Thesis for the degree of Licentiate of Engineering

On Food Price Implications from Expanded Bioenergy Production

David K. Bryngelsson

Department of Energy and Environment
Division of Physical Resource Theory
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2012

On Food Price Implications from Expanded Bioenergy Production
David K. Bryngelsson

Thesis for the degree of Licentiate of Engineering

Department of Energy and Environment
Division of Physical Resource Theory
CHALMERS UNIVERSITY OF TECHNOLOGY
SE-412 96 Göteborg
Sweden
www.chalmers.se
Tel. +46-(0)31 772 1000

Author email: `david.bryngelsson@chalmers.se`

Printed by Reproservice
Göteborg, Sweden 2012

On Food Price Implications from Expanded Bioenergy Production

David K. Bryngelsson
Department of Energy and Environment, Chalmers University of Technology

Abstract

Bioenergy has been put forward as a solution to energy security and at the same time to climate change. It is, however, dependent on productive agricultural land, which is a limited resource. Introduction of bioenergy on a large scale will thus compete with food production and natural forests for productive land, a competition expected to affect food prices.

In this thesis I focus on poverty nourishment issues related to changing food prices and on the mechanisms of land-use competition and how they affect food prices.

In the first paper we use two established indicators for poverty and sensitivity to food-price changes, to capture peoples' vulnerability to rising food-prices, in four Sub-Sahara African countries/regions. In contrast to previous studies, we include all food products instead of just one or a few main staples. We found that the vast majority of people are net consumers of food and that the inclusion of more than main staples increases their net position as consumers and thus vulnerability to high food prices.

In paper two and three a conceptual and transparent partial equilibrium model of global land-use competition is developed, analyzed and applied. The model is to a large degree analytically explored and price differentials between crops are derived. The model is subjected to a detailed characterization of its mechanisms and parameters in which parameters that are critical to results and conclusions from the model are detected and their impacts depicted. We conclude that the total amount of productive agricultural area is of crucial importance to the price impacts from large-scale introduction of bioenergy. Yields of bioenergy crops are also important since they determine the amount of land required to produce the bioenergy.

Keywords: partial equilibrium model, land use competition, bioenergy, food price effects, Sub-Saharan Africa, household survey, staple crops

List of publications

I. David K. Bryngelsson, Andres Åhlén, Christian Azar and U. Martin Persson, "The effect of food-price movements on African households", *International Journal of Agricultural Resources, Governance and Ecology* **Submitted**.

II. David K. Bryngelsson and Kristian Lindgren, "A conceptual agricultural land-use model with illustrations on price effects from competition between bioenergy and food crops", *Resource and Energy Economics* **Submitted**.

III. David K. Bryngelsson and Kristian Lindgren, "Application of a conceptual land-use economics model for analysis of land-use change and price effects of bioenergy policies", *Energy Policy* **Submitted**.

Acknowledgements

First I would like to thank my supervisor Kristian Lindgren for great support and great collaboration. You have been invaluable for this work through your dedicated supervision and long and detailed discussions regarding every aspect of the work.

I also wish to thank my assistant supervisor Stefan Wirsenius for always being available to answer any question, whether it is about teaching, research, travels, or anything else.

I want to thank Martin Persson and Daniel Johansson for valuable comments on my work.

I wish to thank the Swedish Energy Agency and Chalmers Energy Initiative for financial support.

Thank you Christian Azar and Göran Berndes for talking me into becoming a PhD student! Christian, thank you also for informal guidance on both my work, and for generously sharing your insights on how to convey science to the public.

I finally want to thank all PhD students, project assistants, and senior staff at the division of Physical Resource Theory for creating a great workplace. Every lunch or coffee break is a treat because of all the interesting topics that are discussed and the warm atmosphere. You all make going to work a pleasure and I cannot imagine a better place to work!

Göteborg, January 2012
David K. Bryngelsson

Contents

Chapter 1

Introduction

Bioenergy has been promoted as a silver bullet for mitigating climate change by providing cheap carbon free energy and at the same time provide work opportunities for the Global South, and/or revitalize the agricultural sector in the Global North (Dufey et al., 2007; FAO, 2008b).

However, the rapid increase in food prices in 2007–2008 (see Fig. 1.1) brought attention to possible negative effects from a large-scale introduction of bioenergy into an agricultural system already stressed from rapid increases in demand for food products. This rapid food price hike started a discussion of to what extent food prices were affected by increasing demands of bioenergy and what type of damages rising food prices could do. The USDA claimed that the food price hike only to 3% was due to increased bioenergy demand, but the World Bank estimated the price rise to be to 75% due to bioenergy (Ciaian and d'Artis Kancs, 2011). Increased food prices have also been blamed for so called indirect land use change (ILUC), where conversion of cropland into another use—e.g. bioenergy production—leads to a reduced supply of the crop in question and thus conversion of land with native vegetation into cropland elsewhere. Deforestation—regardless of its location—leads to large emissions of CO_2 that significantly reduce the climatic benefits from using bioenergy. These effects received a lot of attention after a widely cited publication by Searchinger et al. (2008) who tried to quantify them. Several subsequent studies have been conducted that aim to quantify ILUC, but there is little agreement between them. Prins et al. (2010) summarizes a number of such studies and presents their dissimilar results.

The initial response from EU was to quickly include an ILUC-factor to

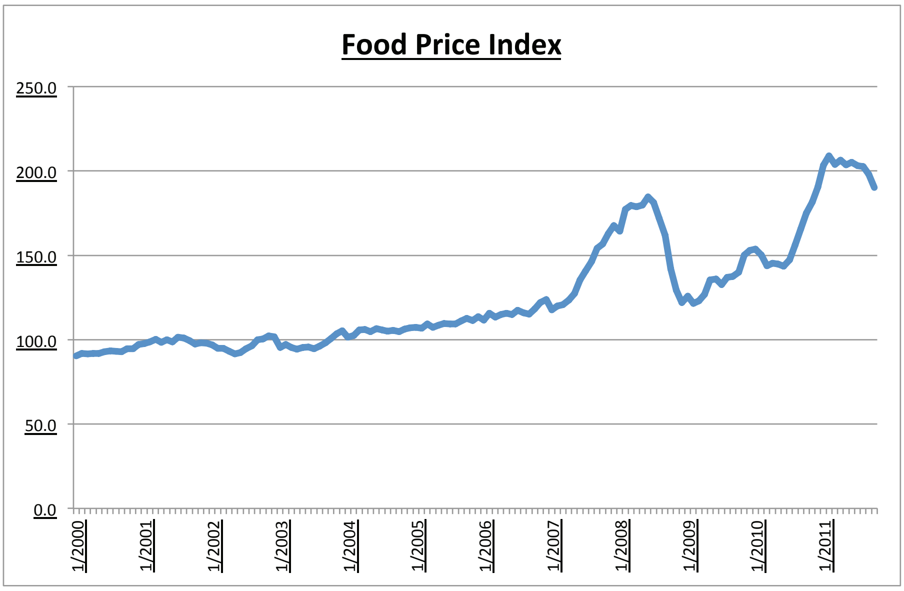


Figure 1.1: Depiction of FAO food price index (2002–04 = 100) and how it went from a gradual increase in 2000 through 2006 into a rapid increase in 2007 and the first half of 2008, after which it fell dramatically back to its slow growth trend. Much less attention has been focused on the fact that food prices once again rose up in 2010 and in late 2011 gone back up to a level even higher than the peak in 2008. Data from FAOSTAT, visited 2011.

penalize bioenergy for this indirect effect, but finding an objective estimate has proven difficult. The aim is however still to introduce some crop specific ILUC factors by 2016 or 2018* in order for them to be considered GHG neutral. To reduce negative climatic impacts from liquid biofuels for transport in the meantime, before ILUC is considered, the direct carbon savings compared to fossil fuels need to be 35% by 2013 and increase to 50% by 2017 and 60% from 2018 (Di Lucia et al., 2012).

This thesis has a focus on connections between increased bioenergy demand and rising food prices and on negative impacts from such price rises. The first paper investigates poor peoples' vulnerability to rising food prices in four Sub-Sahara African countries/regions, by looking at their levels of poverty and their net positions as food producers or food consumers. The second and third papers deal with connections between increased bioenergy demand and changes in food prices with the help of a partial equilibrium model. The model solves for land rent equilibrium and is to a large extent analytically explored. It is also applied to conceptual scenarios of bioenergy expansion to provide insights on critical issues for land competition between food and energy crop production.

*http://www.reuters.com/article/2011/09/08/us-eu-biofuels-idUSTRE7874NP20110908

Chapter 2

Poverty effects of rising food prices

2.1 Background

Historically there has been a global trend of falling food prices from the early 1960s until the mid 2000s, when food prices suddenly leveled out, followed by a rapid price spike in 2008 and then again in 2010–2011. These price spikes are, however, relatively modest compared to the one following the first oil crises in 1973–1974. This development can be seen in Fig. 2.1 and a closer view of the development in the last decade in Fig. 1.1, which offers a continuation to the development depicted in paper I.

The world has thus gotten used to ever decreasing food prices, at a time when the global population has doubled and living standards have improved in many parts of the world. The number of undernourished people in the world has (been relatively stable and) slowly declined during this time, despite the rapidly growing population. The number of undernourished has, however, started to increase in recent years, in response to the rapidly increasing food prices, from a low of about 825 million in 1995–97 to over a billion (1.023) in 2009, with most of the increase in 2007–2009 (FAO, 2009, p. 11) and then down in 2010 to the same level as in 2008 of 925 million (FAO, 2010). There is no estimate for 2011 due to FAO reviewing its methodologies for making such estimations (FAO, 2011, p. 10).

Finding out what negative side effects there may be from a large-scale bioenergy introduction is not a trivial task, and to quantify them is even more daunting. A large-scale introduction of bioenergy over the coming

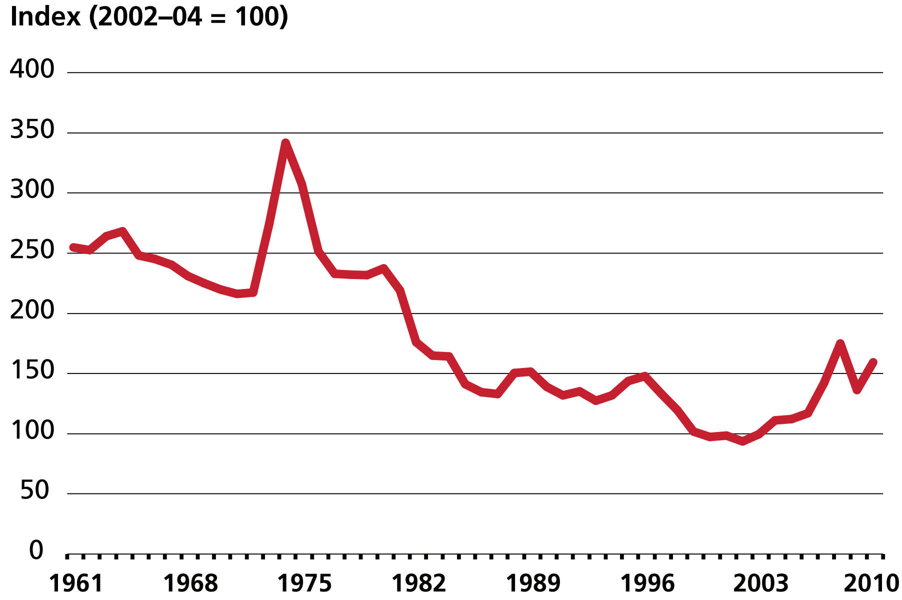


Figure 2.1: Food price index. Source: FAO (2011, Fig. 3, p. 11)

decades can be expected to raise land values and thus production costs for all agricultural products, which means that food prices can be expected to rise. A justified question is thus what the welfare impacts on the world's poor would be if food prices increase even further.

Investigating what the welfare effects on poor households may be if food prices change is difficult. There are many factors that make such an exercise complicated, e.g. a general lack of data, especially for developing countries where most of poor and food insecure people live; and there are dynamic higher order effects—farmers change their behavior in response to price incentives—but it is difficult to know how much and in what directions. Generally, there is a lack of information regarding best agricultural practices, in combination with difficulty in getting access to credit for making investments, for poor subsistence farmers in developing countries. These conditions make it difficult for such people to change their behaviors, but this also makes it more difficult to predict how people can be expected to respond to changing prices.

A second best approach then is to look at a static picture of peoples' net food position, i.e., if they produce more food than they consume, or vice versa. Whether a household has the position of a net producer or a consumer, and by how much, is fundamental for that household's ability to benefit from, or be harmed by, increasing prices on agricultural products, at least in the short term, when dynamic higher order effects—such as changing crops or area cultivated—can be assumed to have less impact.

2.2 Paper I: The effect of food-price movements on African households

In paper I we hence investigate the net food positions and their magnitude, for households in the four Sub-Saharan African countries/regions Ghana, Malawi, Kagera in northeastern Tanzania and South Africa, to estimate their vulnerability to rising food prices.

Much work on vulnerability to changing food prices has already been done, see e.g. Aksoy and Isik-Dikmelik (2008), FAO (2008a), Levinsohn and McMillan (2005), Minot and Goletti (1998),Sahn (1988), Weber et al. (1988), and Zezza et al. (2008), who estimated net food positions and vulnerability by focusing on one or a few staple crops. The focus on few staple crops can be justified for at least three reasons. Firstly, staple crops are the most important ones from a nutritional perspective. Secondly, many of the studies have been conducted with a focus on trade policies, where changing prices affect specific crops, and thirdly, collecting data for few staple crops is much less work demanding—and thus less expensive—than conducting complete household surveys that include all food products.

The work in paper I is however focused on areas where there was access to comprehensive data from the Word Bank's Living Standard Measurement Studies (LSMS), which are based on thorough interviews regarding most economic aspects of the living conditions of a statistically significant sample of each population.

The aim of the paper I is:

- To estimate the shares of household budgets spent on food in four sub-Saharan African countries/ regions (Ghana, Malawi, South Africa, and Kagera in Tanzania).

- To estimate the static real income effect of changing food prices on households in these countries/regions in order to estimate how large shares of the populations that would benefit or lose from rising prices.

- To analyze how the number of food items included in such a food-price–poverty assessment affects the results.

2.2.1 Method

The work is based on comprehensive data from four World Bank LSMS for Ghana (GSS, 2005–2006); the Tanzanian region of Kagera (E.D.I., 2004); Malawi NSO (2004-2005); and South Africa SALDRU (1994). These detailed data sets are investigated with the use of two established indicators for vulnerability to food price changes. The first is the share of a household's income that is spent on food, here called *food over expenditures* (FOE), and the second is net benefit ratio (NBR), which is adopted from Deaton (1989, 1997).

The first indicator is defined by

$$\text{FOE} = \frac{\text{auto-consumed food} + \text{purchased food}}{\text{total expenditures}}, \tag{2.1}$$

where auto-consumed food consists of all food products produced and consumed within the household.

The latter indicator is calculated as follows,

$$\text{NBR} = \frac{\text{sold food} - \text{purchased food}}{\text{total expenditures}}, \tag{2.2}$$

where we have expanded on Deaton's approach by allowing for different prices for sold and purchased goods of the same type, as these activities and prices may differ throughout the year.

To offer yet another view of how choices of crops studied may affect the results we present the economic values for all staple foods (disaggregated) and other food (aggregate) for the urban and rural populations, respectively, divided into terciles based on NBR.

2.2.2 Main findings

The share of net buyers in all regions/countries is high for both rural and urban populations, which is in accordance with previous studies that look at main staples. However, both the shares of net buyers and the extent to which they are net buyers are larger in our study than in other studies published looking at the same countries, such as FAO (2008c) and Zezza et al. (2008).

A likely explanation for the difference is the inclusion of all food products in our study compared to e.g. only rice and maize in Zezza et al. (2008). By taking the example of rural Malawi, non-staples make up large and relatively similar shares of auto-consumed and sold food, but dominate the category purchased food. That they (non-staples) make up large shares of the food economy can explain why their inclusion alters the magnitudes of the indicator values. The magnitudes of the indicator values is not important when only looking at the net position of population groups, but it is when studying how price changes may affect them. That non-staples make up dominating shares of purchased food, however, not only alters the magnitude of the indicator values, but also the net positions of the population samples.

Chapter 3

Equilibrium economics and land use

There is a storm in the making regarding bioenergy consumption.

The European Union has endorsed a mandatory target of 10% biofuels for transport by 2020 and stated that it is appropriate with a binding target as long as the production of the biofuels is sustainable (EC, 2009). USA has a similar goal of 36 billion gallons (136 billion liters) biofuels in the transport sector by 2022, up from 9 billion gallons (34 billion liters) in 2008, implemented through the Energy Independence and Security Act (EISA) of 2007[*]. Based on these and other countries' goals of increased consumption of biofuels for transport the OECD-FAO Agricultural Outlook[†] 2011–2020 expect global biofuel production to more than double between 2008 and 2020. On an energy basis this corresponds to an increase in liquid biofuel production from 1.6EJ in 2006 to over 5EJ in 2020. BP energy outlook 2030[‡] estimates the biofuel production to increase from 2.4 EJ in 2010 to no less than 9.9 EJ year^{-1} by 2030. This can be compared to the aggregate current demand for liquid fuel for transport of 75 EJ year^{-1} (Smil, 2006). In the longer perspective Pacala and Socolow (2004) propose production of 35 EJ year^{-1} of liquid biofuel by 2054, produced on 250 Mha of land, to fill one of their GHG "wedges" and reduce global emissions by 1GtC year^{-1}. There is thus no shortage in demand for bioenergy to be expected in the coming decades.

[*] `www.epa.gov/otaq/fuels/renewablefuels/index.htm`, visited 2011-11-16

[†] `stats.oecd.org`, visited 2011-11-16

[‡] `www.bp.com/sectiongenericarticle800.do?categoryId=9037134&contentId=7068677`, visited 2011-11-16

If the world is to embark on a large-scale expansion of bioenergy, as the mandates in EU and USA indicate, it is desirable to have an ex-ante understanding of what such a development may entail. It is difficult to calculate and agree on the impact from bioenergy on historic price changes, as was made evident in the aftermath of the recent food price hike of 2007–2008 described in the introduction. How would it then be possible to objectively calculate future price impacts from un-known quantities of bioenergy under un-known economic developments?

A fair amount of work has been done to address this question, see e.g. Gillingham et al. (2008); Gurgel et al. (2007); Havlík et al. (2011); Johansson and Azar (2007); Melillo et al. (2009); Schneider et al. (2007); and Searchinger et al. (2008). Focus for most of these studies have been on greenhouse gas (GHG) emissions and market effects for agricultural and land-use markets for quantification of indirect land-use change (ILUC) and only some of them have explicitly calculated food price effects.

Common for these studies is that they rely on large equilibrium models (partial, PE, or general, CGE) with high levels of detail. Because of this high levels of detail, results from the models depend on many parameters (thousands to tens of thousands) and knowledge about their specific values at future times.

Both PE and CGE rely on the same basic principles of the existence of one unique market equilibrium, with market clearing prices, based on perfectly rational and profit maximizing agents, with access to perfect knowledge, in all sectors. These are characteristics that are quite unlikely to be true, due to several reasons such as personal preferences, the future intrinsically being unknown, the economy never being in equilibrium, etc. Even though the assumptions of equilibrium economics never apply in reality, there are tendencies towards equilibrium situations, which has a strong explanatory power and much can be learnt from this. They may indicate in which directions market forces can be expected to pull. Much can thus be learnt from equilibrium models.

An important question arises regarding the usefulness of the high level of detail in large equilibrium models, when it is known that there are flaws to the equilibrium assumption. The only thing one can be sure of when it comes to detailed scenarios is that they will not come true, see Smil (2006) for an entertaining discussion on projections in the energy field.

Another problem with large models and detailed scenarios, brought up by Morgan and Keith (2008), has to do with people's cognitive difficulty to estimate probabilities. The higher the detail in a scenario, the less likely that particular scenario is to come true, but readers assign higher probabilities to such scenarios. As more detail and precise numbers are provided to a reader, his/her own ability to consider other plausible scenarios declines. These important psychological phenomena do not only apply to laymen, but also to experts, even if to a somewhat lesser degree (Morgan and Keith, 2008).

In paper II and III we develop and apply a conceptual partial equilibrium model of global land use, with availability of productive land as the limiting factor. The purpose of the model is to offer an alternative and more transparent way of looking at large-scale perturbations to the global land-use system, such as from the expected future demand for bioenergy. The transparency is thought to help readers to acquire a deeper understanding of the main mechanism in land-use competition and their potential effects, and at the same time avoid an overconfidence in model results, as Morgan and Keith (2008) claim may result from higher levels of detail.

Regardless of the level of detail and type of model, a thorough sensitivity analysis is key to understanding how the model works and what results from the model are robust under changes in parameter values. There is generally a dearth of thorough sensitivity analysis regarding main conclusions from model runs, i.e., how sensitive the main insights and conclusions are to parameter values. When there is a sensitivity analysis they may include some parameters that may, or may not, be important and then little discussion of real implications from this. When ranges in results are large and uncertain it is still common to present some main results—based on parameter assumptions—in quantitative terms and as if they were certain.

3.1 Paper II: A conceptual agricultural land-use model with illustrations on price effects from competition between bioenergy and food crops

In the second paper we develop a conceptual agricultural land-use model that to a large degree can be explored analytically. The limiting factor in the model is availability of productive agricultural land. The main purpose of the model is to be as transparent as possible, but still realistic enough to capture important mechanisms.

The purpose of paper II is to:

- Present a conceptual model of global land use, simple enough to be analytically explored, but complex enough to capture important driving mechanisms for land-use competition.
- Formally show that the problem of maximizing land rent generates an identical optimal solution as the problem of maximizing the combined producer and consumer surplus.
- Show how crops are optimally distributed on land and what characteristics that determine the distribution.
- Present differentials for how different crop prices depend on each other at equilibrium.

The possibility of analytical exploration—we argue—enables a deeper understanding of how mechanisms work.

3.1.1 Model description

Land is assumed to be graded in a continuous and strictly declining manner from the most productive land to the least productive land, which is depicted in Fig. 3.1.

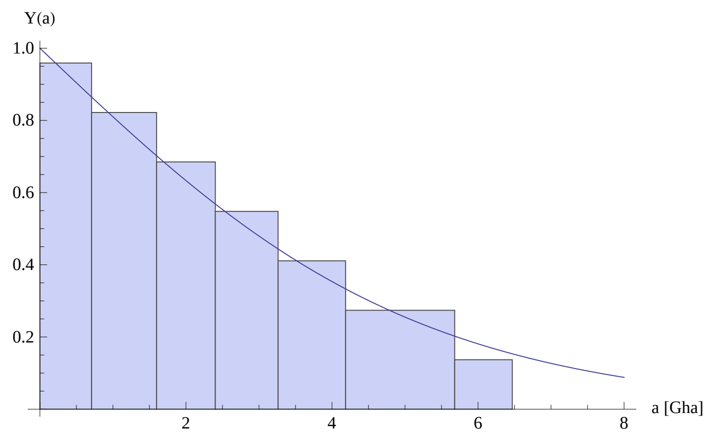


Figure 3.1: Representation of global agricultural land with decreasing productivity. The bars represent data for *Suitability for rain-fed crops (maximizing technology mix)* from (Fisher et al., 2002) and the curve represents an approximation used in paper II.

Crops i are produced on this land and distributed in such a way as to maximize the combined producer and consumer surplus. The combined producer and consumer surplus for each crop is given by

$$\xi_i(q_1, ..., q_i) = \int_0^{q_i} (p_d^{(i)}(q_i) - p_s^{(i)}(q_1, ..., q_{i-1}, \tilde{q}_i))\, d\tilde{q}_i \tag{3.1}$$

where $p_s^{(i)}$ denotes tho supply function for crop i and $p_d^{(i)}$ is the price for quantity q_i. The demands are characterized by constant isoelastic demand functions

$$p_d^{(i)}(q_i) = p_0^{(i)} \left(\frac{q_i}{q_0^{(i)}} \right)^{\frac{1}{\varepsilon_i}} \tag{3.2}$$

with constant own-price elasticity ε_i, which ensure that all demanded crops actually are produced, even though quantities depend on market clearing prices p_i^*. The relative demand for each crop is also set by the constants $p_0^{(i)}$ and $q_0^{(i)}$.

The surplus ($\xi = \sum_i \xi_i$) needs not, though, be calculated directly in order to optimize it. The maximization of the combined consumer and producer surplus indirectly generates the scarcity rent of land, which for each land plot under production is identical with the producer surplus, i.e., the different between market clearing price $p_i^* = p_d^{(i)}(q_i^*)$ and production cost $p_s^i(q_i)$. This is especially interesting at each point a_i on the land where there is a shift in crop produced, because these points are determined by combinations of production costs for the two neighboring crops and their respective demand functions (3.2) so that their land rents are identical at this point.

The fact that land rents coincide at points where there are shifts in crops produced is used to rewrite the model to be based on land rents and that each plot of land is used for the crop with the highest willingness to pay, with crop shifts at points (a_i) where willingness to pay for two different crops are the same. Land rents are given by

$$r_i(a) = (p_i^* - \beta_i)\eta_i Y(a) - \alpha_i = \phi_i Y(a) - \alpha_i \tag{3.3}$$

where β_i [$\$\, GJ^{-1}$] is harvest dependent costs; η_i [$GJ\, ha^{-1}\, yr^{-1}$] is maximum yield for crop i; and α_i [$\$\, ha^{-1}\, yr^{-1}$] is area dependent costs.

3.1.2 Main findings

The optimization problem of the combined producer and consumer surplus from agricultural products is equivalent to the problem land-rent equilibrium when all land owners try to maximize their rents. The land rent problem is also easier to set up and to solve.

The distribution of crops on the land is determined by the crops' respective area-dependent costs α_i. Crops with high such cost are produced on the most productive land and crops with lower such costs on less productive land. This conforms to the intuition that a system with high area dependent costs has high incentives to reduce the area needed to produce a given quantity and can thus afford high land rent costs. A system with low area dependent costs suffers little from extensive production on large areas and cannot support high land rent payments as such a system finds it more attractive to expand the area under production.

A third important finding in the paper is the derivation of price differentials between crop prices at equilibrium.

$$\frac{dp_1}{dp_2} = \frac{\eta_2}{\eta_1} \cdot \frac{1}{1 + (\alpha_1 - \alpha_2)\frac{Y'(a_1)}{Y(a_1)^3}\frac{q_1^* \varepsilon_1}{p_1^* \eta_1^2}}. \tag{3.4}$$

$$\frac{dp_3}{dp_2} = \frac{\eta_2}{\eta_3} \cdot \frac{1}{1 + (\alpha_2 - \alpha_3)\frac{Y'(a_2)}{Y(a_2)^3}\left(\frac{Y(a_3)^3}{Y'(a_3)\alpha_3} + \frac{q_3^* \varepsilon_3}{p_3^* \eta_3^2}\right)}. \tag{3.5}$$

Here the dependence from one crop's price changes (dp_2) on another crop's price can be seen for a crop produced on more productive land (dp_1) and for a crop produced on less productive land (dp_3).

3.2 Paper III: Application of a land rent model for analysis of land-use and price effects of bioenergy policies

The third paper is based on application and further development of the conceptual agricultural land-use model developed for paper II.

The model is applied to 11 different cases/scenarios, which all are conceptual in the sense that they are distinct and conceptual policy situations that are used to show how land-use competition mechanisms work under different conditions. The cases are both with and without bioenergy and allowing for or not allowing for deforestation.

- The first case is a base case with no bioenergy and demand for food crops and forage similar to current levels.

- The second case is based on market based distribution of crops, which with assumed parameters results in extensively produced food crops being grown on the most productive land, bioenergy grown on intermediate land, and extensively produced forage and food crops grow on the least productive land under cultivation.

- In the third case the bioenergy is produced on the most productive land, followed by intensively produced food crops and extensive production on the least productive land.

- The fourth case is the opposite with a strict limit for the the production of bioenergy to land of lower productivity than the most productive 2Gha.

- In the fifth case the crops are distributed like in the first, but the total agricultural area is not allowed to expand.

- In case six, all the bioenergy is produced from relatively low yielding food-type crops, such as maize.

All cases are analyzed with no deforestation, and then all, except case five, are also analyzed when there is no limit regarding deforestation of currently forested land. Some of these cases require small changes to the mathematical description of the model, other only require altered parameter values. Model modifications and parameter values are presented in the paper.

The model is further subjected to a complete parameter analysis, in which all parameter values are tested to the limits of feasibility, to clearly show how model results depend on the different parameters.

The purpose of paper III is thus:

- To produce qualitative pictures—and system-behavioral insights—of economic impacts from competition for land from large-scale bioenergy production by applying the conceptual land-use model developed in paper II.

- Test how the system depends on several conceptual bioenergy policy cases.

- Subject the model to extensive parameter analysis to show which parameters that are most crucial for the conclusions drawn from the model.

3.2.1 Main findings

Price increases on food from increased land-use competition are significant for all cases investigated when deforestation is not allowed. This is a result from that land prices increase significantly at all levels in response to large-scale introduction of bioenergy, regardless of crop distribution, see Fig. 3.2.

Intensively produced food crops are significantly affected in all cases, but at a level less than half the impact on extensively produced forage and food crops. This can be explained since land rent makes up a smaller share of the production cost for intensive production and a relative increase in land rent thus has a smaller relative effect on the total production cost, than for extensive production that uses larger areas of land for each unit produced.

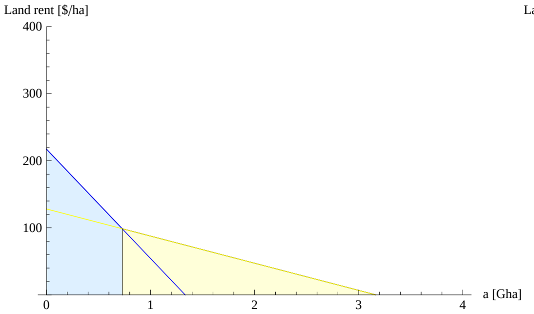
The price effect, on intensively produced food crops, can be somewhat mitigated if bioenergy production is limited to land of lower productivity, see panel 3.2d. This results in a very strong increase in land rent for the land where bioenergy production is allowed, however. Incentives for land owners to cheat and not follow such a restriction would be very strong and implementation of such a scenario would thus be difficult, if not impossible.

Bioenergy production from food-type crops (such as maize ethanol) results in much larger price changes for all intensively and extensively produced food and forage crops alike, stemming from radically increased land-use competition and thus much higher land rents.

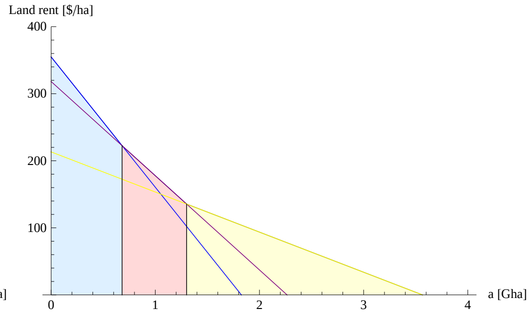
There is, however, room for a large-scale introduction of bioenergy without a significant effect on food prices if deforestation is allowed at a substantial scale. Allowing for deforestation without introducing bioenergy at a large scale would certainly lead to a significant fall in food prices. Bioenergy always raises competition for land and thus land rents compared to developments without bioenergy.

The extensive parameter analysis shows that all price increases fundamentally depend on some crucial parameters. The most important parameters are: The total availability of productive land; Total quantity bioenergy demanded; Potential yields for all crops but specifically bioenergy crops; and price elasticity for extensively produced forage and food crops.

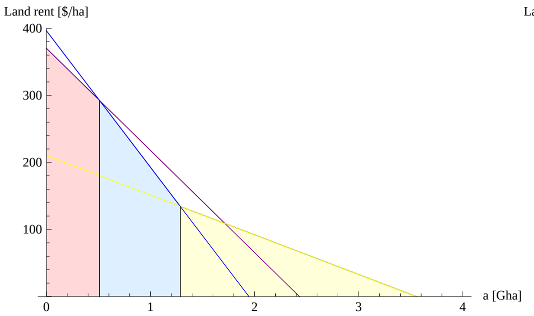
The first implication from this is that introduction of bioenergy on a large scale, raises incentives to deforest land of high productivity, such as tropical rain forests. Secondly, utilizing bioenergy crops with any other yields than the highest available, augments these impacts beyond what is necessary.



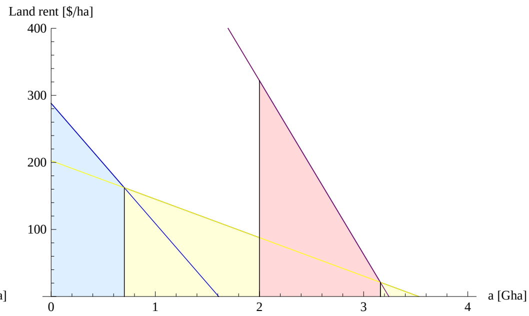
(a) no-BE



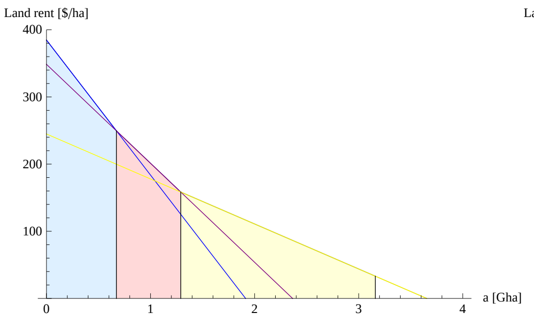
(b) BE-market



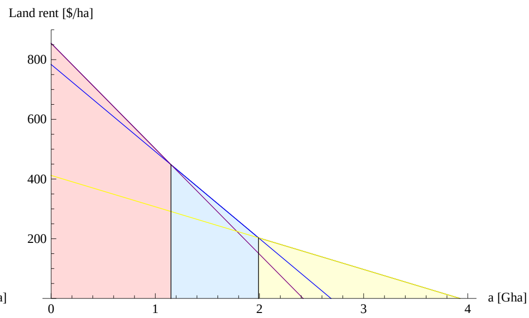
(c) BE-best land



(d) BE-2Gha



(e) Fixed area



(f) Maize ethanol

Figure 3.2: Estimated land rents and land use in the base case and the five bioenergy cases. Colored lines represent willingness to pay for land from a given crop for land of each productivity level. The highest line sets the land rent under free market conditions. Colored areas indicate which crop is produced on the land and thus sets the rent level. Blue lines/areas represent intensively produced food crops, red lines/areas represent bioenergy and yellow lines/areas represent extensively produced forage and food crops.

Bibliography

Aksoy, M., Isik-Dikmelik, A., 2008. Are Low Food Prices Pro-Poor? Net Food Buyers and Sellers in Low Income Countries. Mimeo, World Bank, Washington, DC.

Ciaian, P., d'Artis Kancs, 2011. Interdependencies in the energy-bioenergy-food price systems: A cointegration analysis. Resource and Energy Economics 33 (1), 326 – 348.

Deaton, A., 1989. Household Survey Data and Pricing Policies in Developing Countries. The World Bank Economic Review 3 (2), 183–210.

Deaton, A., 1997. The Analysis of Household Studies: A Microeconomic Approach to Development Policy. Johns Hopkins University Press, Baltimore, Maryland.

Di Lucia, L., Ahlgren, S., Ericsson, K., Feb. 2012. The dilemma of indirect land-use changes in EU biofuel policy – An empirical study of policy-making in the context of scientific uncertainty. Environmental Science and Policy 16, 9–19.

Dufey, A., Vermeulen, S., Vorley, B., 2007. Biofuels: strategic choices for commodity dependent developing countries. Common Fund for Commodities.

EC, Jun. 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union, 1–47.

E.D.I., 2004. Economic Development Initiatives, Kagera Health and Development Survey (KHDS 2004).

FAO, 2008a. Soaring food prices: facts, perspectives, impacts and actions required. Document for High-level conference on world food security: The challenges of climate change and bioenergy. Food and Agriculture Organization of the United Nations.

FAO, 2008b. State of Food and Agriculture 2008: Biofuels: prospects, risks and opportunities. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 2008c. State of Food Insecurity in the World 2008: High food prices and food security – threats and opportunities. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 2009. State of Food Insecurity in the World 2009: Economic crises – impacts and lessons learned. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 2010. State of Food Insecurity in the World 2010: Addressing Food Insecurity in Protracted Crises. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 2011. State of Food Insecurity in the World 2011: How does international price volatility affect domestic economies and food security? Food and Agriculture Organization of the United Nations, Rome, Italy.

Fisher, G., van Velthuizen, H., Shah, M., Nachtergaele, F., 2002. Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results. International Institute for Applied Systems Analysis (IIASA) and Food and Agriculture Organization of the United Nations (FAO), Laxenburg, Austria and Rome, Italy.

Gillingham, K., Smith, S., Sands, R., 2008. Impact of bioenergy crops in a carbon dioxide constrained world: an application of the minicam energy-agriculture and land use model. Mitigation and Adaptation Strategies for Global Change 13, 675–701.

GSS, 2005–2006. Ghana Statistical Service. Fifth Round of the Ghana Living Standards Survey (GLSS 5).

Gurgel, A., Reilly, J. M., Paltsev, S., 2007. Potential Land Use Implications of a Global Biofuels Industry. Journal of Agricultural & Food Industrial Organization 5.

Havlík, P., Schneider, U. A., Schmid, E., Böttcher, H., Fritz, S., Skalský, R., Aoki, K., DeCara, S., Kindermann, G., Kraxner, F., Leduc, S., McCallum, I., Mosnier, A., Sauer, T., Obersteiner, M., 2011. Global land-use implications of first and second generation biofuel targets. Energy Policy.

Johansson, D., Azar, C., Jan 2007. A scenario based analysis of land competition between food and bioenergy production in the us. Climatic Change.

Levinsohn, J., McMillan, M., 2005. Does Food Aid Harm the Poor? Household Evidence from Ethiopia. NBER Working Paper No. W11048. Available at: `http://ssrn.com/abstract=648950`.

Melillo, J. M., Reilly, J. M., Kicklighter, D. W., Gurgel, A. C., Cronin, T. W., Paltsev, S., Felzer, B. S., Wang, X., Sokolov, A. P., Schlosser, C. A., 2009. Indirect Emissions from Biofuels: How Important? Science 326 (5958), 1397–1399.

Minot, N., Goletti, F., Nov. 1998. Export Liberalization and Household Welfare: The Case of Rice in Vietnam. American Journal of Agricultural Economics 80, 738–749.

Morgan, M., Keith, D., 2008. Improving the way we think about projecting future energy use and emissions of carbon dioxide. Climatic Change 90, 189–215.

NSO, 2004-2005. National Statistical Office of Malawi. Second integrated household survey (IHS-2).

Pacala, S., Socolow, R., Aug. 2004. Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. Science 305 (5686), 968–972.

Prins, A., Stehfest, E., Overmars, K., Ros, J., 2010. Are models suitable for determining ILUC factors. Bilthoven, The Netherlands: Netherlands Environmental Assessment Agency, PBL publication.

Sahn, D. A., January 1988. The effect of price and income changes on food-energy intake in sri lanka. Economic Development and Cultural Change 36 (2), 315–340.

SALDRU, 1994. Southern Africa Labour and Development Research Unit. Project for Statistics on Living Standards and Development.

Schneider, U. A., McCarl, B. A., Schmid, E., 2007. Agricultural sector analysis on greenhouse gas mitigation in us agriculture and forestry. Agricultural Systems 94 (2), 128 – 140.

Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T., 2008. Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change. Science 319, 1238–1240.

Smil, V., Sep. 2006. ENERGY AT THE CROSSROADS. OECD, 1–28.

Weber, M., Staatz, J., Holtzman, J., Crawford, E., Bernsten, R., Dec. 1988. Informing Food Security Decisions in Africa: Empirical Analysis and Policy Dialogue. American Journal of Agricultural Economics 70 (5), 1044–52.

Zezza, A., Davis, B., Azzarri, C., Covarrubias, K., Tasciotti, L., Anriquez, G., 2008. The impact of rising food prices on the poor. Unpublished manuscript Food and Agriculture Organization Rome.