ELSEVIER

Energy Policy 36 (2008) 1538–1544

ENERGY POLICY

www.elsevier.com/locate/enpol

Promoting biofuels: Implications for developing countries

Jörg Peters*, Sascha Thielmann

Division "Environment and Resources", Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen), Hohenzollernstr. 1-3, 45128 Essen, Germany

Received 16 June 2007; accepted 10 January 2008

Abstract

Interest in biofuels is growing worldwide as concerns about the security of energy supply and climate change are moving into the focus of policy makers. With the exception of bioethanol from Brazil, however, production costs of biofuels are typically much higher than those of fossil fuels. As a result, promotion measures such as tax exemptions or blending quotas are indispensable for ascertaining substantial biofuel demand. With particular focus on developing countries, this paper discusses the economic justification of biofuel promotion instruments and investigates their implications. Based on data from India and Tanzania, we find that substantial biofuel usage induces significant financial costs. Furthermore, acreage availability is a binding natural limitation that could also lead to conflicts with food production. Yet, if carefully implemented under the appropriate conditions, biofuel programs might present opportunities for certain developing countries.

Keywords: Renewable energy; Environmental policy; Economic development

1. Introduction

Biofuels are enjoying growing worldwide interest as concerns about the security of energy supply and climate change are moving into the focus of policy makers. Many observers consider biofuels to be the only feasible option for the substitution of fossil fuels in the transport sector. Currently, the most important biofuels are biodiesel and bioethanol—commonly referred to as first-generation biofuels. Both can be used either in neat or blended form, though neat usage requires compatible engines. While biodiesel is based on oil crops like rapeseed, sunflower, or soy, bioethanol is made out of starch crops like sugar cane, wheat, or corn. In most cases, these biofuels only use part of the feedstock crop. In contrast, the so-called second-generation biofuels—e.g. biomass to liquid (BtL)—take advantage of the whole crop.

With few exceptions—bioethanol in Brazil or biodiesel from waste oil,—production costs of biofuels are significantly higher than those of fossil fuels. Therefore, promotion measures are indispensable for ascertaining substantial domestic biofuel demand. These promotion measures are most frequently justified by their proponents as a source of environmental benefits, fostering the security of energy supply, and leading to job creation in the agricultural sector. Biofuel promotion policies have led to substantially increased production in several countries since the beginning of the new millennium, most notably Germany and the USA. World ethanol production doubled between 2000 and 2005, while the worldwide biodiesel production increased threefold in the same period (IEA, 2006a, p. 390). Between 2000 and 2004, Brazil expanded its bioethanol production from 8 to 12 Mio t (Schmitz, 2005), while the EU tripled biodiesel production from 1.1 Mio t in 2002 to 3.2 Mio t in 2005 (EBB, 2006).

Given these trends and persistently high crude oil prices, more and more developing countries are examining possibilities to substitute fossil fuels in the transport sector with locally produced biofuels. This seems all the more sensible, as climatic conditions in many developing countries are beneficial for biomass production and biofuel feedstock crops in particular. In fact, the International Energy Agency expects the production of biofuels in developing countries to increase substantially in the

*Corresponding author. Tel.: +49 201 8149 247; fax: +49 201 8149 200.
E-mail address: peters@rwi-essen.de (J. Peters).

0301-4215/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2008.01.013

following years (IEA, 2006a, p. 394). However, increasing biofuel production not only facilitates fuel import substitution and, consequently, the abatement of greenhouse gases (GHG). There is a downside as well. Most importantly, promotion policies that use tax exemptions and blending quotas will burden either the national budgets or the fuel-consuming households and firms. Furthermore, crop production often requires massive acreage and may lead to land-use conflicts in food production. Even the environmental effects have to be regarded as ambiguous. Therefore, biofuel programs implemented by developing countries must be scrutinised carefully in order to avoid welfare losses.

This paper discusses the economic justification of biofuel promotion measures and investigates their implications. The focus is on programs aiming at domestic biofuel usage in developing countries. Based on data from India and Tanzania, we find that substantial biofuel usage induces significant financial costs. Furthermore, acreage availability is a binding natural limitation that could result in conflicts with food production in developing countries. Only if they are carefully implemented under the appropriate conditions, is it possible for biofuel programs to offer feasible opportunities for certain developing countries.

Since exemption from mineral oil taxation is the most frequently applied promotion instrument, Section 2 examines the economic justification of mineral oil taxation, while Section 3 discusses the appropriateness of tax credits for biofuels. Section 4 gauges the financial consequences of biofuel usage in India and Tanzania. Section 5 reappraises the limits and opportunities of biofuels and concludes by suggesting criteria for the successful set-up of programs in developing countries.

2. Theoretical justification for fuel taxation

The economic justifications of excise fuel taxes are summarised by Newbery (2005), who enumerates four main arguments. Fuel taxation can be rationalized

- as a second-best instrument for charging for road infrastructure,
- to internalise external costs that are mainly caused by pollution,
- as part of a second-best tax structure to improve the efficiency properties of the remaining taxes and
- as an optimal import tariff.

Taxation of fuels for transport purposes is warranted to a considerable extent as *road use charges*. The optimal tax would cover all costs caused by vehicle usage, including costs for maintaining and expanding road networks. However, because direct road pricing based on traffic volumes is a more efficient way to charge for road use, fuel taxation is only a second-best solution. Direct road pricing captures the elevated negative impact of each additional car in highly congested regions but it is often also precluded by both political and technical hurdles. Hence, appropriately set fuel taxes can serve as an alternative instrument to charge for road use.

The *internalisation of external costs* caused by vehicle usage is a frequently cited justification for fuel taxation. External costs are incurred by a society or third parties through the consumption of a good for which no compensation is received. A classic example is pollution from automobile use. Without taking account of the costs car drivers impose on others via air and noise pollution, automobiles are used excessively. This type of market failure was originally addressed by Pigou (1920), who proposed the internalisation of external costs by imposing a tax, thereby reducing the consumption of the polluting good. The fuel tax increases consumer prices, which creates immediate financial incentives to economize fuel usage and consequently abate emissions—be it via more efficient engines, fuel-saving driving, or the reduction of car use.

Revenues from fuel taxes can be used to lower the rate of other taxes, thereby *reducing the distortion of the tax system as a whole*. This is due to the fact that the distortionary effect of any tax increases disproportionately with the tax rate. Thus, marginal increases in low or non-existent fuel taxes produce revenues that enable marginal decreases in relatively high tax rates of other goods. Hence, such a policy may increase the efficiency of the tax system (Newbery, 2005).

The argument of fuel taxes as *optimal import tariffs* arises from international trade economics and applies to the case of a large country or free trade area that imports mineral-oil-based fuels from competing oil-producing countries. In this framework, fuel taxes can be used to shift parts of the scarcity rent induced by the exhaustible character of the resource from the exporting to the importing country. The logic behind this takes Hotelling's (1931) theoretical considerations into account, which state that owners of exhaustible resources define the time path of depletion in advance. Therefore, the amount of the resource sold in each year is fixed and suppliers do not adjust their production if taxes or tariffs are imposed. This inflexibility affords the opportunity for importing countries to levy tariffs without triggering cutbacks in supply, thereby increasing government revenues and shifting the tax burden to the oil-producing country (Newbery, 2005; Bergstrom, 1982).[1]

Finally, fuel taxes are often rationalised as a major *source of government revenue* (Parry and Small, 2005). This argument is economically justified by Ramsey (1927), who states that taxes for raising revenue should be higher on goods with smaller price elasticities. The rationale behind this is that the excess burden of taxation is smaller if

[1]The two issues—reducing the distortion of the tax system and fuel taxes as an optimal import tariff—are rather academic arguments. As such, they are certainly not the motivation for taxing fuels in developing countries and are therefore not considered further in the subsequent discussion.

consumers or producers react less to the price increases through the introduction of a tax. In light of these arguments for fuel taxation, Section 3 discusses the extent to which biofuels should also be subject to taxation and assesses potential reasons why they could qualify for receiving tax credits.

3. Preferential taxation of biofuels

Because transport infrastructure is one of the most important prerequisites for economic development, *charging for road use*, or alternatively levying transport taxes, is often crucial in order to finance the maintenance and extension of roads. Given that direct road pricing is frequently an impracticable option and that fuel taxes are an obvious and important second-best instrument, there is clearly no reason for a preferential taxation of biofuels[2]. Such a subsidisation would encourage the use of biofuels, but would also erode the tax revenues. As a consequence, preferential taxation of biofuels could endanger road financing altogether.

Many developing countries raise fuel taxes to *create revenue for the national budget*, though, rather than for traffic-related purposes. Fuel taxation is an attractive source of government revenue from a pragmatic point of view. Compared with an income tax, for instance, a fuel tax is rather easy to implement, since it can be collected at a few refineries or wholesale points. In fact, fuel taxation contributes up to one-fourth of overall tax revenue in many developing countries (Metschies, 2005). Countries such as Côte d'Ivoire, Rwanda, or South Africa, where between 20% and 25% of total tax income stems from fuel taxation, would easily lose more than 2% of their national tax income if tax-exempted biofuels were to substitute for 10% of conventional fuels.

Aside from administrative reasons, taxing fuels as a source of government revenue seems to be rationale from a theoretical point of view: World Bank (1997) reports price elasticities between 0.04 and 0.3 for most countries. This indicates that people do not react strongly to the introduction of fuel taxes, which reduces the excess burden induced by the tax. Since these considerations apply to both bio- and fossil fuels, exempting biofuels from taxation does not seem justified.

Yet, there may be important externalities that motivate the preferential treatment of biofuels. Among environmental externalities, the *abatement of GHG* is the most frequently cited argument for the promotion of biofuels. Although the combustion of biofuels is considered to be GHG neutral, in fact, less than 100% of the GHG emissions are saved compared with fossil fuel usage. This is because it usually requires much more energy to provide biofuels than fossil fuels (Frondel and Peters, 2007; Ryan et al., 2006). Moreover, it is highly unlikely that using biofuels will present an economically viable option for the internalisation of GHG emission costs in the near future. This becomes clear when we assume, for the sake of the argument, that the GHG abatement generated by biofuels could be traded through the European Emissions Trading Scheme (ETS). Böhringer and Löschel (2002), for instance, calculate a long-term prediction of 41\$[3] per ton of GHG in the ETS. According to Ryan et al. (2006), 1000 l of European biodiesel saves 1.3 tons of GHG.[4] Multiplying this figure by the ETS price of 41\$ per ton yields a total of 53\$ worth of abatement savings. If the tax credit granted to biodiesel were to reflect the value of abated GHG emissions, 1 l would qualify for an exemption of around 5.3 US-Cents. The production-cost differential between biodiesel and its fossil counterpart is much higher—according to Ryan et al. (2006), this amounts to at least 75 US-Cents/l for biodiesel in Europe.[5]

In addition to globally harmful GHG emissions *local emissions*, such as particulates or carbon monoxide, harm the immediate environment of highly frequented roads. In fact, neat bioethanol does not emit locally harmful pollutants, whereas using biodiesel only slightly reduces such emissions compared with fossil diesel (ESMAP, 2005). In most cases, intensive usage of fertilizers is required for the cultivation of biofuel feedstocks, inflicting such damage on the *local environment* as the eutrophication and acidification of surface water. Irrigation, if required, can lead to nutrient losses, decreasing the quality of soils. These problems pose a serious threat for developing countries, since a sufficient supply of potable water and soil fertility frequently are major concerns (ESMAP, 2005). The frequently cited loss of rain forest observed in Southeast Asia due to palm oil production is certainly not negligible from either a local or global environmental perspective (IEA, 2006a, p. 393). Altogether, although biofuels are clearly benign with respect to GHG, cheaper abatement options exist and local environmental problems may arise. This necessitates a careful check of the environmental balance, mainly in the area of irrigation as well as fertilizer and pesticide usage (Aßmann and Sieber, 2005).

Two more economic externalities may favour the promotion of biofuels (ESMAP, 2005): rural development and *energy supply diversification*. Regarding the latter, IEA (2006a) estimates that biofuels will substitute for 4–7% of total world fossil fuel consumption in 2030. While this share is certainly not negligible, it also reveals the limitation of biofuel potentials. IEA (2006a) does not expect a new biofuel player comparable to Brazil to emerge among developing and emerging countries. China and

[2]Relating to biodiesel, tax credits are even less justified with respect to road pricing, since the share of biodiesel used by heavy goods vehicles is large and their contribution to road abrasion is disproportionately high.

[3]Underlying exchange rate: 1 Euro = 1.35US\$ (May 2007).

[4]It bears noting, however, that GHG emissions of a particular biofuel strongly depend on the specific characteristics of the cultivation and processing of feedstocks.

[5]The production-cost differentials take into account different energy contents. Biodiesel contains 87% as much energy compared with diesel (see Section 4.).

Africa as a whole are projected to substitute less than 4% and 3% of their total transport fuel consumption, respectively, while Asian developing countries other than China are expected to supplant up to 6.6%.

Regarding the former, it can indeed be expected that biofuel promotion will increase the value added in the agricultural sector, thereby contributing to *rural employment and development*. Providing biofuels or biofuel feedstocks will enable rural farmers and processing firms to access—at least indirectly—regional or even international markets. Lacking access to markets is frequently cited as a crucial barrier to rural economic activity (Barnes, 1988; IFAD, 2003).

In fact, both employment and added value are likely to improve in the feedstock-producing region, particularly if the local share in the production chain is high. However, the net employment effect on the country level remains unclear.[6] The reason is that simply counting the number of workers employed in the biofuel sector is not sufficient to determine net employment effects. Indirect effects—namely crowding-out and budget effects—have to be taken into account: first, the *crowding-out effect* accounts for job losses in the rivalry mineral oil industry. Since mineral oil is typically imported, the crowding-out effect is restricted to the processing and logistic industry, i.e. refineries, ports and transport. In addition, jobs in the food industry could be crowded out, if biofuel feedstocks and food competed for scarce acreage. Second, the increased fuel and food prices incurred by biofuel promotion will reduce the consumers' budget available for other goods. The resulting decrease of the consumption of non-fuel and non-food goods shrinks employment in other industries as a *budget effect*. Yet, provided that the reduction of employment occurs mainly in non-rural areas, exempting biofuels from taxation in order to contribute to rural employment might still be justified as a regional development strategy.

Furthermore, the artificial demand for agricultural biofuel feedstocks increases acreage requirements. As a result, biofuel production based on acreage-intensive feedstocks may crowd out crops for other purposes, leading to rising prices for agricultural products based on these crops (McDonald et al., 2006; ESMAP, 2005). Although this induces additional income for rural areas, it also has negative impacts on the availability and affordability of food.

All in all, environmental effects are the sole valid reason for tax exemptions. Whether the environmental balance is positive is questionable, however, especially if the reduction of local pollution is given priority. Given that mineral oil taxes provide the revenues required for the infrastructure or the national budget of developing countries, tax exemptions should be handled carefully and only be valid for a limited time. If policy makers consider rural development to be an issue of national priority, then biofuels will offer possibilities, but side effects on local food markets and negative employment effects in other industries will still have to be taken into account.

4. Potential promotion costs in India and Tanzania

Production cost figures are particularly scarce in developing countries. This section thus only exemplifies the direct promotion costs[7] that are potentially induced in India and Tanzania, thereby neglecting indirect costs or benefits as discussed in Section 3.

4.1. Current and future production costs

Our calculation of differences between estimated production costs and market prices of fossil fuels are documented in Tables 1 and 2. They include the distinct energy contents of bioethanol, biodiesel and fossil fuels: while 1.09 l biodiesel is required to substitute for 1 l of diesel, 1.49 l bioethanol replaces 1 l of gasoline. To facilitate the comparison of biofuel costs and fuel prices that are based on the Rotterdam spot prices of March 15, 2007, the production costs displayed in Tables 1 and 2 refer to 1.09 l of biodiesel and 1.49 l of bioethanol. Current production costs for Indian biofuels are reported in GTZ (2005a). While current production costs for Tanzanian bioethanol are not available, current production costs of Tanzanian biodiesel are estimated using jatropha oil[8] prices cited in GTZ (2005b) and biodiesel processing costs based on IEA (2004). The reported fossil fuel price–production cost differences are substantial, in particular for Tanzania.

Arguably these production costs have been observed at a level of small-scale production and might decrease as output increases. In addition, production costs strongly depend on a variety of aspects, such as the policy and investment frameworks. For instance, the decision of governments concerning the promotion of large-scale or decentralised production affects the resulting costs substantially. A further critical factor is agricultural research, e.g. research on high-yielding seeds. Thus, we gauge the fossil fuel price–production cost differences using projected production costs.

Projected production costs estimates reported in Table 2 are based on GTZ field studies in East African countries and GTZ (2005a). Both studies assumed large-scale production leading to substantial differences between current and projected production costs for both Indian and Tanzanian biodiesel. Experiences from industrialised

[6] See Pfaffenberger (2006) for a discussion of employment effects of renewable energies in industrialised countries. Dannenberg et al. (2007) assess the employment effects of renewable energy promotion in Europe.

[7] This burden would become most noticeable if a tax exemption or direct subsidy was implemented. Yet, in the case of mandatory blending quotas as well, these costs would arise, hidden as reduced consumers' and producers' surplus as well as a dead weight loss (see Peters and Thielmann, 2007).

[8] Jatropha is a plant that grows on low-quality soils in tropical or subtropical areas and produces oil-containing seeds. It is frequently named as a potentially ideal source of biodiesel.

Table 1
Current biofuel production costs in US$ (2004 prices)

	Current production costs ($/l)	Spot market prices of fossil fuel counterpart ($/l)	Difference ($/l)
India			
Bioethanol	0.65–0.67	0.44	0.21–0.23
Biodiesel	1.4–2.8	0.47	0.93–2.33
Tanzania			
Biodiesel	2.23–2.39	0.47	1.76–1.92

Table 2
Projected biofuel production costs in US$ (2004 prices)

	Projected production costs ($/l)	Spot market prices of fossil fuel counterpart ($/l)	Difference ($/l)
India			
Bioethanol	0.65–0.70	0.44	0.21–0.26
Biodiesel	0.41–1.27	0.47	−0.0 to 0.80
Tanzania			
Bioethanol	0.60–0.70	0.44	0.16–0.26
Biodiesel	0.70–0.80	0.47	0.23–0.33

Table 3
Required amounts of biofuels to substitute for 10% of fossil fuel counterpart[a]

	Fuel consumption in 2004 in Mio l (WRI 2007)		Required amount of biofuel counterpart in Mio l	
	Gasoline	Fossil diesel	Bioethanol	Biodiesel
India	10,243	24,557	1502	2661
Tanzania	228	614	33	67

[a]Current fuel consumption is based on WRI (2007). The WRI figures correspond with IEA data in energetic terms and have been chosen, because IEA (2006b) report total fuel consumption only.

Table 4
Costs of substituting biofuels for 10% of respective fossil fuel consumption (energy content)

	Current production costs (Mio US$)	Projected production costs (Mio US$)
India		
Bioethanol	475–513	464–575
Biodiesel	2699–6760	−180 to 2330
Tanzania		
Bioethanol	n.a.	8–13
Biodiesel	128–139	17–24

countries, however, indicate that cost projections should be handled with caution, since production costs could remain at a high level in spite of large-scale production (Ryan et al., 2006). Further crucial cost factors are the type of employed feedstock and respective yields that clearly depend on soil quality, climatic conditions and research successes. The feedstock considered in Table 2 is jatropha, a principally promising crop with respect to environmental issues and acreage requirements. Yet, despite significant research efforts, it has not yet been possible to produce seeds with reliably high yields (Fairless, 2007). Field research indicates that jatropha yields can vary between 0.1 and 0.9 kg per tree.

Two results stand out: first, the cost range of biodiesel is wide, most notably for India, due to the high variability of jatropha yields. Second, production cost estimates are rather optimistic. This becomes most apparent with Indian biodiesel, for which future costs may even be slightly lower than those of diesel—note the negative sign in the third column. In fact, favourable climatic conditions and low labour costs might enable certain developing countries to produce biofuels at reasonable costs.

4.2. Direct costs of promotion

Given that a positive difference between biofuel production costs and fossil fuel prices characterises the situation for some time to come, the promotion of biofuels necessarily imposes costs on the economy under analysis. In our calculation presented in Table 3 we assume that both bioethanol and biodiesel substitute for 10% of gasoline and fossil diesel in energetic terms, respectively. Based on these figures we then calculate the potential financial burden that may result in such a scenario (Table 4).

Taking the example of Tanzania, the substitution of biodiesel for fossil diesel at current production costs implies a financial burden of around $130 Mio. It would decrease to around $20 Mio if the projected cost decline reported in Table 2 were to be realised. Yet, it is most likely that some financial burden remains. These figures might be considered to be of acceptable magnitude if the potential benefits (e.g. rural income generation) are assessed to be sufficiently high. Nevertheless, it has to be acknowledged that the financial burden of promoting biofuels is not negligible for a country like Tanzania.

This becomes evident when it is placed into perspective by comparing it to the amount of total tax revenues of $1.57 Bn in 2005 (WDI, 2007). Even the lower cost estimates would amount to 1.6–2.3% of total tax revenue if the 10% substitution of both diesel and gasoline was realised. If production costs remained at the current level, costs for substitution of both fossil fuels could easily exceed 10% of total tax revenue. With India's total tax revenue being $100.7 Bn, a 10% substitution policy causes a financial impact of 0–3% in the projected costs scenario and 3–7% in the current costs scenario. In sum, these considerations show that research efforts must be intensified in order to reduce both the costs of large biofuel programs and uncertainties about cost projections.

5. Conclusion

More and more countries consider biofuels as one element of their strategy of addressing environmental problems and the dependence on energy imports. As biofuels are usually not competitive, though, promotion measures are required for stimulating demand. The most frequently used instruments are tax exemptions and mandatory blending quotas. With particular regard to developing countries, this paper has investigated both the justification of biofuel promotion and its implications.

Using current and projected production costs for India and Tanzania, we have found that the financial burden, which is difficult to determine at this point, might become substantial if production costs remained high despite large-scale production. Yet, if the rather optimistic production cost projections offered by some studies proved to be valid, direct economic costs may shrink to manageable size. In this case, the promotion of biofuels might be justified if national benefits through rural development or energy supply security are significant. However, whether these benefits can be realised strongly depends on the specific implementation of biofuel production. Social and environmental problems, such as land-use conflicts and water pollution, have to be taken into account. At any rate, research efforts on both production costs and indirect effects have to be intensified before large biofuel programs are implemented.

This paper argues that global environmental benefits, most notably GHG abatement, currently do not justify the promotion of the domestic use of biofuels in developing countries, since more efficient abatement options are available. Moreover, local effects due to intensified agricultural production may have serious negative consequences for living conditions of people in developing countries. This includes both negative local environmental effects and implications for food markets as a result of increased land competition. Such local effects should be the focus of an examination of specific promotion programs.

Given that the political focus is on employment effects in rural areas, the use of stationary biomass for electricity production should also be taken into account. This option deserves particular consideration because electricity demand is currently outpacing supply in many developing countries that partly rely on diesel generators (Economist, 2007). Many fast-growing crops that can presently not be used for biofuel production perform much better with respect to production costs, environmental impacts and land use (Frondel and Peters, 2007; Henke et al., 2005).

If promotion of biofuels is deemed appropriate, it must be taken into account that the most important promotion instruments—mandatory blending quotas and tax exemptions—are designed to primarily generate economies of scale via increases in demand. The success of these measures critically depends on whether the average production costs can be sufficiently reduced to make biofuels commercially viable. This is most evident in the case of tax exemptions: if the cost spread between conventional fuels and biofuels is too large, granting a tax credit that is clearly limited by the magnitude of mineral oil taxation might not be sufficient. In other words, in an early stage of technological development, exploiting economies of scale is not enough. In this case, learning effects have to be generated by investing in research and development (R&D). Given significant positive external effects of R&D—e.g. security of energy supply and environmental benefits—it might be reasonable to promote R&D of biofuels through public funding. Therefore, before launching instruments that envisage an increase in demand, the availability of a certain stock of technological know-how must be ensured.

To summarise, a comprehensive assessment of the potential of biofuels requires that developing countries carefully examine a variety of factors, e.g.:

- Expected cost differences between bio- and fossil fuels.
- Availability of acreage and potential competition with existing land-use patterns.
- Agricultural and environmental conditions such as availability of water, fertilizer requirements and soil quality.
- Technological know-how and potential to focus on second-generation biofuels.
- Relevance of mineral-oil taxation for the national budget.

Only if this examination results in a favourable assessment, should the application of the discussed biofuel promotion programs be pursued. In an optimal case, those regions providing feedstocks with acceptable local environmental impacts and producing at least costs might also emerge as international biofuel suppliers. This is particularly appealing for developing countries, since direct costs would then be incurred by the importing countries. Yet, significant potentials with respect to land-use efficiency as well as acceptable environmental impacts seem to be restricted to second-generation biofuels in most cases. Therefore, countries should always also consider pathways towards these promising technologies.

Acknowledgements

We are grateful for valuable comments and suggestions by two anonymous referees as well as Christoph M. Schmidt, Colin Vance, Sven Neelsen and, in particular, Manuel Frondel.

References

Aßmann, D., Sieber, N., 2005. Transport in developing countries: renewable energy versus energy reduction? Transport Reviews 25 (6), 719–738.

Barnes, D.F., 1988. Electric Power for Rural Growth. Westview Press, Boulder.

Bergstrom, T.C., 1982. On capturing oil rents with national excise tax. American Economic Review 72 (1), 194–201.

Böhringer, C., Löschel, A., 2002. Assessing the costs of compliance: the Kyoto Protocol. European Environment 12, 1–16.

Dannenberg, A., Mennel, T., Moslener, U., 2007. What does Europe pay for clean energy? Review of Macroeconomic Simulation Studies. ZEW Discussion Paper no. 07-019.

EBB, 2006. European Biodiesel Board—Statistics 〈http://www.ebb-eu.org/stats.php〉.

Economist, 2007. Electricity in Africa—The Dark Continent. The Economist, 18 August 2007, 34pp.

ESMAP, 2005. Potential for Biofuels for Transport in Developing Countries; Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP), Washington.

Fairless, D., 2007. Biofuel: the little shrub that could-maybe. Nature 449, 652–655.

Frondel, M., Peters, J., 2007. Biodiesel: a new Oildorado? Energy Policy 35, 1675–1684.

GTZ, 2005a. Liquid Biofuels for Transportation: India Country sTudy on Potential and Implications for sustainable Agriculture and Energy. The Energy and Resources Institute (TERI), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), German Ministry for Food, Agriculture,and Consumer Protection (BMELV), German Agency for Renewable Resources (FNR).

GTZ, 2005b. Liquid Biofuels for Transportation in Tanzania—Potential and Implications for Sustainable Agriculture and Energy in the 21st Century. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), German Ministry for Food, Agriculture,and Consumer Protection (BMELV), German Agency for Renewable Resources (FNR).

Henke, J., Klepper, G., Schmitz, N., 2005. Tax exemptions for biofuels: is bioethanol really an option for climate policy? Energy 30, 2617–2635.

Hotelling, H., 1931. The economics of exhaustible resources. Journal of Political Economy 39, 137–175.

IEA, 2004. Biofuels for Transport. International Energy Agency, Paris.

IEA, 2006a. World Energy Outlook. International Energy Agency, Paris.

IEA, 2006b. Energy Balances of Non-OECD Countries 2003–2004. International Energy Agency, Paris.

IFAD, 2003. Promoting Market Access. International Fund for Agricultural Development.

McDonald, S., Robinson, S., Thierfelder, K., 2006. Impact of switching production to bioenergy crops: the switchgrass example. Energy Economics 28 (2), 243–265.

Metschies, G.P., 2005. International Fuel Prices 2005. Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn.

Newbery, D.M., 2005. Why tax energy? Towards a more rational policy. Energy Journal 26 (3), 1–40.

Parry, I.W.H., Small, K.A., 2005. Does Britain or the United States have the right gasoline tax? American Economic Review 95 (4), 1276–1289.

Peters, J., Thielmann, S., 2007. The cost of promoting biofuels. In: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and Federal Ministry for Economic Cooperation and Development (Eds.), International Fuel Prices 2007.

Pfaffenberger, W., 2006. Wertschöpfung und Beschäftigung durch grüne Energieproduktion? Energiewirtschaftliche Tagesfragen 56, 22–26.

Pigou, A., 1920. The Economics of Welfare. Macmillan, London.

Ramsey, F.P., 1927. A contribution to the theory of taxation. Economic Journal 37, 47–61.

Ryan, L., Convery, F., Ferreira, S., 2006. Stimulating the use of biofuels in the European Union: implications for climate change policy. Energy Policy 34, 3184–3194.

Schmitz, N., 2005. Innovationen bei der Bioethanolerzeugung. Schriftenreihe Nachwachsende Rohstoffe, Band 26, Landwirtschaftsverlag, Münster.

WDI, 2007. World Development Indicators 2007. World Bank 〈www.worldbank.org/data/wdi2003/index.htm〉.

World Bank, 1997. The Demand for Oil Products in Developing Countries. World Bank Discussion Paper no. 359.

WRI, 2007. World Resource Institute. Earth Trends Environmental Information 〈www.earthtrends.wri.org〉.