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The biofuel controversy

by

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Abstract

About a decade ago, developed countries decided to promote production of biofuels aiming to reduce greenhouse gases, to contribute to energy self-sufficiency and to create additional demand for agricultural commodities. The introduction of mandatory blending requirements and lavish subsidies spurred fast adoption of this technology. The controversy arose when the completely inelastic shift in demand, caused by the blending requirements, contributed to the present food crisis, and when net savings on fossil fuels turned out to be disappointing because of the high fossil fuel intensity of agricultural inputs, processing and transport. The underlying issue is that rising scarcity of fossil fuels will accentuate the competition for land, fertilizers, and labor between food and energy crops, and put nature under additional pressure.

In policy terms, this defines three major tasks. The first is replacing the current excise taxes on energy carriers by a uniform carbon tax, so as to mitigate greenhouse gas emissions in an efficient manner. A second task is to prevent price fluctuations on the oil markets from destabilizing food markets, as happened in recent years. Introduction of upper limits on the use of food for biofuel could prove effective here. A third, much wider, task is then to make the transition to a biomass based energy production possible and sustainable. Technically, this entails to safeguard biodiversity and soil fertility, taking into account the mounting scarcity of minerals needed for fertilizer production. Institutionally, the task is to protect the property and user rights of the plantations where energy crops are to be grown, and to maintain adequate labor standards and living conditions.

1. Introduction[1]

The rapid rise in food and energy prices that started in 2007 persisted into 2008, and so did the debate on its causes and consequences. Biofuels figured prominently among the causes of what soon was referred to as a food crisis (IFPRI 2008; FAO 2008; Ivanic and Martin 2008; Keyzer et al. 2008), and the policies in the EU and the US to promote their use were specifically blamed (Mitchell 2008; OECD 2008; Rosegrant 2008; Tangermann 2008).

Biofuels are liquid fuels for use in transport. They take the form of bioethanol from cereals, sugar beet or cane, and of biodiesel from vegetable oil. They can substitute for and be blended with fossil fuel based gasoline and diesel, respectively, and in low concentration be used in regular combustion engines of cars and trucks, and hence be distributed by oil companies relying on existing infrastructure. They can also increase the octane number of gasoline, and car manufacturers have designed engines to be marketed (e.g. see NEVIS 2008) that promise to increase significantly the fuel efficiency of combustion. In anticipation of these developments, some countries, particularly those with little hydropower and a major domestic car manufacturing industry, will be inclined to bet that such flexible fuel vehicles are the future winners in the contest for the preferred type of combustion. Current experiments with biofuels prepare for this transition.

Biofuels can reduce import dependence on fossil fuels as well as mitigate greenhouse gas emissions, where their use is in principle CO2-neutral, since all carbon emitted after combustion in the vehicle was previously sequestered by the crop. As prices of fossil fuels keep on rising, while supplies of OECD countries increasingly originate from less than secure suppliers, the import dependency argument has gained weight, especially for oil.

Furthermore, the crops used as feedstocks can be tilled and harvested with proven technology, and the conversion processes (fermentation to make ethanol and esterification to make biodiesel) are well developed and operational at commercial scale. Finally, use of food crops for biofuel until recently offered a welcome outlet for agricultural products whose prices had been in a deep glut for quite some time but now with rising food prices doubts have been emerging and various objections that were already raised much earlier have gained prominence.

First, biofuels can only contribute a modest fraction to the overall energy needs in transport, beyond which they would push food production beyond its limits, particularly at a time that income growth and urbanization in Asia lead to fast rising demand for meat and animal feeds. Even the current percentage-wise relatively low levels of biofuel use in transport create major pressure on food markets, witness the present crisis. This pressure would be attenuated if biofuels were obtained from crops grown on land not suitable for food crops and if a greater part of the plant was usable for it. However, progress has been remarkably slow in realizing this so-called second generation technology, particularly because it proves difficult to scale up to industrial level the digestion of cellulose membranes by ruminants. Breakthroughs have been announced repeatedly but have not yet entered the commercial phase (Sims et al. 2006; Royal Society 2008) and even the most optimistic predictions (OECD 2008) do not expect introduction before 2012.

[1] The authors thank Lia van Wesenbeeck for her comments.

Second, detailed studies point out that in practice the production of biofuels requires a considerable amount of fossil fuel inputs along all steps of the processing and transport chain, thus putting to question the environmental benefits and by the same token the import dependence argument that with a wide range of variation estimates a fossil fuel need of about one third of the biofuel produced (see OECD 2008 and Von Blottnitz and Curran 2007 for summaries).

Third, biofuel crops need nitrogen fertilizers that cause increased emissions of NO2, which is a greenhouse gas many times stronger in effect than CO2. In addition, the burning and fallow resulting from land clearing for new biofuel plantations may cause enormous levels of emission. All this might nullify any savings on CO2 emissions from fossil fuels (Crutzen et al. 2007).

Fourth, as the strong demand for biofuel crops has already triggered land use changes world wide, threatening biodiversity, the call for enforcing sustainability criteria and for certification is getting stronger (WWF 2007; WWI 2006).

Finally, in virtually all countries except Brazil biofuel production is far from profitable and fully relies on sizeable subsidies and quantitative restrictions in the form of minimum blending requirements that, moreover, make biofuel demand highly price inelastic hence contributing to price instability on food markets, to increasing malnutrition, and to inflation.

Thus, biofuels have become object of major controversy. In the heat of the debate the use of food as fuel was denounced as unethical (Oxfam 2008), an accusation that could be readily refuted by pointing out that use of nonrenewables such as fossil fuels is possibly more unethical, and that agricultural and forestry products have always been used as fuel, in lighting and heating. In fact, biofuel was used in transport before fossil fuel. The first Diesel engine developed in 1898 ran on peanut oil; the famous T-Ford, introduced in 1908 ran on ethanol, and in the 1920s, 25% of oil sales were non-petroleum related. It was only to disappear in the late 1940s.

In our view, besides the doubts expressed about the significance of the contribution to carbon sequestration and to reduced import dependence, the key objection should be about the brute non-market means through which a new price inelastic demand category is made to force its way into agricultural markets.

At the same time, it would be an oversimplification to attribute all blame of the vagaries on food markets to biofuels, since this would neglect other factors such as speculation and rising demand for meat and animal feeds in Asia. Moreover, even in the absence of biofuels, the rising prices of energy would put food markets under pressure, via the competition for land between food and energy uses. After stopping all production of liquid biofuel as bioethanol and biodiesel from food crops (generation one) and from residues, wood and grasses (generation two), there would always remain a “generation zero” biomass demand in the form of firewood, charcoal, dung and crop residues that has served as fuel for cooking and heating ever since mankind lighted its first fire.

In the remainder of this communication we provide further background on this biofuel controversy. Our main assertion will be that rather than the issue of biofuel use itself, rising scarcity of fossil fuels leading to increased use of land for energy is the central issue that has to be addressed with better policy instruments than those currently activated in promotion of biofuels. Section 2 describes the current role of biofuels within the energy sector and envisages the impact of existing plans in the EU and the US to expand this sector. Section 3 provides an estimate of the implicit subsidy corresponding to the mandatory blending requirements for biodiesel in the EU.

Section 4 considers major policy implications: replacing excise on energy by a carbon tax, implementing caps on biofuel use to help stabilizing world food prices, and finally the more open question of assuring sustainable production of biomass for both food and energy use. Section 5 concludes.

2. Role and impact within the energy and agricultural sector

As shown in Table 1, conventional fossil fuels (gas, oil and coal) are still by far the major source of energy in the world, accounting for about 80% of the total. Next come nuclear energy and a range of renewables, primarily biomass in its traditional form as firewood, the major energy source in many developing countries. The transport sector uses about 20% of total energy, while industry and residents, in equal shares, consume about 40% each. Currently, biofuels contribute close to 1% of the world's energy use in transport, and are mainly used in the OECD countries and in Brazil.

Table 1 World demand for primary energy, and consumption of energy for transport and biofuels, by region, 2005, (EJ)

	OECD countries	India and China	Other developing Countries	Transition countries	World, total
Total energy demand	231.0	95.0	98.2	45.0	469.2
Gas, oil, coal	191.2	76.2	70.6	40.1	378.2
Nuclear	25.5	0.8	0.8	3.0	30.1
Hydro, renewables	14.3	18.0	26.8	1.8	60.9
Energy for Transport	52.3	6.6	21.3	3.8	84.1
Liquid biofuels	0.5	0.0	0.3	0.0	0.8

Note: 1EJ (=exajoule) = 10^{18} Joules.

Source: World Energy Outlook, 2007, p. 592ff, International Energy Agency, Paris

The International Energy Agency projects total energy demand in 2030 to increase by 50% relative to 2005, and still to be originating mainly from gas, oil and coal. Renewable energy is expected to double in size, and biofuel use to increase fourfold, but their shares in total remain small, nonetheless. Thus, irrespective of biofuel policies, the role of renewable energy is taken to remain modest.

The contribution that agriculture could potentially make to energy supply for the transport sector is constrained by the fundamental observation that the energy obtained from a hectare of a typical biofuel crop, say rapeseed in the EU, is equivalent to about 6-7 barrels of oil per year, while the world consumes 85 mln barrels per day. Ethanol in Brazil made from sugar cane under the most favorable conditions yields about 40 barrels per hectare but marginal lands suitable for biofuel will deliver at most 2-3 barrels/ha. Thus, there is no question that land availability puts a severe limit on the use of biofuel worldwide (Royal Society 2008). We briefly review policies pursued by the EU and US in this respect, and consider the prospects for increased biofuel production in other parts of the world.

The US implements its biofuel program through two types of subsidies. One is its general support to corn, bioethanol's major feedstock, the other a subsidy of about .50 USD/gallon to bioethanol processors, while ethanol imports from Brazil are prevented through tariffs. In 2007, ambitious legislation was enacted (EISA, the Energy Independence and Security Act), to expand existing ethanol production, and to promote biodiesel production (mainly from soybeans) as well as ethanol of cellulosic origin, for which adequate technologies need to be developed. The EISA-targets are ambitious: by 2022 this program is supposed to deliver 36 bln gallons of biofuels (approximately 12% of current US demand for transport fuel). Table 2 estimates the impact of the program on agricultural land use in the US, assuming that additional demand is met from domestic corn and soybean production with existing farm and biofuel technology.

Table 2 Land use for biofuels in the US, current and targeted

			EISA targets	
	2005	2007	2010	2022
Corn area (mln ha)	30.4	34.8		
Corn land for ethanol (mln ha)	4.4	8.5	11.3	14.2
(% of corn land)	*14.4*	*24.3*	*32.5*	*40.7*
Soybeans area (mln ha)	28.9	25.4		
Soybeans area for biodiesel (mln ha)	0.6	3.6	4.1	31.7
(% of soyland)	*2.1*	*14.3*	*16.2*	*124.8*

Note: EISA targets used here are 12 bln gallons ethanol and .65 bln gallons biodiesel in 2010 and 15 bln gallons ethanol and 5 bln gallons biodiesel in 2022, while the overall target is 36 bln gallons. For 2010 and 2020 %-areas are relative to the 2007 surface, hence a figure exceeding 100% for soybeans in 2022.

The table confirms that impact on land use will be substantial, especially for the biodiesel program. Since total harvested arable land consists for 50% of corn and soybeans, major reallocations in cropping patterns would be necessary, which since the US is exporter in both crops and a major one in corn, would significantly affect world markets, and far more than was already the case.

The EU on its part adopted in 2003 a directive (Directive 2003/30/EC) stating that member states should set mandatory minimum blending shares of biofuels in their gasoline and diesel use for transport fuel, starting from 2% in 2003 to reach 5.75% in 2010. The directive provides separate minimum targets for both gasoline, to rely on bioethanol, and diesel, to use biodiesel. Consequently, wheat and sugar beet are increasingly used for bioethanol, while rapeseed enters biodiesel production. Table 3 shows estimated current and future land use, based on the targets.

Table 3 Land use for biofuels, EU-27, current and targeted

			EU targets	
	2005	2007	2010	2020
Cereals area (mln ha)	61.2	58.7		
Cereal area for ethanol (mln ha)	0.3	0.5	2.6	4.9
(% of cereals land)	*0.5*	*0.9*	*4.4*	*8.3*
Sugarbeet area (mln ha)	2.2	2.3		
Sugarbeet area for ethanol (mln ha)	0.0	0.0	0.2	0.4
(% of sugarbeet land)	*1.3*	*2.0*	*10.1*	*19.2*
Oilseeds area (mln ha)	9.5	9.8		
Oilseeds area for biodiesel (mln ha)	2.6	4.9	10.3	19.6
(% of oilseed land)	*27.5*	*49.6*	*104.6*	*200.2*

Note: EU targets are 5.75% of transport fuel in 2010 and 10% in 2020. The 2007 crop areas have been maintained to compute %-area in 2010 and 2020, hence the figures exceeding 100% for oilseed land.

The tables show that the targets for oilseed crops are particularly challenging, due to the relatively low energy yields of these crops. The EU target of 10% of transport fuel from biofuel, slightly less ambitious than the US target in 2022, would already take some 15% of its total arable land.

With one third of the world's total ethanol production Brazil is the second largest producer, slightly behind the US, and the world's largest exporter. Its ethanol program started 30 years ago, using sugar cane as feedstock, and the residual cane-waste (bagasse) for process heat and power. Using state-of-the art technology, ethanol from sugar cane already becomes competitive when the oil price exceeds 40 USD per barrel (for reference, the 2008 peak in June of 2008 was around 145 USD). Furthermore, the production process is close to CO2 neutral, because virtually all inputs are of vegetable or biofuel origin themselves.

Brazilian government imposes a mandatory blending of 25% of ethanol with gasoline, which can now be used by all regular gasoline vehicles. Current fuel prices strongly promote ethanol use and a quarter of the Brazilian car fleet now consists of flexible-fuel vehicles, which can run on any proportion of gasoline and ethanol. Consequently, ethanol fuel achieves a 50% market share of fuel consumption of the gasoline-powered fleet in 2008. The ethanol program has not always been as successful. Subsidies were needed in the initial years to kick-start the program and in the early nineties when fossil fuel prices were low, the program slumped and the production of cars fit for ethanol came to a standstill.

Nowadays Brazil is widely believed to be the lowest cost producer of ethanol, and the combined ethanol-sugar facilities even produce a net surplus of electricity. According to OECD (2008) the margin between the gasoline price and net production costs of ethanol (energy, processing and feedstock costs minus the value of joint products) is positive for all the years 2004-'07, raising to some 0.30 USD per liter of gasoline equivalent in 2007.

Several other countries have the potential to become significant biofuel producers, but each is facing specific constraints. Ukraine and Russia currently avail of fertile land that is underutilized due to labor and management shortages and poor export opportunities. Commercial biofuel production with high input levels of fertilizer and pesticides and increased mechanization is currently being considered to supply export crops that would not have to meet the safety standards applying to food. Yet, this advantage would seem to apply for a transitory period only, and gradually food production is likely to become more profitable, particularly if developed countries, the EU in particular, liberalize their agricultural imports, while imposing sustainability criteria on them.

Tropical countries, such as Indonesia, Malaysia, Nigeria and Columbia have increased their palm oil production by about 10% per year since 2000, in response to world-wide demand. They now supply about 90% of world palm oil that contributes about a quarter of vegetable oil production. Commercial palm tree plantations can produce up to three times as much oil per hectare as rapeseed but the growth in production has been severely criticized because it encroaches on forest land, at the expense of biodiversity and, particularly on peat soils, with large emissions of carbon (Fargione et al. 2008).

China over the years 2003-2005 also stepped up its biofuel production, largely from food stocks that built up in the 1990s after years of good crops and limited export opportunities. These stocks had become unsuitable for human consumption. In 2007, however, as these stocks had been processed, and world food prices started rising steeply worldwide, it imposed a ban on the use of maize for this purpose, signaling mounting concerns about competition with food.

Finally, prospects for Jatropha, a bush-like oil producing shrub, have been reported on frequently, in particular because it can grow on road sides and marginal lands with low inputs. However, under such circumstances its yields are low as well, and harvesting of the fruits becomes labor intensive. It would seem that this shrub is best suited for local use, in combination with other purposes such as fencing and as part of land conservation schemes, and can substitute for purchased fuel (Jongschaap et al. 2007).

3. Implicit subsidies on biofuels in the EU

Countries implement their biofuel targets in different ways; see OECD 2008, USDA/FAS 2008 for an overview. As mentioned above, the EU increasingly opts for imposing minimum blending percentages of biofuels in total fuel. This is obviously motivated by the consideration that use of biofuel is not profitable and needs subsidization. Blending requirements are quantitative restrictions that oblige fuel producers to purchase biofuels at prices that exceed the equivalent fossil fuel price, generating implicit cross subsidies while avoiding public spending.

To highlight the significance of this subsidy and its sensitivity to changes in prices of food and fossil fuel, we look further into the case of biodiesel in the EU. We estimate production cost of biofuel under input-output assumptions with biodiesel made from rapeseed oil as raw material, using fossil fuel for the crushing of oil from rapeseed, the conversion of vegetable oil into biodiesel and for distribution, as well as factor inputs (labor and capital) for processing and transportation.

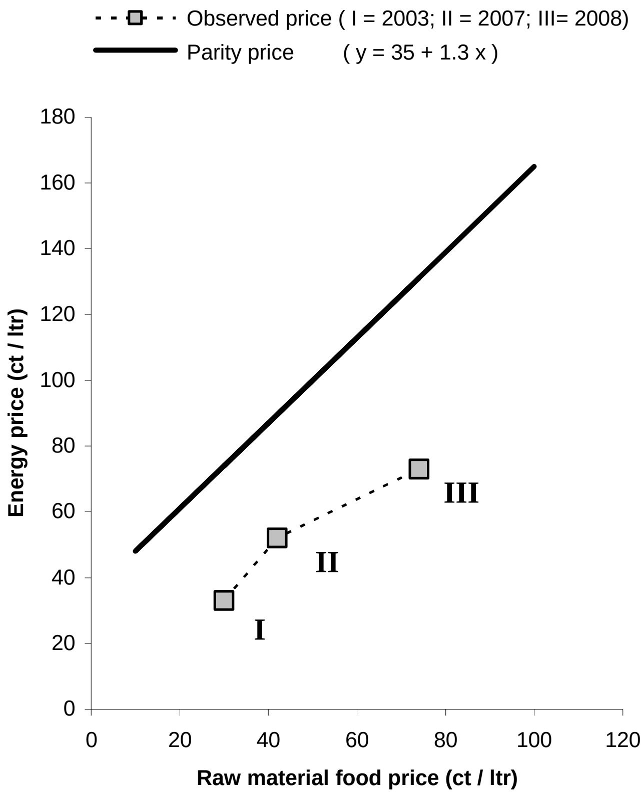
For simplicity, our calculation assumes that all biofuel would be obtained from biodiesel, disregarding bioethanol, which is somewhat more efficient but only plays a minor role in the EU at present. Biofuel and fossil fuel input are expressed in liters of the same energy unit, correcting for differences in caloric content. This makes it possible at constant factor input costs to compute the biofuel cost as a linear function of the raw material price of food.

This is shown in Figure 1 as the straight line, with factor costs of 35 euroscts/liter as intercept, and a net conversion factor of 1.3 measuring inefficiency in energy use as slope, which amounts to a .30 liter energy fuel to produce 1 liter of biofuel. The calculation follows the detailed life cycle analysis in Elsayed et al. (2003) that compares well with the six other studies surveyed in Frondel and Peters (2007). For reference, the total chain, covering biofuel production from rapeseed as well as cultivation and harvesting of the crop, has an energy loss of 44%. The cost of producing biodiesel can be compared with the prevailing energy and food prices, as represented on the I-II-III line, for the calibration year 2003, and for the second quarters of 2007 and 2008, when the crude oil price almost doubled.

Hence the straight line depicts the fossil fuel price above which it would pay to produce biofuel, and the difference with the I-II-III line shows the profitability gap that is covered by implicit subsidization.

It follows that for the second quarter of 2008 the resulting biodiesel subsidy reaches 56 cents per liter, which for a biofuel share of 3%, the current percentage of biofuels used for transport, amounts to a total subsidy of around 7 billion euro annually, or 5% of the 2008 EU budget of 129 billion euro. This subsidy will in principle rise proportionately as the mandate is expanded to 5.75% in 2010 and the prospective 10% in 2020.

Figure 1 Biodiesel parity price and price observations for 2003, 2007, and 2008.



Note. Biodiesel production costs are based on costs of energy inputs, unprocessed food as raw material (here: rapeseed oil) and factor inputs, measured in 2003 and taken from DFT (2003), deflating all prices by the factor input price. Price observations for rapeseed oil and crude oil are for 2003 (I), second quarter of 2007 (II) and second quarter of 2008 (III).

For comparison, current excise on diesel is 36 cts/liter on average in the EU, for a retail liter price of 145 cts/l. Hence for biodiesel an excise tax exemption would not close the profitability gap. For gasoline/ethanol the effect would be more favorable as the current average excise is 50 cts/l on average, which is about equal to the profitability gap for ethanol from wheat, according to data in OECD (2008), Figure 1.7. A full exemption of excise could be justified if the production process for biofuels was completely CO2 neutral, and fell under a carbon tax regime, to which we return below.

Efficiency improvements might allow for a reduction in slope and intercept of the cost line. Also, within biofuels a further shift to bioethanol is to be expected, also because use of diesel itself is to be curbed for health and environmental reasons (EEA 2008). However, OECD-FAO (2008) forecasts a downward modest correction in the course of 2008-2009, followed by a period of constantly high prices, in real terms over the next decade, because of sustained growth in demand for meat in Asia and the Middle East, high cost of production and transport due to high energy prices, and biofuel demand itself. Under such circumstances the profitability gap will remain large in the EU, and is more likely to widen rather than to narrow down.

4. Policies

In response to the massive critique in the media and political circles that biofuel policies are the major cause of high food prices, the European ministers for energy considered in their Council meeting of June 2008 to soften the requirements to the extent that energy used in hydrogen or electricity driven cars would become eligible within the renewable mandate, even when these depend on nuclear power and coal. In addition, it was suggested that the targets themselves are likely to be revised at an appropriate occasion. Thus, the biofuel controversy might seem to be over. Yet, we do not expect this to be the case.

First, while the introduction and relatively fast rise in mandatory blending targets is now widely seen as a major policy mistake, there might be arguments to keep implicit subsidization of biofuels in some different form, on the basis of a Pigovian tax argument to internalize external effects, since after all crop production in itself, as opposed to the fossil fuel inputs it relies on and the changes in soil conditions it may cause, does not generate net CO2-emissions.

Second, the price hike on the food markets has pointed to a tighter interconnection between food and energy markets, which needs to be addressed as it can seriously hurt the poor even in developed countries and also acts as major source of inflation.

Finally, relaxing the biofuel mandates will not prevent the use of biomass for energy. Worldwide, high prices of fossil fuel directly trigger more intensive use of firewood and crop residuals by households and industry and through this sharpen the age-old competition for land between food and energy uses. Abolishment of mandatory blending cannot change this. Producing biomass for energy in an efficient and environmentally sustainable way, therefore, remains an important priority.

This section comments on these three issues.

Carbon tax

Long before the emergence of biofuels, proposals were made to arrive at a carbon tax that would penalize greenhouse gas emissions, with adequate weights on various emissions depending on their greenhouse gas effect, in fact a regular Pigovian tax. For fuels, collecting a carbon tax would be relatively easy and similar to existing levies on gasoline. For other kinds of emissions, such as those from soils directly, special monitoring would be required, and in some cases taxes can be replaced by prohibition. The carbon tax could replace all other taxes on energy but to be effective it should be flat and not allowed to differ between countries. If implemented adequately internationally, such taxes should penalize emissions as they come and arbiter fairly among various types of fuel.

In practice, carbon tax rates vary widely. The San Francisco Bay area applies a tax of 0.044 USD per ton CO2, but in Sweden it is as high as 100 USD, or 20 eurocts/l. The IPCC, in a desk study covering 100 proposals to tax carbon, finds a similarly wide range. The EU has also been envisaging such a system (Dorigoni and Gulli 2002), but could so far not agree on the appropriate level of taxation. Carbon taxes at the higher end of the range, combined with tax exemptions for biodiesel and ethanol would be required to make biofuels a viable option in Europe. Clearly, this would reduce public revenue by significant amounts. The implicit tax computed in Figure 1 suggests a revenue loss in the order of 7 billion euro annually.

There are also implications for trade policy. As long as carbon taxes differ, it will be necessary for energy importing countries to apply corrective levies that have all the appearances of import protection. This may give rise to a host of trade disputes, especially since current WTO-regulations do not look favorably upon such actions (Holmes et al. 2003; Goh 2004).

It is in this connection remarkable that one of the most distortionary instruments, i.e. the present mandatory minimum blending requirements for biofuels, one of the most distortionary instruments for international trade, seems to be acceptable for the WTO. Motaal (2008) mentions that the WTO agenda is now primarily concerned with how to reduce import tariffs on bioethanol and biodiesel and how to make trade figures in biofuels more transparent, which currently have no separate tariff lines for bioethanol and biodiesel. This bypasses the large implicit subsidy to biofuel producers and the important trade distortions resulting from these quantitative restrictions. Yet, legally, transfers qualify only as subsidies when they are explicitly provided by government. Moreover, unlike non-tariff barriers the EU's biofuel restrictions are creating trade rather than reducing it. If the provision of blending mandates became a case in the WTO, the panel committee and the appellate body may still decide that such a policy is acceptable when subjected to the specific formulations in the Legal Texts, which particularly for agriculture were typically drafted to reduce dumping and import protection, and not to avoid exogenous upward shifts in demand.

The carbon tax is a sharpening of the existing system of trade in emission permits, whose implementation started recently (in The Netherlands in 2005) to effectuate the Kyoto Agreement. This trade is open to firms whose emissions exceed given norms, and makes it possible for heavily polluting firms that have no competitive alternative technology available to trade their obligations with firms that can more easily adapt, which in practice often means foreclosure. In parallel, several technical requirements are imposed on smaller energy users such as private cars and heating-apparatus.

Whereas actual implementation is recent, studies on the potential effects of carbon taxes and trade in emission permits started long ago, and were also reported on in De Economist (Smulders 1995; Heijdra and Van der Ploeg 1995; Van Ewijk and Van Wijnbergen 1995; Heijdra and Van der Horst 2000). From an allocation viewpoint, replacing the various excise and value added taxes by a carbon tax would raise economic efficiency as it amounts to eliminate many non-flat taxes by single pricing of previously free resource use, at a socially optimal level. Hence, both climate and the economy would gain. This used to be referred to as the "Double dividend" (Bovenberg 1995).

Trade in permits obviously offers advantages in terms of allocation efficiency and leads in principle to a uniform tax equivalent, but it requires careful monitoring of emission levels and proves to be rather vulnerable to lobbying in this respect. Also it must be decided which part of the tax collected should accrue to the public budget, and within this budget, which fraction should be earmarked for spending on the sectors that contributed the funds as opposed to say, reduction of public debt.

The carbon tax offers the advantage of uniformity but as far as the distribution of the collected taxes is concerned, all the problems of how to divide the proceeds over the owners hold, especially at international, above EU-level. The atmosphere is obviously the most global of all commons. When considering this common resource to be owned by humanity as a collective (Dasgupta 2007), the issue becomes how individual members should benefit. Of course, to the extent the collective needs to incur specific costs for its preservation, these can be subtracted without attribution to individual members. Yet, an entitlement distribution has to be agreed upon to distribute the remaining surplus. The common rules that let the polluter enjoy a major part of the benefits are exclusively concerned with the reduction of price distortions as opposed to the fair distribution of collective surplus. Alternatively, surplus distribution could provide every individual in the world with a base income. Those who spend less on carbon tax than they earn as base income would derive positive net revenue from it, and vice versa for large users of fossil fuels (UNEP 2007). In this logic, proceeds from all ecotaxes should be redistributed fairly, and therefore, generate automatic transfers accruing to the “rightful” owners worldwide. With resource scarcity mounting, it will become politically increasingly difficult to channel the proceeds of carbon taxes back to polluting sectors and countries.

Food price stabilization

Besides a high price level on food and energy markets, the increased price volatility on spot and futures markets requires attention. This volatility is partly originating from factors external to the food and energy sectors themselves, as raw materials have regained importance within financial portfolios, while financial markets are plagued by instabilities of various kinds. Addressing these imperfections requires action in the financial sphere as well as in the macro-economic domain but interventions on food and energy markets may be needed as well.

Large fluctuations in food prices are undesirable, for many well known reasons. The poor not covered by social safety nets are affected; farmers who cannot afford the income risk turn to less risky but on average less profitable crops, which amounts to inefficiency; traditional farmers do this for physical survival, commercial farmers to avoid bankruptcy, as they are more exposed through the non-food inputs they buy; finally, the macro-economy may suffer through the impact on wages and inflation, and the more so in poorer countries where food takes a larger fraction of consumer expenditures.

As a stabilization measure on the food markets themselves, it has been suggested, e.g. by IFPRI (2008), to build up and maintain strategic food stocks that should discourage speculation. However, experience with such stocks is mixed. Keeping emergency reserves situated in remote areas, say, in Ethiopia (DPPC 2004), has proved quite effective in allowing for fast food aid delivery in the wake of a disaster but past efforts with buffer stock operations that aim to stabilize international commodity markets have been far from encouraging. Public stockholding is costly, the nutritive quality of the stored food deteriorates rapidly, and stocks either get overfilled or depleted once speculators become active. This experience largely dates back to the 1980s when funds available for speculation were much smaller, speculative actions much slower, and the share of processed foods in total much smaller. Nowadays, most of the stocks are privately held and not registered as such, because they reside within the commodity pipeline from farmer to consumer, and are kept in trucks, factories and supermarkets. Hence, to affect the market very large publicly controlled stocks would be required. These stocks would by their physical nature be very cost ineffective as compared to holding financial assets, and obviously, the present situation of scarcity is not the time to build up such large strategic stocks quickly.

In this regard, the interconnection between food and biofuel may for a while offer new opportunities for food price stabilization. Fossil fuels are by their very nature more easily stored than food, and oil and gas can simply be kept in the ground. The G8 could for instance put an upper limit on the use of biofuel in gasoline when they find that food prices rise too much. Since the number of oil companies in the world is small, implementation would not have to be difficult. It would surely tamper price expectations in the market and could do without any food reserves. Eventually, as engines become more fuel efficient, they will presumably become less tolerant to the substitution between bio- and fossil fuels. Yet, if such a possible intervention were announced at an early stage it may promote higher flexibility in design, which is precisely what market stabilization would be served by.

Towards efficient and sustainable production of biomass for energy

Once an adequate regulatory system of carbon taxes has been put in place, there is no reason to object on environmental grounds to biofuels in particular, since the severity of the ecotaxes should provide adequate penalization, nor is there any justification for promoting them through subsidies and mandatory mixing. Then, the use of biomass in general and perhaps also of liquid biofuels will continue, and the question becomes how to produce this biomass around the world in a socially and environmentally sustainable manner.

There are basically three ways to address the resulting demand pressure. The first, specifically in relation to biofuels, would be to develop second generation technologies that can use the whole plant as opposed to the seeds or roots only (sugar cane is already more effective in this respect). This requires “cracking” the cellulose membranes, which, however, proves to be quite difficult, as was mentioned earlier. Alternatively, introduction of battery or hydrogen driven cars would make it possible to rely on non-liquid energy carriers at the power plant or hydrogen factory. Both ways, biomass becomes the critical input rather than carbohydrates or vegetable oil. The second way, which also applies to biomass production in general, is to reduce the needs of fertilizers and other inputs, as this would increase the net energy yield per hectare. Here precision agriculture could target the individual crop, say, by coating the seeds with plant nutrients, rather than improving the soil. This is possible with available technology but often is too costly. Finally, the third way is to cultivate energy crops on marginal lands unsuitable for food production. Here the estimated potentials tend to be large. A whole range of studies finds biomass potentials of the order of magnitude of current total energy demand, about 470 EJ (Faaij 2007; Van Dam et al. 2007). However, to effectuate these potentials various inputs are needed in vast quantities. Table 4 gives an stylized example of fertilizer needs, based on data in Fischer and Schrattenholzer (2001).

Table 4 Biomass potentials and use of nutrients

	Land Use [mln ha]	Yield [GJ/ha]	Energy Output [EJ]	Nutrient application [kg/ha]	Total nutrients [mln tons]
Total, World	13013		198		194
Arable land and permanent crops	1562	10	16	12	18
Permanent meadows and pastures	3406	35	119	40	136
Forest area	3952	16	63	10	40
Other land	4093	0	0	0	0

Source: based on Fischer and Schrattenholzer (2001), and expert opinion for nutrient applications.
Note: 1 GJ = 10^9 Joules, 1 EJ =10^9 GJ. Output of arable land and grass land refers to a fraction of crop residues and to energy crops, respectively. Forest output is restricted to sustainable practices only.

The calculation considers three types of land use from which additional biomass could be obtained, which totals some 200 EJ gross energy. Measuring fertilizer requirements as the sum of the pure macronutrients nitrogen, phosphate and potassium leads, under conservative assumptions, to a need of 194 mln tons as compared to current total use of about 160 mln tons.

There is no easy way out on this. For example, crop residues are needed for soil fertilization. Using them as feedstock for energy production affects the productive capacity of land, reduces soil cover and increases erosion hazards (USDA/NCRS 2006). The danger of land degradation is even more severe for grasses, when the entire standing biomass is harvested year after year. Similarly, perennial plants, such as the Jatropha shrub that has gained popularity in arid zones where it can produce vegetable oil under harsh conditions on poor soils, need fertilizer at the very least to compensate for the nutrients lost through harvesting but also to raise yields.

Supplying fertilizers in such quantities will be difficult. Nitrogen is to be captured from the atmosphere through an energy intensive process that should not rely on fossil fuels to be CO2-effective, and could greatly reduce the net energy yield when biomass based. Potassium and phosphate are to be extracted from rock types that have become relatively scarce already and are hard to recycle, while the best quality deposits tend to run out (Steen 1998). Phosphate rock has a ratio of proven reserves to current consumption of about 120 years, and for potash the ratio is twice that large. Yet, large parts of the phosphate reserves, especially those in China, are expected to be of low grade (USGS 2008), and to be significantly contaminated by cadmium and uranium and hence by heavy metals and radioactivity that one would not like to see accumulate in soils, let alone in living organisms (CMA 2008).

Furthermore, beyond the macronutrients, a variety of micronutrients, such as zinc will be required as well on specific soil types. Some of these nutrients are even scarcer, with proven reserves of zinc as low as 22 years of current consumption. Recyling of zinc is possible, but demand from industry is soaring as well, and soils in large parts of the world are zinc deficient (Nubé and Voortman 2008). Also other micronutrients (boron, copper, manganese) have ratios in the range of 30-40 years. Geological surveys indicate that most if not all nutrients have a much larger reserve base, but very little is known as to the quality of the ores and the cost of exploitation.

Hence, scarcity of plant nutrients may become a serious issue that is except for nitrogen, possibly even more pressing than for energy, because there is no substitute such as solar of nuclear ahead.

Nutrients of mineral origin that have washed into the oceans are virtually lost forever. The badly needed intensification of agricultural production, particularly in Subsaharan Africa, will heavily depend on availability of plant nutrients also. Furthermore, the marginal lands on which biomass is to be grown for non-food uses, are likely to require more intensive applications than Table 4 suggests. One way is the precision agriculture mentioned earlier that can greatly reduce needs, but is hard to apply under technologically less advanced conditions. The other option, particularly relevant for energy crops, is to recover the main nutrients at the processing plant, mainly from the process residues, such as ashes. The difficulty is to return these in appropriate proportions to the land of origin.

In short, the EU, the US and other countries may have formulated ambitious targets for biofuel use and the agro-ecological potentials may be large but it is by no means clear where this fuel is to come from and how to produce it in a socially and environmentally sustainable way.

While large-scale production of biomass for energy purposes clearly has consequences for input use, in rural areas biofuels from crops, manure and farm residues could, under adequate soil fertility and water management, offer valuable savings on input costs for farmers. For instance, Jatropha cultivated on marginal lands may help save on fossil fuel purchases, and eventually, commercial sales to local markets may even become possible. This will be a welcome source of additional employment, since it is more profitable to perform fuel extraction locally, given the bulky nature of the raw material, the exclusive interest in the carbohydrate components of the biofuel crop, and the need to return all plant nutrients contained in it to the soil.

Scaling up these production systems to make them an export industry will meet with various constraints. The rising demand for scarce nutrients has been mentioned already, and the introduction of new plantations may require clearing and preparation of land, which may cause significant greenhouse gas emissions, particularly on peat soils (Fargione et al. 2008). In addition, various countries have stated that biofuels need to meet certain sustainability criteria to become eligible for import, which beyond environmental sustainability also cover labor conditions on plantations. Associated to these concerns there is also the question what to do about price fluctuations, particularly for fossil fuels whose prices tend to fall almost as fast as they rise. Plantations in marginal and sub-marginal areas are especially vulnerable to price fluctuations, as well as to changes in the policies such as the strengthening of sustainability criteria, because they will often lack the common fallback strategy of returning to subsistence cultivation on household plots. Moreover, workers on such remote settlements are not likely to have many other cash crops or job opportunities to opt for. Hence, special safeguards will be required in the contracts between workers and employers at the plantation itself, as well as between the plantation and its customers downstream, to maintain a minimum level of social security. For biofuels, various proposals have been issued in the EU recently to arrive at social as well as environmental labeling of imported products. Social security provisions could be made part of these.

High energy prices and the scaling up of biomass production not only affects plantations. They are also the driving force of encroachment into areas currently characterized by low productivity: shrub land, jungles, forests, tundra’s and steppes, which cover more than three quarters of the Earth’s land mass. By their very nature, such areas are characterized by lack of control and law enforcement to protect environment and population. Furthermore, the property rights over these surfaces are poorly established, and often attributed by default to central government. Various countries are currently handing out concessions for large-scale biofuel plantations but without being able or willing to impose the necessary safeguards for social and environmental sustainability. Thus, all ingredients for conflicts and tragedies of the commons seem to be present, and governance aspects need urgent attention.

5. Conclusion

About a decade ago, biofuels appeared on the scene as an ideal way to reduce greenhouse gases, to contribute to energy self-sufficiency and to create additional demand for agricultural commodities suffering from depressed prices. In response, developed countries enthusiastically introduced mandatory blending requirements and lavish subsidies, to spur fast adoption of this technology, and proved all too successful in their endeavor. The net savings on fossil fuels have been disappointing because of the high fossil fuel intensity of agricultural inputs, processing and transport, and the completely inelastic shift in demand, caused by the blending requirements, bears a significant part of the responsibility for the present food crisis.

Therefore, the controversy that arose around biofuels is understandable and highly relevant. It has been instrumental in toning down the unrealistic policy ambitions in this domain, particularly within the EU. However, this backtracking does not resolve the underlying issue that rising scarcity of fossil fuels will accentuate the competition for land, fertilizers, and labor between food and energy crops, and put nature under additional pressure.

In policy terms, this defines three major tasks. The first is replacing the current excise taxes on energy carriers by a uniform carbon tax, so as to mitigate greenhouse gas emissions in an efficient manner. Under a carbon tax, biofuels, unlike the fossil fuels needed to produce them, would qualify for a tax exemption, which obviously would imply a significant loss in tax revenue for the countries concerned. There is a strong need for serious debate on the optimal taxation of biofuels, and energy in general, and preferably also on how to distribute carbon tax revenues among the "owners" of the object of taxation, i.e. the global atmosphere. In Europe, a biofuel tax exemption would presumably be insufficient to make biofuel production profitable, but this depends on the relative prices of food and fuel and on progress in the technology of biofuel production.

A second task is to prevent price fluctuations on the oil markets from destabilizing food markets, as happened in recent years. Rather than building up strategic food stocks that would always be vulnerable to speculation, introduction of caps on the use of food for biofuel could prove effective here. Yet, soon the emphasis will have to shift from food crop based biofuels to biomass based energy production, largely in developing countries on lands less suitable for food production.

A third, much wider task is, therefore, to make such a transition possible and sustainable, technically as well as institutionally. Technically, on these previously scarcely populated lands the task would be to safeguard biodiversity and soil fertility, taking into account the mounting scarcity of minerals needed for fertilizer production, for which no substitutes are known and for which recycling can be quite difficult. Institutionally, the task is to distribute new concessions equitably, to protect the property and user rights of the lands where energy crops are to be grown, and to maintain adequate labor standards and living conditions on these plantations, particularly under adversities after crop failures and unfavorable price movements.

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The Centre for World Food Studies (Dutch acronym SOW-VU) is a research institute related to the Department of Economics and Econometrics of the Vrije Universiteit Amsterdam. It was established in 1977 and engages in quantitative analyses to support national and international policy formulation in the areas of food, agriculture and development cooperation.

SOW-VU's research is directed towards the theoretical and empirical assessment of the mechanisms which determine food production, food consumption and nutritional status. Its main activities concern the design and application of regional and national models which put special emphasis on the food and agricultural sector. An analysis of the behaviour and options of socio-economic groups, including their response to price and investment policies and to externally induced changes, can contribute to the evaluation of alternative development strategies.

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