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Opportunities and constraints for agrofuels in developing countries: Case studies on economic viability and employment effects of Jatropha production

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EXECUTIVE SUMMARY

This dissertation was motivated by controversial statements of politicians and lobby groups for and against first-generation agrofuel production. Therefore this thesis contributes to a more realistic view on opportunities and constraints for agrofuel production based on first-generation technologies. The findings are based on an intensive literature review covering the following topics: current production trends of ethanol and agrodiesel, their potential for fossil energy substitution and greenhouse gas reduction including related costs, rural development and poverty alleviation. This more general overview on agrofuels was deepened by own research on Jatropha seed production in India and Madagascar. In this context the economic viability of Jatropha seed production and possible income effects for households living in the vicinity of a Jatropha plantation were analyzed. For this special agrofuel feedstock the findings allowed shedding some light on important aspects of the much broader topic concerning the production of agrofuels. To cover the above mentioned topics this dissertation is structured around three research papers.

The first paper identifies and discusses the opportunities and constraints of first-generation agrofuel production in developed and developing countries and is based on an intensive literature review. Therefore this paper contrasts arguments used by politicians to justify agrofuel support measures like energy security, greenhouse gas reduction potential, income generation and possible rural development with new scientific findings on each argument. Furthermore data on worldwide trends in ethanol and agrodiesel production were presented.

The revision of recent research showed that highest greenhouse gas reduction potential combined with lowest production cost occur for ethanol production based on sugar cane followed by the use of rapeseed, corn and other cereals. However the U.S. and E.U. focus on the latter ones, although their use revealed to be a very costly strategy for the reduction of greenhouse gases. That originally ascribed greenhouse gas reduction potentials are too high or even false, when including possible land use changes, lead to disillusioning results for possible climate change mitigation via using agrofuels instead of fossil fuels. In addition it was found, that the technical potential of first-generation agrofuel production can only make modest contributions to the replacement of current worldwide fossil fuel consumption. Furthermore it was shown that agrofuel production with current first generation technologies led to increasing food prices. This development was found devastating, especially for poor net buyers of food in developing countries.

Despite this problem worldwide production of agrofuels increased but was found to be driven mainly by subsidies and institutional frameworks than by market forces alone. Thereby agrofuel export chances, especially for land-rich and low cost developing countries were emphasized. To which extent the rural poor in those countries can profit from local agrofuel industries depends to a great extend on whether investors are focusing on large scale or smallholder agrofuel feedstock production, and how they will integrate the rural poor in these systems.

According to the literature review, the main outcome of this paper is, that general statements on opportunities and constraints of first-generation agrofuel production and use are difficult to make. They particularly depend on which feedstock is used, which production system is applied, which institutional and legislative framework conditions are set up and how agrofuels are finally used. This paper closes via summarizing, that in order to achieve positive effects on local employment, investment and income in rural areas, more appropriate policy and institutional frameworks as well as accompanying research are needed.

The second paper focuses on one possible option to lower competition between food and agrofuel production at least partially. This option is seen in the production of Jatropha seeds on marginal land not suitable for food production. In this context an Indian case study revealed the economic viability of Jatropha seed production on marginal land. The database for this study includes data derived from literature as well as experimental field data provided by the 'International Crops Research Institute for the Semi-Arid Tropics'.

As methodological framework the value chain approach was applied to translate different crude oil prices into fossil diesel prices in a first step. Then in a second step those price levels were transcribed into prices for two Jatropha seed based agrofuels and finally into possible market prices for Jatropha seeds. By using these derived market prices for Jatropha seeds the net present values for three Jatropha seed production scenarios, by accounting for different production costs, were calculated to estimate their economic viability with respect to different crude oil price levels. Here economic viability was assumed when positive net present values could be obtained.

Results show that producing Jatropha pure plant oil, as the first considered fossil diesel supplement, was able to generate positive net present values at crude oil prices between US$ 85-115 per barrel, taking into account low and baseline production cost scenarios (interest rate 10%) respectively. In contrast Jatropha agrodiesel, which was considered as second possible fossil diesel supplement, became competitive with fossil diesel at crude oil prices between US$ 105-130 per barrel taking into account low and baseline production cost scenarios (interest rate 10%) respectively. Hence the results show that those two Jatropha agrofuel options were able to compete with fossil diesel under the low and baseline cost scenarios and interest rates from 6% to 10% considering a crude oil price level of US$ 130 per barrel, already observed in 2008. However none of the high cost scenarios reached positive net present values even at a crude oil price of US$ 150 per barrel.

Hence, remaining uncertainties regarding agricultural practices and related costs as well as possible overestimations of yield levels under marginal land conditions can have strong effects on the economic viability of Jatropha projects. The results lead to the conclusion that further research on Jatropha under different soil and climatic conditions as well as on-farm experiments are required. This could fill the currently existing knowledge gaps and variation in available date, so that the uncertainties within the estimates are being resolved.

The third paper addresses possible income effects for rural households offering their labour force to a Jatropha plantation in central Madagascar. The econometric impact assessment is based on a socio-economic household survey undertaken by the author in 2009. To account for possible selection bias the propensity score matching approach was used to estimate the average treatment effect on the treated by comparing the average income of Jatropha plantation households and control households. The findings for 336 households reveal positive income effects for households working at the Jatropha plantation. Those effects are even more significant for the sub-sample of 226 households living below the national poverty line. In this case households working at the Jatropha plantation were able to generate average incomes which were much closer to the national poverty line as the average income among the group of control households.

The dissertation concludes that more investments in research are needed to gain a potential win-win situation for rural households, investors and the environment especially for the case of developing countries. The results lead to the conclusion, that smallholder based Jatropha seed production should not be promoted in developing countries. The reason for this recommendation is that a successful cultivation of Jatropha under smallholder conditions needs more appropriate data, even despite the promising results for economic viable production of Jatropha seeds within India. Especially Jatropha would not be economic viable if Jatropha seed production has to compete with agricultural cash crops for land, and labour as well as capital possibly used in other income generating activities. Another reason for this recommendation are the considerable uncertainties regarding the agronomic potential and adequate crop management practices in general as well as missing markets and value chains for smallholder to sell their Jatropha seeds.

Therefore this dissertation concludes further that it would be far better for developing countries to let international investors set up Jatropha plantations, hence in this case the economic risk is borne by the foreign investors. Furthermore abundant labour in rural areas could find employment opportunities with such plantations and therefore would be able to generate some income for their families. Nevertheless the implementation of Jatropha projects financed by international investor's needs regulations set up by national governments. Those regulations should cover each aspect within the entire value chain of Jatropha agrofuel production and should be embedded in a national energy and rural development policy. Furthermore institutional frameworks such as land tenure security and labour rights have to be enforced. Setting up aforementioned regulations and institutional frameworks can prevent possible constraints such as, land grabbing, exploitation of rural labourers, loss of biodiversity and competition between Jatropha seed and food production e.g. for scarce water, which could occur due to foreign investment in local Jatropha (and other agrofuel feedstocks) cultivation in the worst case.

ZUSAMMENFASSUNG

Diese Dissertation wurde durch die kontroversen Äußerungen von Politikern und Lobbyisten über das Für und Wider von Agrartreibstoffen der ersten Generation motiviert. Ziel dieser Arbeit war es basierend auf einer Durchsicht relevanter Literatur einerseits die weltweite Produktion von Ethanol und Agrardiesel anhand von Produktionszahlen aufzuzeigen und andererseits zur Beantwortung der folgenden Fragen beizutragen. Inwieweit kann die Produktion von Agrartreibstoffen der ersten Generation zum einen eine Strategie darstellen, die die Abhängigkeit von fossilen Treibstoffen reduziert und damit den Ausstoß an Treibhausgasen vermindert, einschließlich der damit verbundenen Kosten? Welche Möglichkeiten bestehen, dass die Produktion von Rohstoffen für die Agrartreibstoffherstellung zur Entwicklung ländlicher Räume und damit zur Armutsminderung beiträgt? Diese eher generelle Übersicht zur Produktion von Agartreibstoffen der ersten Generation wurde vertieft durch eigene Forschung hinsichtlich der Produktion von Jatrophasamen in Indien und Madagaskar. In diesem Zusammenhang wurde analysiert ob die Produktion von Jatrophasamen mit dem Ziel einen wettbewerbsfähigen Agrartreibstoff herzustellen wirtschaftlich betrieben werden kann und welche Einkommenseffekte durch eine Jatrophaplantage für Haushalte in deren Umgebung entstehen können. Die erzielten Ergebnisse erlauben es einen kleinen jedoch wichtigen Aspekt für ein mögliches Rohmaterial der Agrartreibstoffherstellung innerhalb des großen Rahmens der Agrartreibstoffproduktion besser zu verstehen. Diese Dissertation gliedert sich in drei wissenschaftliche Artikel.

Der erste Artikel identifiziert und diskutiert Möglichkeiten und Beschränkungen, denen die Agrartreibstoffproduktion mit Technologien der ersten Generation in Industrienationen und Entwicklungsländern unterliegt anhand einer intensiven Literaturdurchsicht. Diesbezüglich setzt er sich mit den durch Politiker angeführten Argumenten Energiesicherheit, Treibhausgasreduktion, Generierung zusätzlicher Einkommensmöglichkeiten und ländliche Entwicklung auseinander, da diese die Basis für gewährte politische Unterstützung der Agrartreibstoffproduktion darstellen. Weiter wird die Entwicklung der weltweiten Ethanol- und Agrardieselproduktion aufgezeigt.

Das größte Potential zur Treibhausgasminderung verbunden mit geringsten Produktionskosten ist bei der Herstellung von Ethanol auf Zuckerrohrbasis zu finden. Geringeres Potential bei der Treibhausgasminderung und höhere Kosten entstehen bei der Produktion von Agrartreibstoffen auf Basis von Raps, Mais und anderen Getreidearten. Dennoch wird die Verwendung von Raps, Mais und Getreide in den USA und der EU bei der Herstellung von

Agrartreibstoffen präferiert, obwohl deren Verwendung mit hohen Kosten verbunden ist. Das die ersten Berechnungen bezüglich der potentiellen Treibhausgaseinsparung durch die Verwendung verschiedener Agrarrohstoffe zu hoch ausfallen oder sogar als falsch zu bezeichnen sind wurde durch neuere Studien, die mögliche Änderungen in der Landnutzung mit einbeziehen, aufgezeigt. Weiter wurde dargestellt, dass das technische Potential der Agrartreibstoffherstellung mit gegenwärtig verfügbaren Technologien nur geringfügig fossile Treibstoffe ersetzen kann. Zusätzlich wurde aufgezeigt das die Agrartreibstoffproduktion einen negativen Einfluss auf die Preisentwicklung für Nahrungsmittel hat. Eine solche Entwicklung wirkt sich besonders dramatisch auf arme Nettokäufer von Nahrungsmitteln in Entwicklungsländern aus.

Trotz dieser Probleme steigerte sich die weltweite Produktion von Ethanol und Agrardiesel. Jedoch ist diese Entwicklung eher auf staatliche Subventionsprogramme und die vorteilhaften politischen Rahmenbedingungen zurückzuführen als auf Marktkräfte. Durch diese expandierenden Märkte entstanden Exportmöglichkeiten für die Entwicklungsländer, die in ausreichendem Maß über ungenutzte Flächen verfügen und nur geringen Produktionskosten haben. Ob jedoch arme Bevölkerungsgruppen in ländlichen Gebieten von der Etablierung einer lokalen Agrartreibstoffindustrie profitieren können hängt hauptsächlich davon ab wie mögliche Produktionssysteme (Plantagen oder kleinbäuerlichen Anbau) hinsichtlich der benötigten Rohstoffe in diesen Sektor eingebunden werden.

Basierend auf der Durchsicht relevanter Literaturquellen muss gesagt werden, dass verallgemeinernde Aussagen bezüglich des Für und Wieder zur Produktion von Agrartreibstoffen mit Technologien der ersten Generation nur schwer zu treffen sind. Vielmehr hängt deren Erfolg davon ab, welche landwirtschaftlichen Rohstoffe verwendet werden, welches Produktionssystem etabliert wird, wie institutionelle und rechtliche Rahmenbedingungen gestaltet sind und wie das Endprodukt Agrartreibstoff verwendet wird.

Dieser Artikel schließt mit der Erkenntnis, dass positive Effekte für lokale Beschäftigung, Investitionen und ländliche Einkommen nur erreicht werden können, wenn darauf ausgerichtete politische als auch institutionelle Rahmenbedingungen geschaffen werden deren Erfolg jedoch von intensiver Begleitforschung abhängt.

Der Möglichkeit einen Rohstoff für die Agrartreibstoffherstellung auf marginalen Standorten zu produzieren und somit die Konkurrenz zur Nahrungsmittelproduktion zu verringern widmet sich der zweite Artikel. Hierbei wurde in einer Fallstudie die Wirtschaftlichkeit der Produktion von Jatrophasamen auf solchen Standorten am Beispiel Indiens analysiert. Diese Analyse stützt sich auf Sekundärdaten relevanter Literatur und kombiniert diese mit neuen

Ergebnissen basierend auf Feldexperimenten durch das ‚International Crops Research Institute for the Semi-Arid Tropics'.

Für die Wirtschaftlichkeitsanalyse der Produktion von Jatrophasamen wurde der Wertschöpfungskettenansatz angewendet um verschieden Rohölpreise zuerst in Dieselpreise, dann diese in Preise für zwei auf Jatrophasamen basierende Agrartreibstoffe und zuletzt in mögliche Marktpreise für Jatrophasamen zu übersetzen. Anhand der generierten Marktpreise für Jatrophasamen wurde dann der Kapitalwert für drei Szenarien mit verschieden Produktionskosten berechnet, um deren Wirtschaftlichkeit unter Berücksichtigung verschiedener Rohölpreise abzuschätzen. Das Entscheidungskriterium hierfür war das Erreichen eines positiven Kapitalwerts.

Berechnungen für die Option Jatrophaöl zeigten, dass die Produktion von Jatrophasamen bei Rohölpreisen von 85 US$ bis 115 US$ pro Fass unter der Annahme niedriger bzw. durchschnittlicher Produktionskosten (Zinssatz 10%) wirtschaftlich betrieben werden kann. Die Produktion von Jatrophasamen für die Option Jatrophadiesel erreicht, wenn man die gleichen Produktionskosten wie im vorangegangenen Beispiel unterstellt, die Wirtschaftlichkeitsschwelle erst bei einem Rohölpreis von 105 US$ bis 130 US$ pro Fass. Diese Ergebnisse zeigen, dass die Produktion von Jatrophasamen unter den angenommen niedrigen bzw. durchschnittlichen Produktionskosten (Zinsatz 10%) wirtschaftlich betrieben werden kann, wenn Rohölpreise von 130 US$, wie in 2008 beobachtet, erreicht werden. Nichtsdestotrotz führte selbst bei der Annahme eines Rohölpreises von 150 US$ pro Fass keiner der beiden Jatrophatreibstoffe zu einem positiven Kapitalwert für die Produktion von Jatrophasamen unter hohen Produktionskosten,.

Trotz dieser Ergebnisse kann die nicht ausreichend gesicherte Datenbasis über landwirtschaftliche Anbaumethoden und davon abhängende Kosten sowohl als auch mögliche Ertragsüberschätzungen hinsichtlich des Ertragspotentials auf marginalen Standorten einen großen Einfluss auf die Wirtschaftlichkeit von Jatrophaprojekten haben. Deswegen bedürfen die erzielten Ergebnisse zusätzlicher Forschungsarbeit, um das Ertragspotential von Jatropha auf verschiedenen Böden sowie für unterschiedliche klimatische Bedingungen mit Hilfe von Feldexperimenten zu validieren. Diese Erfahrungen können dazu beitragen die bestehende Variation in den Daten zu verkleinern und somit eine noch genauere Berechnung der Wirtschaftlichkeit von Jatrophasamenproduktion ermöglichen.

Der dritte Artikel beschäftigt sich mit der Berechnung von Einkommenseffekten für Haushalte, die auf einer Jatrophaplantage in Zentralmadagaskar arbeiten. Dazu wurde eine ökonometrische Analyse basierend auf den Daten einer sozioökonomischen

Haushaltsbefragung durchgeführt. Die Erhebung der verwendeten Daten erfolgte durch den Autor im Frühjahr 2009. Um mögliche Selektionseffekte der Haushalte zu berücksichtigen wurde die Methodik des „Propensity Score Matching“ angewendet. Diese Methodik erlaubte es Haushalte, die auf der Jatrophaplantage arbeiten, mit ähnlichen Haushalten einer Kontrollgruppe hinsichtlich ihres Einkommens zu vergleichen. Anhand einer Stichprobe von 336 Haushalten konnten positive Einkommenseffekte für Plantagenhaushalte nachgewiesen werden. Bei der Analyse von Einkommenseffekten innerhalb einer Teilstichprobe von Haushalten mit Einkommen unterhalb der nationalen Armutslinie (N 226), wiesen die ermittelten Einkommenseffekte eine höhere Signifikanz als bei der Gesamtstichprobe auf. In der Teilstichprobe konnte gezeigt werden, dass das durchschnittliche Einkommen der Plantagenhaushalte höher und deutlich näher and der nationalen Armutslinie lag, als das durchschnittliche Einkommen der Kontrollhaushalte.

Abschließend muss darauf hingewiesen werden, dass nur durch weitreichende Forschungsarbeiten, speziell für Entwicklungsländer, eine Situation herbeigeführt werden kann, in der die ländliche Bevölkerung, Investoren und die Umwelt gleichzeitig profitieren. Weiterhin führen die Ergebnisse dieser Arbeit zu dem Schluss, dass zum gegenwärtigen Zeitpunkt der kleinbäuerliche Anbau von Jatropha in Entwicklungsländern nicht forciert werden sollte. Der Grund für diese Schlussfolgerung ist, dass für eine erfolgreiche kleinbäuerliche Produktion von Jatrophasamen die Datenbasis als nicht ausreichend zu betrachten ist, obwohl die gezeigten Ergebnisse für Indien als erstes Indiz für die Möglichkeit Jatrophasamen wirtschaftlich zu produzieren anzusehen ist. Weiterhin kann die Produktion von Jatrophasamen nicht mit der Produktion von Nahrungsmitteln um die Produktionsfaktoren, landwirtschaftliche Fläche, Arbeitskräfte und Kapital konkurrieren.

Zusätzlich zu der Problematik, dass noch keine adäquaten Anbaupraktiken für die Kultivierung von Jatropha entwickelt wurden, bestehen noch große Unsicherheiten bezüglich des Ertragspotenzials von Jatropha, besonders auf marginalen Standorten, sowohl fehlen Märkte als auch Vermarktungsketten für Kleinbauern.

Aufgrund dessen sollten Entwicklungsländer vorerst internationale Investoren mit der Etablierung von Jatrophaplantagen betrauen, da diese fähig sind die ökonomischen Risiken eher zu tragen als lokale Kleinbauern. Dieser Fall kann zu einer Belebung des ländlichen Arbeitsmarktes führen, und ungelernten Arbeitskräften und ihren Familien Einkommensalternative bieten. Regierungen sollten jedoch die Aktivitäten ausländischer Investitionen durch das Entwickeln gesetzlicher und institutioneller Rahmenbedingungen für eine nationale Produktion von Agrartreibstoffen begleiten. Besonders anzuraten ist die

Einbindung einer möglichen Jatrophatreibstoffproduktion und ihrer einzelnen Produktionsschritte in einen nationalen Energie- und Entwicklungsplan. Weiter sollten Anstrengung zur Sicherung von Landbesitz und gegen eine mögliche Ausbeutung von Plantagenarbeitern auf nationaler Ebene unternommen werden. Durch diese gesetzlichen und institutionellen Rahmenbedingung können negative Auswirkungen, von Auslandsinvestitionen in Jatrophaproduktion (sowie in andere Rohstoffe für die Gewinnung von Agrartreibstoffen), wie Landraub, die Ausbeutung von Plantagenarbeitern, Biodiversitätsverluste und eine mögliche Konkurrenz zwischen Jatropha und Nahrungsmittelproduktion z.B. um knappe Wasserressourcen verringert bzw. vermieden werden.

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INTRODUCTION

1.1 Problem background

Developed countries reached their present level of development due to the long use of non-renewable fossil energy sources. Their economies are still highly dependent on such fossil energy sources. However fossil energy sources are non-renewable. Stern (2003:31), therefore concludes "energy is a limiting factor in economic growth". The developed nations are not the only ones that depend on fossil energy. The growing economies of China and India will strongly influence future worldwide energy demand as well (IEA, 2008:39).

Due to the fact that fossil energy stocks are limited it is questionable if their exploitation will be able to keep up with the forecasted worldwide energy demand. This is especially visible in the case of potential crude oil production, as the peak in oil production is forecasted to be reached in 2014 (Nashawi et al. 2009:1795). Decreasing production coupled with increasing demand will drive crude oil prices up again. Due to this, public awareness has risen and it is now known that levels of energy use can not be maintained as they are at present. Possible solutions for future fossil energy shortages are the development of alternative renewable energy sources and improvements in energy efficiency.

Beside the problem of decreasing stocks of fossil energy Stern (2007) revealed in his report the consequences of which are our excessive fossil energy use on climate change as well as its possible economic impacts. In order to reduce the impact of climate change worldwide release of greenhouse gases like CO_2 have to be essentially cut back. To reach this target fossil energy consumption has to be decreased. Considering the problem of climate change it is even questionable if we should exploit our fossil energy stocks to their limits. Therefore the substitution of fossil energy sources by renewable energy sources like solar, wind and biomass becomes even more urgent and has received remarkable political support during the last decade, especially in the U.S. and Europe.

With current first generation technologies, different forms of biomass like sugar cane, cereals and oil seeds can be transformed into liquid agrofuels. Common agrofuels are ethanol and agrodiesel. They are applicable to current engines used in transport and therefore represent a preferable solution for fossil fuel substitution within the transport sector. Besides lowering pressure on crude oil production, agrofuels are often falsely assumed to be CO_2 neutral as effects on land use changes are not always included in those calculations. However those first generation technologies depend on biomass used also for food production. Growing biomass for agrofuel production competes with food production as both biomass and food production depends on agricultural land and on other potentially limiting factors of agricultural production, such as agricultural labour, capital, and water. In view of this situation, agrofuels were blamed in some parts of the press for dramatic worldwide food price escalations in 2008. Especially a report written by Mitchell (2008:17) caused a stir in worldwide press when announcing that agrofuel production combined with low levels of grain stocks, export bans, and large shifts in land use as well as speculations were found responsible for a 70-75% increase of worldwide food prices from January 2002 until February 2008.

To lower competition between agrofuel and food production different options are under discussion. The most drastic one was announced by Ziegler (2007). He applied for a five-year moratorium on agrofuel production. A less radical alternative suggests shifting agrofuel feedstock production towards marginal areas not suitable for food production purposes. The development of second generation technologies which is targeting the transformation of agricultural residues and waste into agrofuels provides additional hope. However those technologies are still on trial status and until now no breakthrough has been obtained. To address competition between agrofuel and food production and at the same time to include environmental and social criteria related to agrofuel production, certification schemes for agrofuel feedstock production are under development.

1.2 Research questions

Apart from the above introduced relevance for replacing fossil energy via renewable energy sources to mitigate climate change and to answer worldwide energy needs, further motivation for this research were the strong debates in politics and press on the issue of food vs. fuel and the possible chances that agrofuels can provide for rural development. For example, the widely stressed infant industry argument combined with targets on national energy security have been applied by politicians in developed countries to justify their different support measures for agrofuel production. These are mainly tax exemptions and obligatory blending quotas to mix agrofuels into fossil fuels. Furthermore producing feedstocks for renewable energy purposes is assumed to create additional income opportunities for farmers in developed and developing countries. To take this current discussion further and to contribute to policy-relevant knowledge on agrofuels in general and Jatropha, a specifically agrofuel feedstock, this dissertation combines existing literature and own field research to answer the following research questions and hypothesis:

Question 1: What are global agrofuel production trends with respect for ethanol and agrodiesel?

Hypothesis 1: In developed countries agrofuel production is up to now driven by subsidies and institutional frameworks and not by market forces alone and few developing countries have reached the technological stage to produce significant quantities at competitive prices.

Question 2: What are the opportunities and constraints seen in first-generation agrofuels?

Hypothesis 2: Depending on feedstock used, first-generation agrofuels provide opportunities for fossil energy substitution, for climate change mitigation, for rural development and poverty alleviation.

Question 3: At which crude oil price does Jatropha seed production in India obtain economic viability?

Hypothesis 3: Jatropha pure plant oil and Jatropha agrodiesel are only competitive with fossil diesel at the filling station when the crude oil price reaches 100 US$ per barrel .

Question 4: Can large scale Jatropha plantations provide positive income effects for the rural population living in the vicinity of such a plantation?

Hypothesis 4: Due to working on a Jatropha plantation positive income effects for the rural population living in the vicinity of such a plantation can be generated.

The motivation to focus in research question three and four especially on Jatopha seed based agrofuel production was influenced by the fact, that Jatropha can be grown in marginal areas not suitable for food production purposes. However different plant species are supposed to grow under such conditions. In this context the most propagated ones are Sweet Sorghum, Castor, Jatropha and Pongamia. The profound analysis including all suitable plant species was found to go beyond the scope of this work. Preference therefore was given to Jatropha, as investors together with development aid and non-governmental organizations have already started to support the setup of Jatropha production systems worldwide. This increasing interest in Jatropha cultivation can be seen in the GEXSI report of 2008. The report provides the first analysis of Jatropha projects worldwide. According to the GEXSI (2008:17) report in total 242 Jatropha projects and approximately 900,000 hectares did exist in 2008. Asia leads worldwide planted Jatropha area with 796,000 ha followed by Africa with 119,000 ha and Latin America with 21,000 ha in 2008 figures. Within Asia larges Jatropha cultivation takes place in India, followed by Cambodia and China. Other leading countries in Jatropha cultivation outside Asia are Brazil, Zambia, Tanzania and Madagascar. Furthermore the GEXSI (2008:6) report estimates that global investments in Jatropha plantation could sum up to 1 billion US$ per year worldwide and that Jatropha plantations could reach 13 million hectares in 2015. The GEXSI (2008:36) report further states that outgrower schemes alone ore in combination with own plantations account for around two third of all projects.

Additional motivation in Jatropha cultivation was raised by the possibility of fossil fuel import substitution through national agrofuel production. According to GEXSI (2008) Jatropha agrofuel production is primary designated to meet domestic market demand than to be exported. Furthermore unrefined Jatropha oil is seen equally important for domestic markets as refined Jatropha agrodiesel. Governments in developing countries became interested in designing proper agrofuel action plans and therefore started to foster the implementation of local Jatropha production systems. According to the GEXSI (2008) report "more than 50 governments worldwide have announced national biofuel targets, with a growing number located in emerging markets" (GEXSI, 2008:32). Among those countries several developed draft policies for Jatropha promotion purposes including energy supply, poverty alleviation and environmental protection targets. National policies cover a broad range of instruments like "national targets for Jatropha plantations, different types of plantation or reforestation programs, financial support for growers, for research and/or for investors as well as a mandatory biodiesel blending" GEXSI (2008:32). For many Asian governments Jatropha production plays a strategic role and therefore governmental support programmes can be seen as main driver for Jatropha cultivation in Asia.

Within Africa "the governments in Senegal, Mali, Nigeria, Ethiopia and (in particular) Zimbabwe have formulated policies which explicitly focus on the promotion of Jatropha" GEXSI (2008:32). Furthermore many African countries promote renewable energy investments via active support programs "or facilitate the access of land to interested investors" GEXSI (2008). In the case of Latin America targets and programs for Jatropha cultivation have been developed e.g. by the governments of Mexico and Colombia. However highest expectations on Jatropha production are seen in the possibility to including Jatropha in the social agrofuel program of Brazil. The GEXSI (2008) report concludes that "today, the global Jatropha industry is dominated by government supported programs and a few larger internationally oriented private players" (GEXSI, 2008:6). However, increasing crude oil prices can lead to strong agrofuel demand and therefore "major oil companies and international energy conglomerates entering the field with plans for large-scale investments" (GEXSI, 2008). This development will result in more general governmental regulations for the agrofuel sector framework regulations.

First evidence of Jatropha oil use for fossil fuel substitution purpose was reported by Banerji et al. (1985), Münch and Kiefer (1986; 1989), Hackel (1994), Helberg (1994) and GTZ (1995). Despite these early works Jatropha missed continuous interest in research. Due to this fact no distinct knowledge about how to successfully establish Jatropha production systems exist. Even as breeding programmes for Jatropha are established nowadays Jatropha still has to be classified as non domesticated plant species. Due to new research efforts on Jatropha further knowledge gains can be observed. However those gains still do not satisfy the required information to ensure successful implementation of smallholder Jatropha production systems (GTZ, 2009:10).

Strongest Jatropha research activities are located in India. Leading research centres are the International Crop Research Institute for the Semi-Arid Tropics, the Energy and Resources Institute and the Central Salt & Marine Chemicals Research Institute. The research activities of these centres are nestled in a 'National Biofuel Policy' released by the Indian government in 2008. Besides targeting the substitution of fossil fuel imports, the Indian government recognizes the propagation of Jatropha based agrofuel production as favourable to generate rural employment. Since up to 20 million hectare within India are classified as marginal or waste land they are therefore available for setting up Jatropha plantations. In contrast to India's policy on agrofuels focusing on developing small scale Jatropha production systems, foreign investors usually favor the establishment of their own plantation systems in developing countries (GEXSI, 2008:34). This approach can be seen as favorable strategy for developing countries as the risk of investing in Jatropha production stays with these investors and local farmers do not have to carry this burden like in the case for contract farming or independent small scale production. This is of special importance as Jatropha does not provide any returns during the first 2-3 years.

As agronomic knowledge on Jatropha production is still lacking there is little evidence at what point of crude oil prices Jatropha production could become economically competitive to fossil diesel at the filling station within India. A first overview on expected benefits due to the establishment of Jatropha based agrofuel production in India was presented by Francis et al. (2005). However Francis et al. (2005) did not cover how different crude oil price levels would affect the economic viability of Jatropha seed production. But this relation is essential, as

Jatropha based agrofuels have to be competitive with fossil diesel at the filling station. The price level of crude oil can either push or block the sale of Jatropha agrofuels and seeds. However, the increasing worldwide investments in Jatropha cultivation show a certain confidence that profitable Jatropha seed production is possible.

Profitable Jatropha seed production does not depend on crude oil price levels alone. A large share of production costs result from expenditures on agricultural labour force, as labour is needed for installation, maintenance and harvesting purposes. Beside the relative high availability of suitable marginal areas, investors focus on growing Jatropha mainly in developing countries because agricultural wages are very low and therefore allow reducing Jatropha seed production costs.

Under rural development perspectives the installation of Jatropha plantations is seen as possible source for income generation and poverty alleviation. Nevertheless concerns on possible exploitation of labour are stressed by consumers and politicians in developed countries. Most Jatropha projects are quite young and therefore no evidence on real income effects exists. Therefore the GEXSI report 2008 states that very low knowledge "about the social and ecological impact of the current projects as well as of future large-scale investments and ambitious governmental programs on Jatropha" (GEXSI, 2008:14) does exist. Therefore question 4 aims to provide first scientific evidence on such effects by analyzing households in the vicinity of a Jatropha plantation in central Madagascar.

Answering the questions three and four can provide urgent information needed to investors and national governments to give advice and support for setting up sustainable Jatropha seed production systems and their integration in national agrofuel and rural development policies.

1.3 Outline

In the following, the content of each of the thesis chapters is briefly described. Chapter 2 briefly introduces the following methods which are used in the analysis in Chapter 4 and 5: value chain analysis, sampling procedure employed for socio-economic household survey and impact assessment methods. The aim of this section is to provide additional information which enables the reader to gain a broader understanding of the methodological frameworks applied in chapter 4 and 5. However this chapter does not discuss alternative options for, e.g. impact assessment in detail, as it is intended to only provide an expansion on information given in chapter 4 and 5.

Based on a literature review, chapter 3 identifies and discusses the opportunities and constraints of agrofuels in developing countries, thereby addressing the first two research questions. As discussion about opportunities and constraints of agrofuels cover a wide range of scientific topics, the research presented in this chapter consists of a review and synthesis of major findings from existing studies. In a first step worldwide ethanol and biodiesel production is examined to reveal which countries are leading producers of ethanol and biodiesel[1]. Furthermore expectations on cereals, oilseeds and sugar consumption quantities and their probable shifting towards agrofuel production for U.S. and E.U. will be demonstrated. Then, in a second step, the extent to which current first generation technologies for agrofuel production will be able to replace present fossil fuel consumption is exposed, based on their technical production potential and associated production costs. Furthermore possible environmental effects of agrofuel production and their related costs are compared in a fourth step to investigate the claim that agrofuel production can be one strategy to mitigate climate change. Agrofuels were blamed for the dramatic food price escalations worldwide in 2008. The potential social costs related to this competition are discussed in a fifth step. Here special evidence is given to who could suffer or benefit from such an increase in global agrofuel production and use.

Jatropha, a specific possible feedstock for agrofuel production purposes, is investigated in-depth in chapter 4 and 5. To provide a more distinct analysis chapter 4 reveals the economic viability of Jatropha production via assessing possible Jatropha seed prices due to a value chain approach and successive net present value calculations for different production cost scenarios. Apart from a baseline scenario, different scenarios for production costs and interest rates of Jatropha production as well as for prices of crude oil and fossil diesel are investigated. The analysis draws on experimental agronomic data on Jatropha seed production provided by the International Crops Research Institute of the Semi-Arid Tropics. Additional agronomic data on yields and labour demand for harvesting Jatropha seeds is obtained based on a literature review. This information constitutes the database for modeling three different Jatropha production cost scenarios. Those scenarios are assumed to cover the existing range of available data.

The literature reports yields for Jatropha which range between 0.8 and 12 tons per hectare. Most of the yields mentioned in the literature have little scientific basis, and can be viewed as

[1] After finishing the first paper I did not use the term biodiesel anymore and used agrodiesel instead. The reason for this is that in my point of view the word “bio” in biodiesel is misleading, as it might suggest that biodiesel is produced by organic agriculture or related standards. This is not the case. However the term biodiesel was used widely in literature and press.

best guesstimates of different authors. As this analysis seeks to explore the potential of Jatropha to be economically viable when using marginal lands, a conservative maximum yield of 1.5 tons Jatropha seeds per hectare was assumed. Future fluctuations of crude oil prices as well as interest rates over time are hardly predictable. Therefore for each Jatropha production scenario possible crude oil prices in the range of US$ 70-150 per barrel and different interest rates were applied for simulation purposes. However for net present value calculations stepwise applied crude oil prices as well interest rates were hold constantly over the productive lifetime for all three scenarios for Jatropha seed production costs.

The assessment of income effects for households working on a large scale Jatropha plantation is revealed in chapter 5 based on a case study of a Jatropha plantation in central Madagascar. Here the propensity score matching approach was applied to assess possible income effects for households living in the vicinity of a Jatropha plantation. The primary data used for this study came from a socio-economic household survey designed and implemented by the author in 2009. This socio-economic research is embedded in an interdisciplinary research project. This project is targeting an analysis of renewable energy production based on Jatropha oil which can become a valuable economic perspective for rural households within Madagascar. The project is funded by two foundations. First the foundation for energy research Baden-Wuerttemberg (Stiftung Energieforschung Baden-Württemberg) and second the EnBW rainforest foundation (EnBW Regenwaldstiftung). General conclusions about the results as well as their critical reflections are discussed in the closing chapter 6.

METHODOLOGICAL FRAMEWORK

Chapters 4 and 5 were submitted as journal papers, and restrictions on space did not allow to sufficiently describing the underlying methodology or to provide aditional background information. The aim of this chapter is to provide additional information on the methods used within chapter 4 and 5.

2.1 The value chain approach and assumed production cost scenarios

The value chain approach covers all activities required to "bring a product or service from conception, through the different phases of production … , delivery to final consumers, and final disposal after use" (Kaplinsky and Morris, 2001:4). Furthermore a value chain consists of different stakeholders like suppliers of raw materials, processors as well as exporters and buyers which are relevant to bring a special product or service from its first design to end use. According to Bammann (2007) "the value chain concept has proven particularly useful for the identification and formulation of projects as well as in the development of strategies for improved agricultural and rural development" (Bammann, 2007:113). Similarities exist between the value chain concept, the French method *filière* and global commodity chain analysis. The French filière approach originated from technocratic agricultural research, whereby the global commodity chain analysis was primarily developed for industrial commodity chains. The global commodity chain analysis was "introduced into the literature by Gereffi during the mid-1990s" (Kaplinsky and Morris, 2001:8). An in depth comparison of the concept *filiere* and global commodity chain analysis is presented in Raikes, Jensen and Ponte (2000).

In the case of chapter 4 the value chain approach was used to design a possible production chain starting with Jatropha seed production until the final fossil diesel supplements namely Jatropha pure plant oil (JPPO) and Jatropha methyl ester (JME). Here accruing costs of each step from feedstock production over processing until the final product is reached are included. The applied concept steps are presented in Figure 2.

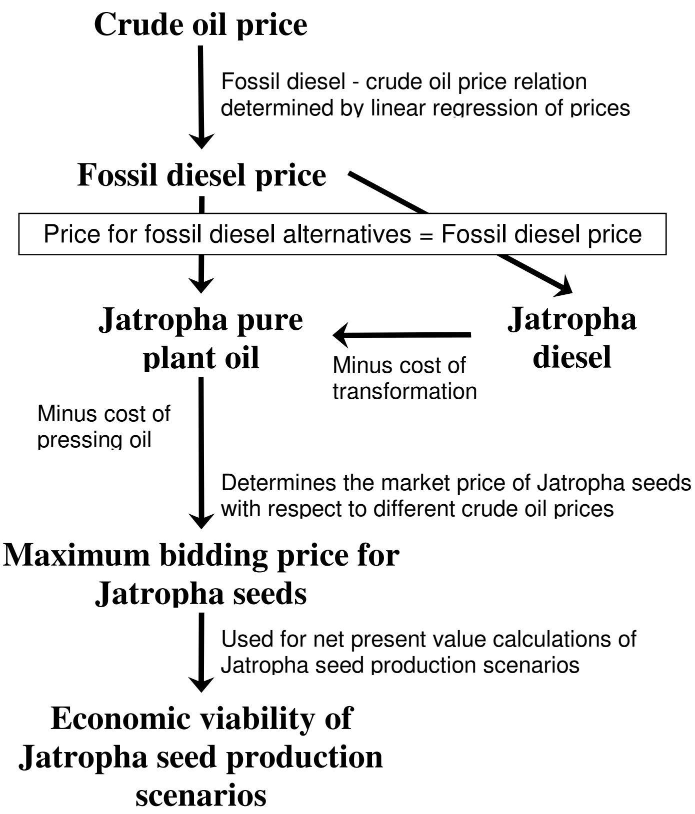

Figure 2: Overview of value chain systematic

The economic viability of Jatropha seed production depends on the strength of JPPO and JME to compete with fossil diesel at fuel markets in India and in addition with crude oil price levels worldwide. The relation between diesel prices and crude oil prices is presented in figure 3 graphically. The data presented is based on information collected from the US Energy Information Administration with respect to crude oil prices and diesel prices in the USA. The data for diesel prices in India is collected from the Indian Ministry of Petroleum and Natural Gas. To establish interlinkages between crude oil prices and fossil diesel prices in a first step their relation was calculated using historical data from January 2000 to October 2007.

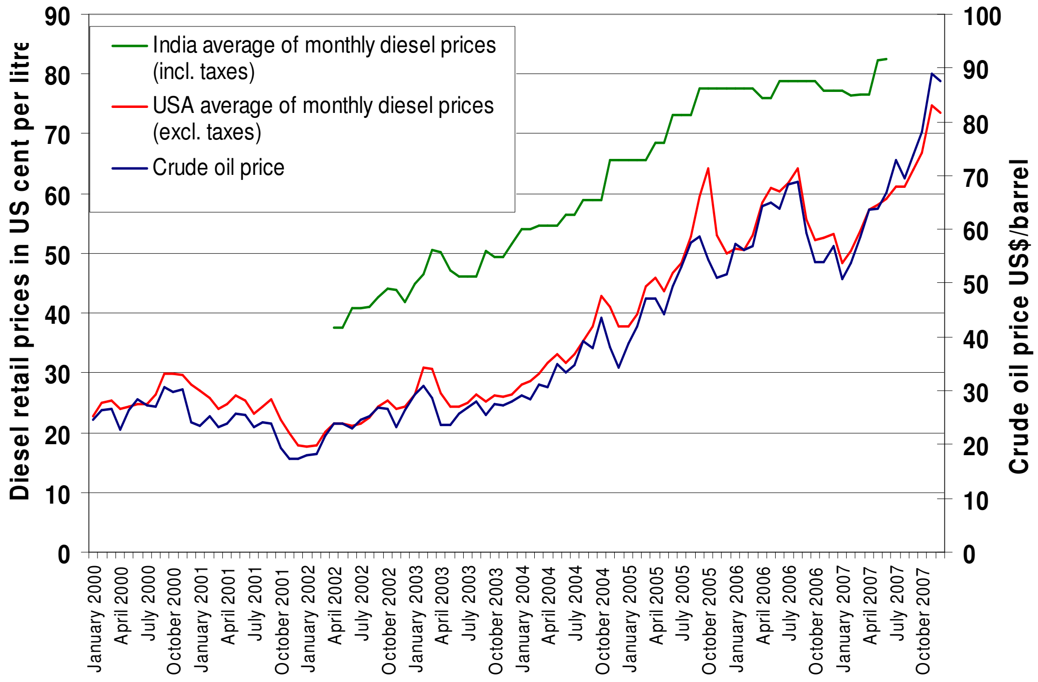

Figure 3: Crude oil and fossil diesel price developments

Source: own calculations

To make prediction on how fossil diesel prices will change when crude oil prices reach even higher levels as the already observed ones this historical data was applied to construct a formula (Figure 4) via linear regression. This calculation used an adjusted approach from Henniges (2007:133). Due to this formula possible crude oil prices could be directly translated into probable fossil diesel price levels.

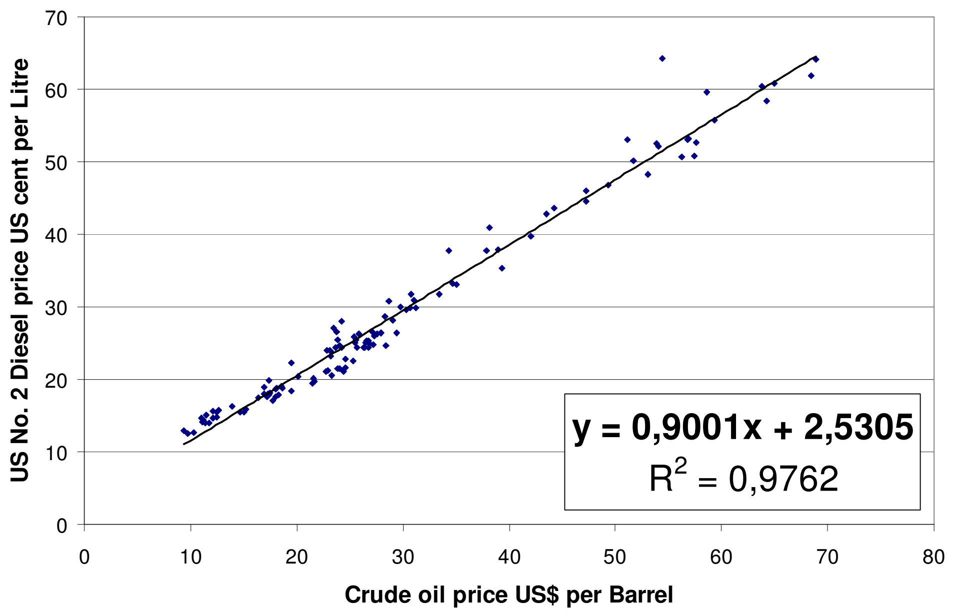

Figure 4: Crude oil price - fossil diesel price relation

Source: own calculations

Furthermore those fossil diesel price levels serve as benchmark prices for JPPO and JME at the retail station. When production cost for JPPO and JME would be higher as fossil diesel prices they are assumed to be not competitive as long as they are not targeted by subsidies or policy blending obligations. Therefore only when they obtain equal or lower price levels as fossil diesel a market demand for JPPO and JME arises. For further calculation processing costs of Jatropha seeds into JPPO and its possible transesterification into JME were subtracted from different fossil diesel price levels and a maximum bidding price for which Jatropha seed could be purchased was determined. This maximum bidding price is defined as Jatropha seeds price a processor will pay at maximum when counting for a specific crude oil price level.
As reliable agronomic data on Jatropha production systems is lacking three different cost scenarios with respect to Jatropha seed production are applied to cover the existing range of information of agricultural practices available. The main differences in these cost scenarios result from different wage levels for harvesting activities and harvesting efficiency. To determine if those production scenarios will generate positive net present values the maximum bidding price was used as possible selling price for Jatropha seed producers. Additional information for applied production cost scenarios is described in chapter 4. Furthermore an extended overview on results not presented in chapter 4 is given in Appendix (A 1-6).

2.2 Introduction of research region and of sampling applied

The research region for income effect analysis presented in chapter 5 is located in the district of Ambalavao, province Fianarantsoa, central Madagascar. Since 2007 a German investor is setting up via its Malagasy subsidiary company a Jatropha plantation which targets to cover between 3,000 to 4,000 hectares of Jatropha when completed. The aim of this plantation project is to produce agrofuels based on Jatropha oil to supply the national transport market as well as to generate electrical power. To maintain and enlarge the plantation local labour force is recruited among the rural villages in the vicinity of the plantation. Population density data for 2003 reveal that the district of Ambalavao has population density of 52.7 persons per km².

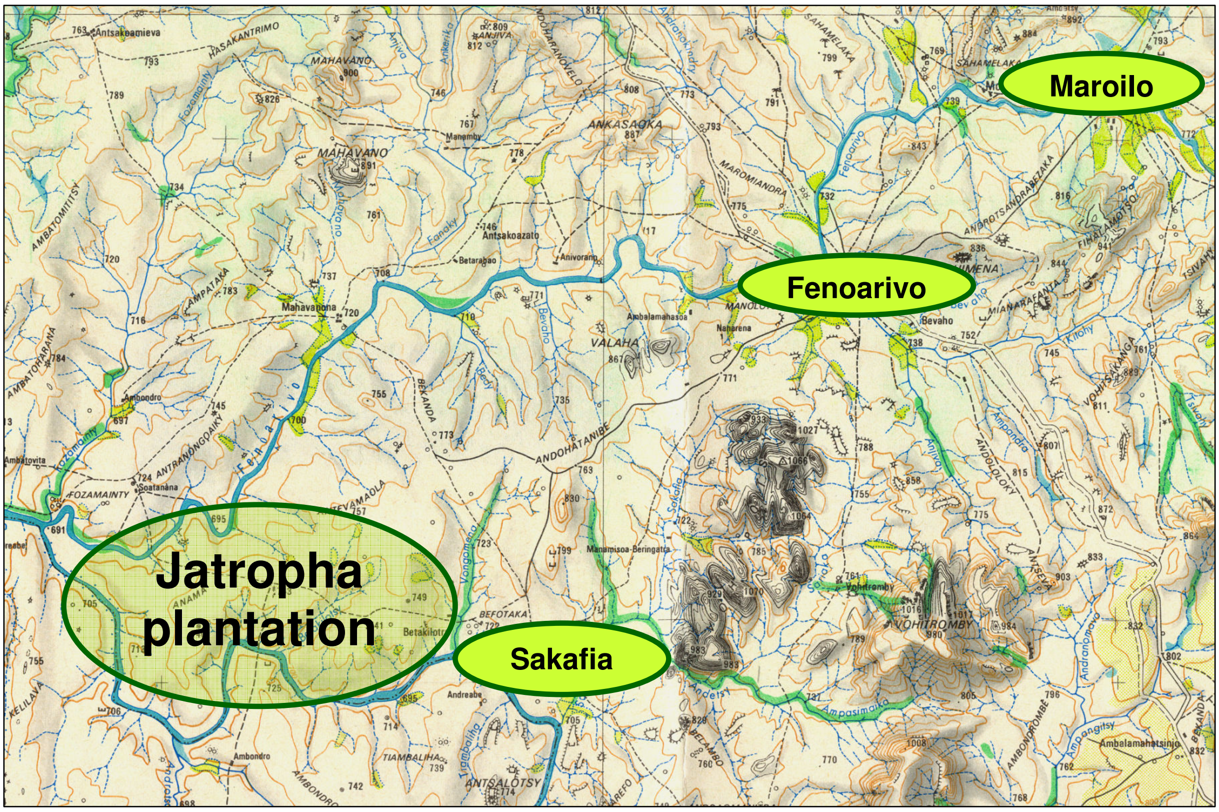

Figure 5: Research region

Source: FTM, Feuille L 54, Antananarivo

The latest national study on poverty was undertaken by the Institut National de la Statistique de Madagascar (INSTAT) in 2005. The results determine that in urban areas 52.0% and in rural areas 73.5% of the population lives from incomes below the nation poverty line of 305,300 Ariary per capita (INSTAT, 2005:2).

The incentive for socio-economic research in this special region was to assess how the possibility to generate additional income via working for this Jatropha plantation would affect rural livelihoods nearby the Jatropha plantation. A sample size of 50% of total households per village was chosen randomly from three villages in the surrounding area of the plantation. The three villages where purposeful selected and reflect the villages that provide the majority of the labour force working for the plantation.

However local conditions, budget and time constraints did not allow for to survey additional villages. Important restrictions for this field research contained security issues, as the research region lies in close vicinity to a so called ‘red zone’. In Madagascar a ‘red zone’ is classified as a region with large banditry activities mainly focusing on cattle stealing possibly encouraged due to its remote area and poor infrastructure connections to the next paved road.

This situation did not allow for intensive travelling. Furthermore staying overnight in remote villages far from Fenoarivo was not suggested by local authorities like the village head of Fenoarivo as well as the chief of Fenoarivo police station. Beside this no other means of transportation were available as walking by foot and using zebu wagons. However using a zebu wagon was not faster as walking by foot but it represented a good opportunity for transporting material. Those constraints already decreased the possible number of villages able to select. Villages achievable for being surveyed were Fenoarivo, Sakafia and Maroilo. A further village named Mahavanona was not accessible as due to the rainy season the river to be passed had high water. Because of the presence of large caimans interviewers refused to cross. Despite the non-random selection of those three villages included in the survey they still represent a considerable range of distance to the plantation. Furthermore Jatropha plantation officials stated that the major share of plantation workers come from those villages. When looking in Figure 5 the closest village is Sakafia (4km) followed by Fenoarivo (12km) and Maroilo (18km).

A first indication on how many household live in targeted villages was derived from an earlier work done by Bünner 2009. Bünner (2009:12) stated that about 614 households are living in Fenoarivo, Maroilo and Mahavanona. For this research Mahavanona was exchanged by Sakafia. For all villages a total amount of around 600 households was assumed. However no complete household lists could be provided by local authorities and village heads on day of arrival. Therefore together with each village head such lists were compiled via visiting and recording households for each house within those villages.

With this approach an updated list of households per village was established, showing that about 700 households live in these three villages. After obtaining this number those three villages were included in the survey. However due to time and budget constraints not all households could be interviewed with the complete questionnaire. This complete socio-economic questionnaire was covering information on demographics, assets owned, non agricultural activities and revenues, information about own agricultural production and husbandry as well related production cost, a wide range of expenditures and open questions related to prospects and challenges occurring since the Jatropha plantation took place. Therefore a 50% share of households within each village was chosen randomly to be interviewed with the complete questionnaire and the remaining 50% were interviewed with a reduced questionnaire. Due to this practice additional information on census and occupation data for the overall population could be obtained. This allows for additional comparisons between the sample used for impact assessment and the overall population. However the generated household list did not provide information on whether the household registered was already offering labour force to the plantation or not. Within the sample of households interviewed with the complete questionnaire (N = 336) it was found that 180 households did already allocate some of their working force towards the Jatropha plantation and 156 households did not. To motivate households to invest 2-3 hours to answer the questionnaire a small compensation in form of one bar of soap and two kapoaka[2] of sugar were offered. Furthermore during the first 10 minutes the interviewers explained the survey motivation and made sure that the information provided would be treated confidentially.

2.3 Overview: treatment / program evaluation methods

A broad overview how the assessment of program evaluation developed is presented in Imbens and Wooldridge (2009). Within their paper "*Recent Developments in the Econometrics of Program Evaluation"* Imbens and Wooldridge (2009) describe that the central problem studied in this field of research "is that of evaluating the effect of the exposure of a set of units to a program, or treatment, on some outcome" (Imbens and Wooldridge, 2009:6). In the case of economic studies focusing on program or treatment evaluation a broad range of units like individuals, households, companies or countries are possible observation units. The term treatment can be interpreted highly diverse such as participation in programs focusing e.g. on job assistance, poverty reduction, education, health care, laws or regulations as well as introducing new technologies.

For studying the treatment effect a critical feature occurs when each unit can obtain multiple treatment levels. However the majority of relevant literature focuses on binary treatment frameworks (Imbens and Wooldridge, 2009:8).

In the binary treatment setting a unit i either was exposed to treatment (W_i =1) and received outcome Y_{i1} or was not exposed to treatment (W_i =0) and received outcome Y_{i0}. Therefore the impact evaluation includes the measurement of how outcomes for units' changed due to a program or a treatment.

In order to measure this, one need to know the possible outcome Y_{i0} of unit i (W_i =1) and the possible outcome Y_{i1} of unit i (W_i =0). The difference in received outcome and possible outcome is usually considered as the program impact. However the possible outcome for these units can not be observed. To solve this problem different approaches exist to identify a

[2] Nestle milk can which is widely used for measure agricultural goods at local markets in Madagascar. Two kapoaka of sugar are equivalent to approximately 500 g.

suitable estimation of the unobserved possible outcome (sometimes referred as counter-factual outcome Y_{i0}) for unit i (W=1). To solve this problem ex post treatment evaluation methods often use the ‘potential outcome framework’ (Cobb-Clark and Crossley, 2003:492).

2.3.1 The potential outcome framework

If we want to evaluate the impact of some program (or treatment) on some interesting outcome Y (like income) usually we observe the random variables Y_{i1} and Y_{i0} which capture the outcome for a unit i if the unit does (W_i =1) and does not (W_i =0) participate in the program, respectively. The derived outcomes of these random variables for unit i are determined by Y_{i1} and Y_{i0}. Therefore the impact of participation for this unit is given by $\Delta_i = Y_{i1} - Y_{i0}$. For those units i who participate (W=1) only the outcome of participation (Y_{i1}) can be observed, whereas for units i who do not participate (W=0) only the nonparticipation outcome (Y_{i0}) can be observed. “Paul W. Holland (1986) refers to this as the fundamental problem of causal inference” (Imbens and Wooldridge, 2009:6). Therefore for each unit the observed outcome can be written as:

$$Y_i = W_i Y_{i1} + (1 - W_i) Y_{i0} \qquad (1)$$

In this formula W_i represents a dummy variable which provides information about units’ participation. If the unit did participate it becomes W_i = 1 and if the unit did not participate it becomes W_i = 0. As for each unit i either the outcome Y_{i1} or Y_{i0} can be observed, it is generally not possible to obtain the treatment effect $Y_{i1} - Y_{i0}$ at individual level for any unit i. Furthermore within the potential outcome framework heterogeneity in program impacts (Δ_i) and in outcomes of no participation (Y_{i0}) are explicitly allowed (Cobb-Clark and Crossley, 2003:493).

$$Y_i = Y_{i0} + \Delta_i W_i \qquad (2)$$

However even as the potential outcome framework allows heterogeneity in both impacts and outcomes it includes restrictive assumptions like the stable-unit-treatment-value assumption (STUVA). Cobb-Clark and Crossley (2003) describe STUVA[3] as: “The impact of an

[3] Additional descriptions of STUVA can be found in Fröhlich (2004) and Imbens and Wooldridge (2009).

intervention may vary across individuals but is assumed to be constant for a particular individual. This means, for example, that the impact of a program on an individual is assumed to be independent of whether other individuals are also participating in the program" (Cobb-Clark and Crossley, 2003:493)

2.3.2 Parameters for evaluation of treatment effects

As already explained in the former section it is generally not possible to obtain the treatment effect $Y_{i1} - Y_{i0}$ at individual level for any person i. Therefore Heckman and Vytlacil (2007) suggest "to reformulate the problem at the population level rather than at the individual level and therefore to identify certain mean outcomes" (Heckman and Vytlacil, 2007:4880). Common approaches calculating the impact effects based on mean outcomes are the average treatment effect (ATE) shown by formula 3 and the average treatment effect on the treated (ATT) presented by formula 4.

$$\begin{aligned} \text{ATE} = E[\Delta_i] &= E[Y_{i1} - Y_{i0}] \\ &= E[Y_{i1} - Y_{i0} | W_i = 1] P(W_i = 1) \\ &+ E[Y_{i1} - Y_{i0} | W_i = 0] P(W_i = 0) \end{aligned} \tag{3}$$

$$\begin{aligned} \text{ATT} = E[\Delta_i | W_i = 1] &= E[Y_{i1} - Y_{i0} | W_i = 1] \\ &= E[Y_{i1} | W_i = 1] - E[Y_{i0} | W_i = 1] \end{aligned} \tag{4}$$

In ex post evaluation of impacts, usually the main research interest lies on the effect on outcomes for individuals which were subject to a program or treatment. The ATT does focus especially on this issue. In observational studies the outcome $E[Y_{i1} | W_i = 1]$ can be easily estimated based on observed data. However the outcome $E[Y_{i0} | W_i = 1]$ for the units which participated in the program can not be observed. Therefore the problem of missing data for $E[Y_{i0} | W_i = 1]$ has to be overcome. The possibility to use the outcome $E[Y_{i0} | W_i = 0]$ as approximation for $E[Y_{i0} | W_i = 1]$ yields a biased estimation for ATT shown in formula 5.

$$\begin{aligned} & E[Y_{i1}|W_i = 1] - E[Y_{i0}|W_i = 0] \\ & = E[Y_{i1} - Y_{i0}|W_i = 1] + E[Y_{i0}|W_i = 1] - E[Y_{i0}|W_i = 0] \\ & = E[\Delta_i|W_i = 1] + (E[Y_{i0}|W_i = 1] - E[Y_{i0}|W_i = 0]) \end{aligned} \qquad (5)$$

The equation $E[Y_{i0}|W_i = 1] - E[Y_{i0}|W_i = 0]$ "captures the bias due to selection effects" (Cobb-Clark and Crossley, 2003:494). This problem in the evaluation of treatment effects is described by economists often as a 'selection problem'. Depending on available data (observations) this selection problem can be differentiated in the following way. First, selection on observable characteristics such as gender, age and education means that treated and non-treated units differ from each other and these differences can be explained using observed data available. Second, selection on unobservable characteristics such as personal preferences, social capital and traditional restrictions means that treated and non-treated units differ from each other and these differences can not or only hardly be explained by observed data.

When random assignment to participation or treatment (like in experimental studies) is not given, econometric methods need to deal with heterogeneity in the untreated outcome (Y_{i0}). This means a solution to the already explained selection problem in equation 5 needs to be found. Econometric methods applicable for ex post impact evaluation and able to overcome this problem are linear regression, matching and instrumental variables. These methods differ from each other in two ways. First, each method makes an assumption on how untreated outcomes are varying across individuals. Based on this assumption suggestions are made how the counterfactual outcome (Y_{i0}, W_i =1) of treated units should be estimated. Second, depending on applied econometric method treatment effects can be aggregated or weighted "either explicitly or implicitly" (Cobb-Clark and Crossley, 2003:498) for different individuals.

2.3.3 Estimation of treatment effects by using linear regression

When using standard linear regression analyses the impact estimation of a "treatment" is done "under the assumption of selection on observables" (Black and Smith, 2003:10). Cobb-Clark and Crossley (2003) state that within equation 2 "Δ_i and Y_{i0} are random variables" (Cobb-Clark and Crossley, 2003:495). Hence they can be used to transform the potential outcomes framework to a random coefficient model. Within this model heterogeneity is present in the slope and the intercept.

If homogeneous treatment effects are assumed, the treatments effect “is to shift the intercept for those individuals receiving treatment” (Cobb-Clark and Crossley, 2003:498). This linear regression model[4] can be written as:

$$Y_i = Y_{i0} + \Delta W_i = \alpha + \beta W_i + \varepsilon_i \tag{6}$$

As long as ignorable treatment assignment[5] $E[\varepsilon_i | W_i = 1] = E[\varepsilon_i | W_i = 0] = E[\varepsilon_i] = 0$ can be assumed this result in an unbiased estimation of β for Ordinary leas squares regression of Y_i on W_i. However if selection effects occur, this selection problem can originate from an omitted or confounding variable $E[\varepsilon_i | W_i]$ which expands equation 6 to:

$$Y_i = \alpha + \beta W_i + E[\varepsilon_i | W_i] + \varepsilon_i^* \tag{7}$$

where $\varepsilon_i^* = \varepsilon_i - E[\varepsilon_i | W_i]$.

In the case of heterogeneous untreated outcomes regression relies on the assumption that variation within Y_{i0} across untreated units “can be captured by observable characteristics (such as age, gender or labour market experience)” (Cobb-Clark and Crossley, 2003:498). In this case “the linear projection of Y_{i0} on x” (Cobb-Clark and Crossley, 2003:498) can be expressed by:

$$E[Y_{i0} | x_i] = \alpha + \gamma x_i \tag{8}$$

where x_i represents observable individual characteristic.

Furthermore when assuming conditional mean independence and u_i are random one can generate an unbiased result for β by linear regression using the following formula:

$$Y_i = \alpha + \beta W_i + \gamma x_i + u_i \tag{9}$$

4 Imbens and Wooldridge (2009:10) state that this regression function can be “interpreted as structural equation, with“ β representing the causal effect. However here is unclear “whether the causal effect is constant or not, and what the properties of the unobserved component, ε_i are“ (Imbens and Wooldridge, 2009:10).

5 Ignorable treatment assignment is given when $E[Y_{i0} | W_i = 1] = E[Y_{i0} | W_i = 0]$. Thereby it is assumed that there is no selection bias (Cobb-Clark and Crossley, 2003:495).

This conditional mean independence assumption implies that if one can control for differences in the observable characteristics (x) the potential outcomes (Y_{i0}) "do not vary systematically between treated and untreated groups" (Cobb-Clark and Crossley, 2003:498).

For the estimation of treatment effects by using linear regression models Cobb-Clark and Crossley (2003) point out that "under standard assumptions least squares is the best linear unbiased estimator" (Cobb-Clark and Crossley, 2003:500). Imbens and Wooldridge (2009) support this argument but only if the "assumption of linearity of the conditional expectations of the potential outcomes given covariates is combined with the unconfoundedness assumption" (Imbens and Wooldridge, 2009:24). However Imbens and Wooldridge (2009) mention there is a movement in empirical literature "to more sophisticated methods for adjusting for differences in covariates" (Imbens and Wooldridge, 2009:24) such as the matching and instrumental variable approach.

2.3.4 Estimation of treatment effects by using the matching approach

The idea of the potential outcome framework within matching is that the unobserved (potential) outcome $E(Y_{i0})$, for units which received treatment, could be derived from the observed outcome $E(Y_{i0})$, for units which did not receive treatment, by conditioning only on the observables characteristics X_i of each unit i. That means, one needs to select a group of units which did not receive treatment to make them resemble the participating units in all relevant pre-treatment characteristics X_i. After that the differences in outcomes of units which did and did not receive treatment are assumed attributed to treatment only. To identify those groups of units the assumption of conditional independence[6] presented in formula 10 has to be made.

$$Y(0), Y(1) \amalg W | X \qquad (10)$$

[6] Imbens (2004:4) state this assumption was explained by different authors as 'unconfoundedness', 'selection on observables' or 'conditional independence'. However Imbens (2004:4) assume that these words can be used interchangeably. Furthermore Caliendo and Kopeinig (2008:35) state that this assumption is a strong one and has to be justified by data quality. However to assume unconfoundedness might not always be appropriate, "as it assumes that beyond the observed covariates X_i there are no (unobserved) characteristics of the individual associated both with the potential outcomes and the treatment" (Imbens and Wooldridge, 2009:26).

where $\coprod$ represents independence and does explain that for a "set of observable covariates X which are not affected by treatment, potential outcomes are independent of treatment assignment" (Caliendo and Kopeinig, 2008:35).

However there can be a high number of relevant covariates. Therefore conditioning on all relevant covariates is limited and can lead to a dimensional problem, if the vector X represents many dimensions. Rosenbaum and Rubin (1983:43) advise the use of a balancing scores $b(X)$, which can be seen as a function of relevant observable covariates X. This balancing score can be used to transform these multidimensions to only one. To underpin the use of such a balancing score Rosenbaum and Rubin (1983) argue that: "If treatment assignment is strongly ignorable given *X,* then it is strongly ignorable given any balancing score. At any value of a balancing score, the difference between the treatment and control means is an unbiased estimate of the average treatment effect at that value of the balancing score if treatment assignment is strongly ignorable" (Rosenbaum and Rubin, 1983:43). Following this argument of strongly ignorable assignment of treatment unbiased treatment effects can be estimated by "pair matching on a balancing score, subclassification on a balancing score and covariance adjustment on a balancing score" (Rosenbaum and Rubin, 1983:43-44). The widely used balancing score is the propensity[7] score P(X), which is given by the probability for an unit to get treatment given his observed covariates X (P(W=1|X)). Under the assumption of conditional independence (Rosenbaum and Rubin, 1983) and the assumption of a common support or overlap condition has to be fulfilled. This condition counts for the case of perfect predictability of W given X and excludes these cases from analysis.

$$0 \prec \Pr(W = 1 | X = x) \prec 1 . \tag{11}$$

Heckman and Vytlacil (2007:4883) state that assumptions (10) and (11) justify matching. Therefore under the conditional independence assumption the matching of treated and untreated units on the propensity score one can estimate "the mean difference of outcomes over the common support, appropriately weighted by the propensity score distribution of participants" (Caliendo and Kopeinig, 2008:36). The following figure 6 provides a graphical description of the matching method. Observed participants are represented by "P" and "N" represents non-participants. From this figure one can see that by matching on the propensity

[7] In the case of nonrandomized experiments Rosenbaum and Rubin (1983) state that the unknown propensity score function "may be estimated from observed data, perhaps using a model such as a logit model" (Rosenbaum and Rubin, 1983:43).

score, one can generate the mean difference of matched participants and non-participants which is obviously different from the mean difference between all participants and non-participants

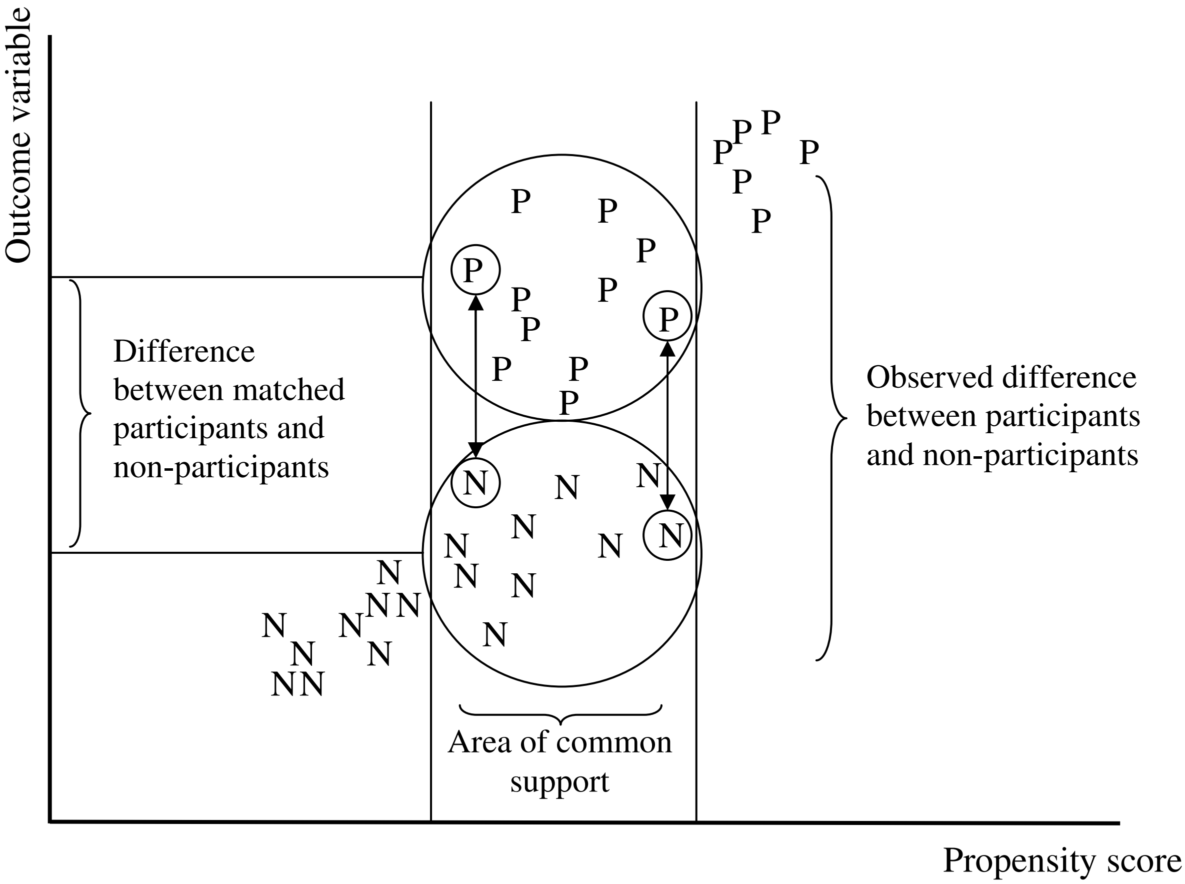

Figure 6: Graphical representation of matching on the propensity score

Source: Adapted from European Commission, 2010a

However, the outcomes of units belonging to either treated or control group differ and this can lead to problems of selection bias especially as E(Y_0|W=1, X) is approximated via using E(Y_0| W=0, X). Heckman, Ichimura and Todd (1998:264) calculate the possible selection bias (B(X)) due to this approximation with the following formula.

$$\mathrm{B}(X) = E(Y_0 | W = 1, X) - E(Y_0 | W = 0, X). \tag{12}$$

In the case of matching Heckman, Ichimura and Todd (1998) conclude that "matching on X, or regression adjustment of Y_0 using X, is based on the assumption that B(X) = 0 so conditioning on X eliminates the bias" (Heckman, Ichimura and Todd, 1998:264).

Caliendo and Kopeinig (2008:36) point out that for the calculation of ATT one can weaken the conditional independence assumption in the way that only conditional independence for control units $Y(0) \amalg W|X$ as well as weaker overlap $P(W = 1|X) \prec 1$ has to be assumed.

To implement propensity score matching different matching algorithm like e.g. nearest neighbour with and without replacement, stratification and kernel matching can be used. Those matching algorithms define how the neighbourhood of treated units is restricted to serve as possible matching partners for treated units, but also vary in the way weights are assigned to possible matching units. Therefore depending on the choice of matching algorithm trade-offs in terms of bias and efficiency arise. There is no general matching algorithm for which is applicable for all situations. The success of those algorithms varies case-by-case and strongly depends on the richness of data at hand.

When comparing regression approaches with matching estimators Cobb-Clark and Crossley (2003) conclude that in contrast to regression in matching "the weighting of estimated treatment effects across different individuals remains under the explicit control of the researcher rather than being implicit in the estimator, as in OLS" (Cobb-Clark and Crossley, 2003:501). Furthermore Black and Smith (2003) state that "the key difference between matching and linear regression is that regression makes the additional assumption that simply conditioning linearly on X suffices to eliminate selection bias" Black and Smith (2003:10). Further advantages of matching are: It takes into account the problem of common support and it does not require functional form assumptions for the outcome equation. However even when applying matching hidden bias may occur when there is an unobserved variable which influences simultaneously assignment to treatment and the outcome variable (DiPrete and Gangl, 2004:272).

2.3.5 Instrumental Variable approach

The instrumental variable (IV) method supports impact assessment if e.g. the exposure to a policy or treatment is not determined only by the decision of individuals involved, but also, by unobservable processes and effects outside their control. Therefore Heckman and Vytlacil (2007) state that the instrumental variable approach is used in the case that unobservables "violate the matching assumption" (Heckman and Vytlacil, 2007:4907).

The IV method has to fulfill two important conditions: First, in contrast to matching the method of instrumental variables[8] needs at least one variable Z that does affect program participation decision and not the potential outcomes. Consequently the potential outcomes do not vary with Z. Second, the instrumental variable approach assumes that "any difference in the mean observed outcomes of two groups differing only with respect to Z can only be due to consequent differences in the participation rates and composition of the treatment group with respect to potential gains from treatment" (Blundell and Dias, 2009:606).

Following the IV methods will be explained based using a policy programme to support private Research and Development (R&D) projects as example. This explanation was drawn from the European Commission (2010b). In this example only companies located in regions with low population density could enroll in this governmental R&D support programme. This regional dimension is assumed not to be correlated the companies' technological R&D capacity. In this special case companies located in such regions do have access to this R&D support programme and companies not located in such regions do not. However in general a companies' propensity to undertake own R&D is assumed to be not directly affected by the regions population density in general. Therefore a situation similar to randomization could be created if all companies who are allowed to participate in the program (the companies located in regions with low population density) would actually participate. In this case a simple comparison of average expenditures on R&D between participants and non-participants could show the impact of this special R&D support programme. However there might be the case not all companies allowed to participate in the programme actually take advantage of this programme, as in reality companies "self-select themselves according to their expected return from conducting R&D projects" (European Commission, 2010b).

In this case simple comparison of average expenditures on R&D between participating and non-participating companies would lead to overestimations of the programme effect, due to positive selection bias. Further it could be that participating companies would have spent however the same amount of resources in the absence of the programme. In this case the real programme effect would be lower than the estimated one.

To derive appropriate programme effects one has to "scale up" the effect for companies who are allowed to participate by the fraction of the companies who actually do participate. "In practice, in this case one divides a difference by a take-up rate" (European Commission, 2010). In other words "the differences in R&D expenditures between" companies who are

[8] Further formulation about the postulates of instrumental variable analysis can be found in Basu et al. (2007) and in Angrist, Imbens and Rubin (1996).

allowed and who are not allowed to participate "is accounted by the fraction of" companies who are allowed to participate and actually do participate (European Commission, 2010). Therefore the correct effect of the programme can be calculated via dividing the differences of R&D expenditures between companies who are allowed and not allowed to participate by the proportion of participating companies among the companies who are allowed to participate in this programme.

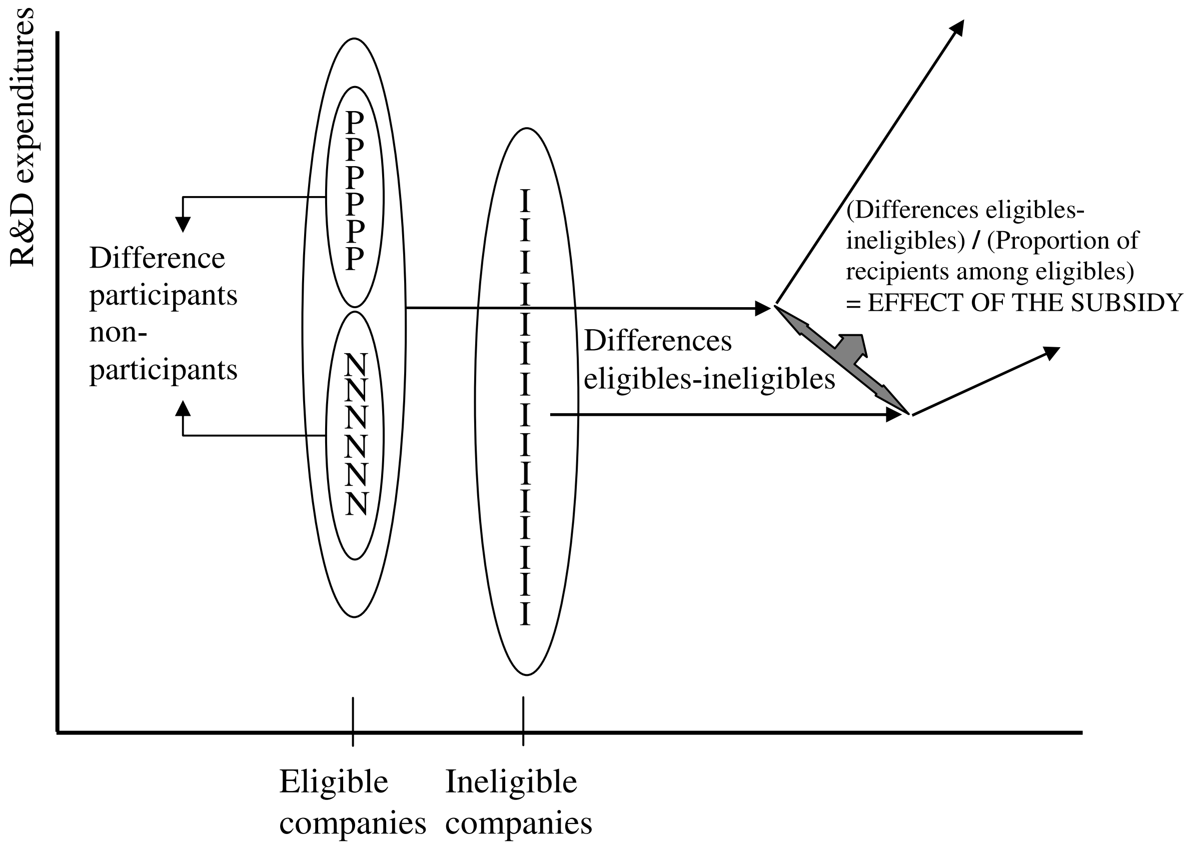

Figure 7: Graphical representation of the IV method

Source: Adapted from European Commission, 2010

Note: P companies who are allowed to participate and do so

N companies who are allowed to participate and do not participate

I companies who are not allowed to participate

The corresponding mathematic expression is represented by the "Wald estimator"[9] and can be written as:

$$\delta = \frac{E[Y|Z=1] - E[Y|Z=0]}{P(W=1|Z=1) - P(W=1|Z=0)}$$

[9] A more detailed example how to derive this Wald estimator is provided in the Appendix (A 7).

Where:

δ	effect of the programme on R&D
Y	outcome variable, e.g. R&D expenditures
W	binary indicator for participation, W=1 company is participating, W=0 otherwise
Z	instrument which does influence the participation (W) but which is uncorrelated with U, e.g. Z=1 if company is located in an area of low population density and therefore is allowed to participate in the programme, Z=0 otherwise
P	probability that the variable is equal to 1
E[]	represents "mean of"
E[l]	represents "conditional mean"

The major drawback of the instrumental variable approach is to find an instrument (observable variable) that satisfies the aforementioned conditions, namely "determines programme participation but is not itself determined by the factors which affect outcomes" (Bryson, Dorsett and Purdon, 2002:6). Further problems with the instrumental variable approach occur when the instruments "are only weakly correlated with the receipt of treatment" which "can result in biased and incorrect inferences even in very large samples" (Cobb-Clark and Crossley, 2003:504).

2.3.6 Conclusion

In general there is no blueprint for doing ex post impact assessment. Each method depends on different assumptions and the amount of data available. However to my opinion the obtained cross sectional household database represents a sufficient amount of household characteristics to justify the choice of propensity score matching for the impact assessment presented in chapter 5. Furthermore sensitivity analysis after matching provides some evidence, that matching was able to balance out the distribution of all covariates for the treatment and control group. In addition the distribution of the propensity scores for treatment and control households showed that applying a common support restriction to avoid bad matches was necessary. The obtained reduction of bias confirmed that the consideration of bias for the assessment of income effects was a correct one.

Agrofuel boom or doom? Opportunities and constraints for agrofuels in developing countries

Abstract[1]

Progress towards substituting renewable energy sources for fossil fuels can contribute to the mitigation of climate change. Biomass may provide one such source, in addition to wind, solar, and water. However, the extent to which agrofuels, such as biodiesel and bioethanol, can sustainably replace fossil fuels will partly depend on whether their current competition with the traditional food, feed and fiber sectors can be substantially reduced. This paper describes the production and policy trends for biodiesel and bioethanol in developed and developing countries and analyses data on the production, social, and environmental costs. Agrofuels hold a number of opportunities, but also present formidable constraints, especially for poorer, food-deficient developing countries. We conclude that in order to address the constraints and capitalize on the opportunities that agrofuels hold for sustainable development, more investments in socio-economic and technological research, especially for agrofuels produced from cellulosic materials and agricultural byproducts and waste are required. Furthermore, policies need to be improved to better address the constraints and opportunities for agrofuels with respect to equity, efficiency and environmental constraints.

Key words: Climate change, agrofuels, developing countries, food security
JEL codes: O13, Q4, Q13, Q54

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1. Introduction

Two drivers of global change will have a decisive influence on the future of the world's agriculture and forestry, and therefore on food security, poverty reduction, the environment and economic growth in developing countries. The drivers are on-going climate change and our increasingly pressing need to find renewable and sustainable energy sources. The Stern report states that developing countries situated in the tropics and subtropics will be severely affected by climate change (STERN, 2007; see also TOL et al., 2003). One key causal factor of human-induced global warming is the emission of carbon dioxide and other greenhouse gases (GHGs) from the use of fossil energy. At present, fossil energy accounts for about 80 % of the worldwide total primary energy supply. Agriculture and agriculture-related deforestation also contribute to the emissions of GHG on a substantial scale (WORLD BANK, 2008). The per-capita consumption of energy widely differs from country to country. Residents of the United States of America use more than twice the energy used by Europeans. Europeans use about ten times the energy used by Africans (IEA, 2005). Economic growth in countries like China and India will undoubtedly result in a significant increase in energy demand in the developing world.

To address the global problem of climate change, as well as the scarcity of fossil energy resources, carbon neutral and sustainable alternative energy sources need to be found. Probably the most important approach is to save energy through more efficient energy use, supported by appropriate policies for the taxation of energy use or the resulting pollution. Apart from saving energy, substitution of renewable energy for fossil fuels is required. A number of technologies for renewable energy are being tested or are already in use, one of which is the development of agrofuels, i.e. ethanol and biodiesel. These agrofuels offer some economic prospects, especially for land-rich developing countries in the tropics, but also pose considerable challenges at global, national and local levels.

The objective of this paper is to identify future opportunities as well as challenges that arise from world-wide agrofuel production for developing countries. We begin by reviewing the worldwide trends in agrofuel production and the policies responsible for the rapid expansion of agrofuels. In the remainder of the paper, we seek to evaluate the mainly policy-driven boom in agrofuels against several commonly stated policy objectives justifying the promotion of agrofuels: energy security, economic growth, equity and poverty reduction, and the mitigation of climate change through reduction of GHG emissions.

2. World-wide trends in the production of agrofuels

2.1 First- and second-generation agrofuels

Biomass can be used as a primary or secondary energy source. Primary energy sources such as plants, organic waste and manure can be transformed into secondary energy sources, which can be liquid (such as biodiesel and bioethanol), gaseous (such as methane) or solid (such as wood pellets).

At present, the conventionally used feedstock for the production of ethanol is biomass with a high content of sugar and/or starch. Diesel, on the other hand, is currently produced from oil crops such as rapeseed, soya and castor bean, or from animal fats. Hence, most agrofuels at present are produced from traditional food and feed crops. They therefore directly compete with the food, feed and fiber sector.

The competition between agrofuels and food can potentially be reduced to a great extent by so-called second-generation fuels. For example, the Fischer-Tropsch process allows the production of liquid fuels out of cellulosic biomass (BTL), in which biomass is vaporized and synthetic fuels are produced. On-going research seeks to improve the energy efficiency and the carbon balance, as well as lowering the production costs of agrofuels produced from cellulosic materials. The result would be the use of any cellulosic plant material, such as cornstalks, fast growing trees (e.g. poplar), switch grass, and waste from the forest products industry, in the production of liquid agrofuels (ORTIZ et al., 2006; RAGAUSKAS et al., 2006). Hence, not only byproducts from agriculture and forestry, but also biomass grown on soils or in climatic regions not fit for agriculture could be used as feedstock for second-generation fuels. Second-generation agrofuels based on cellulosic biomass could thereby reduce, but not fully eliminate the competition between the energy and the food and feed sector because cellulosic feedstock could still compete with food and feed crops on agricultural land. However useful the second-generation fuels technology may be, the current trends in agrofuel production are overwhelmingly dominated by first-generation technologies that convert food crops into energy.

2.2 Global trends in the production of ethanol and biodiesel

It is estimated that the world production of ethanol amounted to 47.156 million tons in 2007 (FO LICHT´S, 2006a). The major feedstocks used for ethanol production are corn (USA) and sugar cane (Brazil). Figure 1 shows the growth of ethanol production between 2003 and 2007. During the past five years, ethanol production has increased by more than 50 % and exhibits rising annual growth rates. The major agrofuel producing regions are North and South America. In North America the major agrofuel producer is the United States, which supports the production and use of ethanol for the transportation sector through a mix of subsidies to ethanol producers as well as federal and state-level environmental legislation (KÄRGER, 2006) which mandates blending of fossil fuels with agrofuels. It is expected that the strong production trend seen for the United States will continue in the near future as current U.S. policy foresees a significant expansion of agrofuel production capacity. The second largest ethanol producing continent is South America, with Brazil as the leading producer. As illustrated in Figure 1, the world ethanol production has strongly expanded. The USA and Brazil currently account for 70 % of the global ethanol production, followed by China, which is the third largest producer (HENKE, 2005). In Europe, ethanol production is also increasing, with France and Germany as the leading countries.

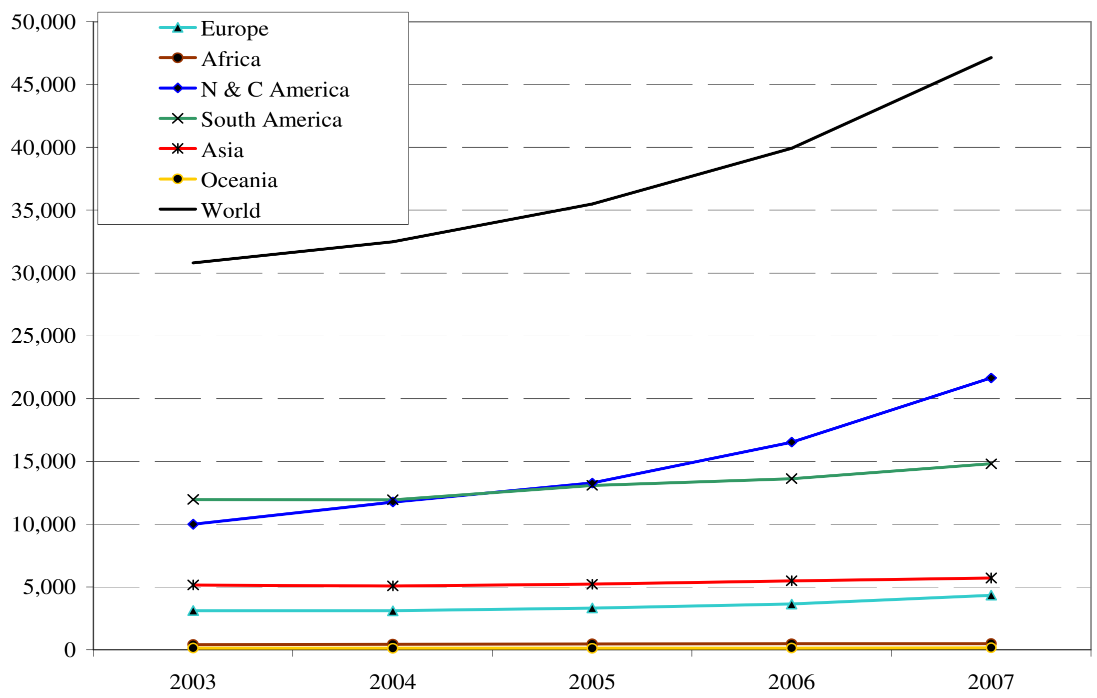

Figure 1: World ethanol production, by continent (in 1,000 tons)

Source: Own graph, based on data published by FO LICHT`S, 2006a

In 2006, the world's production of biodiesel reached 5.6 million tonnes worldwide (FO LICHT´S, 2008). Figure 2 shows that most of the world's biodiesel production occurs in Europe, mainly in Germany and France. The United States, Brazil and Australia are new entrants to this market. Since any vegetable oil can be used for the production of biodiesel, there has been a resulting increase in the demand for cheaper vegetable oils such as palm oil. The major exporters of palm oil are Malaysia and Indonesia. However, the expansion of palm oil production is likely to cause deforestation and destruction of pristine rainforest habitats.

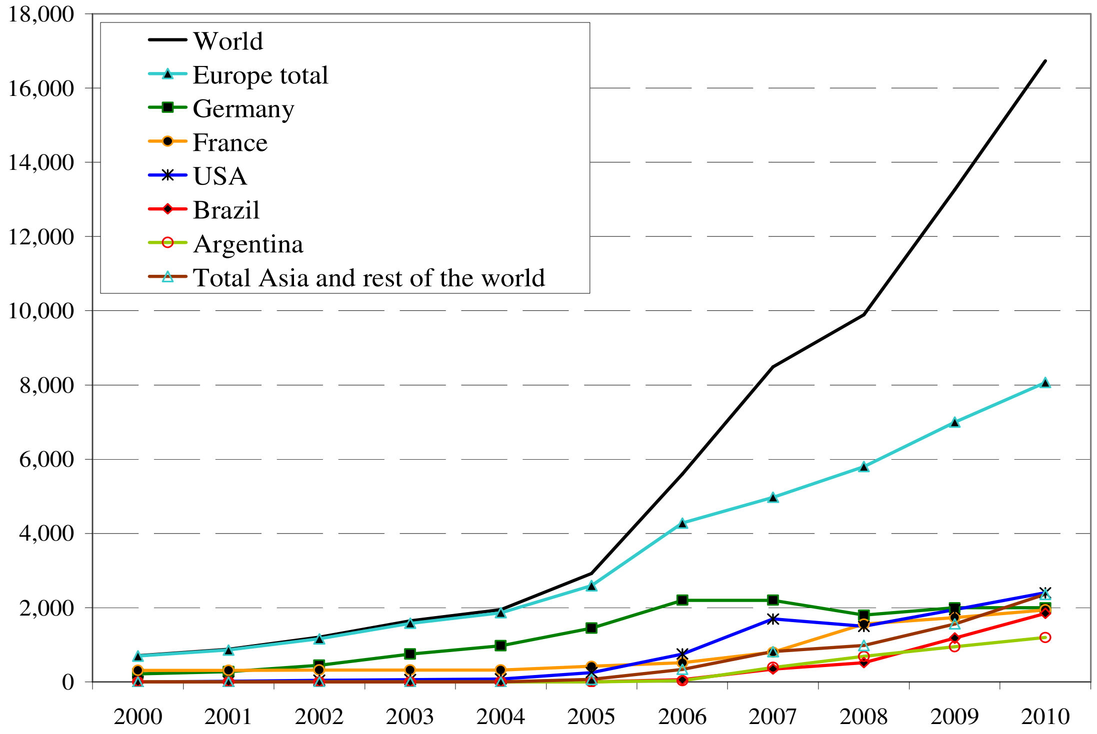

Figure 2: World biodiesel production* (in 1,000 tons)

Source: Own graph, based on data published by FO LICHT`S, 2008

Note: * Based on estimates regarding the output of industrial-scale producers

Below, in table 1 and table 2, we show projections for the use of feedstock in the EU and the U.S. for 2006 through 2014. The estimates for the 27 member countries of the EU (see table 1) are derived from the European Commission. The used major assumptions on the macro-economic environment and the agricultural and trade policies are described by EUROPEAN COMMISSION (2008).

Table 1: Agrofuel feedstock balances for the European Union for 2006-2014 (in million tons)

	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cereals*									
Usable production	242.3	256.0	294.4	288.2	293.6	297.6	300.7	303.9	305.7
Consumption	247.4	265.6	270.6	271.7	272.9	275.5	278.7	282.9	285.5
of which bioenergy	2.5	1.9	4.8	4.5	5.5	7.5	10.3	15.7	18.4
Oilseed*									
Usable production	20.4	24.0	23.6	28.2	28.6	29.5	30.3	31.2	32.6
Consumption	46.2	48.7	50.3	55.4	57.5	59.8	62.3	65.6	67.5
of which bioenergy	8.2	9.2	12.4	17.0	17.7	18.4	19.4	21.0	21.4
Sugar**									
Usable production	17.4	16.1	16.4	16.6	16.8	16.7	15.2	15.7	15.6
Consumption	17.4	18.6	19.2	19.4	19.8	20.1	20.5	20.8	20.9
of which bioenergy	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.2

Source: *EU Commission, 2008; **EU Commission, 2007

The data in Table 1 suggest that by 2014, nearly two third of the EU's production of oilseeds and more than six percent of the EU's cereal and fourteen percent of sugar production will be used in the production of agrofuel. TANGERMANN (2007) estimates for 2016 even a share of more than 10 % for wheat and 55 % for oilseeds of the EU's agriculture output will be used for agrofuel production.

Similar production trends for agrofuels have been forecasted in the United States. The U.S. Department of Agriculture (USDA) predicts an increased use of corn in ethanol production, as well as an increasing share of the U.S. soybean crop being used for the production of biodiesel. The baseline projection in table 2 assumes that the tax credit for domestically produced ethanol and biodiesel, as well as the import tariff for these products, will be maintained. Both the U.S. and the EU use tax credits and other subsidies, as well as trade barriers, to protect their domestic agrofuel industry from more competitive producers in developing countries.

Table 2: Projections for USA corn and soybean production and utilization

	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Corn production (million bushels)	10,535	13,168	12,515	13,150	13,635	13,645	13,650	13,820	14,070
Ethanol for Fuel (%)	20.1	24.3	32.8	32.7	32.1	32.6	33.2	33.3	33.2
Feed & residual (%)	53.1	42.9	43.5	41.3	40.5	40.7	41.0	40.9	40.5
Exports (%)	20.2	17.8	17.2	16.3	15.6	15.6	15.8	15.9	16.0
Soybean production (million bushels)	3,188	2,594	2,950	2,920	2,930	2,935	2,970	3,000	3,005
Soybean oil production (million pounds)	20,484	20,715	21,215	21,575	21,880	22,240	22,545	22,850	23,100
Biodiesel use, soybean oil (%)	13.6	20.3	19.8	19.5	19.4	19.1	19.3	19.3	19.0

Source: Based on: USDA Agricultural Projections to 2017, USDA, 2008

The considerable increase in the use of cereals, oilseeds and sugar by major traditional surplus producers, the EU and the U.S., will have a large impact on the world agricultural trade. Moreover, as reviewed later, the ambitious policy objectives in the U.S. as declared by President Bush in his State of the Union speech in early 2007, as well as the similar ambitious objectives in the EU to increase the use of agrofuels in the transportation sector, will lead to a surge in a policy-induced, not market-induced demand for agrofuels by consumers. The USDA estimates that more than 30 % of corn produced in the U.S. will be used to produce ethanol by 2008/09 (USDA, 2008). However, KAMALICK and GIBSON (2007) estimate that as soon as the year 2008, half of the U.S. corn production will be used for ethanol. Despite this increase in ethanol production, the U.S. cannot fulfil its target goal of greatly reducing the U.S. dependence on crude oil imports. In 2006, U.S. ethanol production (5 billion gallons) could only substitute 1.5 % of U.S. crude oil imports. Thus, the U.S. may need to import increasing quantities of ethanol and biodiesel, most likely from Latin American countries. Brazil for example could transform 60 % of its sugar output into bioethanol by 2016 (TANGERMANN, 2007). It is therefore expected that the trade in biodiesel and bioethanol will significantly increase during the next few years, allowing low cost producers such as Brazil or Indonesia and Malaysia (for palm oil) to either export feedstock or the refined agrofuel to the U.S., Japan and the EU. At present, ethanol imports into the EU and the U.S. are relatively low due to prohibitive import tariffs which have been set for the protection of the domestic industry. Imports, as a percentage of the domestic production, account for only 4 % in the US and only 0.5 % in both the EU and China (DIMOPOULOS, FO LICHT´S, 2006b).

Internationally traded biomass feedstocks are molasses, sugar from sugar cane or sugar beet, tapioca chips, rapeseed oil, palm oil, soya oil and cereals such as corn, feed wheat and feed rye. But other feedstocks can also be used. Research is currently exploring the use of sweet sorghum, cassava, sweet potato, wood, switch grass, edible and non-edible oil, animal fats, jatropha oil, palm oil, coconut, cotton, cellulose, manure and other biomass generators. Some of these newly explored crops, for example jatropha, have the potential to be grown on marginal or degraded land that is not suitable for traditional food and feed crops.

By far the largest cost component in the production of first-generation agrofuels is the cost of the feedstock itself. Thus, the yields and the cost of producing the biomass are a critical factor in determining the overall competitiveness of the agrofuel sector. With respect to biodiesel production based on plant oil, yields for different feedstock crops range from 713 kg/ha/year for sunflower, 468 kg/ha/year for soybean, 1,060 kg/ha/year for Groundnuts, 6,000 kg/ha/year for palm oil (DA SILVA and PEREZ, quoted in ELZ, 2007) and 125 - 3,000 liters for Jatropha[2].

3. Are the policy arguments for first-generation agrofuels valid?

3.1 Policies for promoting agrofuels and energy in developed and developing countries

To foster domestic agrofuel development, politicians in the EU and U.S. stress three main policy arguments. First, agrofuels are presented by politicians as a measure for strengthening energy security and becoming less dependent on oil and natural gas imports. While agrofuels certainly offer some potential for energy source diversification, the estimates by UGARTE (2006) as well as DOORNBOSCH and STEENBLIK (2007) show limits of the agrofuel expansion due to technological capacity constraints. Second, proponents of agrofuels stress the positive energy balance of agrofuel production and the potential for reducing greenhouse gas emissions compared to that of continued fossil fuel use. We will explore this argument further in a later section of the paper. A third, but relatively hidden argument in the policy discourse, is the fact that agrofuels offer considerable potential growth for domestic agriculture in developed countries without running the risk of creating new butter mountains and milk lakes. The energy market is huge, and can absorb any amount of agrofuels produced by agriculture and forestry. Hence, the past problem of (subsidized) agricultural surplus linked with export subsidies and dumping that has plagued agricultural policies in the U.S. and the EU for so long does not exist anymore with the subsidization of agrofuel production or with the

[2] The yield estimates for Jatropha are based on Francis et al. (2005) who collected reported Jatropha yields for India. We agree with von Urff (2007) that there is quite some variation and sometimes even contradictions regarding data on the biodiesel production potential from one hectare of Jatropha.

mandatory blending regulations imposed on consumers in the EU or the U.S. In view of the current and expected development of rising agricultural commodity prices which appear partially driven by the agrofuel boom, agricultural surpluses and export subsidies are certainly not a major policy issue at the moment. Nevertheless, support to the agrofuel industry might offer a relatively attractive long-term measure for politicians in developed countries that face strong agricultural producer lobbies, especially if direct subsidies to agrofuel producers can be eventually phased out through regulations imposing mandatory blending of fossil fuels with agrofuels. This policy trend can be observed for both the U.S. and the EU. With such a policy, however, the consumers and tax payers pay twice: First, through higher fuel prices, and second, through higher food prices. The poor in developed and developing countries are hurt by such a policy more, because a relatively larger share of their budget is spent on food and less on transport fuels, compared to wealthy consumers. At the global level, the current subsidies and regulations in the EU and U.S. for the production of agrofuels tend therefore to further widen the already growing income disparity between developed and developing countries. Within any given country, subsidization of agrofuels is regressive as well because they benefit the wealthier (energy) consumers at the expense of the poor (food) consumers.

To support domestic agrofuel sectors, governments have introduced a mix of policy instruments. The main instruments used are the introduction of mandatory quotas for blending gasoline or diesel with agrofuels to reach certain fuel standards, the exemption from value added tax in the production of agrofuels, and the introduction of prohibitive import policies to protect the domestic industry. The latter policy may be justified in the short run, allowing necessary technology developments and industry growth to occur (i.e. the so-called infant industry argument), but can entail the risk of creating a sector that is highly dependent on subsidies in the long run, at least in countries with high production costs such as the EU and the U.S. However, as pointed out by the Scientific Council of the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), the infant industry argument is not really a valid one in the case of first-generation agrofuel because the conversion technology has been already developed for a long time (BMELV, 2007, p.174). STEENBLIK (2007) further points out that governments should be aware that once the subsidies for the first generation of agrofuels are established it can be difficult to withdraw them. In summary, in all major production countries, including Brazil, government interventions have been critical for the expansion of the agrofuel sector.

According to BACON and KOJIMA (2006), about half of developing countries spend subsidies on either production of energy or reduction of the consumer prices for energy. Given that energy is a good which is disproportionately consumed by mainly wealthy consumers, this subsidy policy appears regressive. The subsidization of the use or production of energy is also highly questionable if the government wishes to guide the economy towards sustainable development pathways for the long-run, given that the price of fossil energy is expected to increase further during the next decades. Governments may therefore be well advised to raise the costs of energy through taxation so as to promote energy-saving technologies and sustainable consumption patterns and development. In addition, policies internalizing the environmental cost of fossil energy use by taxation need to expand, and will put additional upwards pressure on energy prices so those consuming and polluting are held accountable.

A large number of developing countries currently invest in pilot programs and first production capacities for agrofuels. Apart from China and India, which have devised very ambitious production targets for agrofuels, other Asian countries (namely Thailand, Indonesia, Malaysia, The Philippines), as well as African countries (for example Tanzania, Kenya, Mozambique, Madagascar) and Latin American countries (Argentina, Ecuador, Columbia, Mexico, as well as Caribbean countries) enter the agrofuels market. Given the current policy-driven boom in agrofuels, mainly fuelled by subsidies or legislative measures requiring its blending with fossil-based fuels, it is important to analyze the validity of the arguments regarding agrofuel's contribution to energy security and to benefiting the environment.

3.2 Technical potential for agrofuel production and energy security

As discussed above, the expansion of agrofuel production so far has been mainly driven by policy decisions, motivated by a host of political factors. In the long run, however, the main driving factor will be the price of oil and other fossil fuels compared to prices of feedstocks and food. Oil prices above 45 US$ to 50 US$ per barrel are seen as favourable for agrofuel production by UGARTE (2006) and by IEA (2006), as low cost producer countries like Brazil can profitably produce significant amounts of agrofuels at such oil price levels.

At current prices in April 2008 of over 110 US$ per barrel, low-cost producers of agrofuels are eager to expand the production of sugar and other crops for agrofuel production. Taking into account the present conversion technologies for agrofuel production, UGARTE (2006) estimates the potential demand for sugarcane and corn, in the case that agrofuels were to fully replace the use of fossil fuels. Based on the data that each day worldwide, 21 million barrels of gasoline and 21 million barrels of diesel are consumed, UGARTE (2006) extrapolates these figures into a potential demand of roughly 30 million barrels of ethanol and 23 million barrels of biodiesel per day. To answer the question regarding the amount of land that must be reallocated to agrofuel production in order to fill this demand for ethanol, UGARTE (2006) calculates that 300 million hectare of sugarcane or 590 million hectare of corn (maize) must be planted for energy production. This means an increase by a factor 15 and 5, respectively, in comparison with the current world hectarage of these crops. To replace all fossil diesel with biodiesel, the potential demand would necessitate an additional 225 million ha of palm, 20 times the current world plantings.

These figures show that the expansion of first generation agrofuels can only make a very modest contribution to the satisfaction of the world demand for transport fuels, a conclusion that is also shared by the proponents of agrofuels. In fact, a recent study by DOORBOSCH and STEENBLIK (2007) predicts that the technical potential of production only allows for satisfying 11% of total world demand for transport fuels in 2050. By definition, the assessment of a technical production potential does not account for the environmental costs of agrofuel production, for example the use or destruction of scarce resources such as water, biodiversity and rainforests as carbon sinks. It also does not account for the social costs of agrofuels, for example the exorbitant human costs of hunger and malnutrition amongst poor net buyers of food, caused by rising food prices. The above cited studies on technical potential on agrofuels also did not account for the indirect effect of rising food prices on the expansion of cropping area into grassland and forested area which will create additional environmental costs (see section 3.4 on newer studies). When considering the technical potential alone, agrofuels can only make a very modest contribution to energy security and to meeting the future demand in transport fuels.

3.3 Production costs of agrofuels: A cross-country comparison of competitiveness

There is a large amount of variation in energy efficiency, the cost of production, and the cost of greenhouse gas abatement between the different types of agrofuels (BROWER et al., 2006; HENKE, 2005). The efficiency and costs are largely a function of the type of feedstock, the agro-ecological and socio-economic conditions of biomass production, and the conversion technology used.

Figure 3 shows the production costs of ethanol, differentiated by feedstock and country. The costs are differentiated into gross production costs, net costs of production after subtracting the value of byproducts, and the feedstock costs as a component of net cost of production. The figure shows that feedstock costs constitute the largest cost component. As these feedstocks directly compete with traditional uses in the food industry, rising food prices also imply rising prices for feedstocks, and vice versa. Brazil exhibits the lowest production costs, followed by Thailand. China does not have a cost advantage in agrofuel production, compared to Australia and the U.S. According to HENNIGES (2006), production costs are highest in Europe.

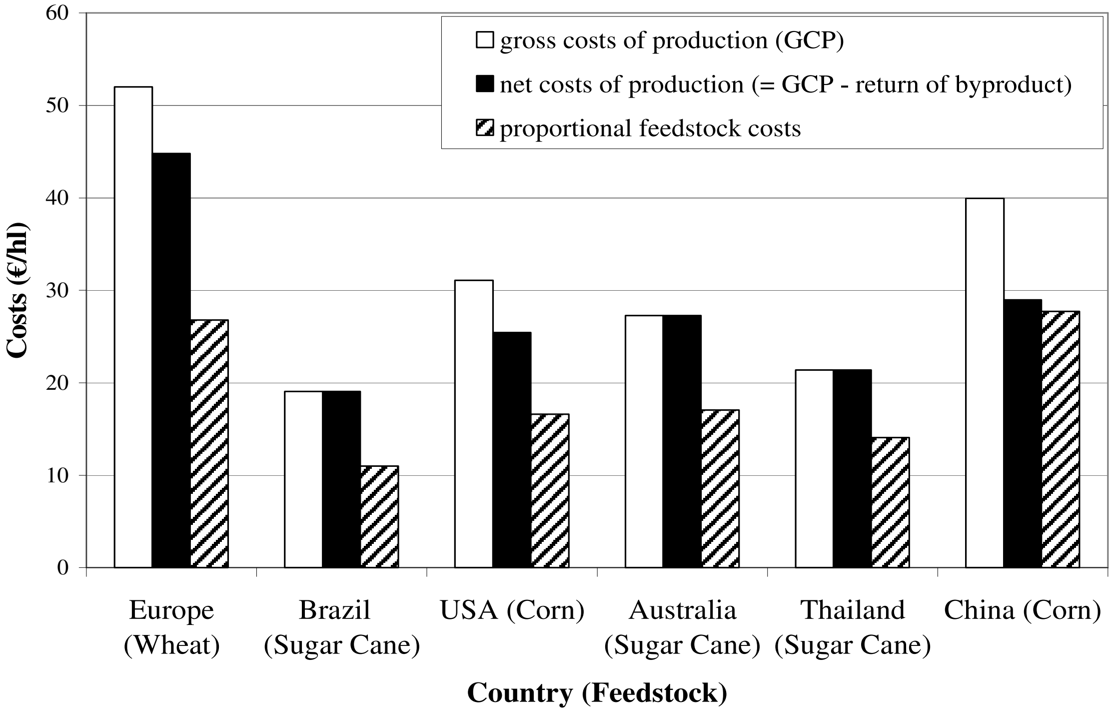

Figure 3: Gross and net cost of the production of ethanol, by country and feedstock
Source: HENNIGES, 2006

UNICA (2007) has estimated that the present ethanol yield of Brazilian sugar cane is between 6,900 and up to more than 9,000 litres per ha depending on the growing region. At present in Brazil, sugarcane is grown on roughly 6 million hectares of land, representing just 2 % of the total land used for agriculture and pasture and 0.7 % of the country's total land mass. According to a study commissioned by the Ministry of Science and Technology of Brazil:

> "For the past three decades, sugarcane plantations have been spreading north and west across Brazil's hinterlands, replacing coffee, citrus and pasture. Investors are planning to spend some $12.2 billion on 77 new ethanol plants over the next five years, as well as $2.4 billion to expand existing ones. By 2012, a total of 412 distilleries will be churning out 9.5 billion gallons of ethanol. Ultimately, Brazil would like to see ethanol traded as freely and widely as oil. In that case, it could

> potentially boost exports from the current 3 billion litres to as much as 200 billion litres by 2025. That would be enough to replace one-tenth of the world's petrol consumption." (THE ECONOMIST, 2007)

Other developing countries likely to be major agrofuel producers are the large traditional exporters of agricultural products, mainly Argentina, and Indonesia and Malaysia as major palm oil exporters. In comparison with Brazil, Argentina has a comparative advantage in the production of oilseeds (GABRIELA SUSTAITA at FO LICHT´S, 2006b). Agrofuel production may also be heavily expanded in other land-rich developing countries, such as Mozambique, Angola, Zambia, and Democratic Republic of Congo.

In summary, a number of land-rich countries in the tropics and subtropics may actually gain from the production of agrofuels, at least in terms of aggregate gross domestic product, but not necessarily with respect to national or household food security, social equity, poverty reduction or to the environment. A review of policy frameworks for developed and developing countries shows that the latter group is mainly positioning itself to become exporters of agrofuels or its feedstocks, with the exception of China, India and other Asian producers that have fast-growing domestic demand for transport fuels as well as food.

3.4 Environmental effects and related costs

In the policy discourse, the potential of agrofuels for reducing greenhouse gas emissions is highly emphasized by the proponents. Negative environmental effects, such as those identified by ZAH et al. (2007), are hardly mentioned. For Brazil e.g. "the mean annual soybean price during 2001 – 2004 was related to the amount of deforestation for cropland in Mato Grosso" (MORTON et al. 2006) and as well the expansion of sugarcane into pasture land may push the forest frontier further into the Amazon rainforest. Similar concerns arise for the expansion of palm oil production, for example, in Indonesia (JUNGINGER et al. 2006). In the following, we focus on only the economics of reducing greenhouse gas emissions through agrofuels.

Figure 4 shows the range of GHG emission reductions for various agrofuels and countries. According to DOORBOSCH and STEENBLIK (2007), the best performance is achieved by ethanol produced from sugar cane in Brazil, which has the potential to reduce GHG emissions by up to 90% compared to the consumption of equivalent amounts of gasoline. DOORBOSCH and STEENBLIK (2007) estimate that in 2050, agrofuels could provide a GHG reduction potential of 2.5 gigatonne (Gt) of CO_2 from the annually demanded 39 Gt of CO_2, to limit the increase in global warming to 2-3 °C. In addition, second-generation agrofuels based on cellulosic feedstocks offer a relatively high potential for reduction of greenhouse gas emissions.

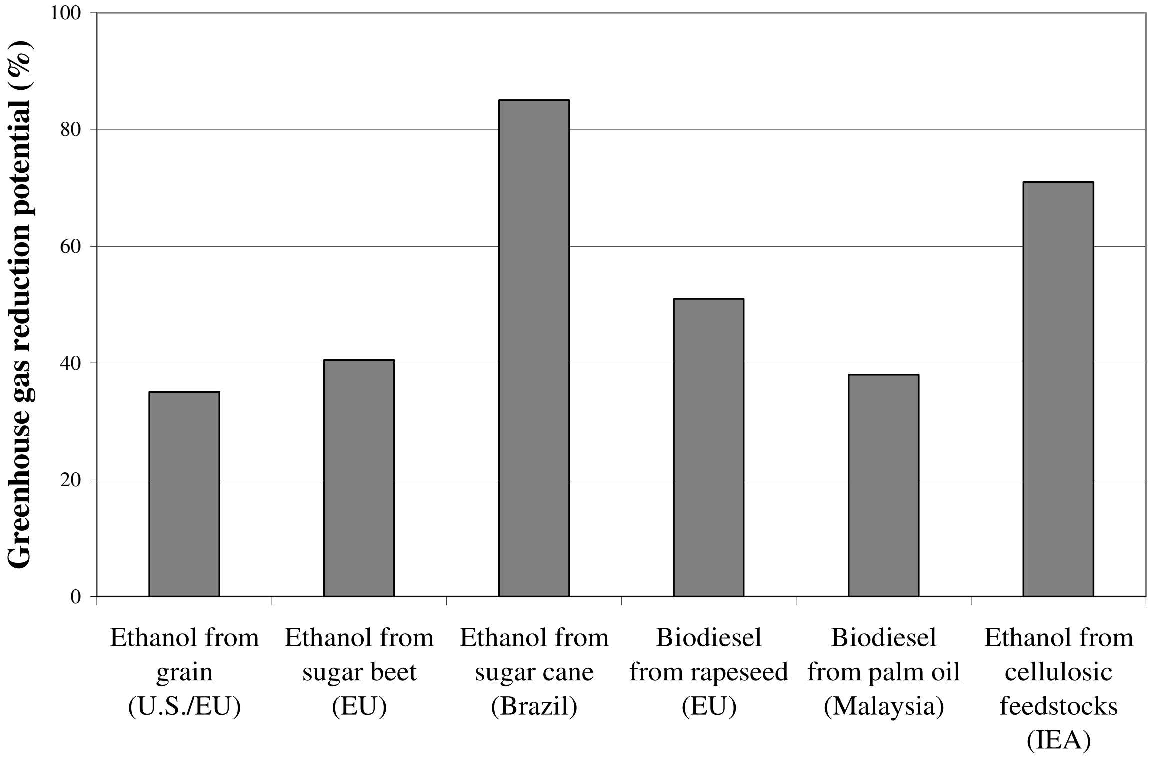

Figure 4: Range of estimated annual greenhouse gas reduction from agrofuels (in %) compared with fossil gasoline or diesel

Source: DOORBOSCH and STEENBLIK, 2007

According to DOORBOSCH and STEENBLIK (2007), the costs of reducing GHG emissions through ethanol production in the U.S. amount to about 545 US$ per ton of CO_2-equivalent. In Europe, these costs can be much higher. A comparison of these costs with the prices paid for a ton of CO_2-equivalent traded at the European Climate Exchange (ECE) or the Chicago Climate Exchange (CCE) shows that "a typical transfer of around US$ 500 per tonne of CO_2-equivalent through the use of biofuels is 10 times the maximum price yet observed for a CO_2-equivalent offset on the European Climate Exchange (around US$ 33) or more than 100 times the maximum price on the Chicago Climate Exchange (around US$ 4)" (STEENBLIK, 2007). Hence, governments could have achieved the same reductions in greenhouse gases with a negligible fraction of the public funds spent on agrofuels.

A new study of SEARCHINGER et al. (2008) seeks to include – apart from direct changes on land use due to the production of agrofuels- the indirect effects on land use change caused by

rising crop prices due to agrofuels, and argues that farmers worldwide will respond to higher crop prices by converting forest and grassland to agricultural area, thereby releasing greenhouse gases. SEARCHINGER et al. (2008) find "that corn-based ethanol, instead of producing a 20 % savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50 %." FARGIONE et al. (2008) calculated the agrofuel carbon debt of different feedstocks grown on different cleared ecosystems. They conclude that "biofuels, if produced on converted land, could for long periods of time, be much greater net emitters of green-house gases than the fossil fuel that they typically displace" (FARGIONE et al., 2008).
Several authors have suggested that certification of agrofuels may be a solution. A recent review by the Scientific Committee of the BMELV argues that – apart from the huge constraints in administering and controlling the certified value chain, such a measure might only push the production of non-certified food crops or non-certified agrofuels elsewhere (BMELV, 2007). Hence, certification might not offer an effective contribution, because it does not solve but simply spatially reallocates the underlying problem.
We conclude that first-generation agrofuels based on food crops are a grossly inefficient mitigation strategy to reduce the emission of greenhouse gases. Sustainable agrofuel strategies should seek to minimize competition with the food and feed sector as much as possible. Much more research is therefore needed to improve the use of wasteland, residues and agricultural byproducts as well as to promote innovative agrofuel crops such as Jatropha and other plants that might have the potential to produce feedstock for agrofuels in locations that are not suited for food and fiber production and that do not threaten the world's remaining areas protected for biodiversity and other environmental services.

4. Social costs of agrofuels: Rising food insecurity and hunger among poor net buyers of food

The future policy and technology developments in the agrofuel sector may create a high level of uncertainty in agricultural markets (OECD-FAO, 2007). For example, the politically driven increase in first generation agrofuel production (using cereals, sugar, and oilseeds) will create upward pressure on food prices, and therefore also on feedstock prices, so that "a competition between bioenergy and food supply is practical inevitable" (KERCKOW, 2007).
The OECD-FAO (2007) report further raises the question of whether the observed increase in energy and related food prices during recent years is a long term phenomena caused by

changing market structures, i.e. by having established a stronger direct link between the output markets for energy and food through the agrofuel industry in addition to the already existing link that energy prices have a major impact on prices of agricultural inputs. Moreover, they question whether the observed relationship between food and energy prices will increase uncertainty and result in higher price variability in the food market. In our view the answer to both questions is undoubtedly, yes. Modelling approaches, such as those of the International Food Policy Research Institute (IFPRI) seek to provide a more thorough analysis and an answer to these questions.

Using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) at IFPRI, ROSEGRANT et al. (2006) investigated the interaction between the demand for agrofuel feedstock crops and the demand of crops used for both food and feed. The IMPACT model uses three different scenarios to estimate how projected growth in agrofuel production could affect food availability, prices, and consumption at global and regional levels, between now and 2020. Scenario I investigates how the increasing use of actual feedstock, driven by the increasing replacement of gasoline (10 % in 2010 and 20 % in 2020), affects the world prices of these feedstocks. Scenario II takes into account possible large scale conversion of cellulose to agrofuel in 2015. Scenario III is similar to scenario II, but additionally considers the effect of investments in crop technology, that would result in increased productivity of biomass over time. The results of the scenarios are shown in table 3.

Table 3: Percentage changes in world prices of feedstock crops under three scenarios, compared with baseline

Feedstock crop	Scenario I: Aggressive agrofuel growth without technology improvements		Scenario II: Cellulosic agrofuel	Scenario III: Aggressive agrofuel growth with productivity change and cellulosic conversion
	2010	**2020**	**2020**	**2020**
Cassava	33	135	89	54
Maize	20	41	29	23
Oilseeds	26	76	45	43
Sugar beet	7	25	14	10
Sugarcane	26	66	49	43
Wheat	11	30	21	16

Source: ROSEGRANT et al., 2006

Scenario I seeks to predict the situation in 2020 if the current aggressive policy decisions and strategies in regards to the expansion of agrofuels using first-generation feedstocks are implemented in developed as well as developing countries. The resulting impact on food prices will be astounding from the perspective of agrofuel producers, while it will be devastating from the perspective of poor consumers. The expected rise of food prices by 2020 is predicted to range from 25 % to 135 %, depending on the crop. In scenario II, with the use of cellulosic agrofuel, the impact of agrofuel expansion on food prices is less dramatic. Cellulosic agrofuel will not compete so strongly with the production of food and feed, as much of it can be supplied by the forestry sector from non-arable land or from byproducts of the agricultural sector. Scenario III is seen as "the most plausible of the three" by ROSEGRANT et al. (2006). It assumes rapid technological progress in agricultural production as well as energy conversion. In Scenario III, food prices are estimated to rise in the range of 10 % to 54 %.

These scenarios indicate that the good old days of the past 200 years during which food and energy prices were only loosely connected are finally over. ELOBEID and HART (2007) estimate the impacts of an increase in the crude oil price on the costs of food baskets in developed and developing countries. They use a multi-country, multi-commodity agricultural modelling system that takes into account the effect of increasing agrofuel production triggered by higher oil prices, and the resulting effects on the supply and prices of foods. ELOBEID and HART (2007) conclude that the highest percentage increases in food basket costs will be seen in Sub-Saharan Africa and Latin America.

The increasing interdependency between energy and food prices can only be effectively addressed through institutional and technological progress, guided by appropriate policies focusing on long-run sustainability of the food, agriculture and energy systems. Because of the direct competition of first-generation agrofuels with the food sector, the future of a sustainable agrofuel sector should focus on second generation agrofuel technologies, in feedstocks from low value agricultural byproducts or from crops suited for marginal or degraded lands. It is regrettable, however, that much of current subsidies in developed and developing countries is invested in first-generation agrofuels instead of socio-economic and technological research for the aforementioned technologies that hold promise for long-term sustainability. A shift in policy is urgently required, so as to conduct research for more cost-efficient agrofuels using biomass sources that do not compete directly with food production.

The proponents of agrofuels in developing countries argue that agrofuels can have beneficial employment and income effects for rural laborers, including the poor. However, the size of these effects critically depends on the type of institutional framework chosen for the production of agrofuel (WOODS, 2006). At present, large scale factories provide the dominant share of the world production of agrofuel in developed and developing countries. This allows for exploitation of the existing economies of scale, benefiting large-scale producers. While the processing activities might indeed require larger production units in order to be cost-efficient, the production of the biomass itself might benefit poor smallholder if appropriate institutional arrangements were used. Instead of plantation estates run by large companies where the poor might only benefit as wage workers from agrofuels, the production of feedstock in more decentralized systems could be organized through contract farming with smallholders or through cooperative institutions.

Upon analysis, the plantation model may have limited employment and welfare effects, and therefore negligible multiplier effects for the local economy. In comparison, the smallholder led production under contract farming or cooperative arrangements could be more labour intensive and less capital intensive. It could therefore be more suitable to the production conditions in low-income developing countries. In Brazil, with its highly unequal land distribution, the preferred institutional framework of the agrofuel industry is so far the mill-owned estate which employs wage workers. There are a number of projects seeking to promote small scale bioenergy development for decentralized and local consumption. Yet, according to WOODS (2006), there exist a number of technological and socio-economic research issues, especially with regard to social organization and profitability of small-scale and decentralized bioenergy development. More research and pilot experiments are therefore needed to further develop and test small scale production of agrofuels for decentralized energy systems. These systems can be especially attractive for remote rural areas that face energy shortages or do not have access to public grids.

Overall, the current trends and technological and institutional development seem to be a pathway leading towards the large scale production of agrofuels. More socio-economic research and pilot projects are needed that test the economic, social and environmental viability of other institutional arrangements. Even for the large-scale export market, mill-owned estates as nucleus similar to oil palm plantations may – coupled with outgrower schemes and contract farming – benefit smallholder farmers. Depending on the crop, technology and institutional arrangement, smallholders may not only benefit from producing bioenergy for local and regional markets, but also for export markets. Appropriate policy and institutional frameworks could enable smallholders to take part in the production of biomass for agrofuel, with positive effects on local employment, investment and income in rural areas.

5. Conclusions

Agrofuels offer a number of important prospects for development. First, they are a renewable energy source. Second, they can potentially contribute to the reduction of greenhouse gases, although the greenhouse gas abatement costs of agrofuels are quite high, further technological progress, especially with respect to second-generation agrofuels, could greatly reduce these costs. Third, for low-cost producers of agricultural raw materials in developing countries, agrofuels offer the potential of increasing export prices for agricultural goods and creating an additional export market, provided that the developed countries, in particular the EU and the U.S., eliminate the current protection of their agrofuel industries and allow for increased imports from developing countries. Forth, for these countries with highly subsidized agricultural sectors, such as the EU and the U.S., the promotion of agrofuels is a politically attractive measure for support of income of domestic farmers and rural employment, while increasing national energy security.

However beneficial they may be, agrofuels also pose some important challenges. First, the effect on income and employment for the rural poor and smallholders, especially in developing countries, remains to be seen. Much will depend on how agrofuels are eventually produced and distributed worldwide, and whether smallholders or rural labourers are able to find rewarding income or employment in the agrofuel sector. The discussion on certification of first-generation agrofuels with respect to environmental and social criteria cannot solve the problem because these agrofuels compete worldwide for land, whether certified or not. A certified production in one area may only push the production of other food or agrofuels into other, not certified areas. Second, the expansion of agrofuel production will create upward pressure on food prices. The effect of rising food prices on the rural population will depend on whether households are net buyers of food or net sellers of food. For the net sellers, agrofuels will provide the prospect of rising incomes. For the net buyers of food in rural and urban areas, especially for the poor, agrofuel is likely to increase food insecurity and poverty. If the current trends in agrofuel production, without major technology improvements, persist over the next decade, the effect on food prices – as predicted by IFPRI – will be very detrimental for food security and the poor. Consumers in developing countries have already begun and are likely to continue exerting pressure on politicians because of rising food prices. Consumers and taxpayers in developed countries are likely to do the same as they have to carry the burden either as tax payers or at the gas station or food store. Third, a massive expansion of agrofuel production in the tropics and subtropics is likely to provide incentives for deforestation, soil mining, and water logging, thus increasing the environmental pressures from agriculture and forestry. Fourth, there is a risk that the agrofuel boom will be dominated by large scale agribusiness firms that produce biomass through mill owned plantations, rather than by involving smallholders. In the former scenario, the effects on local employment and pro-poor investment in rural areas would be much weaker than in the latter scenario. Fifth, agrofuels are a very costly mitigation strategy for climate change. The current subsidization of the agrofuel sector in developed as well as developing countries needs to be reviewed in view of the high cost of reducing greenhouse gas emissions. Other measures, such as insulating houses and designing more fuel-efficient engines, are likely to yield much more cost-efficient reduction in greenhouse gases while at the same time averting the adverse effects of the current agrofuel boom on food prices and poverty.

Thus, in order to reap the potential win-win-win scenario that agrofuel could potentially offer for economic growth, poverty reduction, and the environment, it is clear that massive investments in research need to be made. Agricultural research, conversion technology research, as well as research regarding appropriate policy and institutional settings promoting pro-poor and sustainable agrofuel production is needed. Research on the use of agricultural byproducts and on second-generation agrofuels based on cellolusic biomass should especially be promoted. Policy makers in the developed and developing world should reduce or best eliminate current subsidies for the agrofuel industry and regulations for mandatory blending and instead invest more public funds into research that promotes sustainable production of renewable energy out of multiple sources (biomass, wind, water, solar) as well as more efficient energy use.

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Jatropha fuel from India's wastelands: A financial analysis of different Jatropha production scenarios linked to possible crude oil price developments

Abstract[1]

India's increasing energy consumption motivates the search for and the development of alternative energy sources. This research investigates the potential of Indian agro fuel; especially Jatropha-based fuel production on wastelands as alternative to fossil fuel. Further we discuss how Jatropha's potential can be utilized by farmers to reclaim up to 20 million ha of the 55 million ha of wastelands in India thus expanding their income potential and reducing the environmental impact of economic development.

We use a value chain approach to link the price of crude oil with that for Jatropha seeds. This is done via supplementing fossil diesel with Jatropha fuel - Jatropha pure plant oil and Jatropha methyl ester. We further apply financial analysis to three different Jatropha producton scenarios using the derived maximum price for Jatropha seeds. Our focus is on the range of crude oil prices and interest rates at which Jatropha seed production becomes an economically viable investment as measured according to the net present value criterion.

We found that at crude oil prices above US$ 75 per barrel (low cost scenario JPPO, interest rate 6%), Jatropha fuel production on India's wasteland starts to be economically viable. We conclude that both JME and JPPO have potential to serve as renewable energy source.

The findings can serve the Indian state and federal governments to further develop appropriate political and economical framework conditions for the future diffusion of Jatropha fuel production in India.

Keywords: agro fuel, bio fuel, India, Jatropha curcas, renewable energy, wasteland

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1. Introduction

During the last 5 years agrofuels have gained increasing attention on the international agenda. In America and the European Union, strong agrofuel policies targeting domestic energy security, rural development, and greenhouse gas abatement have been forged. But not only developed countries increasingly pay attention to agrofuel production; the possibility of supplementing crude oil imports and the increasing demand from America and the EU motivates developing countries like Brazil, Indonesia, Malaysia, India and China to enter and support the agrofuel business.

The International Energy Agency (IEA) expects that developing countries with fast growing populations and economies will contribute a share of 74% to the increase in global primary energy use. India and China will be responsible for up to 45% of this increase. For India, one driver behind the growing demand for energy is the transport sector which "currently consumes 27% of total primary oil demand" [1]. This share "will increase to 47% by 2030" [1].

As oil is and will remain the main source for transport energy in near future, India's crude oil import dependence will increase from today's 70% to 90% in 2030. Therefore India could become third largest oil importer after the U.S. and China in 2024. The fact that diesel "makes up almost 70% of the oil used in Indian road transport" and that "the share of transport in final energy demand in India doubles … from 10% in 2005 to 20% in 2030" [1] leads to the growing interest in developing a domestic agrofuel industry in India. Strengthening this interest is the agrofuel sector's potential as an employment generator for India's huge rural population and the possibility of greening the wastelands [2].

However, in India the incentives to produce agrofuels domestically are challenged by the difficulties of its integration into the existing fossil fuel sector and with the issue of food security.

In India, pure vegetable oils for human consumption are under short supply. Therefore they, as well as fertile agricultural land, will not be available for the provision of transport energy. For this reason non-edible tree-borne seed oils have been identified by the Indian Government as possible sources for agrodiesel production. Of the 100 – 300 different tree species producing oil-bearing seeds in India, only a few, such as Pongamia pinnata, Jatropha curcas, Mahuca indica and Azadirachta indica (neem) are under consideration to be primarily exploited for the "National Mission on Biodiesel" announced in 2003. The "Ministry of Rural Development" is responsible for supporting the implementation of Jatropha-based agrofuel.

This is expected to occur in two phases: “Phase-I as demonstration project and Phase-II a self-sustaining expansion of Bio-diesel Programme ... to produce the required quantity of Jatropha curcas seed” [3].

As the first demonstration sites have now been established within India, phase II is planned to start this year. Accompanying measures for agrofuel expansion planned in Phase II are credit facilitations for plantation, raising nurseries, establishing seed collection centres and oil extraction units. The costs incurred shall be shared between the entrepreneurs, the Small Industries Development Bank of India and the National Bank of Agriculture and Rural Development in a 10:60:30 ratio. The Ministry of Petroleum & Natural Gas announced its plan for direct financial assistance mainly based on an agrodiesel purchasing policy that provides the oil marketing companies a fixed agrodiesel price of 25 INR per litre (inclusive of taxes, duties, transportation cost) to commence January 1st 2006 [4].

Several federal states have invented their own support instruments for agrodiesel production. The Government of Andhra Pradesh introduced a minimum support price of 10 INR per kg for agrofuel seed effective January 1st 2007. In its Andhra Pradesh policy draft 2004, farmers from Scheduled Castes and Tribes as well self-help groups were identified for preferential support. Farmers could apply for financial support for the first three years of cultivation. Over this period, bank loans would cover 40% of on-going costs with the remainder provided through the state.

Wani and Chaliganti [5] explore how the rural population might participate in agrofuel production through an overview of possible models of stakeholder involvement in Jatopha seed production. As India’s wastelands are mainly in state property, we focus on the collector’s model, which will be explored later in this paper.

In regards to the integration of agrofuels into the Indian fossil fuel sector, it must be understood that the Indian fossil fuel sector was and still is regulated by the Government through the administered pricing mechanism. This system protects the domestic prices of some petroleum products from volatile international crude oil prices and grants subsidies to certain other petroleum products. Within this policy the Indian Government assures a “return of 12% post-tax on net worth” [6] and compensates oil refineries, oil marketing companies and the pipelines for operating costs. This policy of fuel pricing “resulted in an economically inefficient fuel mix and distorted allocation of energy and financial resources” [1]. Further action at the national level has not occurred to date, however the fixed price, which includes taxes of US$ 0.60 (25 INR) per Litre of agrodiesel, might be adjusted in light of the increasing price of crude oil.

The aim of this study is twofold: First, to answer how crude oil prices can provide the basis for the price of Jatropha seeds and second, to show under which production scenarios and crude oil price that Jatropha seed production becomes economical viable. This is done by restricting Jatropha production to wastelands in order to reduce its competition for land use with areas used for food production and that the used agronomic data reflects the current knowledge in this field.

To address the first aim, we apply a value chain approach linking the prices of crude oil price and Jatropha seeds via the fossil diesel price and its Jatropha fuel substitutes (Jatropha methyl ester and Jatropha pure plant oil). The undertaken steps and findings are discussed in chapter two.

As depending on the crude oil price and the Jatropha fuel alternatives to fossil diesel different prices for Jatropha seeds can be offered to Jatropha growers, these prices offered will strongly influence the decision to invest or not to invest in Jatropha seed production. These price variations are combined with agronomic data for Jatropha production under wasteland conditions derived by a literature review, the findings of a field study and key person interviews in India done by the authors in 2007. In chapter three this data serves to answer the second question where financial analysis using market prices based on Gittinger [7] is applied to different Jatropha seed production scenarios. We do not apply cost-benefit analysis to answer the above questions as this requires a much broader approach on the effects of Jatropha-based agro fuel production on the society and the environment.

2. The linkage between crude oil price and Jatropha seed price

As we apply a value chain approach to determine the Jatropha seed price, special evidence is given hereby to the production costs within every part of the chain. The underlying assumptions and calculations will be provided in the following sections.

2.1 Relation between crude oil price and the fossil diesel price

This chapter focus on the derivation of the relation between crude oil price and fossil diesel price following the approach used by Henniges [8]. The underlining assumption is that there is a linear correlation between the crude oil price and the net selling price for petrol (in our case diesel) at the retail station. The net selling price applied at the retail station includes the purchase cost of crude oil, refinery processing costs, cost to transport diesel to the retail station and the industry margin. In addition to this price, the consumer pays the added taxes. Despite intense research we were unable to determine the exact retail price[2] for diesel before taxes in India. To overcome this restriction we searched for alternative applicable diesel price levels.

As policy suspension of market prices for fossil fuels can be observed in nearly all countries worldwide [9, 10] it is difficult to compare national fuel prices. To assess the political influence on national fossil fuel prices and to make worldwide fossil fuel price comparisons possible, a benchmark price which reflects mainly the production costs for fossil fuels without policies that can negatively influence price should be established. Within its International Fuel Price Survey 2007, the "Deutsche Gesellschaft für Technische Zusammenarbeit" (GTZ) suggest using American retail fuel prices as the international minimum benchmark for a non-subsidised road-based transport policy.

Following GTZ's argument that "the fuel market in the USA is characterised by a high intensity of competition and pricing reflects commercially calculated full-cost prices" [9], we decided to use American retail prices for diesel (before taxes) as benchmark price to compete with Indian agrofuels. We further point out that, in the long term, the Indian refinery and distribution system could achieve costs as low as those in the USA. The American retail prices for diesel are derived from the Petroleum Marketing Annuals of the U.S. Energy Information Administration (EIA) [11 – 15]. The data consists of average monthly prices for U.S. No. 2 diesel fuel (cents per gallon excluding taxes) focussing on sales to end users and taking into account low-sulfur and high-sulfur diesel fuel for the period between January 1997 and December 2006. For the same period, we oppose the average crude oil prices to the derived diesel prices. The data for crude oil prices consist of data derived from EIA weekly time series data for world crude oil prices [16]. The chosen prices reflect a price level determined by: all countries spot price[3] free on board (FOB)[4] weighted by estimated export volume (Dollars per Barrel). We extrapolated the monthly average prices using these weekly prices to compare with the diesel price data series. Fig. 1 shows the results of a regression analysis for world crude oil prices development comparing American diesel prices before taxes to different retail diesel selling prices in India.

[2] Only here we violate the rule of using only market prices. This is done because the market prices for fuel in India are highly distorted and policy driven; to reach a price level possible for comparisons we had to deviate from the rule of using market prices within India.

[3] "An average calculated using specific crude oil prices weighted by the estimated crude oil export volume for each oil-producing country." EIA, Weekly Petroleum Status Report, Appendix A, Explanatory Notes

[4] "Pertains to a transaction whereby the seller makes the product available within an agreed on period at a given port at a given price; it is the responsibility of the buyer to arrange for the transportation and insurance." EIA, Definitions

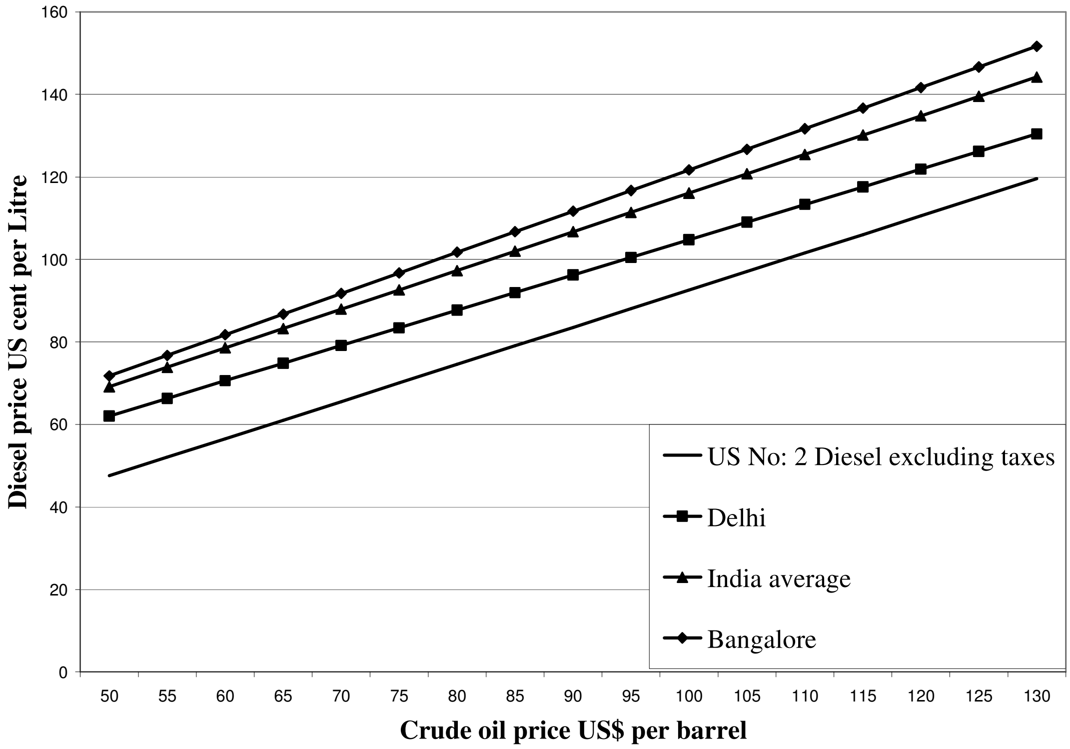

Figure 1: Relation between crude oil world market price, American diesel (excluding taxes) and Indian policy set retail diesel prices (including taxes)

Source: own calculations

The retail prices for India are derived from the Government of India's Ministry of Petroleum & Natural Gas and show the politically-set price for fossil diesel in different regions of India [17]. The price adjustment steps in this data are averaged per month according to the month they occurred. The month's corresponding average exchange rate was used to convert the prices into US cents per litre. Then the regression line was calculated for the fore-mentioned prices using the corresponding monthly crude oil world market prices and extended for higher crude oil price levels.

Under the assumptions that the American diesel prices used are the retail prices excluding taxes and that India could achieve same retail price levels, the price differences can be assumed to represent the range of taxes on diesel in India. The outcome of the regression between the world crude oil price and the American retail diesel price (excluding taxes) can be expressed with the following formula 1[5]:

[5] Note: $\mathbf{p_0}$ is the Crude oil price in US$ per barrel

Formula 1:

Fossil diesel retail price excluding taxes (US cent / Litre) = 0.9001 * $\mathbf{p_0}$ + 2.5305

This formula makes predictions of diesel retail prices based on changes of the crude oil price possible and therefore can serve to calculate the price of agro fuel as it competes with diesel.

2.2 Linkage between fossil diesel, Jatropha methyl ester (JME), Jatropha pure plant oil (JPPO) and Jatropha seed price

Two possible Jatropha-based agro fuels can be considered for fossil diesel substitutes. As simple engines such as those required for water pumps and electricity generators can run already with only filtered JPPO. Further processing is required to manufacture JME if Jatropha-based agrofuel is going to be a substitute for fossil diesel in the transport sector. The process of transesterification increases the fuel properties allowing for use in car motors. Table 1 presents how much of JPPO and JME is needed to substitute one litre of fossil diesel [18]. The shown figures will later be applied to the corresponding production cost of JPPO and JME to allow comparisons which take into account the physical differences of the two Jatropha fuel alternatives to fossil diesel.

Table 1: Physical interrelation of fossil diesel, JPPO and JME

	Unit	diesel	JPPO	JME
Density at 15 °C*	kg/dm³	0.85	0.94	0.88
Calorific value of 1 kg*	MJ	42.00	38.65	39.23
Calorific value of 1 Litre	MJ	35.70	36.33	34.52
to substitute 1 litre of diesel	litre	1	0.98	1.03

* **Source:** Tiwari et al. [18]

In the next sections we explore how the production costs of JME and JPPO in relationship with the price for fossil diesel translates into the maximum bidding price for Jatropha seeds as determined by the Jatropha fuel processing option. Maximum bidding price is defined here as the price a JME or JPPO processor pays for seeds including production costs. A potentially valuable by-product of each processing option is revealed as well.

2.3 JME production example

The first approach to determine the cost of JME production was done by Francis et al. [19] who calculated a fixed purchase price of US$ 0.11 per kg of Jatropha seed. For the assumed small-scale agro diesel production plant[6], his results show the cost of producing one litre of agrodiesel was US$ 0.53. He argued that this price could be subsidized by selling the incurred by-products such as glycerol (US$ 0.08 per litre) and seed cake (US$ 0.05 per kg) to arrive at a net cost of US$ 0.40 per litre for JME. However, as explained in Chapter 2.5, we did not include the subsidization of agrodiesel via the sale of processing by-products.

To estimate the production cost of JME, we used data from a multi feedstock agrodiesel plant with a daily JME production capacity of 40,000 litres. For the underlying processing ratio of 1 kg of JME produced from 4 kg Jatropha seeds, Kumar [20] estimates the price (break-even price) for 1 kg JME at US$ 0.27[7]. This is the minimum price needed to cover production costs. As in our study the price for Jatropha seeds is linked with the crude oil price by its substitution of fossil diesel for JME, the maximum bidding price for Jatopha seeds is as followed: For each crude oil price used in Formula 1, the resulting diesel price per litre is reduced by the JME production cost depending on its physical interrelation. To determine how many kilograms of Jatropha seeds are needed to produce sufficient JME to substitute one litre of fossil diesel (here 3.64 kg of Jatropha seeds) this price is divided by the required weight of Jatropha seed. The results are shown in Table 2. JME production can be defined as a centralized production system where the agrodiesel plant purchases the seeds and sells the agrodiesel and by-products. To meet the plants daily production capacity requires the harvest[8] of approximate 107 ha wasteland.

2.4 JPPO production example

To produce JPPO nothing more than an oil press is needed. In the presented example, experiences and data from Tanzania based on Metzler [21] are adapted for India. The oil press tested is the Sayari oil expeller[9] which requires a total investment of approximately US$ 3,550. The detailed annual costs which occur are shown in Table 2.

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[6] Annual processing capacity of 2,000 tons of raw vegetable oil.

[7] Average exchange rate 2007 is used for all calculations, exceptions mentioned: 1 US$ = 41.37 INR

[8] Assuming maximum yield of 1,500 kg Jatrpha seeds per ha under wasteland conditions

[9] Was developed by FAKT consulting engineers Dietz, Metzler, Zarrate for the use in Nepal and is now produced in Tanzania.

Table 2: JPPO production costs per year

	Years	1	2	3	4	5
Labour cost	US$/year	1,574	1,574	1,574	1,574	1,574
Maintenance of expeller and engine	US$/year	545	545	545	545	545
cost for diesel (US$ 0.8143 per litre)*	US$/year	3,707	3,707	3,707	3,707	3,707
payment of Interest (10%)	US$/year	355	297	233	162	85
Total cost (undiscounted)	US$/year	6,182	6,125	6,062	5,993	5,916
Annuity cost	US$/year	6,065	6,065	6,065	6,065	6,065
Capacity	kg seed/ year	262,558	262,558	262,558	262,558	262,558

Source: Own calculations based on Metzler [21]

* adapted to Indian diesel price, average 06.06.2007 [17]

As the calculation of annual average cost does not take into account the opportunity cost of capital (capital represented as interest), we calculated the net present value (NPV) for the total costs of each year (interest rate 10%) to derive the cost of processing 1 kg Jatropha seed. The sum of the NPV forms the total NPV which is used to calculate the annuity (5 years, interest rate 10%). This annuity represents yearly costs including the opportunity costs for capital. Hence the yearly costs are divided by the processing capacity. Using this calculation, we have determined that it costs US$ 0.023 to process 1 kg of Jatropha seed.

Assuming the conversion rate of 4 kg seed to 1 kg of oil, the cost of producing 1 kg of JPPO would be US$ 0.092. To substitute 1 litre fossil diesel would then cost US$ 0.085. To meet the production capacity of this oil press would require an annual harvest of approximately 178 ha.

2.5 By-products of Jatropha fuel production

As shown by Francis et al. [19] the Jatropha fuel production process creates valuable by-products (Glycerol and seed cake) that could reduce its market price. In the following two sections we present why we decided not to include these as possible cost subsidies in the financial analysis.

Glycerol:

Glycerol is a by-product of the JME refining process. Within this process, 1 kg JPPO combined with 10 % of wage methanol react and result in 1 kg JME and 10 % of wage Glycerol. Glycerol can be sold for up to US$ 1 per kg in India [20]. However, Francis et al. [19], assume US$ 0.08 per litre and an OECD working paper assumes that: "with an increased glycerine production at biodiesel plants, the market price of glycerine has already dropped and may drop to zero or become even negative" [22]. This possible obsolescence of the value for Glycerol is shared by Bharadwaj et al. [23]. For this reason Glycerol prices in this study are assumed to be zero in the long run and cannot subsidise the price of Jatropha production.

Seed cake:

Current monetary value for Jatropha seedcake is determined exclusively by the amount of Nitrogen it can substitute for in chemical fertilizers. The calculation shown in Table 3 includes the three main fertilizer components (N, P, K) required to use Jatropha seed cake as a substitute for chemical fertilizer. Its value changes from US$ 0.05 per kg of seedcake [19] to US$ 0.03 per kg of seedcake when compared to Indian chemical fertilizer prices. To adjust for differing fertilizer prices from country to country, we explain the assumed nutrition discharge as follow: If the wastelands can achieve the maximum annual yield of 1,500 kg of seed per ha, this wasteland will lose 68.6 kg of N, 13.8 kg of P and 8.8 kg of K per ha per year once the seedcake's (with 75% of seed yield) nutrition. If the farmers want to fertilize the wastelands according to this nutrition's removal yearly fertilizer costs would raise to US$ 36 per ha.

Table 3: Valuation of Jatropha seed cake as fertilizer

	Unit	N	P	K	Price INR/kg
Jatropha seed cake[a]	g/kg	61	12.28	7.82	
Urea[b]	g/kg	460	0	0	5.00
Diammonium phosphate (DAP)[c]	g/kg	180	200.56	0	10.00
Nitrophosphat with K[d]	g/kg	150	65.40	124.50	6.98
	Ratio (g)	N	P	K	Price INR
Urea	96	44.24	0	0	0.48
DAP	41	7.34	8.18	0	0.41
Nitrophosphat with K	63	9.43	4.11	7.82	0.44
Total	200	61.01	12.29	7.82	**1.33**

[a] Average: Francis et al. [19], GTZ [24]; [b, c] Market price in India [25]; [d] The Fertilizer Organisation of India [26]

If farmers sell their seeds and then have to purchase fertilizer to compensate for the soil's nutritional losses, they have to get at least cent US 2.25 per kg of Jatropha seeds more to reach their break even point as they would get only counting for the possible price levels of the two Jatropha fuel options. This higher price for Jatropha seeds would negatively influence the development of NPV and therefore Jatropha seed production would become economic viable only at higher crude oil prices. Nevertheless the costs of sustaining the wasteland's fecundity depends on fertilizer prices which are also correlate with the crude oil price. However, in order to sustain or even enhance the wastelands soil, the amount of nutrition shown in Table 3 must be returned to the fields. One solution could be the promotion of small scale JPPO oil mills where the farmers process their seed for a set price covering the processing costs and there are given their seedcake for free.

Another concern rises regarding the toxic nature of Jatropha seeds which is also true for the seed cake used as fertilizer. The question on the possible effects of using the toxic seedcake as fertilizer is summarized in Jongschaap et al. [27]: "The toxic components (porbol esters) of J.curcas decompose quickly as they are very sensitive to elevated temperatures, light and atmospheric oxygen [28]. Porbol esters decompose completely within 6 days [29]." Hence for safe use as fertilizer, the seedcake should at least be stored for 6 days before using it to mitigate negative effects. According to the assumption that farmers will use the seedcake to maintain the soil fertility at zero cost the estimated seedcake price is not included into the following financial analysis of Jatropha production.

3. Cost of Jatropha seed production

As agronomic data on Jatropha seed production varies widely and current market prices for Jatropha seeds do not reflect production costs, we conduct a scenario analysis detailing the range of possible production costs with the most current data available and the direct linking of possible Jatropha seed prices to different crude oil prices. The possible market price (determined by the maximum bidding price) reflected by the crude oil price development is presented in Fig. 2. The costs for transporting the seeds from the plantations to the JME or JPPO plant, which must be subtracted from the maximum bidding price, can be minimized. In our case we are following Wani and Sreedevi [30] which assume: "There is a need to promote and utilize the expellers available locally, as it will minimize the cost of transport of raw material and will generate employment in rural areas." Therefore we assume that the Jatropha seed production is located near the processing plants and therefore transport costs are negligible.

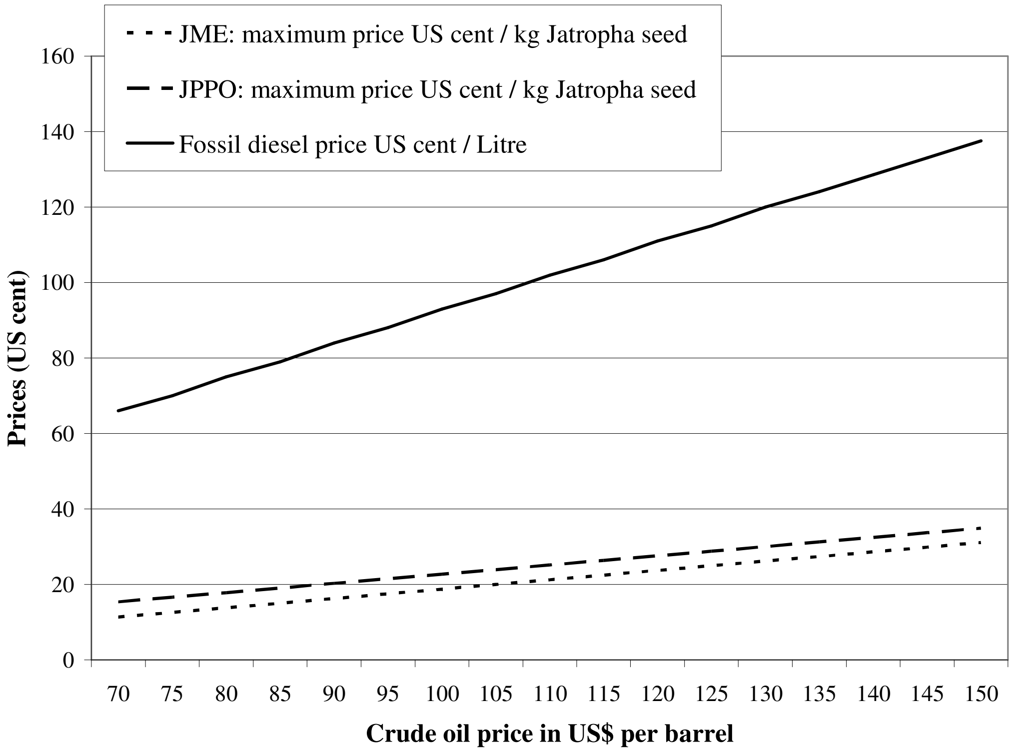

Figure 2: Relation between crude oil price, fossil diesel price and the maximum bidding price for Jatropha seeds according its processing alternatives (JME, JPPO)

Source: Own calculations

The changing crude oil prices reflect in the different prices for Jatropha seeds and so the financial analysis uses price levels between US$ 70 – 150 per barrel of crude oil to determine the economic viability of Jatropha seed production. This is done by the calculation of the NPV for the different production scenarios.

We combine data from literature and information culled from a visit to India in spring 2007 for the study's scenarios. The resulting scenarios cover and describe the ranges of Jatropha production data available. The assumed production figures are based on the following assumptions and further research should increase their reliability.

Although different spacing for Jatropha production are still being tested, within the wastelands a spacing of 2x3 meter per plant is recommended to allow intercropping. Intercropping is strongly recommended by the International Crop Research Institute for the Semi-Arid Tropics to further motivate the participating farmers as it can provide an initial income as well as increasing food security through the production of staples (e.g. sorghum, millet). The plant survival rate is about 65%, supplemented with replanting in the second year. Different assumptions regarding labour demand to establish and then maintain Jatropha production are shown in Table 4. To determine the total labour demand (excluding harvest) for all scenarios, the more conservative data of Wani [25] is used as it takes into account higher labour needs because "in long-term as we will need basins to be reworked and removal of silt from the trenches to ensure water conservation" [25].

Table 4: Labour needed to establish and maintain Jatropha cultivation (days ha^{-1} /year)

	1st year	2nd year	3rd year onwards
Francis et al. [19]	200	50	50
Becker [31]	91	46	40
Kashyap [2]	75 - 80		
Wani* [25]	165	115	110

* Based on 160 ha Jatropha plantation without any supplementary irrigation

According to Francis et al., the Jatropha seed yield reported "varies from 0.5 to 12 tons/year/ha – depending on soil, nutrient and rainfall conditions" [19]. However, under wasteland conditions, the assumed yields follow Kashyap [2] and start in year three with 500 kg, year four 750 kg, year five 1 ton and to a maximum yield of 1.5 ton per ha from year six onwards. This maximum yield is assumed to stay constant over the productive lifetime of the plantation. The productive period again follows Francis et al. [19] and is assumed to be 30 years. Estimates by Wani [25] regarding fertilizer and plant protection costs include for year one US$ 66.47, for year two and three US$ 90.64 and US$ 30.21 per year from year four onward. Fertilizer costs from year four onwards are assumed to be zero because farmers can use their own seedcake to sustain the soil's Fecundity.

Capital, provided by a bank loan calculated at 10% interest, will fully finance the cost of Jatropha seed production over years 1 to 5. As the maximum yield is achieved in year six, a five year grace period is needed before loan repayment can start. The interest and compound interest is included with the yearly capital lent resulting in a repayment period of 10 years at 10% interest rate starting in year 6 to recover the total investment. We did not include mixed financing scenarios in the calculations.

The scenarios' different production factors are shown in Table 5. The wage of US$ 0.97 per day reflects the wage rate agricultural labourers earned in the Velchal village by working on farmers´fields [5]. As wage rates up to US$ 2.42 per day can be earned by labourers in nearby towns, the assumed rate of US$ 2.18 per day reflects this alternative. How efficiently pickers can harvest Jatropha seeds remains unclear. The literature mentions ranges starting at 2 kg/hour [32] and goes up to 18 kg/hour [33]. Rates of 50 kg/hour are mentioned but were not substantiated and felt exaggerated.

Table 5: Scenario Assumptions

	Unit	Low cost	Average cost	High cost
Wage rate	US$/Day	0.97	1.45	2.18
Labour productivity	kg seed/hour	18	10	2

We presume that Jatropha seed production will only occur on wasteland as it provides little economic and ecological benefits and will then not be competing with food production for land use. In our calculations we assume that using the wastelands will have no opportunity costs. However, a study of Rajagopal [34] claims that: “A majority of such wastelands are classified as common property resources (CPR).” He concludes that the use of such land contains “an integral part of the livelihood of rural poor.” Therefore, the financial analysis for Jatropha production must include this current use as well as accounting for the proposed alternative use of wasteland. (Currently no data found to include this) If one target of the Government is to enhance the situation of this group via employment generation in Jatropha seed production, a suitable model could be the collector’s model explained by Wani and Chaliganti [5], where the rural poor have the right to use the Jatropha plants they grow on this wasteland but not to the land itself.

4. Results

The key determinant of the financial analysis to estimate the economic viability of Jatropha production is the calculation of the NPV. The investment in Jatropha seed production is judged as economic viable when the NPV is above zero. Different interest rates (6%-16%) are used to simulate investment alternatives which are also applied to the NPV calculations.

The results showed that for the low cost scenario, the production of Jatropha seed to be used for JPPO becomes economical viable at rates above a crude oil price of US$ 75 per barrel (interest rate 6%). For JME the NPV (interest rate 6%) for Jatropha seed production first becomes positive at crude oil prices above US$ 90 per barrel. At an interest rate of 16% and under the low cost assumptions, the use of Jatropha seeds for JPPO needs a crude oil price greater than US$ 105 per barrel and JME needs a crude oil price above US$ 120 per barrel.

For the average cost scenario, Jatropha seed production becomes economical viable for JPPO at crude oil prices above US$ 100 (interest rate 6%) whereas JME requires crude oil prices of at least US$ 115 (interest rate 6%).

The economic viability of Jatropha seed production under wasteland conditions can differ considerably depending on the applied interest rate and production costs. As shown in Fig. 3 and 4 even at a crude oil price of 150 US$ per barrel the high cost scenario reaches no positive NPV for both Jatropha fuel options.

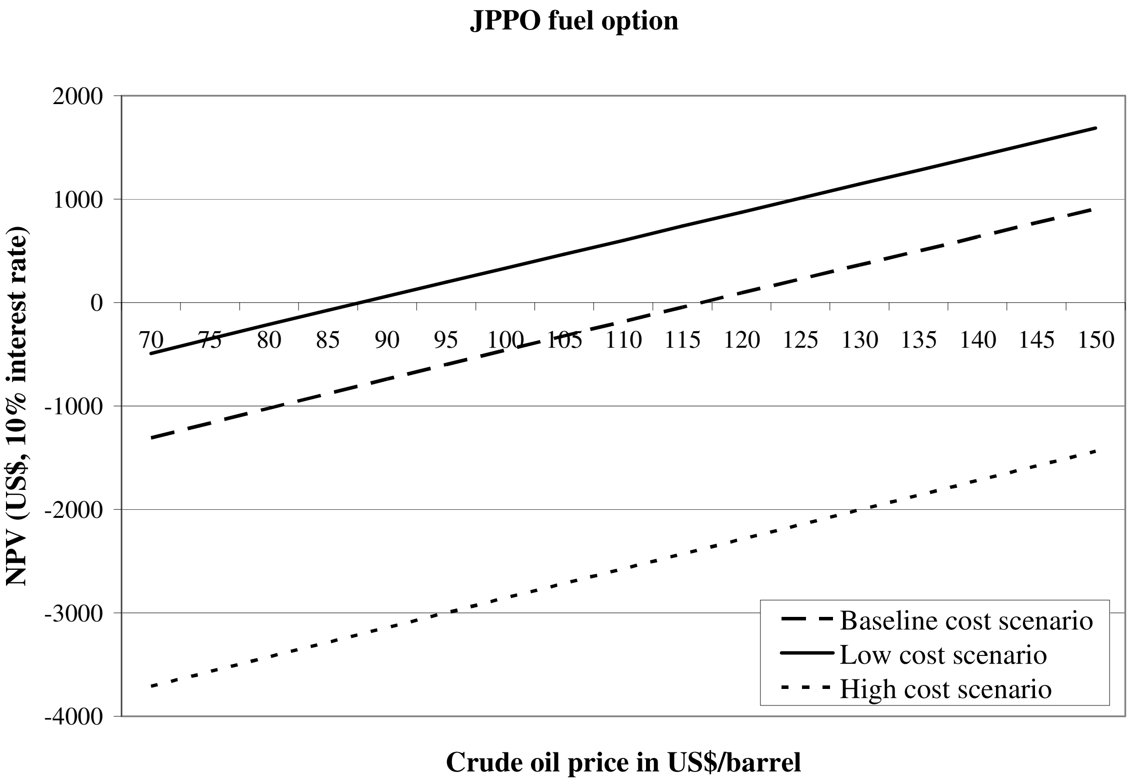

Figure 3: Net present value for Jatropha seed production per hectare according the JPPO fuel option and different crude oil price levels

Source: Own calculations

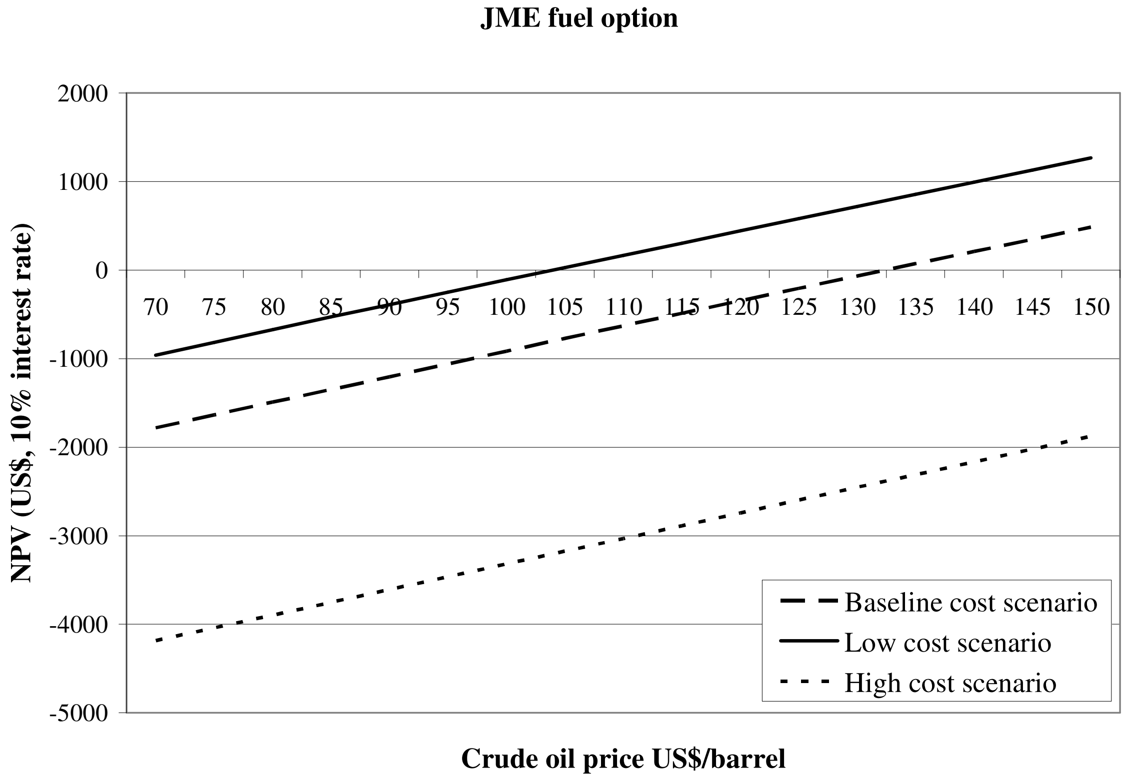

Figure 4: Net present value for Jatropha seed production per hectare according the JME fuel option and different crude oil price levels

Source: Own calculations

5. Conclusions

This research shows that although the production of Jatropha seeds for use as JPPO is more economically viable than their use as JME, both options can be used to supplement fossil diesel. Under low cost assumptions (interest rate 6%) and between crude oil prices of US$ 75 – 90 per barrel, depending on the applied Jatropha fuel option, the production of Jatropha seeds becomes interesting. As the current oil price level is approximately US$ 130 per barrel, a positive NPV is shown even for the average cost scenario using the JPPO option with an interest rate of 13% and for the JME option at an interest rate of 9%.

In the analysis, we neglect opportunity costs for wasteland use and the transport cost of Jatropha seed, but include the cost to maintain soil nutrients in the financial analysis. If opportunity costs for land accrue or transport costs for Jatropha seed from the farm gate to the oil mill are significant Jatropha seed production may in fact only become economically viable at somewhat higher oil prices than estimated. Our high cost scenario underlines how the labour cost and labour productivity, as well as yields, are crucial components for the economic viability of Jatropha fuel production. To enhance the yield of Jatropha under wasteland production, in 2007 the Delhi-based Energy and Resources Institute started an India-wide germplasm selection followed by a breeding program with the aim of developing a stable breed of Jatropha within 8 years. The breeding objectives are oil content of more than 35 % within the seeds and a yield of 2 kg seeds per tree per year [35]. However the present supply of planting material is of varied quality and makes plantation's yields unpredictable.

In the following section we examine economic instruments that could support India's agro fuel sector. The fossil diesel retail prices used in our earlier calculations are excluding taxes. One possible way to support the agrodiesel production sector would be exempting Jatropha fuel from the taxes applied to fossil diesel. This argument is supported by Saxena [36]. The current fixed price, which includes taxes of US$ 0.60 (25 INR) per litre of agrodiesel, does not reflect an open market situation. With oil at US$ 130 per barrel, the agrofuel price could be raised to US$ 1.20 per litre excluding taxes making the sale of Jatropha fuel options on the world market (reference market is the US diesel market) more attractive as to supply the Indian market. For Andhra Pradesh, the prevailing minimum price for Jatropha seed of US$ 0.24 is the equivalent of a crude oil price of US$ 105 – 120 per barrel and clearly favours Jatropha growers, but lowers the competitiveness of JME and JPPO fabricants. When oil prices increase, the case is reverse.

The calculations show that the three to five years that it takes to cultivate 1 ha of Jatropha has production costs between US$ 740 and US$ 920. As Jatrophra has such a long period without any financial return, there must be provisions to ensure the economic stability of the farmers. Flexible and long term financing options could facilitate the expansion of agrofuel production. The assumed bank loan covering the initial expenditures could be broadened, providing different financing options for farmers, as well as increasing overall access to financial support and reducing the interest rate for repayment.

The authors can only agree with Wani and Chaliganti [5] that empowering mandal revenue officers with "the power of removing the trees at any time without compensation" under the user-fruct right agreement in the federal state of Andhra Pradesh could be more counter-productive if executed in future.

One of the arguments for national agrofuel production is that Jatopha production can provide additional income to the rural population by diversifying their employment opportunities. Small scale farmers could benefit even more "if they become part of the chain (rural electricity production or local fuel supply) or if they can convert the raw material to added value products, like lamp oil or soap" [37]. Nevertheless there is the danger that depending on the profitability of the market for agro fuels, fertile agricultural land will be shifted from food production to agrofuel production causing food security problems. Intercropping Jatropha on wasteland with low demand staple crops could enhance the food supply for poor families because intercropping can help farmers access the scarcest resource - agricultural land.

According to the energy security target agrofuels expand the possible sources of energy, but it has yet to be decided how this energy can be used most efficiently according to the fossil energy substitute options as well as to the use of these options. The results of Reinhardt et al. [38] conclude that "along its entire life cycle, Jatropha biodiesel – under certain boundary conditions – holds considerable potential to help save fossil energy carriers and greenhouse gases." In terms of the production of JPPO or JME, a clear advantage for JPPO has been revealed, because of the lower energy intake within its production compared to JME. For the by-product seedcake they advised first use as energy carrier, and as animal feed or fertilizer for the second and third use according the possible impact on the live cycle. Here an economic choice has to be made between the substitution of a fossil energy carrier and the substitution of seedcake to sustain the fertility of the Jatropha production system. For Jatropha seedcake it might be possible that its high price leads to it being substituted by cheaper alternatives or an even higher exploitation of degraded soils by zero substitution. Awareness training for the farmers involved in production can address this.

For Jatropha production in India to become sustainable, it must be embedded into the Indian overall energy and rural development policy and its instruments need a time horizon of 30 years to assure maturity of this long term investment. The overall agrofuel policy could also diversify the supply of raw materials as there is a huge range of indigenous oil plants in India and a diverse potential for its use because this agrofuel could serve for transportation purposes as well as for decentralized rural electrification.

Further research is needed to improve and differentiate the Jatropha production and use system before a widespread dissemination of Jatropha can take place. Restrictions identified on this work are the transport costs for Jatropha seeds as well as the opportunity costs for wasteland which are assumed to be zero. Furthermore, the especially long time period of 30 years increases the risk of the calculations especially regarding to the crude oil price assumptions. As crude oil prices increase, at a certain point other renewable energy production technologies become competitive. The costs to produce energy from Jatropha seed has to compete with other alternative fuel sources as well as with crude oil. Nevertheless this work can serve as tool to compare different agro fuel options according to their economic competitiveness.

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Rural employment and income effects of a Jatropha plantation in Madagascar

Abstract[1]

This paper assesses the potential impact of wage work generated by a Jatropha plantation on household income and poverty alleviation using socio-economic characteristics of rural Malagasy households. We analyse data from 336 randomly selected households from three villages in the vicinity of a Jatropha plantation in central Madagascar. To overcome the problem of selection bias we apply a propensity score matching method to assess the effect of offering labour to the Jatropha plantation on household income. The findings show that households working for the Jatropha plantation have on average higher incomes per person compared to control group households. These differences are more distinct among poor households.

Key words: Madagascar, impact assessment, poverty, propensity score-matching, Jatropha, plantation

JEL codes: C21, I 32, J 30, Q 42

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1. Introduction

In light of increasing fossil fuel prices and concerns about climate change, the quest for sustainable alternative energy sources is of growing political importance globally. One partial solution is to substitute fossil fuels with agrofuels, which for their production need agricultural raw materials, residues, and by-products which are feedstocks. Ethanol derived from sugar cane in Brazil, and agrodiesel from palm oil mainly produced in South-East Asia, when valued at market prices are economically competitive with fossil fuels, despite potential negative environmental impacts (e.g. deforestation and the social costs if plantations displace smallholder agriculture). Since agrofuel as it is currently produced is dependent on the same feedstocks and production areas that are needed for food production, von Braun (2008) concluded that the production of agrofuels poses an additional threat to food security.

Especially if food prices rise, poor net consumers of food in developing countries will lose first. Will rural populations in developing countries lose in general? The case of Brazil shows that agrofuel production can be beneficial for rural employment; von Braun and Pachauri (2006) stress that the bioethanol sector provided employment for about one million people in 1997. Domac et al. (2005) present further evidence on employment generation due to renewable energy production. If income generation from employment in agrofuel production is able to overcompensate rising food expenditures, there is a chance that this new technology can in fact improve food security in developing countries. As the production of agrofuels is a new business, it bears, like all innovations, the risk of creating socio-economic inequalities if the benefits remain only in the hands of a few. When driven by stakeholders seeking only to maximize profit large scale agrofuel production can cause deforestation, loss of biodiversity, land grabbing and land degradation. Von Braun and Pachauri (2006) conclude that policy makers must monitor the development of the agrofuel industry to ensure that agrofuel production is regulated and managed in a way that avoids these pitfalls.

One possible solution might come from a plant called Jatropha *(Jatropha curcas)*, a bush which produces nuts containing a high level of non edible oil suitable for the production of biodiesel. This alone does not make Jatropha special; but it is suggested in the literature as reviewed by Grass et al (2011) that Jatropha could be grown under semi-arid conditions on marginal land not suitable for food production. Hence, some authors argue that Jatropha may not compete directly with food production. However, this assumption is not yet confirmed by empirical evidence, and critical to the success of Jatropha production on marginal lands not fit for food production would be obtaining economically viable Jatropha seed yields under different production costs and crude oil prices as calculated by Grass et al. (2011). At the present low-yielding technology level for Jatropha production, we reckon that conflicts with food production have been underestimated.

Early estimates of possible Jatropha production expansion worldwide are given in a study presented by GEXSI (2008): planted areas could reach 1.8 million ha in Asia, 2 million ha in Africa and 1.6 million ha in Latin America by 2015. One important outcome of this study shows that Jatropha will likely be produced on plantation estates rather than by smallholders or contract farmers. Will this focus on Jatropha plantations offer local income opportunities which enable at least part of rural populations to overcome poverty? This question is highly relevant as most of the Jatropha production will be located in poor, developing countries. Unfortunately, knowledge on the issue is limited as a large scale production of Jatropha just began three or four years ago. An earlier, more in-depth description of the Jatropha sector in Madagascar is presented by Uellenberg (2007; 2008). He shows that within Madagascar five currently active enterprises plan to establish more than 600,000 ha of Jatropha, and the entrance of other firms could further increase these numbers to more than one million ha. As of now, no studies are available in order to shed light on the environmental and social impacts of such projects.

In order to quantify the possible impact on income generation, we focus on a project implemented in the region of Fianarantsoa, Madagascar by a German-Malagasy joint venture in 2007. This Jatropha plantation reached a cultivated area of approximately 500 ha in early 2009 and could be extended to 3,000 ha. The plantation employs rural labourers for enlargement and maintenance. The question of whether this additional income opportunity enables at least part of the rural population to overcome poverty is of special importance for Madagascar, as in rural areas about 71.3% of the population lives below the national poverty line (HDR, 2009). Based on a socio-economic household survey undertaken by the authors in 2009, we analyze 336 randomly selected households from three villages near the Jatropha plantation. The surveyed households represent about 50% of total households in each village. As household members are free to decide whether to work on the Jatropha plantation or not, we have to overcome the problem of selection bias for impact assessment.

2. Conceptual framework

In the analysis of treatment effects for binary outcomes we work with a randomly selected number of units N indexed by $i = 1, \ldots, N$, where each unit is characterized by two realized outcomes Y_{i1} and Y_{i0} where Y_{i1} reflects realized outcome for unit i if treatment was received[2], and Y_{i0} reflects realized outcome for unit i without treatment. Furthermore, each unit i has a vector of characteristics (covariates) denoted by X_i which should not be affected by the treatment status. Finally, each unit possesses a single treatment value; $W_i = 0$ if unit i receives no treatment and $W_i = 1$ when unit i receives treatment. In non-experimental studies we observe for each unit i either the realized outcome Y_{i1} when unit i was exposed to treatment or the realized outcome Y_{i0} when unit i was not exposed to treatment. But we never observe the possible outcome Y_{i0} when unit i was exposed to treatment, nor Y_{i1} when unit i was not exposed to treatment. Therefore estimating the causal effects of treatments is a missing data problem, since either Y_{i1} or Y_{i0} but never the contrary are possible observed outcomes for unit i. The problem of unobserved possible outcome $E(Y_0|W=1)$ for the treatment group can be overcome by using $E(Y_0|W=0)$ as proxy to estimate the counterfactual $E(Y_0|W=1)$. Caliendo and Kopeinig (2008), state that the standards approach "to formalize this problem is the potential outcome approach or Roy-Rubin model". "The widely-used evaluation parameter" (Heckman et al., 1998) is the average treatment effect on the treated (ATT) for persons with characteristics X, given by:

$$ATT = E(Y_1 - Y_0|W=1, X) \quad (1)$$

Since the outcomes of units belonging to either the treated or the control group differ, serious problems of selection bias can arise, especially as $E(Y_0|W=1)$ is approximated by using $E(Y_0|W=0)$. Heckman et al. (1998) calculate the selection bias (B(X)) due to this approximation with the following formula.

$$B(X) = E(Y_0|W=1, X) - E(Y_0|W=0, X). \quad (2)$$

Furthermore Heckman et al. (1998) state that "matching on X, or regression adjustment of Y_0 using X, is based on the assumption that B(X) = 0 so conditioning on X eliminates the bias."
This assumption implies that treatment assignment W (0, 1) and response (Y_1, Y_0) are conditionally independent on a vector of (observable) attributes X. The vector X includes all covariates which are used for treatment assignment W and which are at the same time possibly related to the response (possible outcome Y_1, Y_0). For this assumption different

[2] Two reasons may result in sample selection bias: "First, there may be self selection by the individuals or data units being investigated. Second, sample selection decisions by analysts or data processors operate in much the same fashion as self selection" (Heckman, 1979).

interchangeable terms are used in the literature, "ignorable treatment assignment" (Rosenbaum and Rubin, 1983), "conditional independence" (Lechner, 2002), "exogeneity" (Imbens, 2004), "unconfoundedness" (Imbens and Wooldridge, 2009).

For this ignorable treatment assignment, Rosenbaum and Rubin (1983) conclude that if the assignment of treatment is strongly ignorable for given X, then it is also strongly ignorable for any given balancing score. Assuming complete data, Rosenbaum and Rubin (1983) define the propensity score as possible balancing score for unit i (i=1,…, N) as the "conditional probability of assignment to" particular treatment (W=1) versus nontreatment (W=0), given a vector of observed covariates, X_i. When comparing units via propensity score matching, the multidimensional covariates which are included by the vector X are reduced to a one-dimensional score. In our analysis we apply a binary logit regression model to calculate the propensity score. After the propensity score is calculated we focus on the average treatment effect on treated.

To estimate the treatment effects via propensity score matching, a wide range of matching algorithms can be applied. An in-depth overview of possible choices is presented in Caliendo and Kopeinig (2008). Depending on data diversity and sample size, the choice of a matching algorithm can be important (Heckman et al. 1998), as related to the chosen matching approaches trade-offs[3] between bias reduction and variance have to be considered. In our analysis we compare results derived via Nearest Neighbour matching with and without replacement. Caliendo and Kopeinig (2005) conclude that Nearest Neighbour matching is "the most straightforward matching estimator". Furthermore we apply Epanechnikov Kernel matching and calculate the weighted average of control units to create the counterfactual outcome. In this way more information is used, so lower variance levels can be obtained. Furthermore, we restrict our sample to the common support region and we apply Bandwidth and Caliper restrictions to ensure that only units with equivalent characteristics (propensity scores) are compared (Caliendo and Kopeinig, 2008). Units (in our case households) which participated but were impossible to match within the Caliper or Bandwidth are excluded from the analysis.

To verify if matching on the propensity score was able to balance the distribution of all covariates for the control and treatment group we apply several procedures: standardised differences test, estimation of pseudo-R^2 and likelihood ratio test. The theory behind these tests is to use before and after matching comparisons to discover if "the matching procedure is

[3] Occurring trade-offs between bias and variance depending on matching approach is explained in detail by Caliendo and Kopeinig (2008).

able to balance the distribution of the relevant variables in both the control and treatment group" (Caliendo and Kopeinig, 2008). The standardised bias or standardised differences (SD) test was suggested by Rosenbaum and Rubin (1985) to assess whether or not the reduction in bias relied on the matching based on the propensity score. This approach was used in evaluation studies by Lechner (2000), Sianesi (2004) and Rosenbaum and Rubin (1985). Here the distance in marginal distribution of the X-variables (covariates) can be expressed as standardised differences using the following formula:

$$SD_{before}(X) = 100 \times \frac{\overline{X}_T - \overline{X}_C}{\sqrt{\frac{[V_T(X) + V_C(X)]}{2}}} \quad SD_{after}(X) = 100 \times \frac{\overline{X}_{TM} - \overline{X}_{CM}}{\sqrt{\frac{[V_T(X) + V_C(X)]}{2}}} \ . \tag{3}$$

For each covariate $\overline{X}_T$ and $\overline{X}_{CM}$ are the sample means for the full sample of treatment and comparison groups, $\overline{X}_{TM}$ and $\overline{X}_{CM}$ are the sample means for the matched sample of treatment and comparison groups, $V_T(X)$ and $V_C(X)$ are the mean (variance) of treatment and comparison groups. Rosenbaum and Rubin (1985) suggest that absolute values of standardised difference should be lower than 20% for all covariates.

To further validate the results of SD we re-estimate the pseudo-R^2 after matching on the new sample. Here the pseudo-R^2 before and after matching shows how well the regressors X explain the participation probability. After matching, the pseudo-R^2 should be lower than before, as this would indicate that there are no systematic differences in the distribution of covariates between both groups.

Propensity score estimations are not robust against hidden bias that is rooted in the existence of unobserved variables such as entrepreneurial attitudes or work ethic which simultaneously affect participation and the outcome variable. One solution can be the calculation of Rosenbaum-bounds[4] suggested by Rosenbaum (2002). With this method[5] it can be determined how strongly an unmeasured variable must influence the selection process to change the implications derived by the matching analysis. However, this test is not able to directly prove the unconfoundedness assumption. Therefore no statement exists on "whether the conditional independence assumption does (not) hold for the given setting (including, among others, the

4 For the calculation of Rosenbaum bounds we used the STATA application rbounds from Gangl (2004). Here rbounds calculates Rosenbaum bounds for average treatment effects on the treated in the presence of unobserved heterogeneity (hidden bias) between treatment and control cases. Currently, rbounds implements the sensitivity tests for matched (1x1) pairs only. Therefore it was not possible to calculate Rosenbaum bounds for Nearest Neighbour matching with replacement or Epanechnikov Kernel matching, as here several control households were matched to each JP household.

5 DiPrete and Gangl (2004) stated that Rosenbaum bounds could be used in a worst-case scenario.

used data, the chosen covariates, and the specification of the propensity score)" (Becker and Caliendo, 2007).

3. Data and descriptive statistics

This study is based on data obtained from a survey carried out by the authors from January to March 2009, in the district Ambalavao in the province Fianarantsoa of central Madagascar. According to Minten and Ralison (2005) this province is the poorest within Madagascar. The research area is characterized by grassland used traditionally as pasture for zebu keeping, and to a lesser extent for subsistence rain fed agriculture. Access to the area is limited by secondary road conditions. The nearest paved road is 55 km from Fenoarivo village. Within the region neither piped water nor a permanent electricity supply exists. Three villages were chosen according to their distance from the plantation and local field work restrictions. These villages represent the majority of households offering labour to the plantation and make up the majority of the population which lives within about 10 km of the plantation. Based on a census of all households, we estimate the total population in the three villages at 3,432 persons from 685 households. To assess the impact of the plantation on rural livelihoods we selected 50% of total households in each village randomly. The resulting sample contains 336 households. These households where interviewed using a structured questionnaire with modules covering demographics, household assets owned and purchased, cost and revenue of plant and animal production, as well as off-farm income sources, including rural employment. Furthermore, information on short, medium and long term food security, as well as expenditures was asked for. In our total sample of households (n=336) the mean population age is 20.4 years. Citizens aged 17 and older attended on average 3.18 years in school, 25% reported that they had never attended school, even though compulsory schooling exists.

For the impact assessment, we focus on household income generated in the 12-month time span between February 2008 and January 2009. This recall period for income was chosen so as to account for the seasonality of rural on-farm and off-farm income sources which include net income derived from farming and non-farming activities, as well as net money transfers (i.e. remittances/gifts received and given). For the purpose of this study, participating households are defined as JP households when at least one household member worked a minimum of one day on the Jatropha plantation during the 12-month recall period. Female and male plantation workers earn an average daily salary of 3,000 Ariary. According to our data on wages and rural employment, this salary level is comparable with local salaries for agricultural wage work.

On average, persons working for the Jatropha plantation (n=269) spend 115.95 days working on the plantation (S.D. 81.15 person days, range 2-312 person days). Twenty males and 26 females recorded working on the Jatropha plantation as their primary occupation; they worked on the plantation an average of 132.34 (S.D. 85.17 person days, range 7-288 person days) and 113.75 (S.D. 74.88 person days, range 18-288 person days) person days, respectively. One hundred and fourteen males and 109 females recorded working on the Jatropha plantation as their secondary occupation; they worked on the plantation an average of 116.10 (S.D. 80.80 person days, range 3-308 person days) and 113.31 (S.D. 82.92 person days, range 2-312 person days) person days, respectively. Because of the questionnaire's design, it was not possible for specific persons in each household to record working on the Jatropha plantation as their tertiary occupation. Of the JP households, 8.6% invested less than 20 person days for working at the Jatropha plantation during the recall period. The distribution of labour allocation over one year fluctuates given the seasonal nature of work on the Jatropha plantation. This labour allocation is presented in Figure 1. Here the primary and secondary occupation with one's own agriculture and animal husbandry, as well as wage work for local farmers and the Jatropha plantation labour supply on a monthly basis are shown for persons above the age of ten years. This is an age at which it is quite common to see children make a significant contribution to domestic or agricultural work within the household. Working for the Jatropha plantation seems to be less attractive than working on one's own agricultural and animal husbandry endeavours in general, but it is as lucrative as agricultural salary work for local farmers, especially during the rainy season between December and March. The increasing number of persons working on the Jatropha plantation and the effect of seasonality is evident in the recorded secondary occupation data.

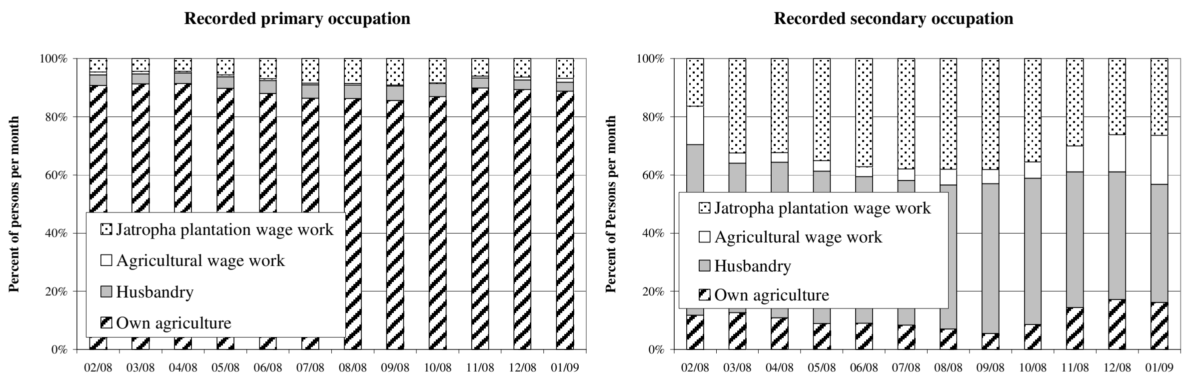


Figure 1. Distribution of primary and secondary occupation during one year

Source: Own calculation

Following the standards[6] of the International Labour Organization, people under 18 years of age are not officially accepted as Jatropha plantation workers. This control mechanism, however, is only weakly enforced as evidenced by the fact that 8.8% of the hired labour force (n=26) was between 14 and 17 years of age and worked an average 84 days (S.D. 68 days). Nearly all persons met the minimum age requirement for hiring (15 years) according to the national regulations of Madagascar[7]. The existence of child labourers could be due to children claiming to be older in order to be hired, or it could be a result of incorrect reporting during interviews. It is common for young people of the area to help their parents with field work, to guard zebus, or even to do agricultural wage work during school holidays. The biggest group of plantation workers, namely 71%, consists of workers between 18 and 40 years of age (n=210) who worked an average of 118 days on the plantation (S.D. 82 days). Only 21% of the plantations workers were 41 years and older (n=61) and worked an average of 135 days during the observed time span (S.D. 97 days).

To compare the findings of the local poverty level with nationwide data we adjusted the national poverty line of 305,300 Ariary per capita for 2005 (INSTAT, 2005) with respect to inflation rates (IMF, 2008) to 407,433 Ariary per capita at the end of 2008. According to INSTAT (2005) the share of rural households living below the national poverty line was 73.5% in 2005. Comparing this official rural poverty level with our findings shows a slight decline in the rural poverty level, to 69.3%, within our research region in 2008.

To present a more detailed picture of the determination of JP households and the related impact on JP households' income, we use a two-step approach. In a first step we analyse all sampled households (n=336) and then focus on a subsample of households (n=233) which represent the households obtaining incomes below the national poverty line. It is important to take a close look at households living below the poverty line because we want to observe which income effects occur in this group. Descriptive statistics including mean differences between control and JP households with respect to full and subsample are presented in Table 1.

From these mean comparisons between JP and control households insight into JP household characteristics can be gained. When comparing JP households with control households within

[6] Following the ILO (1999) convention 182 the term "child" applies to all persons under the age of 18 and therefore persons below this age should not be involved in labour activities. However, ILO (1973) convention 138 may allow employment at 16 years of age under the condition that "the health, safety and morals of the young persons concerned are fully protected" (ILO, 1973). This principle should be applied to work for "plantations and other agricultural undertakings mainly producing for commercial purposes, but excluding family and small-scale holdings producing for local consumption and not regularly employing hired workers" (ILO, 1973).

[7] Madagascar ratified Convention 182 (1999) in 2001 and Convention 138 in 2000 (ITUC, 2008). However in 2004, the Malagasy parliament adopted the "*LOI N° 2003–044*" which states that children have to be at least 15 years old before they can be employed (Section 100).

the full sample, significant mean differences show that JP households are poorer, are relatively new to the region, are bigger in household size, possess smaller amounts of land and zebus, are less involved in agricultural wage work and business activities, and have significantly lower rice yields. These differences suggest that JP households are generally worse off than control households.

The differences between JP households and control households change when one only considers the subsample of households with incomes below the national poverty line. In this case JP households are able to obtain significantly higher incomes per capita than control households. JP households are newer residents and have a significantly larger household size, but possess fewer houses. No significant differences are revealed for land ownership and rice yield. Furthermore, JP households own fewer zebus and work less as agricultural labours. These results suggest that differences between JP and control households are smaller within this subsample. The significantly higher income of JP households suggests that working for the Jatropha plantation might have had a positive effect on JP household incomes.

Table 1: Mean differences between JP and control households' characteristics, differentiated by full sample and subsample

	Full sample (n=336)					Subsample (n=233)				
	Control Group (156)		JP Group (180)			Control Group (104)		JP Group (129)		
	Mean	S. D.	Mean	S. D.	Sign. Levels	Mean	S. D.	Mean	S. D.	Sign. Levels
Outcome variables										
Income per capita (in 1,000 Ariary)	465.68	511.96	383.72	280.85	**	203.91	109.20	246.49	94.05	***
% income at national poverty line	114.30	125.66	94.18	68.93	**	50.05	26.80	60.50	23.08	***
Number of meals with rice (last 7 days)	14.26	6.00	14.17	5.10		13.19	6.23	13.88	5.08	
Days with not enough to eat (last 30 days)	7.92	11.61	6.59	10.98		9.09	11.87	7.25	11.42	*
Months with less than three meals per day (last 12 months)	1.30	2.77	1.05	2.37		1.30	2.78	1.27	2.69	
Independent variables										
Residency (Year)	1990	14.73	1995	12.36	***	1988	15.38	1996	11.18	***
HH Head Age (Years)	41.38	13.91	41.68	13.73		41.69	13.88	41.57	12.75	
HH Head Education (Years)	3.58	3.16	3.64	3.42		3.01	2.55	3.42	3.31	
HH Size (1; 2)	2.52	1.09	2.76	0.94	**	2.69	1.05	2.90	0.90	**
Total Dependency Ratio (2)	0.95	0.85	1.02	0.79		1.15	0.88	1.13	0.74	
% Illiterate Adults (2)	24.32	35.09	24.97	34.01		25.76	34.92	24.38	33.09	
% Secondary Education Adults (2)	3.95	11.83	5.67	15.34		3.23	9.89	6.24	16.10	
No. children attending public school	1.19	1.36	1.32	1.34		1.34	1.39	1.43	1.36	
No. children attending private school	0.06	0.40	0.04	0.32		0.03	0.22	0.05	0.37	
No. children up to one year old	0.35	0.51	0.39	0.51		0.37	0.52	0.44	0.53	
Mean age possible JP worker (4)	33.77	8.77	33.32	8.11		33.86	8.70	33.43	7.97	
% woman on possible JP worker (4)	55.48	27.20	54.06	19.00		58.78	25.08	56.08	18.04	
No. Houses	0.92	0.66	0.80	0.57		0.94	0.65	0.75	0.58	**
Av. house value by HH Size (1,000 Ariary)	201.13	348.27	124.46	216.04		176.49	372.38	101.95	167.49	
Val. HH assets owned in 01/08 by HH size (1,0000 Ariary)	83.56	95.28	68.02	162.78		65.08	78.08	55.17	47.84	
Val. agr. assets by HH Size (1,000 Ariary)	94.03	226.15	70.47	77.98		67.04	144.57	57.66	148.75	

Table 1: continued

	Full sample (N 336)					Subsample (N 233)				
	Control Group (156)		JP Group (180)			Control Group (104)		JP Group (129)		
	Mean	S. D.	Mean	S. D.	Sign. Levels	Mean	S. D.	Mean	S. D.	Sign. Levels
Tot. land ha per workforce (3)	1.29	1.86	0.87	1.39	**	0.82	1.45	0.62	0.92	
% Riceland on total land size	43.53	23.74	43.04	24.86		45.91	24.32	41.62	26.10	
% Riceland cultivated 07/08	83.26	32.54	84.48	30.55		84.56	32.29	82.63	33.87	
% Dry land cultivated 07/08	77.71	35.07	82.06	33.29		76.83	36.25	81.02	35.10	
Yield Rice 07/08 (t)	1.35	1.51	0.97	1.05	**	0.92	0.99	0.76	0.79	
Yield Manioc 07/08 (t)	3.44	15.45	1.84	2.19		1.41	1.77	1.40	1.51	
Yield Peanuts 07/08 (t)	0.10	0.21	0.10	0.18		0.05	0.10	0.06	0.14	
Dummy more than 2 Zebu owned 01/09	0.38	0.49	0.23	0.42	**	0.35	0.48	0.19	0.40	**
No. Zebu lost during last 12 months	0.17	0.60	0.41	2.13		0.23	0.71	0.23	0.97	
No. Chickens 01/09	4.20	7.50	5.93	10.28	*	4.20	7.87	4.75	8.09	
No. Turkeys 01/09	0.39	1.92	0.13	0.82		0.44	2.12	0.09	0.45	
% Workforce with self-employment in own agric. (3)	84.25	27.82	84.47	26.22		84.49	27.92	83.40	27.66	
% Workforce with employment in agric. wage work (3)	17.45	32.67	11.41	25.80	*	21.09	34.67	12.49	26.78	**
Dummy for village commune center being near plantation	0.48	0.50	0.67	0.47	***	0.44	0.50	0.70	0.46	***
Dummy recording own business	0.35	0.48	0.21	0.41	**	0.26	0.44	0.19	0.40	
Dummy recording public and military service employment	0.06	0.23	0.03	0.18		0.04	0.19	0.03	0.17	

* Significant at 10%, ** Significant at 5%, *** Significant at 1%

Note: Test statistics for significance levels for mean differences are Fischer's exact test for Dummy Variables and Mann-Whitney U rank sum test for all other variables.

(1) Based on OECD modified

(2) Adults 13 - 65 years old, Children < 13 year and old > 65 years.

(3) Workforce of HH is defines in this case all persons between 13 and 65 years. This definition follows informal employment practices in the region.

(4) Possible workforce for Jatropha plantation employment took into account persons between 17 to 65 years of age.

Source: Own calculations

4. Empirical results

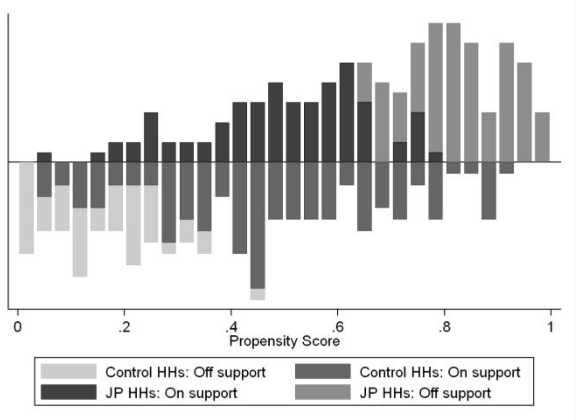
Based on the requirements for propensity score matching analysis, appropriate covariates were chosen from the socio-economic survey data. They take into account the restriction that covariates should influence the participation decision and the outcome variable simultaneously, but are at the same time unaffected by participation (Heckman et al. 1998). The collection of covariates which appear appropriate for determining household participation decision and are at the same time adequate for the propensity score calculation[8] represents household characteristics including demographics, household asset endowment, own farm activities, access to other income possibilities, and location characteristics. That chosen variables influence the households' participation is proven by the results of binary logit regressions shown in table A1. Here, we were able to correctly predict control and JP households in total for the full and subsample at 73.8% and 74.7% level, respectively.

We decided to use Nearest Neighbour matching as this approach was classified by Caliendo and Kopeinig (2008) as "the most straightforward estimator". Furthermore, we use Epanechnikov Kernel matching as one possibility to introduce weights for control households. These weights take into account the propensity score distance of control households to compared JP household propensity scores. The distribution of matched JP and control households with respect to applied matching methods are shown in figure 2.

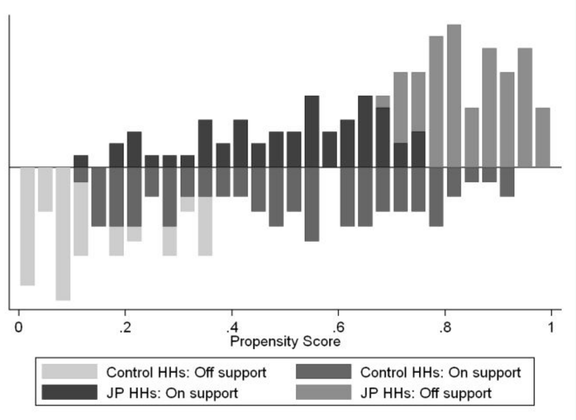
[8] We used STATA and psmatch2 programs for our empirical analysis. The program psmatch2 accounts for the latest version developed by Leuven and Sianesi (2003).

Full sample (n=336) **Subsample (n=226)**

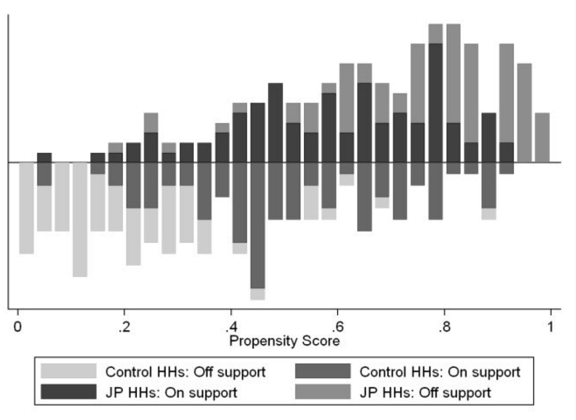
NN matching without replacement (Caliper 0.13)



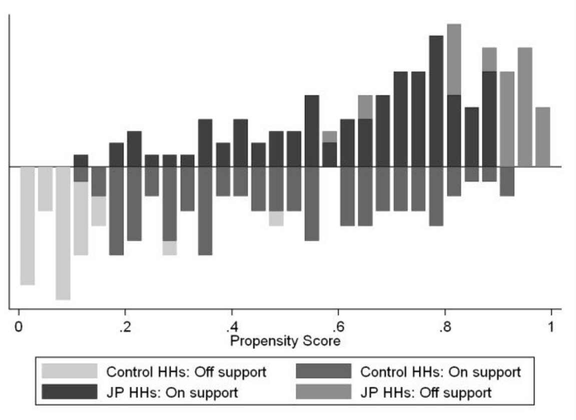
NN matching without replacement (Caliper 0.14)



Matching alternatives (Caliper 0.13)



NN matching with replacement (Caliper 0.013)



Epanechnikow kernel matching (Bandwidth 0.49)

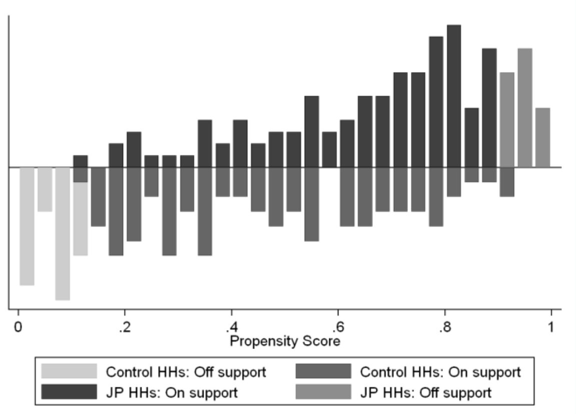


Figure 2. Frequencies of estimated propensity score for JP and control households, full and subsample

Source: Own calculation.

As already presented by the binary logistic regression results our covariates explain participation slightly differently for the full and the subsample. To account for these differences we estimate propensity scores for each sample separately. The results for the

average treatment effect for the treated (ATT), which in our case are JP households, are shown in table 2. In order to confirm that propensity score matching worked out we checked if the covariates are balanced for control and JP households after matching. For this purpose Caliendo and Kopeinig (2008) suggested to test for standardized differences, pseudo-R^2 and to apply the likelihood ratio test. The results presented in table 3 follow this suggestion.
The findings show that working on the Jatropha plantation has a significant positive effect on households' income for JP households compared to control households in both samples. Only the Nearest Neighbour matching without replacement provided significant results for the full sample case. Here the resulting ATT of 93,008 Ariary per capita is significant at the 10% level and was able to decrease mean standardized differences by 72.3%. Sensitivity analysis using rbounds presents critical levels (upper bound, 5% significance level) of gamma 1.25-1.3 for hidden bias. Further propensity matching methods reported lower ATT effects but were all insignificant with respect to full sample data. Within the matched full sample the share of JP households living below the national poverty line still accounts for 67.4%.
For the subsample of households living from incomes below the national poverty line Nearest Neighbour matching revealed an ATT of 69,509 Ariary per capita. This effect is significant at the 1% level and it reduced mean standardized differences by 52.7%. In this case, hidden bias can be assumed to be less likely to influence the result as gamma values between 1.65 and 1.7 are quite high. Alternative matching methods as Nearest Neighbour with replacement and Epanechnikov Kernel matching obtained highly significant results too. Their ATT levels for income per capita are as low as the ones obtained by Nearest Neighbour matching without replacement. To account for the fact that with Nearest Neighbour matching without replacement bad matches can occur, either Nearest Neighbour matching with replacement can be used, or an Epanechnikov Kernel matching which increases matching quality but at the same time decreases the level of possible standardized differences reduction. When comparing these three methods as applied to the subsample, we obtain three different results of ATT with respect to total income per capita and percent income on poverty line. These effects are all significant at the 1% level. Taking this into account, we believe Nearest Neighbour matching with replacement provides the most appropriate results: they are highly significant under severe restrictions. Therefore, we determine that the ATT of households' income per capita is 50,526 Ariary, and that a reduction of mean standardized differences of 42.9% was reached.
One possible distortion of the applied calculations could be that households working for the plantation would have had other income opportunities had the plantation not existed. In our

opinion, the probability that alternative income opportunities, like own agriculture and off farm labour, would lead to a distortion is quite low. The variables of self-employment in one's own agriculture, agricultural wage work and running one's own business show a particularly negative influence on the decision to work on the Jatropha plantation. Therefore, we conclude that it is unlikely that a household offering labour to the plantation would have many other income opportunities if the Jatropha plantation did not exist.

On average, matched JP households spend more than 60% of their salary on food purchases. The results show that there are not any significant differences for matched pairs with respect to several indicators of food security, namely “Number of dishes with rice during the last seven days”, “Number of days with less than three dishes during the last 30 days” and “Months with less than three dishes per day during the last 12 months”. Rice is the major food staple in Madagascar. We used these indicators as they are widely used in the literature among severely undernourished populations. The survey took place at the beginning of the hungry season, from the end of the dry season to the start of the rainy season when most of the households usually suffer from food insecurity and when their own food stocks are depleted.

The lack of a significant effect on food security can be explained as follows. The chosen indicators of food security are frequently used, but they are fairly imprecise and fail to give more exact measurements, such as caloric intake, which can be gathered with food expenditure surveys or 24-hour recalls. Furthermore, it is well known that the income elasticity for total food demand is below one even for poor households. Given that the estimated income effects are quite small as shown above, it is on the other hand also possible that even with more precise indicators no significant effect would be observed.

Table 2: Average treatment effects for JP households

Matching algorithm Restrictions:	Full sample (n=336) NN without replace-ment Caliper 0.13	NN with replace-ment Caliper 0.00343	Epan. Kernel Bandwidth 0.00343	Subsample (n=223) NN without replace-ment Caliper 0.14	NN with replace-ment Caliper 0.013	Epan. Kernel Bandwidth 0.49
Income per capita during 12 months observed time span (1,000 Ariary)						
JP HHs	444,900	406,626	406,626	267,851	257,422	253,668
Control HHs	351,892	336,130	335,022	198,343	206,896	194,042
ATT	93,008 *	70,496	71,604	69,509 ***	50,526 ***	59,626 ***
S.E.	46,279	59,716	54,954	19,093	21,643	16,285
% income on national poverty line						
JP HHs	109.20	99.80	99.80	65.74	63.18	62.26
Control HHs	86.37	82.50	82.23	48.68	50.78	47.63
ATT	22.83 *	17.30	17.57	17.06 ***	12.40 ***	14.63 ***
S.E.	11.36	14.66	13.49	4.69	5.31	4.00
Dishes with rice (last 7 days)						
JP HHs	14.69	13.98	13.98	13.85	14.10	14.02
Control HHs	13.92	12.31	12.38	13.42	13.09	13.15
ATT	0.77	1.67	1.60	0.44	1.01	0.87
S.E.	0.88	1.19	1.14	1.09	1.31	0.93
Days with less than 3 dishes (last 30 days)						
JP HHs	6.37	6.64	6.64	7.38	6.56	6.99
Control HHs	6.67	8.19	7.88	8.76	10.34	8.40
ATT	-0.32	-1.55	-1.25	-1.38	-4.07	-1.41
S.E.	1.65	2.22	2.17	2.23	2.50	1.73
Months with less than 3 dishes per day (last 12 months)						
JP HHs	0.90	1.13	1.13	1.25	1.03	1.24
Control HHs	1.13	1.07	1.14	1.00	0.86	1.03
ATT	-0.23	0.05	-0.02	0.25	0.17	0.21
S.E.	0.37	0.56	0.52	0.50	0.58	0.42
No. treated	85	98	98	56	95	106
No. control	111	88	88	69	67	77

* Significant at 10%, ** Significant at 5%, *** Significant at 1%

Source: Own calculations

Table 3: Results of assessing propensity score matching quality

Matching algorithm	Pseudo R^2 before matching	Pseudo R^2 after matching	$p > \chi^2$ before matching	$p > \chi^2$ after matching	Mean SD before matching	Mean SD after matching	% SD reduction
Full sample							
NN without repl. (Caliper 0.13)	0.235	0.019	0.000	1.000	14.94	4.14	72.3
Alternative matching algorithm (1)	0.235	0.059	0.000	0.995	14.94	5.88	60.6
Subsample							
Matching algorithm	**Pseudo R^2 before matching**	**Pseudo R^2 after matching**	**$p > \chi^2$ before matching**	**$p > \chi^2$ after matching**	**Mean SD before matching**	**Mean SD after matching**	**% SD reduction**
NN without repl. (Caliper 0.14)	0.274	0.057	0.000	1.000	15.34	7.26	52.7
NN with repl. (Caliper 0.013)	0.274	0.088	0.000	0.944	15.34	8.76	42.9
Epan. Kernel (Bandwidth 0.49)	0.274	0.113	0.000	0.648	15.34	9.59	37.5

Note: (1) Nearest Neighbor with repl. Caliper 0.00343, Epannechnikov Kernel Bandwidth 0.00343

Source: Own calculations

5. Conclusions

This study presented the possible impact of employment opportunities generated by a Jatropha plantation on the incomes of nearby households. We applied different propensity score approaches to deal with the potential of selection bias, a common research issue in the analysis of the impact of rural employment. The revealed bias in the distribution of covariates between JP and control households confirmed that it was important to take into account possible selection bias.

The impact assessment was conducted to determine the average treatment effects on households offering labour to a nearby Jatropha plantation with respect to income and food security in central Madagascar. The results point out that labour demand by the Jatropha plantation increased JP households' per capita income with respect to comparable control households.

The findings show that households working for the Jatropha plantation have on average a higher per capita income compared to control group households. While full sample analysis showed a 93,008 Ariary higher mean income per capita for JP households, the analysis of subsample households found that mean income per capita of JP households is 50,526 to 69,509 Ariary higher than that of control households. With respect to short-, mid-, and long-term food security, no significant effects could be detected when applying propensity score matching.

In summary it can be stated, that households working for this Jatropha plantation generated significantly higher incomes during the observed time span than comparable households not working for the plantation, even though there exists a difference in man days worked per household. Even with this additional income source only a few households could overcome poverty with respect to national poverty line figures, but results show that significantly more JP households earn better incomes than control group households within the subsample and therefore are found to be much closer to the national poverty line than control households. Nevertheless the Jatropha plantation can offer a possibility to generate income in a permanent way. Especially in a rural region, where labour demand for unskilled persons is limited to agricultural work during the rainy season, this plantation offers valuable opportunities to households with abundant labour. We further conclude from the analysis that households with higher opportunity costs for labour tend to participate less as wage labourers on the plantation. This is shown in the significant differences between the two groups for households having alternative income possibilities such as running their own business or already having salaried employment in agriculture. Moreover, the income effects calculated must be interpreted as net additional income effects for those households that choose to work on the plantation in comparison with matched control group households.

This study analyses the situation with respect to one Jatropha investor and a young Jatropha plantation where the wages have been pre-financed by the investor only and are not yet recovered through revenues from the plantation. That other investors behave in the same way cannot be concluded. Nevertheless the findings show that if wages are similar to those offered for local agricultural wage work and (seasonal) unemployment exists, positive income effects for rural households can be achieved. A possible major constraint on wage rates at Jatropha plantations is the yield level of Jatropha seeds that can be obtained on marginal land. The paper does not provide any empirical evidence on the economic viability of Jatropha plantations and therefore cannot speculate whether such plantations can sustainably offer additional employment at competitive wage rates. Apart from the yield level of Jatropha, other critical variables here are the opportunity costs of labour and potential costs of food production losses, as well as crude oil prices and production and marketing costs of biodiesel derived from Jatropha seeds.

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Table A 1: Determinants of household decision to work or not to work for Jatropha plantation

	Full sample (n=336)				Subsample (n=233)			
	Coef.	S.E.	Sign. Level	Odds Ratio	Coef.	S.E.	Sign. Level	Odds Ratio
Residency (Year)	0.055	0.013	***	1.057	0.083	0.019	***	1.087
Age of household head (Years)	0.041	0.015	**	1.042	0.039	0.021	*	1.04
Formal education of household head (Years)	0.038	0.056		1.038	0.06	0.076		1.062
Household size (1; 2)	0.772	0.239	***	2.165	0.981	0.33	**	2.667
Total Dependency Ratio (2)	-0.005	0.199		0.995	-0.027	0.262		0.974
% illiterate adults in household (2)	0.004	0.005		1.004	0.002	0.006		1.002
% adults with secondary education (2)	0.001	0.01		1.001	0.006	0.013		1.006
No. of children in public school	-0.035	0.153		0.966	0.04	0.187		1.041
No. of children in private School	-0.67	0.475		0.511	-0.623	0.896		0.536
No. of children younger than one year	-0.08	0.287		0.923	0.049	0.34		1.05
Mean age of possible JP workers (4)	-0.023	0.021		0.978	-0.022	0.027		0.978
% female among possible JP worker (4)	-0.008	0.006		0.992	-0.006	0.009		0.994
No. of houses possessed	-0.383	0.279		0.682	-0.347	0.333		0.707
Per-capita value of house (in 1,000 Ariary)	0	0		0.999	0	0		0.999
Per-capita value of household assets owned in 01/08 (in 1,000 Ariary)	0	0		1	0	0		1
Per-capital value of Agricultural assets (in 1,000 Ariary)	0	0		1	0	0		1
Per-capita cultivated land (in hectare) (3)	0.096	0.109		1.101	0.097	0.217		1.102
% of riceland of total cultivated land	0.003	0.007		1.003	0.002	0.008		1.002
% of riceland cultivated in July 2008 (07/08)	0.003	0.006		1.003	-0.002	0.007		0.998
% of dry land cultivated in 07/08	0.001	0.005		1.001	0.006	0.006		1.006
Yield of rice in 07/08 (in kg/ha)	0	0	**	0.999	0	0		0.999
Yield of manioc in 07/08 (in kg/ha)	0	0		0.999	0	0		0.999
Yield of peanuts in 07/08 (in kg/ha)	0.001	0.001		1.001	0	0.001		1
Dummy =1 if more than 2 zebu owned in 01/09	-1.063	0.373	**	0.345	-0.977	0.451	**	0.377
Number of zebu lost during last 12 months	0.272	0.208		1.312	-0.006	0.214		0.994

Table A 1: continued

	Full sample (n=336)				Subsample (n=233)			
	Coef.	S.E.	Sign. Level	Odds Ratio.	Coef.	S.E.	Sign. Level	Odds Ratio
No. of chickens in 01/09	0.041	0.021	**	1.042	0.028	0.028		1.029
No. of turkeys in 01/09	-0.149	0.111		0.861	-0.237	0.161		0.789
% workforce with self-employment in own agric. (3)	-0.003	0.006		0.997	-0.002	0.008		0.998
% workforce with employment in agric. wage work (3)	-0.015	0.005	**	0.986	-0.013	0.006	**	0.987
Dummy for village commune center being near plantation	1.126	0.302	***	3.085	1.451	0.386	***	4.267
Dummy recording own business	-1.206	0.337	***	0.299	-1.065	0.438	**	0.345
Dummy recording employment with public and military service	-1.636	0.774	**	0.195	-0.993	1.063		0.371
Constant	-111.692	26.332	***		-169.148	37.734	***	
Log likelihood	-177.555				-116.214			
Pseudo-R^2	0.235				0.274			
% of JP households correctly predicted	77.2				81.4			
% of control households correctly predicted	69.9				66.3			
% correctly predicted	73.8				74.7			

* Significant at 10%, ** Significant at 5%, *** Significant at 1%
Note:
(1) Based on OECD modified
(2) Adults 13 - 65 years old, Children < 13 year and old > 65 years.
(3) Workforce of HH is defines in this case all persons between 13 and 65 years. This definition follows informal employment practices in the region.
(4) Possible workforce for Jatropha plantation employment took into account persons between 17 to 65 years of age.

Source: Own calculations

SUMMARY and CONCLUSIONS

This dissertation identifies and discusses opportunities and constraints for first-generation agrofuel production in developing countries with respect to political arguments and agrofuel production trends. Furthermore evidence on Jatropha as possible agrofuel feedstock is examined in the form of case studies undertaken within India and Madagascar. Hereby special focus is laid on how different crude oil price levels influence the economic viability of Jatropha seed production on marginal areas not fit for food crop production in India. In addition, possible effects on household income due to employment at a Jatropha plantation in Madagascar are determined. The results are presented in three research papers which will be summarized below.

The first paper (Chapter 3) discusses different political arguments like energy security, economic growth, equity and poverty reduction and climate change mitigation motivating the promotion of first-generation agrofuels. Current trends in worldwide ethanol and agrodiesel production as well as possible trends of agrofuel feedstocks are shown.

According to the argument of climate change mitigation potential Brazilian ethanol production based on sugar cane provides the cheapest source for agrofuel production combined with the highest GHG reduction. In contrast ethanol production based on cereals and corn is more expensive and reaches only 40% of possible GHG reduction when comparing it with ethanol produced on a sugar cane basis. However production data show that the U.S. and E.U. focus on cereals and corn for ethanol production. They even bypassed the former leading ethanol producer Brazil in 2004. When regarding worldwide agrodiesel production leading production takes place in Europe focusing on oilseeds as feedstocks. Here the possible GHG reduction potential of rapeseed based agrodiesel is 50%. This is higher as for ethanol based on the use of grain but lacks around 35% behind estimates for ethanol on sugar cane basis. When comparing achievable GHG reduction and related costs of agrofuel production with other possible measures for climate change mitigation, agrofuel production was revealed to be very costly especially for current actions in the U.S. and E.U.

Studies by Searchinger et al. (2008) and Fargione et al. (2008) point out those first calculations of possible GHG reduction, used to justify first-generation agrofuel support, were misleading. They conclude that possible land use changes due to agrofuel production can cause higher GHG emissions as compared to fossil fuel use. Furthermore Ugarte (2008) points out that with current first-generation technologies total substitution of fossil fuel would need an incredible expansion on world sugar cane, corn and even palm oil hectarage. As this would not be feasible, not least because of effects on food availability and biodiversity, he concludes that the possible contribution to fossil fuel substitution via exploring the technical potential of first-generation agrofuels would only be modest in the face of worldwide demand for transport fuels.

Nevertheless production figures of ethanol and agrodiesel show that policy-introduced first-generation agrofuel industries and markets especially in the E.U. and the U.S. developed and therefore demand ethanol and agrodiesel to fulfil their mandatory blending quota. As original tax exceptions for agrofuels are cut back and fossil fuel companies are free to purchase agrofuels worldwide, new chances of gaining access into those markets rose for competitive developing countries with low production costs. This is especially the case of Brazil which shows that international investors seek to foster agrofuel production in developing countries with the will of exploring those chances. Therefore agrofuel production offers some economic prospective for aggregated gross domestic product especially for land-rich developing countries in the tropics.

Depending on feedstock produced, applied production system and institutional framework conditions, smallholders or rural labourers can find beneficial income or employment in the agrofuel sector. Agrofuel feedstocks like cash crops (e.g. cereals and oilseeds) produced in developed countries offer a politically attractive measure of income support for domestic farmers and rural development and therefore considerable growth potential for domestic agriculture. However they do not represent the only strategy for rural income transfer in the frame of the European Common Agricultural Policy. Even as the renewable energy sector is highly subsidized the total energy market is huge and can absorb any amount of agrofuels produced. Therefore, if the agrofuel option would be chosen no further need seems to exist for subsidizing large parts of the agricultural sector. However the focus on transferring cereals, oilseeds and sugar to first-generation agrofuel production together with competition on food production for land is revealed as a cause for higher price variability in the food market (OECD-FAO, 2007; Rosegrant et al., 2006, Mitchell, 2008). Thus Elobeid and Hart (2007:2-3), state that the highest effects on food prices will occur in Sub-Saharan Africa and Latin America.

With respect to those findings several challenges for politics and research with respect to first-generation agrofuel production have to be addressed. First, if these agrofuel strategies are retained, the disastrous effects this will have on food security of poor net consumers of food in developing countries will only be a question of time. Second, there is the risk that the agrofuel sector will be dominated by large scale agribusiness which provides only small effects on income and employment generation in rural areas. Therefore to which extent the rural poor can gain by participating in this agrofuel sector remains to be seen. Third, besides the social costs, agrofuel production can have negative effects on the environment as this activity increases the pressure on scarce resources like water, biodiversity and rainforests. Fourth, their production is a costly strategy for climate change mitigation.

Even as strong political support for a first-generation agrofuel sector establishment might be justified in the short term, this situation can lead to a sector depending on subsidies in the long term. This could therefore boost mainly first-generation agrofuels. This situation is regrettable as the provided financial resources would have been better invested in technological progress like second-generation agrofuel development, introduction of alternative feedstocks suitable to grow on marginal lands, the use of agricultural by-product and residues, energy efficiency improvements, development of multiple sources of renewable energy (biomass, wind, solar, water) and socio-economic research.

Possible countermeasures of favouring first-generation agrofuels could be the increase of energy costs in long term. These needs to be done before increasing exploration costs and demand for fossil energy would lead to such a development. A further argument for increasing energy prices is that energy is mainly consumed by wealthy consumers.

Furthermore possible social and environmental costs related with first-generation agrofuel production could thereby be internalized. This can yield desired improvements of more efficient energy use, can lower total energy demand and therefore can be a vivid part of a climate change mitigation strategy. Furthermore certification of agrofuel production cannot solve their environmental and social problems as long as worldwide agriculture is certified in total and control mechanism are enforced widely.

However biomass based renewable energy supplies seem to maintain an option for fossil energy substitution for developed and developing countries at least in midterm. Therefore interdisciplinary research on interdependencies between biomass based renewable energy, food security and rural development must be done. Only with this information politicians and institutions will be able to choose appropriate actions for long-run sustainable food, agricultural and energy sector development.

Until such information is made available they have to monitor current agrofuel sector developments and occurring positive and negative effects via legislation and regulative frameworks. Furthermore active research is needed to extend agrofuel feedstock production on marginal land not suitable for food production. Here cultures with modest requirements for soil quality and water use like Jatropha and Sweet sorghum could be a point of departure.

Furthermore biomass based renewable energy activities have to keep sight of rural development perspectives like the possible inclusion of small scale energy and feedstock production for rural markets (local and regional markets might favour smallholders) as well as the possible implementation of decentralised energy systems. Remote areas especially could gain from those systems as they either face energy shortages or even do not have access to public grids. Therefore pilot experiments have to reveal the most appropriate approaches to fulfil those targets.

Despite the fact that setting up large scale agrofuel feedstock plantations might have limited employment effects, their installation can serve as nucleus for regional renewable energy development, including the creation of local agrofuel feedstock markets, and furthermore provides a possible link for gaining international market access. To make positive effects on local employment, investment and income in rural areas, more appropriate policy and institutional frameworks are needed.

However, all actions of biomass based renewable energy production systems have to be controlled for their CO_2 and energy balances depending on feedstock and final use. Furthermore, their impacts on environment like land use change and social aspects like competition with food production, as well as land grabbing via international investors, have to be Argus-eyed.

The main outcome of chapter 3 is that general conclusions on opportunities and constraints of first-generation agrofuel production and use are difficult to make. Opportunities and constraints of agrofuels strongly depend on feedstock used, applied production system, institutional and legislative framework conditions and their final use.

Whereas the first paper discusses agrofuel opportunities and constraints, the second paper presented in chapter 4 starts to partially answer the addressed question of renewable energy production via processing a feedstock which is suitable to grow under marginal land conditions. Apart from developing second generation agrofuel technologies, this represents a way to circumvent the competition between agrofuel and food production, and is advocated by many in the use of marginal lands which are not suitable for food production.

Here especially Jatropha curcas L. reached the attention of national governments and investors worldwide. The country with the most ambitious targets for agrofuel production on areas classified as marginal is India. However, little experience and appropriate agronomic data on Jatropha production under such conditions exist, and therefore possible competition of agrofuels based on Jatropha as feedstock to fossil diesel remains unclear. To propose guidance to those projects chapter 4 presented new evidence on Jatropha production derived from ICRISAT. Here the value chain approach and different production cost scenarios were applied to determine at which crude oil price level Jatropha production under marginal land conditions could reach economic viability due to the generation of positive net present values.

The findings show that direct use of Jatropha oil becomes economically competitive with fossil diesel at crude oil prices between US$ 75-110 per barrel assuming low production costs for Jatropha seeds and interest rates between 6-16 percent. Baseline production costs and same range of interest rates shift the results towards US$ 105-140 per barrel. High production cost assumptions did not obtain positive net present values for Jatropha seed production even at a crude oil price of US$ 150 per barrel.

Further processing of Jatropha oil into agrodiesel bears additional costs and therefore lowers the competitive strength of this chain. Here, first positive net present values for Jatropha seed production were obtained at crude oil prices of about US$ 95 per barrel with respect to the low production cost scenario and an interest rate of 6%. Hence the results show that agrofuel based on Jatropha can compete with fossil diesel especially at the crude oil price level of US$ 130 per barrel, already observed in 2008. However, uncertainties regarding agricultural practices and related costs as well as possible overestimations of yield levels under marginal land conditions can have strong effects on the economic viability of such Jatropha projects. Future research may aim to intensify agronomic research on Jatropha under different soil and climatic conditions as well as on-farm experimentation. This could fill the existing data gaps so that the uncertainties presented in this dissertation regarding yield level and agronomic practices are being resolved.

To enhance the competitive strength of Jatropha seed production more research in plant breeding targeting the creation of robust uniform plant material with high seed oil content under marginal conditions has to be undertaken. Further research is needed to develop appropriate management practices to ensure successful Jatropha production schemes under marginal land conditions. This should be done even before starting investments in large scale Jatropha production. But political action within India should focus primary on research. Until there are no clear data on Jatropha production only venture capital should be attracted for investments in Jatropha cultivation. Especially the presented data in this thesis on Jatropha seed production scenarios and the value chain analysis can be used by investors. Based on the findings investors can compare their production system and related costs and are therefore able to estimate their strengths to compete with fossil diesel at the national market of India.

In addition the Indian agrofuel sector development has to be embedded in overall energy and development policies at the same time. Furthermore the established fix price level for agrofuel has to be revised or even abolished.

While chapter 4 dealt with economic viability of smallholder Jatropha seed production chapter 5 focused on large scale Jatropha plantation estates and possible income effects for rural households working at such a plantation. International investors prefer especially setting up large scale Jatropha plantation estates over contract farming and smallholder production systems to gain economies of scale, the question to what extent households living in the vicinity of such a plantation could benefit from offering their labour force and therefore generate additional household income was of special interest. The findings are based on a socio-economic household survey in the vicinity of a Jatropha plantation under construction in central Madagascar. It was shown that especially during the dry-season abundant labour force was offered by a large share of households living in three villages with varying distance to the plantation. This plantation was providing salary levels equal to local salaries for agricultural wage work for hired labour.

To estimate the effect of income generation for households working for the Jatropha plantation, propensity score matching was applied. This approach takes into account the problem of selection bias. By testing different algorithm applicable for propensity score matching, the following robust results were obtained:

For the full-sample of 336 households covering 50% of the total population within three villages, the mean income for households working at the plantation was 93,008 Ariary (31 €) per capita and therefore 26.4 percent higher as it was within control group households. However the used approach of nearest neighbour matching without replacement obtained this result at 10% significance level only. Furthermore none of the additional applied matching algorithm could reveal significant results for the full-sample.

Stronger evidence about the effect on households' income for households working for the plantation was obtained in the sub-sample case. Here the sub-sample includes households with an income per capita level equal or below the national poverty line only. For this case all three applied propensity score matching algorithm revealed positive effects on mean household income at a 1% significance level. However, results vary between 50,526-69,509 Ariary (16.8-23.2 €) per capita of additional mean income for plantation households. Nevertheless Jatropha plantation households did obtain in average 24.4 to 35.0 percent higher per capita incomes as control group households. The most appropriate result was seen in 50,526 (16.8 €) Ariary per capita as only here plantation and control group households were compared using smallest propensity score restrictions which ensured that only households with similar characteristics are compared with each other. In this case the average annual per capita income for Jatropha households was 24.4 percent higher as the average annual per capita income of control households. With respect to food security no significant differences for full and sub-sample were seen.

Additional second round effects which are positive were not assessed in the impact assessment. However several effects are important to be mentioned here. First, before the plantation was set up regional households in total suffered from high levels of thievery for zebu and agricultural production. Since the plantation is in place discussion with local authorities revealed that this problem was strongly reduced. Second, local traders reported increasing amounts of own business turnover. Especially when household members reported working for the plantation this seemed to increase the trust of traders. Therefore there is some chance for persons working for the Jatropha plantation to purchase goods on credit basis. Third, most households appreciated to find wage work with the Jatropha plantation all year long and to be paid weekly. Such a possibility was unknown before.

However this study observes a situation with respect to one company only. Whether other investors will behave similar is questionable. Furthermore obtaining accurate data for analysis was very difficult due to existing low educational levels and because of time intensive interviews. Another constraint was to create trust between the interviewer team and the households. Especially within several observed households concerns exist that the information given would not be treated confidential. However those concerns could be overcome.

In order to gain a potential win-win-win situation for rural households, investors and the environment especially for developing countries investments in research areas where knowledge gaps hamper such a development are needed. Such a win-win-win situation can be generated if knowledge increases and appropriate policies focusing on pro poor institutional setting are developed. Again it has to be stated that appropriate data on whether Jatropha is commercial viable is still lacking. Therefore smallholder Jatropha production should not be enforced in developing countries as long as production methods and market chains are in place to reduce the investment risks for smallholder production. It would be more advantageous for developing countries to let investors set up Jatropha plantations. Furthermore they should provide political regulations to accompany the implementation of those projects together with the rural community to be able to account for their needs and to diminish possible constraints. Especially foreign investors are more likely able to bear the current economic risks of Jatropha production and are more powerful to establish a functioning market and processing channels. Only when Jatropha production proved to be economically beneficial smallholder production should be promoted.

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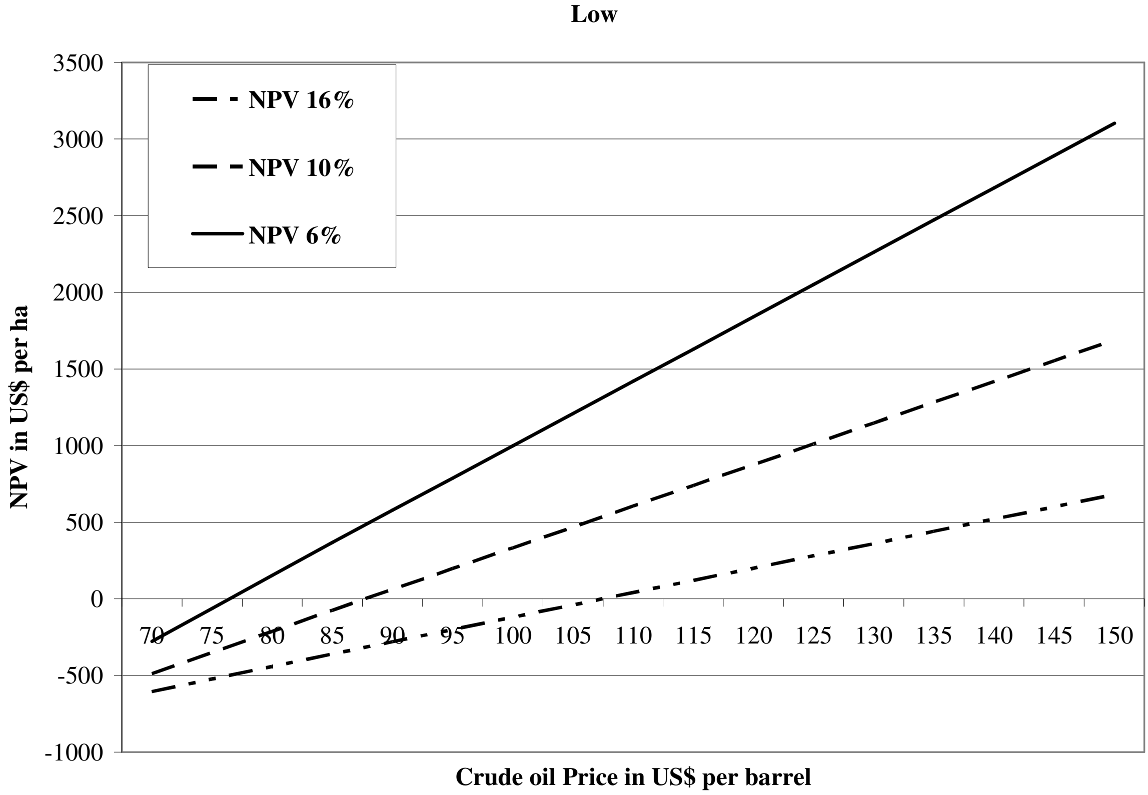
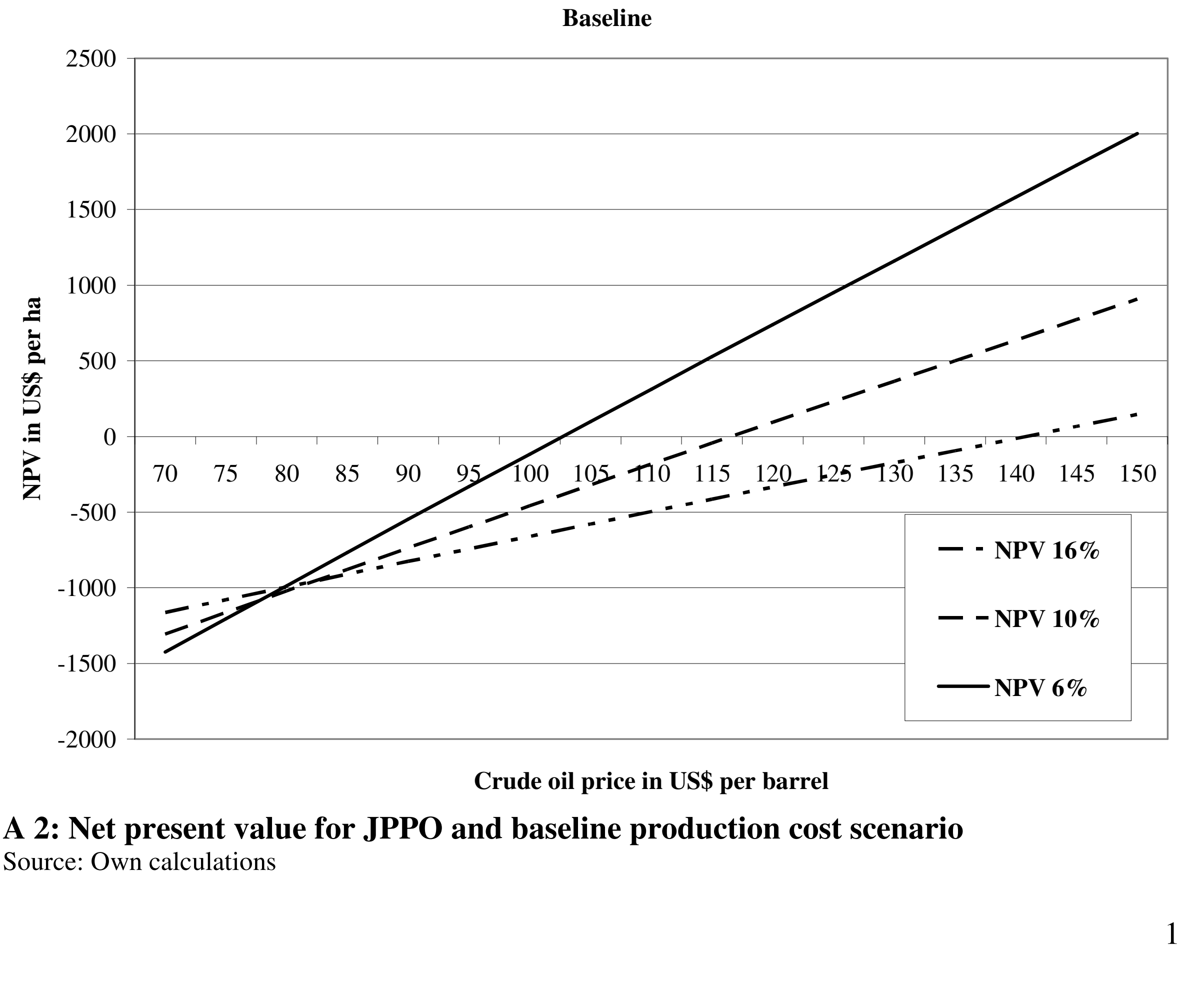
APPENDICES



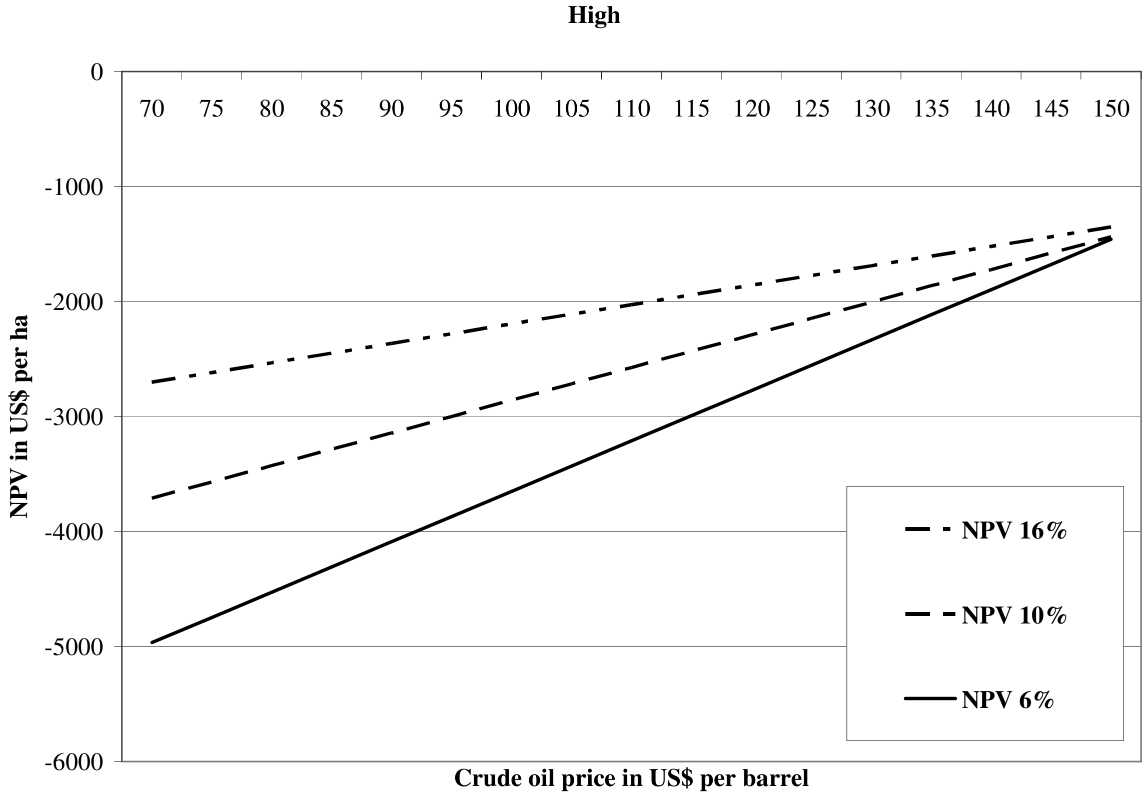
Source: Own calculations

A 1: Net present value for JPPO and low production cost scenario

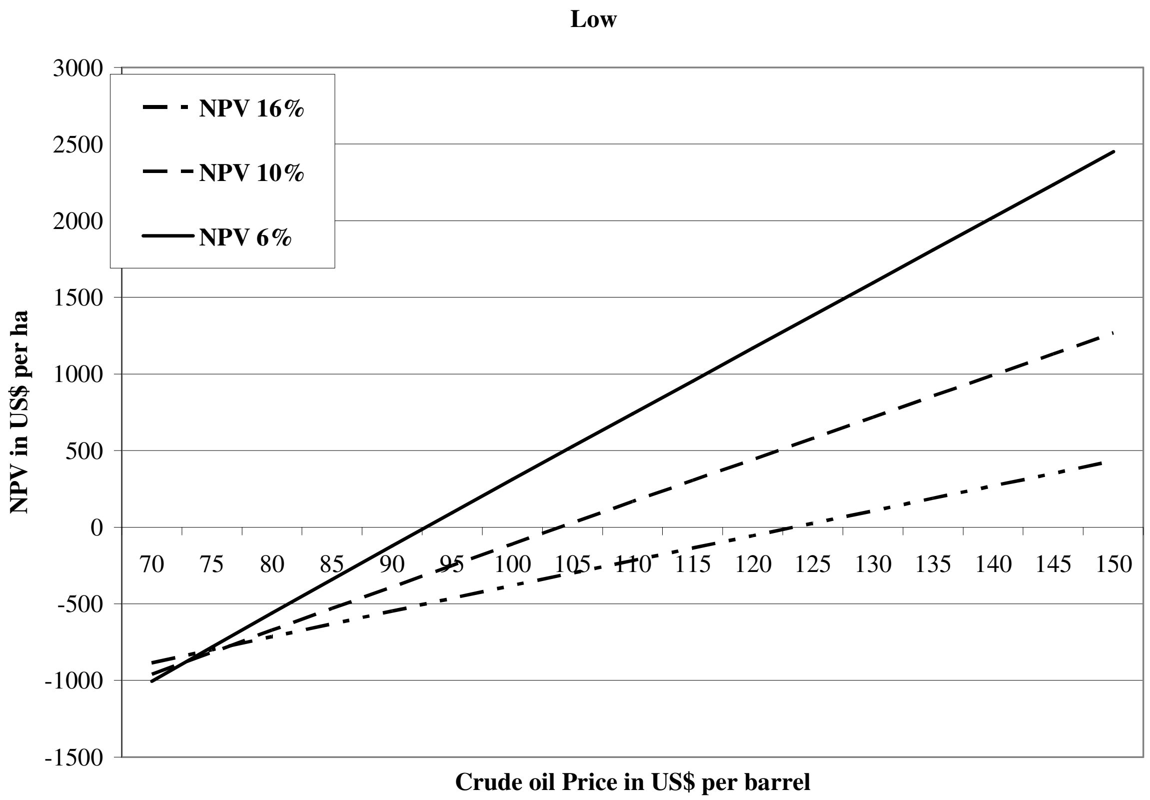


A 2: Net present value for JPPO and baseline production cost scenario

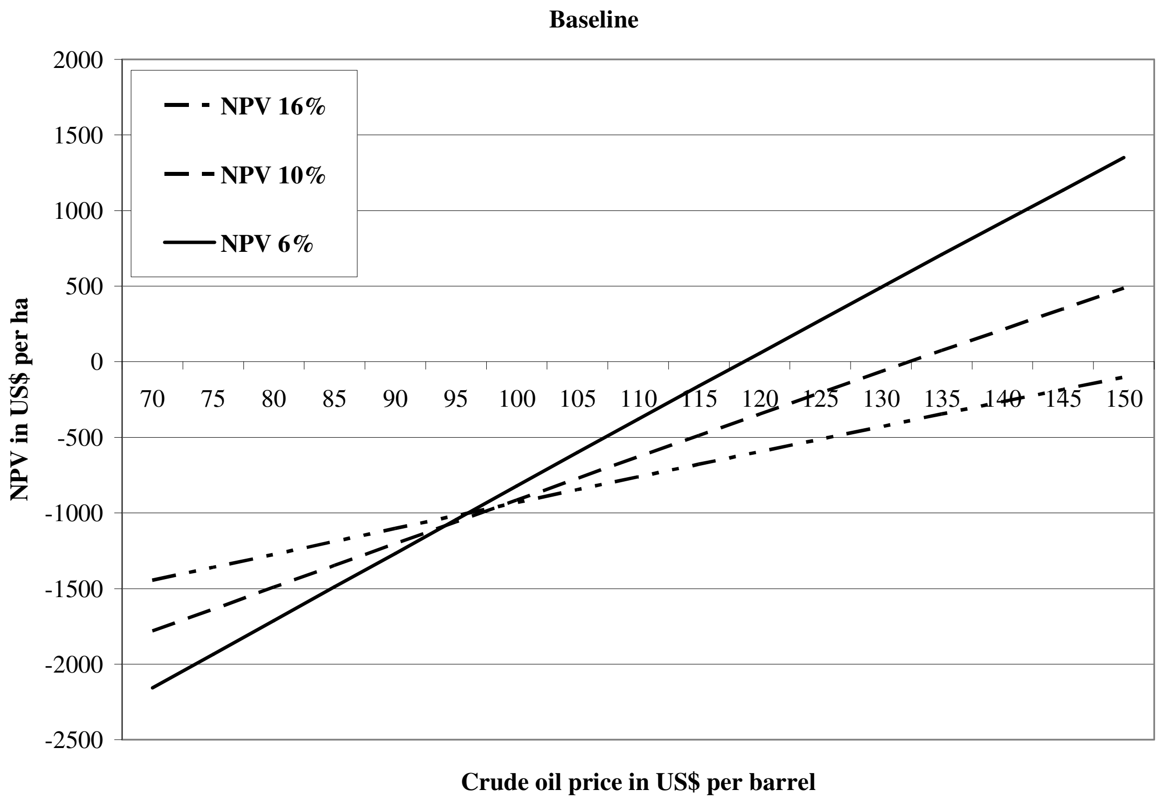
Source: Own calculations



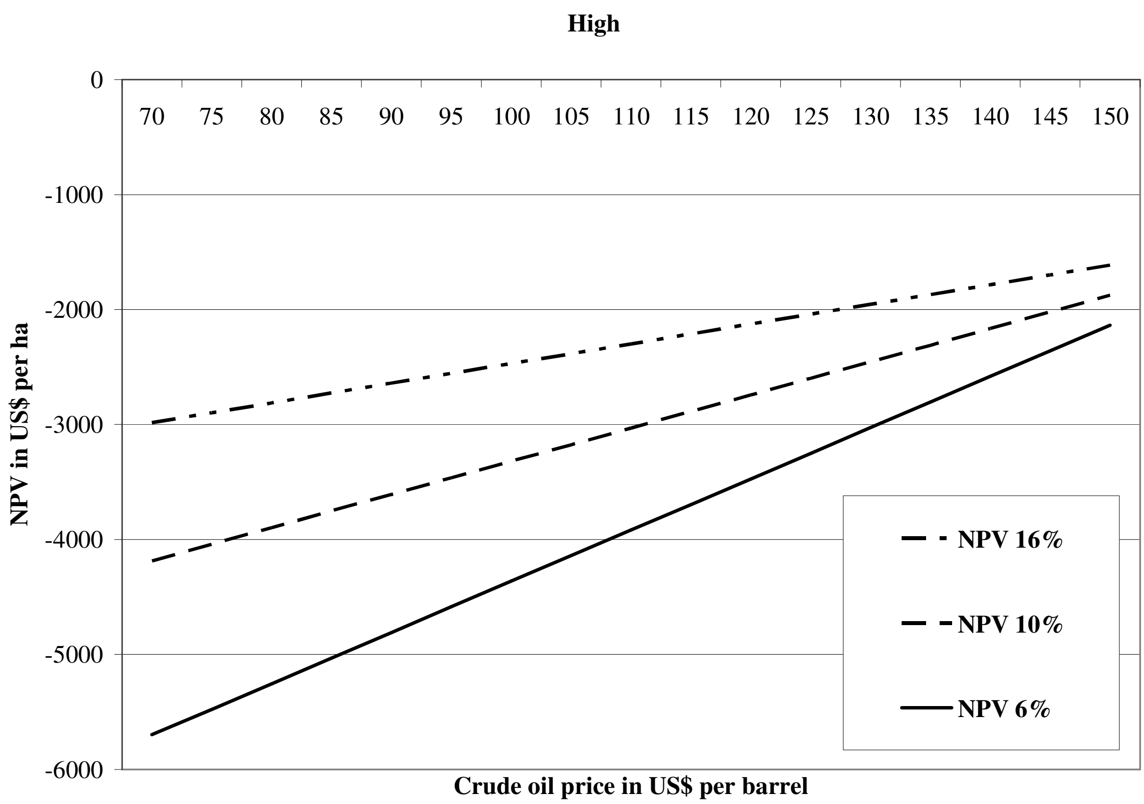
A 3: Net present value for JPPO and high production cost scenario
Source: Own calculations



A 4: Net present value for JME and low production cost scenario
Source: Own calculations



A 5: Net present value for JME and baseline production cost scenario
Source: Own calculations



A 6: Net present value for JME and high production cost scenario
Source: Own calculations

A 7: Background for the derivation of 'Wald estimator'

The following section draws from the example of European Commission 2010b and adjusts their format to the formatting used in chapter 2.3.

Definition of signs used:

δ	effect of the policy programme on R&D
Y	outcome variable, e.g. R&D expenditures
W	binary indicator for participation, W=1 company is participating, W=0 otherwise
U	unobservable variable determining the outcome variable Y, e.g. R&D expenditures
Z	instrument which does influence the participation (W) but which is uncorrelated with U, e.g. Z=1 if company is located in an area of low population density and therefore is allowed to participate in the programme, Z=0 otherwise
P	probability that the variable is equal to 1
E[]	represents "mean of"
E[l]	represents "conditional mean"

Point of departure is to describe how the chosen instrument does influence the companies' participation in the programme.

(1) $$P(W=1|Z=1) \succ P(W=1|Z=0)$$

The outcome of R&D expenditures for companies can be written as function of participation in the programme and of an unobservable variable U.

(2) $$Y = T * \delta + U$$

If companies are able to self-select into participation the difference in the outcome variable ($E(Y|W=1)-E(Y|W=0)$) of participating and non-participating companies can be calculated adding up the true effect (δ) and the selection bias ($E(U|W=1)-E(U|W=0)$):

(3) $$E(Y|W=1)-E(Y|W=0)=\delta+[E(U|W=1)-E(U|W=0)]$$

In the case the instrument Z in uncorrelated with the unobservable variable U and under the assumption that the instrument does not directly influence the outcome Y one can state:

(4) $$E(U|Z=1)-E(U|Z=0)=0$$

The expression (4) is the "identifying assumption", and can not be tested as the variable U is unobservable.

Furthermore when combining the computation of means for Z=1 and Z=0 (formula 5 and 6) one results with formula 7 calculating the mean differences:

(5) $$E(Y|Z=1) = \delta * E(W|Z=1) + E(U|Z=1)$$

(6) $$E(Y|Z=0) = \delta * E(W|Z=0) + E(U|Z=0)$$

(7) $$E(Y|Z=1) - E(Y|Z=0) = \delta * [E(W|Z=1) - E(W|Z=0)] + [E(U|Z=1) - E(U|Z=0)]$$

Following the assumption under point 4 $E(U|Z=1) - E(U|Z=0) = 0$ from formula 7 remains:

(8) $$E(Y|Z=1) - E(Y|Z=0) = \delta * [E(W|Z=1) - E(W|Z=0)]$$

According the fact, "that the expected value of a binary variable is the same as the probability that the variable is equal to 1" (European Commision, 2010b) on can exchange:

(9) $E(W|Z=1) = P(W=1|Z=1)$ and $E(W|Z=0) = P(W=1|Z=0)$

Therefore one can generate from formula 7 the 'Wald estimator' shown under 10.

(10) $$\delta = \frac{E[Y|Z=1] - E[Y|Z=0]}{P(W=1|Z=1) - P(W=1|Z=0)}$$

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Erklärung: gemäß Promotionsordnung vom April 2010; § 8 Abs. 2 Ziff. 2

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