Impacts of future energy price and biofuel production scenarios on international crop prices, production and trade

*Gerald Schwarz, *Harald von Witzke and #Steffen Noleppa

* Department of Agricultural Economics and Social Sciences, Humboldt University Berlin
# agripol – network for policy advice GbR

Corresponding author:
Gerald Schwarz
Humboldt University Berlin
Department of Agricultural Economics and Social Sciences
Chair of International Agricultural Trade and Development
Unter den Linden 6
10099 Berlin, Germany
Phone: +493020936787
Fax: +493020936301
schwarzg@agrar.hu-berlin.de

Paper prepared for the international conference "The Economics of Alternative Energy Sources and Globalization: The Road Ahead", November15 – 17, 2009, Orlando, Florida, US.

Abstract

In this article we discuss the impacts of future energy prices and biofuel production levels on agricultural market prices, production and trade and present the results of a partial equilibrium model of international agricultural trade with interconnected markets. The results of the model suggest that the long term trend of declining real agricultural commodity prices has been reversed. A key result in this regard is that the price of energy has become a major driving force of agricultural world market prices. For instance, in the period of analysis until 2016/18 the price of wheat can be expected to increase by about 16 percent, 35 percent and 91 percent depending on an oil price of US$ 45, US$ 70 and US$ 102 per barrel, respectively. The 2016/18 baseline projection shows an increase in total world production from 10 percent for wheat to 30 percent for oilseeds. Variations in energy cost have the biggest impact on sugar production in the EU, corn production in North America, other grains production in Brazil, sugar production in China, other grains production in Australia and corn production in CIS. Increasing bioenergy demand has the biggest impact on corn production followed by sugar and oilseeds production. The impacts and importance of energy prices and biofuel production for agricultural trade varies between commodities and regions. Future medium to long term biofuel scenarios might change considerably depending on the breakthrough of different technologies and the support for different types of bioenergy production pathways.

Key words: International agricultural trade, international agricultural market prices, energy prices, biofuel production, partial equilibrium model

JEL codes: Q11, Q17

Introduction

For more than a century world agriculture was characterized by an economic process which has become known as the Agricultural Treadmill. During this time period, global food demand grew at a rapid pace for essentially two reasons. One was a rapid growth in world population which quadrupled in just a century. In 1900, 1.5 billion humans were living on this planet. By 2000 this number had gone up to around 6 billion. The other was a significant increase in per capita food consumption in today's rich countries.

However, the growth in the global supply of food outstripped the growth in demand during this period of time. Again there have been two main reasons for this. One has been the expansion of the agricultural acreage. This process began to slow down significantly during the second half of the 20th century. The expansion of the agricultural acreage has by no means come to a standstill, it has, however, slowed down. The other reason has become much more important; namely productivity growth in world agriculture. In the 1960s and 1970s agricultural productivity growth was so rapid that this period is now referred to as the Green Revolution.

The result of these changes in global demand for and supply of food has been a long term decline in real international agricultural commodity prices which, in turn led to structural adjustments in today's rich countries and a declining agricultural work force. This is why this process is referred to as the Agricultural Treadmill (Tyers and Anderson 1992). Farmers have become ever more productive. Figuratively speaking, they have run ever faster, but economically they did not get very far because time and again the income effect of productivity growth was eroded by declining prices.

The turn of the millennium marks a reversal of the megatrend of declining agricultural commodity prices. Since then the growth in global demand for agricultural commodities has outstripped the growth in supply. As a consequence, the trend in prices has been positive. A number of studies have analysed the different factors contributing to the increase in food prices at the beginning of the millennium (e.g. Trostle 2008; De Gorter 2008). Other studies (e.g. Banse et al. 2008, Miller et al. 2009, Hazes et al. 2009 and Tokgoz 2009) focussed on the implications of future energy prices and biofuel production on agricultural production and land use changes. Those studies emphasise the critical role of levels of energy prices and biofuel production for future agricultural market prices as well as production and trade developments. While it is now the consensus in the agricultural economics profession that real international food and agricultural commodity prices will tend to increase in the decades to come, the open questions are: to what extent are prices likely to rise, to what extent will potential future developments of energy prices and biofuel production contribute to higher prices and what are the impacts on agricultural production and trade.

In the remainder of this paper, we will first review the reasons for higher prices in the new few decades than in the past. In particular, we will discus the roles of the price of energy as well as the extent of bioenergy production for international markets. This discussion draws heavily on von Witzke et al. (2008) and Schwarz et al. (2009). Then we will present the results of a projection of world market prices of selected agricultural commodities for

2016/18 and the potential impacts on demand, supply and trade quantities in the EU. The paper concludes with a discussion of the implications of our findings and factors which affect future market developments.

Determinants of global food supply and demand growth

In the first half of the 21^{st} century, the global demand for food is likely to double. About half of the demand growth will be accounted for by a continued rapid population growth (table 1).

Table 1. Global Population Growth, 1950-2050

Year	Population (millions)	Average annual population growth (millions)
1950	2557	38
1975	4084	71
2000	6072	76
2025	7959	68
2050	9402	46

Source: US Census Bureau (2008).

The other half will be the result of per capita income growth in developing and newly industrializing countries which will result in a significant growth in food consumption. This is exemplified for grain consumption in table 2.

Table 2. Change in Grain Consumption by Region, 1997-2025

Region	Change in grain consumption (in million tons)
China	192
India	92
West Asia and North Africa	77
Other Asia	107
Sub-Sahara Africa	100
Latin America	92
Developed countries	107
World	767

Source: Adapted from Runge et al. (2003).

The growth in global food supply is not likely to keep pace with the growth in demand for a variety of reasons. One reason is that on a global scale the land that is available for agricultural production is limited. The most productive land is already being farmed. In many parts of the world there are no major land reserves which could be mobilized for farming. Although there are significant land reserves in some regions of the world, much of this land, such as the tropical rain forests, should not be used for farming for environmental concerns. Von Witzke (2008) estimates that between 2000 and 2020 the world's cropland could be expanded by about 5 percent provided that agricultural commodity prices are favorable. His estimate is in line with findings by others (e. g. Hofreither 2005; IFPRI 2005). For the production effect of this additional cropland it must be kept in mind that this land will tend to be less productive than the land that was farmed already at low prices.

According to FAO (Bruinsma 2003) there is ample supply of land around the world which is considered “suitable” or “very” suitable for agricultural production. However, these estimates are grossly misleading at best, as they disregard the availability of water and other resources for agricultural production. In addition some of this land is suitable only for a particular use. For instance, FAO’s numbers suggest that Spain has significant areas of land which are “suitable” or “very suitable” for agricultural production. However, this land could only be used for olive production, if at all.

Essentially the expansion of cropland can only be assessed realistically if the time dimension is included. Expansion of cropland requires not only suitable soils but also sufficient amounts of water, public and private infrastructure for storage, handling and processing, capital investment, skilled farmers and so on.

The limited availability of agricultural land implies that the production growth necessary to meet the world’s rapidly growing needs in the decades ahead must come predominantly from productivity growth of the land already being farmed (e. g. von Witzke 2007; Runge et al. 2003). In the 1960 to 2000 period almost 80 percent of global production growth was the result of productivity growth and only around 20 percent were accounted for by the expansion of the agricultural acreage (Bruinsma 2003). In the decades ahead, an even higher percentage of the production growth around the world will have to come from productivity growth (e. g. von Witzke 2007 and 2008). Additional evidence of increasing scarcity of agricultural land is provided by the fact that globally per capita availability of cropland has declined from 0.4 ha in 1961/63 to 0.25 ha in 1997/98 (own calculations based on Bruinsma 2003).

However, a sufficiently high productivity growth will be difficult to achieve. Since the times of the Green Revolution agricultural productivity growth has been declining. From the 1960s to the 1980s annual productivity growth in world agriculture averaged around four percent. This number is now down to one percent with a continuing tendency towards further decline (FAO 2008a and b; Pardey et al. 2007).

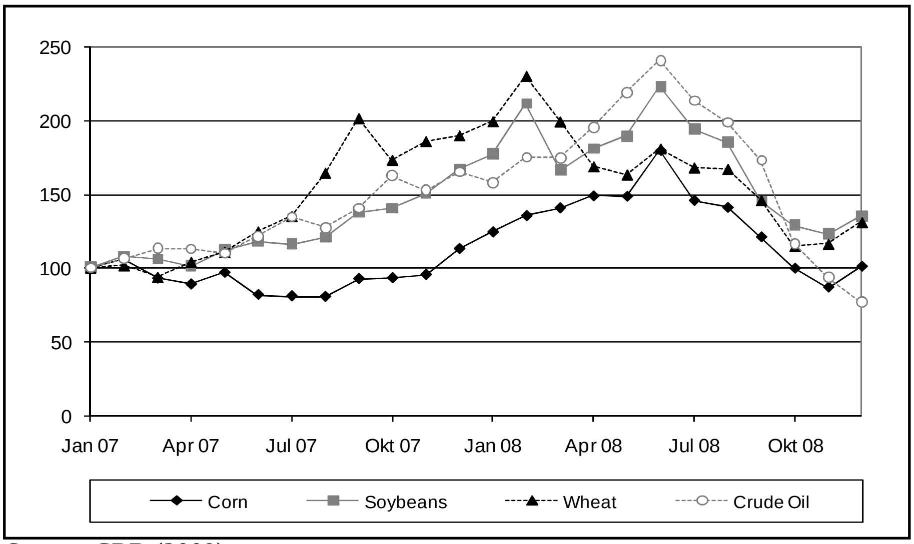
There are two central reasons for the declining agricultural productivity growth. One is that the law of diminishing returns also applies to agricultural research. That is, with its traditional breeding methods agricultural research has increasingly captured the productive potential of crops and livestock such that additional productivity gains can only be realized by ever increasing agricultural research investments. The other is that exactly this has not occurred. To the contrary, beginning in the 1980s when the rich countries of the world felt that they were awash with food, agricultural research has been reduced significantly in the industrialized countries where about 80 percent of agricultural research takes place (Pardey, et al. 2006). In general, there is significant underinvestment in agricultural research, as evidenced by the fact that the social rate of return to agricultural research is high (e. g. Alston et al. 2000; von Witzke et al. 2004).

Land suitable for agricultural production is not the only natural resource constraint to increasing food production, however. In the past agricultural production growth has always been paralleled by increased use of water for farming. Water is increasingly becoming a constraint to production as well and acts to slow down productivity growth (e. g. FAO 2007).

Furthermore, global warming will affect agriculture significantly. On balance, global production is expected to decline, all other things being equal. The tragedy in this regard is that the poorest countries of the world tend to be located in agro-climatic zones which will be most negatively affected by global warming. These countries tend to be food deficit countries and all too often they do not have sufficient foreign currency reserves to buy enough food in international markets. To make things worse, these countries tend to have only rudimentary agricultural research systems, making it difficult for them to develop technologies which would permit farmers to adapt to climate change.

In the rich countries of the world there has been a significant growth in the demand for quality components in food and agriculture. This also includes process quality. Consumers in these countries increasingly expect that the food they buy is not only healthy and wholesome and does not include residues of substances that may pose a health risk, but also that agricultural production technologies are sustainable and preserve natural resources. In essence, this implies that agricultural research now has to observe the additional constraints of sustainability and natural resource preservation and – from a societal perspective – rightly so. But in essence, observing these additional constraints also acts to slow down productivity growth.

The public debate about high food prices in 2008 has been fuelled by high energy prices and biofuel production. As OECD (2006, 2008) rightly points out, agriculture is a fairly energy intensive industry. Tractors and other farm machinery need fuel. Energy is needed to dry crops. And many farm inputs require a lot of energy in their production such as synthetic nitrogen fertilizers. For instance, the share of energy in variable cost of US corn production is around 50 percent (Doane 2008).



Source: CRB (2009).

Figure 1. Agricultural commodity prices and the price of crude oil, 2007-2008

Energy markets have changed significantly in the past few years. Despite the recent decline, the expectation is for generally higher energy prices in the future (U. S. Energy Information Administration 2009). Higher energy prices, thus, result in significantly higher cost of production which acts to result in reduced production. The close interrelationship between the price of agricultural commodities and the price of energy is depicted in figure 1.

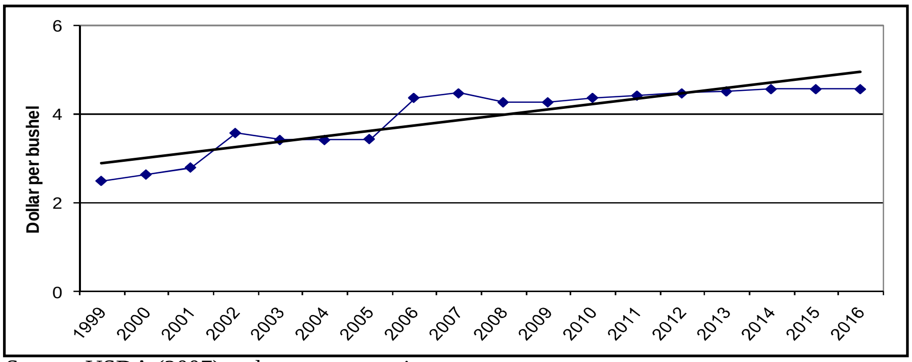
Agricultural commodity and energy prices have become cointegrated for another reason as well and that is the production of biofuels. Increasing energy prices increase production of biofuels. Government programs which aim at increasing biofuel production by means of subsidies, targets or other instruments also appear to be correlated with the price of energy.

To the extent that biofuel crops are produced on land which is suitable for food production this acts to reduce the availability of food. However, for a variety of reasons the trade-off between food production and biofuel production may be less pronounced than it is sometimes argued. More than 95 percent of the global biofuel production is based on solids for burning. This includes wood, charcoal, animal manure and other agricultural by-products. Less than five percent of bioenergy is liquid fuel, based on grains, sugar cane, oil seeds and other crops (FAO 2008c). In some cases the production of biofuels also results in high protein animal feed such as oilseeds used as inputs in the production of biodiesel. Another by-product is fertilizer in the production of biogas which has the added advantage of reducing agricultural greenhouse gas emissions (von Witzke and Noleppa 2007).

In short, global food demand growth is likely to exceed supply growth. As a consequence real international food and agricultural commodity prices will tend to increase in the decades to come. This is now the consensus in the agricultural economics profession. The open questions are: to what extent are prices likely to rise, to what extent will potential future developments of energy prices and biofuel production contribute to higher prices and what are the impacts on agricultural production and trade. The following analysis presents the projection of world market prices of selected agricultural commodities for 2016/18 and the impacts on key crop markets in main trade regions and countries.

International Agricultural Market Prices in 2016/18

There are a number of empirical analyses which arrive at the result that food prices will be higher in the future than they have been in the past. Figure 2 illustrates this for wheat. It depicts the actual prices of wheat between the turn of the millennium and 2006 and the prices projected by USDA (2007) for the 2007 to 2016 period. As can be seen, the general tendency is for a higher wheat price, although the price increase is rather modest.



Source: USDA (2007) and own computations.

Figure 2. The market price of wheat (1999-2016)

Von Witzke et al. (2008) have developed a multi region multi-market model of international agricultural trade. They analyzed driving forces of changes in agricultural world markets and their implications for European Union agriculture for the time period 2003/05 - 2013/15. The analysis considered population growth, changing food preferences due to per capita income growth, and bioenergy on the demand side and productivity growth and the availability of crop land on the supply side. The results of their analysis are summarized in table 3. As is evident, their analysis appears to support the findings by USDA (2007) and others in that prices may be expected to be higher in the future than they have been in the past, albeit only modestly.

Table 3. Real World Market Price Changes of Selected Agricultural Commodities, 2003/05-2013/15 (in percent)

Crop	**Percent change**
Wheat	14
Corn	30
Oilseeds	32
Other grains	13

Source: von Witzke et al. (2008).

However, their analysis is based on projections about biofuel production by OECD and FAO (2007) which have turned not to be in line with the actual growth in global biofuel production. Moreover, their analysis is based on the assumption of a constant energy price. As discussed above, the consensus among energy economists is that the times of inexpensive energy are over and that energy prices will be higher than in the past.

In the following, we will present the result of an analysis which is based on a regionally disaggregated version of the model developed in our earlier studies (von Witzke et al. 2008, Schwarz et al., 2009). The model is an agricultural multi-region, multi-market trade model developed to quantify the price, supply, demand and net trade effects of various policy and non-policy induced shocks. The model is based upon the principles of the VORSIM modelling framework and its predecessor the Static World Policy Simulation Modelling Framework (Roningen 1986; Roningen et al. 1991) developed by Jechlitschka et al. (2007).

In this model each market in each region is characterized by a Cobb-Douglas supply and demand function. Each market is linked with other markets through a set of cross-price elasticities. The model is static and assumes that domestically produced and foreign goods are perfect substitutes in consumption. International trade is the difference between domestic supply and demand in each region. The model is closed by the assumption of market equilibrium. This means, trade flows are such that world supply equals world demand and that total global exports equal total global imports.

The impacts of the different drivers of change of agricultural markets are integrated in the model through multiplicative shift factors in supply and demand functions, an approach commonly used in partial equilibrium models (see, e.g., Kazlauskiene and Meyers 1993, 2003; Cagatay et al. 2003). The implementation of a multiplicative shift factor allows for a percentage change of the supply and demand quantities depending on the specific impacts to be analysed with the model. Supply shift factors are implemented in the supply function while demand shift factors are implemented in food, feed and energy demand functions of the different commodities in each of the model regions. A more detailed description of the model and its specification can be found in von Witzke et al. (2008).

The model has been expanded to enable a more detailed regional analysis of the impacts of energy prices and biofuel production on crop markets. The model now explicitly covers wheat, corn, oilseeds, other grains and sugar markets of the EU, France, Germany, USA, Canada, Brazil, Australia, China, CIS and a residual Rest-of-the-World region. The base period of our analysis is 2004/08 to reduce the impacts of the price peaks in 2007/2008. Prices are now projected to 2016/18 rather than 2013/15 and 2015/17 in previous analyses. New assumptions concerning bioenergy demand have been derived based on data from the OECD-FAO Agricultural Outlook 2009 – 2018 (OECD and FAO 2009) and FAPRI 2009 US and World Agricultural Outlook Database (FAPRI, 2009). The price of energy is no longer assumed to remain constant over the entire period of analysis. Rather it has been assumed that the price goes up by 55 percent (which reflects an oil price increase from US$ 45 per barrel in 2005 and 2009 to US$ 70 per barrel in 2016/18, OECD and FAO 2009). The simulations include a new base scenario for 2016/18 which considers population growth, changing food preferences due to per capita income growth, and bioenergy on the demand side and productivity growth and the availability of crop land on the supply side as well as an increase in the energy price by 55.5 percent.

Table 4. Real world market prices of selected agricultural commodities in 2016/18

Market	Prices in base period (US$/mt)	2016/18 (US$/mt) base scenario	Change (in percent)
Wheat	225	304	35
Corn	152	274	80
Oilseeds	374	546	46
Other grains	127	185	46
Sugar	283	415	47

Source: Own calculations.

Table 4 exhibits the world market prices of selected agricultural commodities for the base period and for 2016/18 under the new base scenario which will be referred to as the ‘2016/18 base scenario’. As is evident, capturing the swift growth in bioenergy production and assuming an increase in the price of energy dramatically alters the results. Rather than going up modestly, prices under the new scenario rise by between around 35 percent (wheat) to 80 percent (corn).

For the calculations in table 5 the 2016/18 base scenario was modified to compare the impacts of different energy price and biofuel production levels including a higher energy prices of $ 102 per barrel, as predicted in the OECD 2008 outlook, a constant energy price at the assumed base period level and, in the fourth scenario, a constant level of biofuel production at its respective base period level. As can be seen, with the price of energy held at the base period level, the price increase is significantly lower. On the other hand, a higher energy price results in large price increases. For instance, in the price of wheat would increase only by about 16 percent during the time period analyzed here when the price of energy is held constant at the base period level, while the wheat price would increase by 91 percent under a sharp increase of the energy price.

Assuming a constant biofuel production also lowers the price increase, but to a smaller extent than under a constant energy price. The exception is the corn price due to a high share of bioenergy demand. This confirms that biofuel production has an impact on rising market prices, but it in particular demonstrates that the price of energy will be a major determinant of the price of food in the decades to come.

Table 5. Price changes under alternative scenarios (in percent)

Market	Prices in base period (US$/mt)	2016/18 base scenario	2016/18 with high energy price	2016/18 with base period energy price	2016/18 with base period biofuel production
Wheat	225	35	91	16	27
Corn	152	80	163	52	40
Oilseeds	374	46	97	28	32
Other grain	127	46	85	31	32
Sugar	283	47	98	27	28

Source: Own calculations.

Crop production in selected key countries and regions in 2016/18

It is now interesting to explore changes in supply and trade under the projected market situations for these crops in the selected countries and regions in 2016/18. First, we look at changes in production starting with a more detailed look at production impacts in the EU and USA.

The changes in supply in the EU and USA under the 2016/18 base scenario are shown in table 6. Despite the increase of energy costs in the 2016/18 base scenario crop production generally increases in the EU and the USA. Only sugar production in the EU experiences a small decline.

Higher market prices driven by population growth and higher feed demand offset the potential negative production effect of higher energy cost. However, higher oil prices than the assumed US$ 70, would change the results (compare with the discussion below – table 7). Corn and oilseeds acreages are significantly expanded in both regions, increasing competition with other land uses and potentially increasing the pressure on eco-systems services from semi-natural land.

Table 6. Changes in Supply between base period and 2016/18

EU			
Market	**Base period (k tons)**	**2016/18 (k tons) base scenario**	**Change (in percent)**
Wheat	134676	140324	4.19
Corn	57966	72049	24.29
Oilseeds	27634	39631	43.41
Other grains	149955	169191	12.83
Sugar	18535	18091	-2.39
USA			
Wheat	53400	53745	0.65
Corn	294000	382077	29.96
Oilseeds	97103	121835	25.47
Other grains	314843	371565	18.02
Sugar	7174	9351	30.35

Source: Own calculations

Table 7a. Changes in Supply under Alternative Scenarios in Europe (in percent)

Market	2016/18 base scenario	2016/18 with high energy price	2016/18 with base period energy price	2016/18 with base period biofuel production
EU				
Wheat	4.19	-3,16	7.70	4.22
Corn	24.29	17,00	27.31	9.07
Oilseeds	43.41	40,82	43.23	35.35
Other grains	12.83	6,49	13.82	10.31
Sugar	-2.39	-16,61	5.34	-4.06
Germany				
Wheat	2.78	-5.53	6.76	3.17
Corn	26.20	13.39	31.74	7.80
Oilseeds	46.52	46.9	45.00	37.45
Other grains	13.01	6.11	14.22	9.59
Sugar	-2.24	-16.29	5.41	-3.93
France				
Wheat	7.13	1.79	9.66	6.40
Corn	19.55	9.63	23.89	7.09
Oilseeds	46.08	45.95	44.78	37.12
Other grains	8.49	0.01	10.63	8.10
Sugar	-2.16	-16.27	5.51	-3.89

Source: Own calculations

Higher costs of energy use in crop production leads to a decline in the supply of wheat and sugar in the EU as a whole as well as in Germany (table 7a). Wheat production still increases in France although only by less than 2 percent. The growth in corn and oilseed supply reflects substitution in production. Corn and oilseed acreages are expanded at the expense of other crops such as wheat and sugar. The importance of the energy price is also evident from the production increase on the EU sugar markets under low oil price of US$ 45 per barrel. On the other hand, the important role of biofuel production is particular evident for the corn and, to a lesser extent, oilseeds market. Without an increase in biofuel production the increase in corn production would decline from 26 percent to 8 percent in Germany and 24 percent to 9 percent in the EU as a whole. This effect is mainly caused by a substantially lower market price for corn. The impact on the oilseeds market is less pronounced, as favourable relative prices partly offset the impact of the lower bioenergy demand at base period level.

Similarly to European crop production, higher energy costs result in a decline in wheat production in the USA and reduce production increases on other crop markets (table 7b). In addition, Canadian oilseeds production decreases, as increased oilseeds demand is satisfied by main oilseeds regions such as the USA and Brazil. A low energy price at base period level generally increases crop production in both regions. The impact of different energy costs is especially reflected in the production changes on the Canadian oilseeds and sugar markets. Changes in oilseeds production vary from -3 percent to +25 percent depending on the assumed energy price. In the US constant bioenergy demand at the base period level leads to smaller production increase on corn, sugar and oilseeds markets, reflecting their use as feedstock for biofuel production and to small substitution effects from corn, oilseeds and sugar production to wheat and other grains production, in comparison to the 2016/18 base period.

Table 7b. Changes in Supply under Alternative Scenarios in North America (in percent)

Market	2016/18 base scenario	2016/18 with high energy price	2016/18 with base period energy price	2016/18 with base period biofuel production
USA				
Wheat	0.65	-7,71	4.57	4.25
Corn	29.96	22,51	33.95	17.14
Oilseeds	25.47	23,70	26.53	22.53
Other grains	18.02	14,44	20.07	20.31
Sugar	30.35	21,98	33.50	22.23
Canada				
Wheat	4.15	-4,29	8.00	4.02
Corn	21.73	11,17	27.33	13.27
Oilseeds	15.95	-2,85	25.38	12.67
Other grains	24.37	19,67	26.76	20.62
Sugar	22.23	9,22	27.95	17.42

Source: Own calculations

Higher energy costs generally reduce expected production increases in 2016/18. This impact is particularly evident on the other grains markets in Brazil and Australia, the sugar market in China, and the corn in CIS (table 7c). The exception is the oilseeds production in Australia, where the production increase further rises from 43 percent 51 percent due to favourable changes in relative prices compared to other crops. Lower energy cost at the base period level change the production impacts on Australian corn from +26 percent with a high oil price to +41 percent and from +13 percent to +29 percent on the corn market in CIS.

Table 7c. Changes in Supply under Alternative Scenarios in other regions (in percent)

Market	2016/18 base scenario	2016/18 with high energy price	2016/18 with base period energy price	2016/18 with base period biofuel production
Brazil				
Wheat	7.17	-0,66	11.24	7.27
Corn	38.62	35,08	40.83	23.93
Oilseeds	28.63	24,36	30.55	24.62
Other grains	6.92	-5,27	13.12	9.68
Sugar	32.40	29,04	33.32	23.74
China				
Wheat	8.48	0,67	12.36	7.15
Corn	28.87	23,87	31.78	16.77
Oilseeds	23,75	20,66	25.19	19.05
Other grains	16,92	12,18	19.38	15.81
Sugar	22,23	9,22	27.95	17.42
Australia				
Wheat	13,24	9,92	14.36	13.07
Corn	35,63	26,41	40.57	18.52
Oilseeds	42,86	50,85	39.96	33.76
Other grains	11,21	-2,76	18.08	13.03
Sugar	31,93	25,71	34.29	23.40
CIS				
Wheat	17,32	11,41	20.47	15.85
Corn	23,65	13,25	29.17	13.55
Oilseeds	36,71	35,66	37.27	31.35
Other grains	22,65	20,74	23.75	18.82
Sugar	23,35	12,90	27.95	18.50

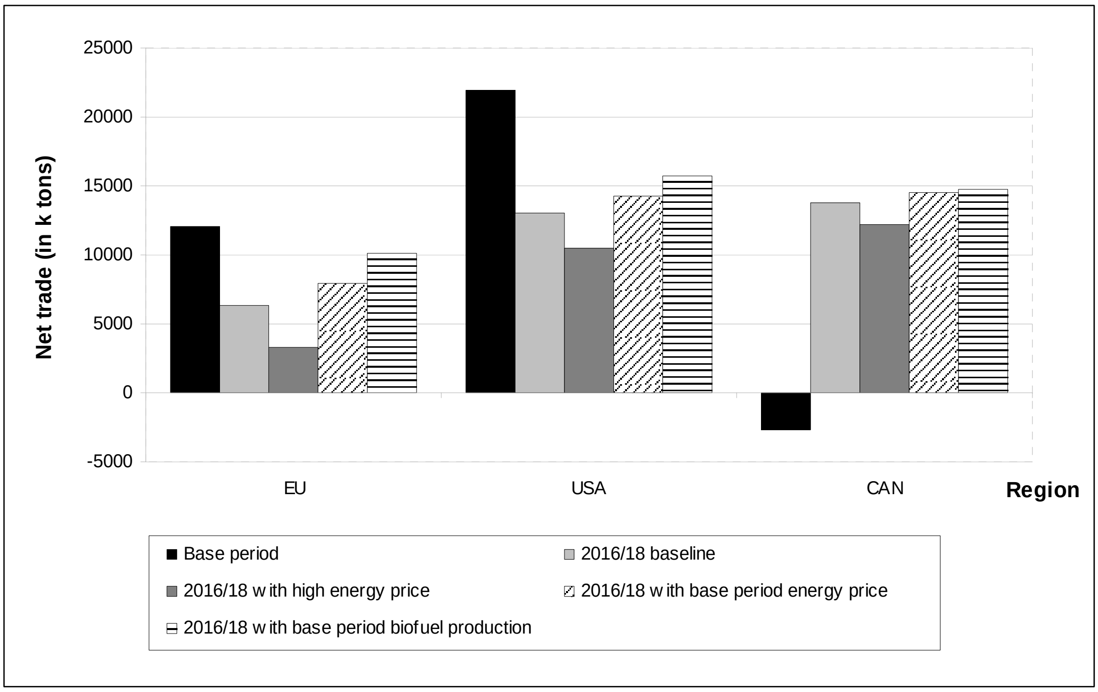
Source: Own calculations

Constant bioenergy demand at base period level reduces expected increases in corn and sugar production in Brazil from 39 percent to 24 percent and 32 percent to 24 percent, respectively. The projected increase in corn production in China decreases from 29 percent to 17 percent, while corn production in Australia increases only by 19 percent instead of 36 percent. In addition, the increase in Australian oilseeds production is reduced from 43 percent to 34 percent.

Overall, the 2016/18 baseline projection shows an increase in total world production from 10 percent for wheat to 30 percent for oilseeds and are in line with recent OECD projections of production increase by 10 - 40 percent on agricultural markets until 2018 (OECD-FAO 2009).. Variations in energy cost have the biggest impact on sugar production in the EU, corn production in North America, other grains production in Brazil, sugar production in China, other grains production in Australia and corn production in CIS. Increasing bioenergy demand has the biggest impact on corn production followed by sugar and oilseeds production.

Trade impacts in selected key countries and regions in 2016/18

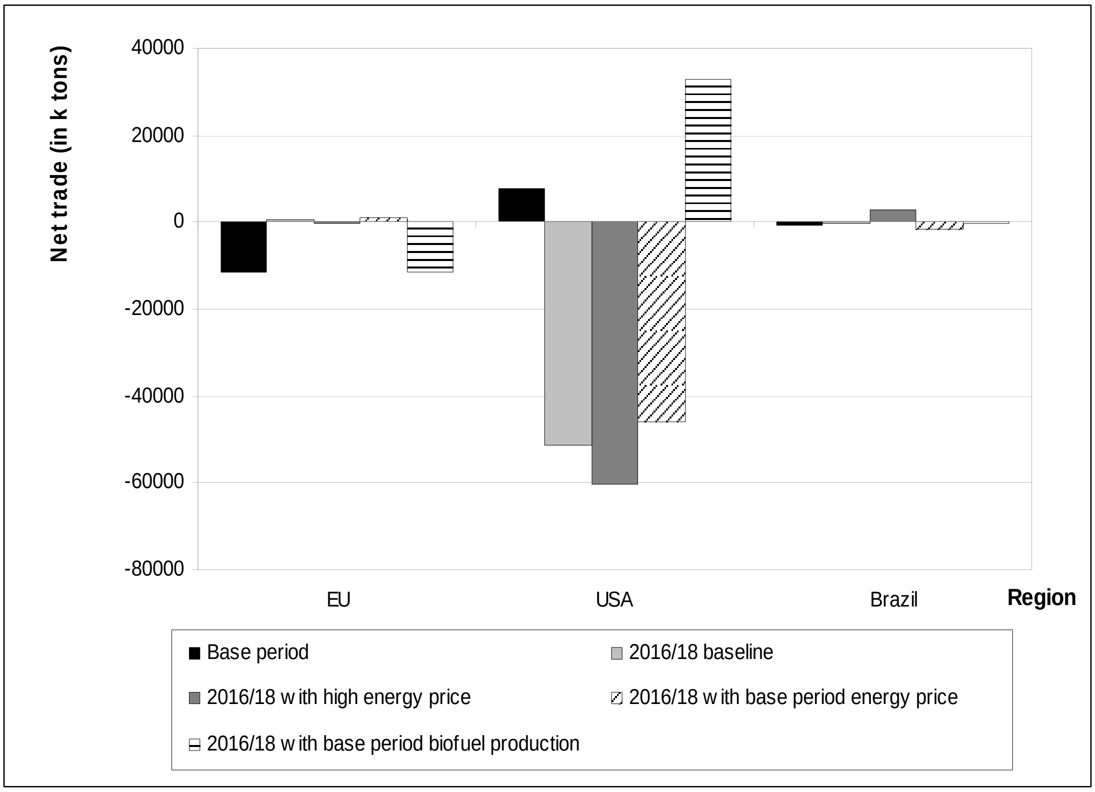
Generally, comparing demand and supply changes, the results show that development of supply lags behind the growth in demand on most crop markets. Corn and sugar are the exception in this regard. The discussion of trade impacts of increasing energy prices and biofuel production focuses in this paper on examples of selected regional wheat, corn and oilseeds markets. Figure 3 compares the net trade position on the wheat market.



Source: Own calculations

Figure 3. Net trade position on the wheat market under alternative scenarios

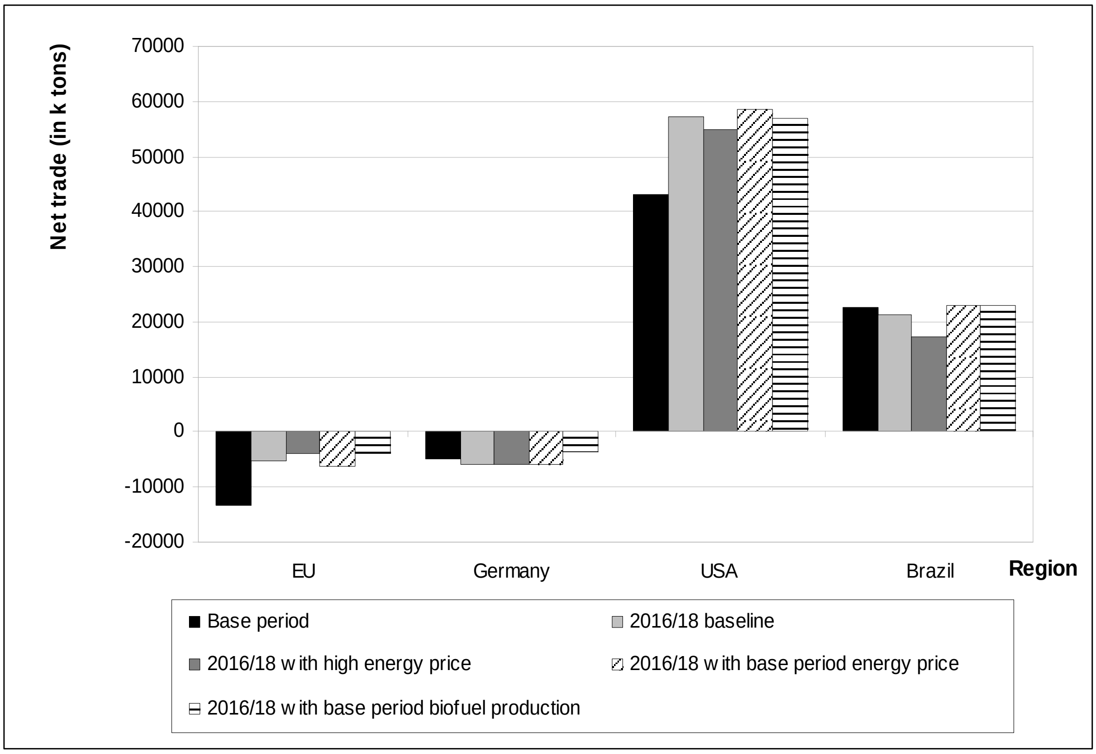
The projection of the 2016/18 baseline shows that supply lags behind the growth of demand on the EU wheat market (figure 3). The decline in net trade further expands with higher energy costs. Without the increase in biofuel production, the decline in net trade is substantially smaller and a comparison with the scenario without the increase in energy prices suggests a stronger impact of biofuel production on net trade on the EU wheat market. However, the outcome of this comparison strongly depends on the level of the implemented oil price and biofuel production in the 2016/18 baseline. The changes in net trade on the US wheat market are similar, although at larger absolute level. Net trade of Canadian wheat benefits from higher market prices and the Canadian wheat market turns from a net-importing into a net-exporting market.



Source: Own calculations

Figure 4. Net trade position on the corn market under alternative scenarios

Figure 4 shows the dominant impact of increasing biofuel production on the US corn market. The US corn market becomes a net-importing market in all three scenarios which assume an increase in biofuel production, with only small variations depending on the level of the energy price. Simulating the 2016/18 projection without an increase in biofuel production substantially increases net trade on the US corn market. In fact, higher energy costs have a small positive impact on net trade on the Brazilian corn market reflecting a competitive advantage of corn producers in Brazil.



Source: Own calculations

Figure 5. Net trade position on the oilseeds market under alternative scenarios

The increase in biofuel production in the 2016/18 projections is the main determinant for changes in net trade on the German oilseeds market, reflecting that Germany is the leading biodiesel producer in the EU. The increase in biofuel production increases net imports independently from the level of energy prices (figure 5). Without an increase in biofuel production net imports are reduced. At EU level, however, the impact of increasing biofuel production is less important. Higher market price driven by higher oil prices reduce oilseeds feed demand in the EU and thus reduce net-imports. Net trade on the US oilseeds market benefits from higher market prices and higher food and feed demand on the Chinese oilseeds market. A higher market price in the 2016/18 baseline projection leads to bigger production increases which balances additional bioenergy demand in comparison to the scenario without an increase in biofuel production and leads to a similar net trade level. Higher energy prices reduce net exports of Brazilian oilseeds. Without any increase in energy prices in comparison to the base period increased production due to higher market prices balances higher food, feed and bioenergy demand and net exports remain at a similar level as in the base period. A similar situation occurs without an increase in biofuel production.

Overall, from an EU and US perspective, the 2016/18 baseline projection has negative trade impacts on the corn and wheat markets in the US and the wheat market in the EU. On the other hand, net exports improve on the oilseeds and other grains markets in the US (as well as a reduction of net imports on the US sugar market) and net exports rise on the EU corn, other grains and sugar markets. The impacts and importance of energy prices and biofuel production for agricultural trade varies between commodities and regions. Energy prices are more important for net trade on corn and oilseeds markets in Brazil and the wheat market in Canada. Biofuel production is the main determinant of changes in net trade on the US corn market as well as a major driver of net trade on the German oilseeds market and the Brazlian sugar market. Substantial increases in net imports on the corn, oilseeds, other grains and sugar markets increase provide new export opportunities for main exporting regions such as the US (oilseeds) and CIS (other grains).

Conclusions

In this paper we have analysed the determinants of the global demand for and supply of food and their impacts on international agricultural market prices, production and trade in the EU, USA and other key agricultural trade regions. In the decades ahead, global food demand is likely to outstrip the growth in supply. As a consequence, the price of food can be expected to be higher in the future than it has been in the past. The demand growth will occur almost exclusively in today's developing and newly industrializing countries. This will significantly change the international agricultural trade flows (e. g. von Witzke et al. 2008; Bruinsma 2003). The poor countries of the world who once were net food exporters have now become net food importers and the food gap of the poor countries is expected to quintuple in the first three decades of the 21st century (Bruinsma 2003). This together with increasing prices of agricultural commodities and food is a cause for concern for both world food security and agricultural greenhouse gas emissions.

The results of our analysis suggest that the price of important agricultural commodities will rise from 35 percent to 80 percent until 2016/18. The single most important determinant of price increases turned out to be the price of energy. Price increases in the order of magnitude suggested by the results of this analysis have the potential to result in grave consequences for the world's poor who live on the equivalent of one US$ a day or less.

Overall, the 2016/18 baseline projection shows an increase in total world production from 10 percent for wheat to 30 percent for oilseeds. Variations in energy cost have the biggest impact on sugar production in the EU, corn production in North America, other grains production in

Brazil, sugar production in China, other grains production in Australia and corn production in CIS. Increasing bioenergy demand has generally the biggest impact on corn production followed by sugar and oilseeds production. Trade impacts of the 2016/18 baseline projection are mixed for the EU and US. Positive trade impacts can be identified on the oilseeds, other grain and sugar markets in both regions as well as on the EU corn market. Biofuel production is the main determinant of changes in net trade on the US corn market as well as a major driver of net trade on the German oilseeds market and the Brazlian sugar market. However, the impacts and importance of energy prices and biofuel production for agricultural trade varies between commodities and regions. Substantial increases in net imports on the corn, oilseeds, other grains and sugar markets provide new export opportunities for main exporting regions such as the US (oilseeds) and CIS (other grains).

The projected increase in global crop production shows that current productivity growth rates are not sufficient to satisfy food demand in 2018. Given that natural resources for agricultural production, including land, water and fossil energy, are limited, higher productivity growth in world agriculture is the key to the production growth necessary to meet the growing needs of the world's population. Productivity growth is also crucial for the reduction of agricultural greenhouse gas emissions resulting from the conversion of forests and pasture into cropland.

The realisation of the projected large production increases on the EU corn and oilseeds markets strongly depend on the availability of additional agricultural land for crop production. In the absence of significant substitution effects in agricultural production it is unlikely that large amounts of additional land would be available for crop production in the EU. In fact, growing competition between agricultural land use and nature conservation and housing demand could further reduce the amount of land available for agricultural production in the EU. In addition, demand outgrowths supply on other crop markets such as wheat, reducing EU net exports to the world market. The results of this study already project an increase in crop production in the Rest-of-the-World region, which includes developing countries, from 15 percent (wheat) to 36 percent (oilseeds). Further shifts of agricultural production from the EU to other regions could increase the pressure on food production in developing countries.

Many developing countries have a significant agricultural production potential but are far from realizing it. Making productive technologies such as modern seed varieties, synthetic fertilizer and crop protection available for farmers in developing countries has the potential to reap benefits quickly, in particular if they are paralleled by agricultural extension education services as well as a sound macroeconomic and monetary policy and a liberal agricultural trade policy. These investments will only be undertaken if the economic, political, institutional and legal environment is such that innovation in agriculture is encouraged. Increasing agricultural research and education investments now is crucial for achieving productivity growth in the future. Research suggests that it may take between 25 and 50 years for such investments to fully pay off for society (Pardey 2009).

However, the modelling results strongly depend on assumed increases in oil prices and biofuel production. To highlight the impacts of variations in oil prices different scenarios with different energy price levels have been analysed, which confirm the important role of oil prices for agricultural production and trade. Assumptions in relation to future biofuel production strongly depend on future development of biofuel policies. Current biofuel production is largely driven by policy mandates and targets as well as other specific support measures such as tax cuts and changes in biofuel policies will thus strongly affect the demand for agricultural crops for bioenergy production.

The implemented shift effects for increasing biofuel production in the EU are smaller than in previous analyses reflecting a more conservative outlook for biofuel production Germany. Recent changes in biofuel policies in the EU, e.g. changes in tax cuts and reductions in biofuel quotas in Germany, could also indicate a rethinking of policy support strategies for biofuel production (BMU 2008, Schwarz 2009). Future medium to long term biofuel scenarios might change considerably depending on the breakthrough of different technologies and the support for different types of bioenergy production pathways.

References

Alston, J.M., C. Chan-Kang., M.C. Marra, P.G. Pardey and P.J. Wyatt. 2000. "A Meta Analysis of Rates of Return to Agricultural R&D: Ex Pede Herculeum?" Washington, DC: IFPRI, 2000.

Banse, M, Meijl, H.v. and Woltjer, G. 2008/ Consequences of EU biofuel policies on agricultural production and land use. *Choices*, 23 (3), 22 - 27

Bundesministerium fuer Umwelt, Naturschutz und Reaktorsicherheit (BMU) 2008. Weiterentwicklung der Strategie zur Bioenergie. Berlin; April 2008.

Bruinsma, J. ed. 2003. "World Agriculture towards 2015/30". London: Earthscan, 2003.

Cagatay, S. C. Saunders and A. Wreford. 2003. Lincoln Trade and Environment Model (LTEM): Linking trade and environment, Agribusiness and Economics Research Unit, Research Papers, No: 263, Commerce Division, Lincoln University.

CRB (Commodity Research Bureau). 2009. Continuous Commodity Index (CCI) and Reuters CRB-Indexes. (www.crbtrader.com/crbindex/ of 22/02/2009).

De Gorter, H. 2008. "Explaining Agricultural Commodity Price Increases: The Role of Biofuel Policies". Corvalis: Oregon State University, 2008. http://arec.oregonstate.edu/faculty2/PerryFiles/deGorter%20paper.pdf (last accessed 10/06/2009)

Doane (Doane Advisory Services). 2008. "An Analysis of the Relationship between Energy Prices and Crop Production Costs". St. Louis, MO: Doane, 2008.

EC (European Commission). 2008. MAP Newsletter, October 2008. Brussels: EC.

FAO (Food and Agriculture Organization). 2007. Spotlight: Coping with water scarcity. April 2007.

FAO (Food and Agriculture Organization). 2008a. FAOSTAT. Rome: FAO, 2008a.

FAO (Food and Agriculture Organization). 2008b. World Agriculture Towards 2030/2050. Rome: FAO, 2008b.

FAO (Food and Agriculture Organization). 2008c. The State of Food and Agriculture, 2009. Rome: FAO, 2008c.

FAPRI 2009. FAPRI 2009 US and World Agricultural Outlook Database. Iowa: FAPRI, 2009. http://www.fapri.iastate.edu/tools/outlook.aspx (last accessed 02 November 2009)

Hayes, D.J., Babcock, B.A., Fabiosa, J.F., Tokgoz, S., Elobeid, A., Yu, T.H., Dong, F., Hart, C.E., Chavez, E., Pan, S., Carriquiry, M. and Dumortier, J. 2009. Biofuels: Potential Production Capacity, Effects on Grain and Livestock Sectors, and Implications for Food Prices and Consumers. Working paper 09-WP-487, Centre for Agriculture and Rural Development, Iowa State University. Published online: http://www.card.iastate.edu/ (last accessed 02 November 2009)

Hofreither, M.F. 2005. "Von Malthus zum Treibhauseffekt – Landwirtschaft und Welternährung als Prognoseproblem". Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie 10 (2005):1-32.

IFPRI (International Agricultural Food Policy Research Institute). 2005. New Risks and Opportunities for Food Security: Scenario Analyses for 2015 and 2050. Washington, DC: IFPRI, 2005.

Jechlitschka, K., D. Kirscke and G. Schwarz. 2007. Microeconomics using Ecxel. Milton Park: Routledge.

Kazlauskiene, N. and W. Meyers. 2003. Implications of EU Accession for Trade Regimes and Trade Flows of CEECs. Paper presented at the International Conference "Agricultural Policy Reform and the WTO: Where are we Heading?". Capri, June 23-26, 2003

Kazlauskiene, N. and W. Meyers. 1993. Modelling Agricultural Markets for Policy and Trade Analysis in Lithuania. Baltic Report No. 93-BR13. Vilnius: Lithuanian Institute of Agrarian Economics.

Miller, D., Schwarz, G., Sutherland, L-A., Morrice, J., Aspinall, R., Barnes, A., Blackstock, K., Buchan, K., Donnelly, D., Hawes, C., McCrum, G., McKenzie, B., Matthews, K., Miller, D., Renwick, A., Smith, M., Squire, G. and Toma, L. 2009/ Changing rural land use in Scotland – Analysis of drivers and decision-making. Report to the Scottish Government.

OECD (Organization for Economic Cooperation and Development). 2006. Agricultural Outlook 2006-2015. Paris: OECD, 2006.

OECD (Organization for Economic Cooperation and Development). 2008. Policy Briefs, August 2008.

OECD (Organization for Economic Cooperation and Development) and FAO (Food and Agriculture Organization). 2008. OECD-FAO Agricultural Outlook 2008-2017. Paris: OECD, 2008

OECD (Organization for Economic Cooperation and Development) and FAO (Food and Agriculture Organization). 2007. OECD-FAO Agricultural Outlook 2007-2016. Paris: OECD, 2007.

Pardey, P.G. 2009. Determinants of Agricultural Innovation and Productivity Growth. Paper presented at the meeting of the Humboldt Forum for Food and Agriculture, Davos, Switzerland, February 1-3, 2009.

Pardey, P. G. , N. Beintema, S. Dehmer and S. Wood. 2006. Agricultural Research: A Global Divide? Washington, DC: IFPRI, 2006.

Pardey, P.G., J. James, J. Alston, S. Wood, B. Koo, E. Binenbaum, T. Hurley, P. Glewwe, J. Mayer, R. Jones, H. De Groote, F. Kanampiu, J. Mc Dermott, C. Jost and J. Mariner. 2007. Science, Technology and Skills. University of Minnesota, St. Paul, MN: Science and Technology Practice and Policy Center, 2007.

Roningen, V.; F. Sullivan and P. Dixit. 1991: Documentation of the Static World Policy Simulation (SWOPSIM) Modeling Framework. U. S. Department of Agriculture, ERS Staff Report No. AGES 9151. Washington D. C.

Roningen, V. 1986. A static world policy simulation (SWOPSIM) modeling framework (Staff Report AGES860625). Washington, DC: USDA, Economic Research Service.

Runge, C.F., B. Senauer, P.G. Pardey, and M.W. Rosegrant. 2003. Ending Hunger in our Lifetime. Baltimore: Johns Hopkins University Press, 2003.

Schwarz, G. 2009. Biofuel targets and land use change in Germany: A discussion of the future potential of biofuel production and their land use implications. Paper presented at the conference XXIII European Society for Rural Sociology congress, Vaasa, Finland 17-21 August 2009.

Schwarz, G., von Witzke, H. and Noleppa, S. 2009. Determinants of International Agricultural Market Prices: The roles of energy prices and biofuel production. Paper presented at the International Agricultural Trade Research Consortium (IATRC) Symposium "Confronting Food Price Inflation: Implications for Agricultural Trade and Policies, Seattle, June 22 – 23, 2009.

U. S. Census Bureau. 2008. Total Midyear Population for the World: 1950-2050. Washington, DC: U. S. Census Bureau, 2008.

USDA (U. S. Department of Agriculture). 2007. USDA Agricultural Projections to 2016. Washington, DC: USDA, 2007.

U. S. Energy Information Administration. 2009. Annual Energy Outlook, Washington, DC: U. S. Energy Information Administration, 2009.

Tokgoz, S. 2009. The Impact of Energy Markets on the EU Agricultural Sector. Working paper 09-WP-485, Centre for Agriculture and Rural Development, Iowa State University. Published online: http://www.card.iastate.edu/ (last accessed 02 November 2009)

Trostle, R. 2008 Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices. Report WRS-0801, Washington, DC: Economic Research Service/USDA, 2008.

Tyers, R. and K. Anderson. 1992. Disarray in World Food Markets: A Quantitative Assessment. Cambridge: Cambridge University Press, 1992.

Von Witzke, H., K. Jechlitschka, D. Kirschke, H. Lotze-Campen and S. Noleppa, 2004. Social Rate of Return to Plant Breeding Research in Germany. German Journal of Agricultural Economics 53 (2004): 206-210.

Von Witzke, H. and S. Noleppa. 2007. Methan und Lachgas - die vergessenen Klimagase, Berlin: WWF, 2007.

Von Witzke, H. 2007. Landwirtschaft in der *Ökologischen* Marktwirtschaft: Sicherung der Welternährung vs. Klimaschutz und Bioenergie. Wirtschafts- und Sozialwissenschaften an der Humboldt Universität zu Berlin, Working Paper 80/2007, Berlin, 2007.

Von Witzke, H. 2008. Teure Lebensmittel: Strohfeuer oder neuer Megatrend auf den Weltagrarmärkten. Berlin: Humboldt Universität zu Berlin, 2008.

Von Witzke, H., S. Noleppa and G. Schwarz. 2008. Global Agricultural Market Trends and their Impacts on European Union Agriculture. Institut für Wirtschafts- und

Sozialwissenschaften der Humboldt Universität zu Berlin, Working Paper 84/2008, Berlin, 2008.