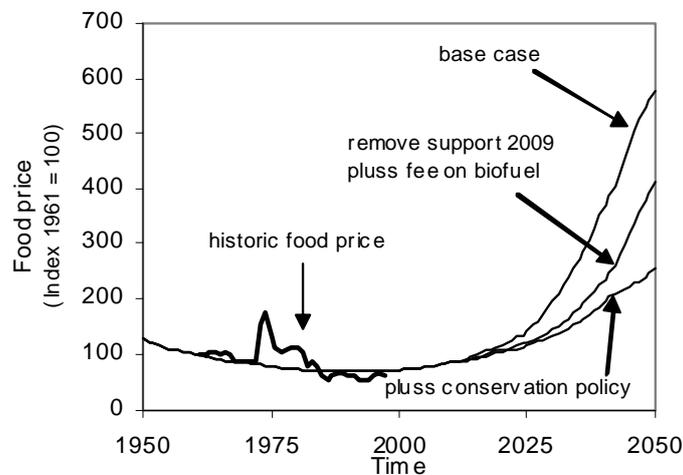


Figure 14: Effect on food price of conservation policy in addition to previously best policy

The main reason for the rising food prices is still the oil price. When demand is reduced through conservation, Figure 15 shows that the increase in oil price is delayed by only 3 years. The lower oil price, however, is sufficient to delay investments in conventional oil and in non-food alternatives to oil. Hence lower demand means lower supply and consequently the effect on oil price will be limited.

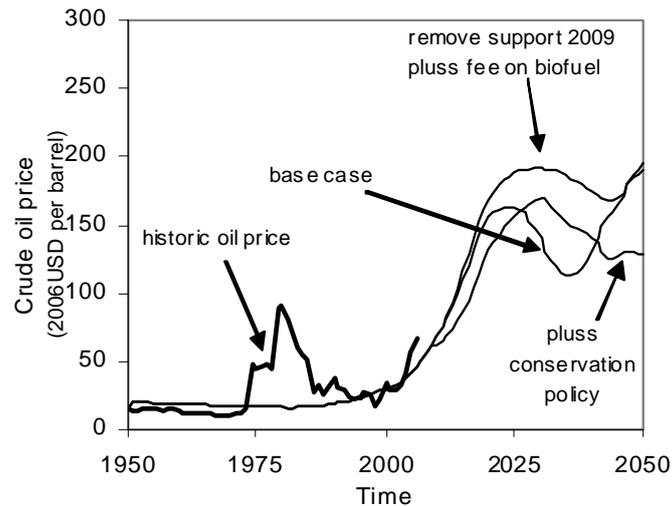


Figure 15: Effect on oil price of conservation policy in addition to previously best policy

Another policy to reduce oil prices is measures to boost oil production. Clearly this policy will not lead to reduced CO₂ emissions and it will not lead to reduced import dependence for countries that have no domestic oil resources. More supply will in the short run lead to lower oil prices. However, as in the case with higher efficiency, in the long run this effect will be counteracted by increased demand. In addition, accelerated depletion of oil resources will lead to more rapid increases in oil production costs. In sum, delaying the increase in oil prices by a few years will not hinder food prices from rising.

On the other hand, technological breakthroughs leading to limitless production of low cost alternative liquid or easily transportable fuels, would ensure lasting low oil prices and would remove biofuels as a profitable option. Before such options eventually materialize, one should prepare for the possibility that they will not arrive in time.

While the tested policies are all likely to increase the availability of food somewhat, the simulations suggest that the main effect is only to delay problems and not to cure. Therefore it is important to seek creative solutions. One seemingly farfetched option is to prohibit production of biofuels worldwide; that is, biofuels from land areas suitable for food production. However, the idea is in many ways related to international agreements to prohibit slavery, to limit child labour, to protect endangered species etc.

Food is, unlike most other goods, needed for survival. People have lived without access to fossil fuels and most modern products, but never without food. Agricultural production has been ideal for and has depended on the institution of private property rights. As long as the frontiers for production have been extended, resource rents in agriculture have been limited by competition. If, however, profits and resource rents come to increase dramatically, debates over private property rights will surface. Conflicts similar to those seen in countries where few landlords own most of the land could be the result. Historically, hunger has been the motivation for upheavals and revolutions. One possibility is to tax away the resource rent, as is discussed for fisheries. A slow development in this direction for fisheries suggests that this is politically very difficult, at least over a few decades. It seems easier to enact and enforce a ban on production of biofuels.

5. Conclusions

We have built a simulation model to test a hypothesis of food shortages due to increased biofuel production. Even before biofuel production is considered our model suggests that food prices will rise due to population and income growth on the demand side and dwindling idle resources for food production on the supply side. Depletion of oil reserves and increasing demand due to population and income growth cause oil prices to rise. This makes easily substitutable biofuels profitable and makes biofuel production take off. Since the biofuels we have focused on use food as feedstock, biofuel production leads to a significant increase in the demand for food and to rapidly escalating food prices.

Removing subsidies on biofuels and politically feasible fees on biofuels only work to delay food price increases, not to avoid them. Efforts to reduce demand and to increase supply of oil have similar effects. One cure is to invent a cheap substitute to oil that leaves biofuels unprofitable. In case this does not materialize, one should start discussions of an international ban on biofuel production from land areas suitable for food production. It is important to start this process now because the policy process is likely to take years.

There are many options to improve our model with better formulations and better data. However, the problem at hand will always be a problem complicated by uncertainty. Therefore the analysis should be extended by risk analysis.

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