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Determinants of International Agricultural Market Prices and the European Union: The Roles of Energy Prices and Biofuel Production

by

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Abstract

In this article we discuss the determinants of international agricultural market prices 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 and that the EU will become a net importer of grains, as it was the case before the late 1970s. EU net imports of oilseeds will increase by 135%. Significant increases in productivity would be required in order to maintain the present level of self-sufficiency on crop markets in the EU. Moreover, we quantify the impact of changes in the price of energy and biofuel production on world prices. 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 (2003/05 – 2015/17) the price of wheat can be expected to increase by about twenty percent, provided that the price of oil remains at the 2003/05 level. With a price increase to $100 per barrel towards 2015/17 the price of wheat will go up by about 70 percent.

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). Those studies emphasise the critical role of levels of energy prices and biofuel production for future agricultural market prices. 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 and to what extent will potential future developments of energy prices and biofuel production contribute to higher prices.

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 analyze the roles of the price of energy as well as the extent of bioenergy production for international markets. Then we will present the results of a projection of world market prices of selected agricultural commodities for 2015/17 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 for both world food security and policies for the sustained alleviation of global undernutrition.

Determinants of global food supply and demand growth

In the first half of the 21st 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).

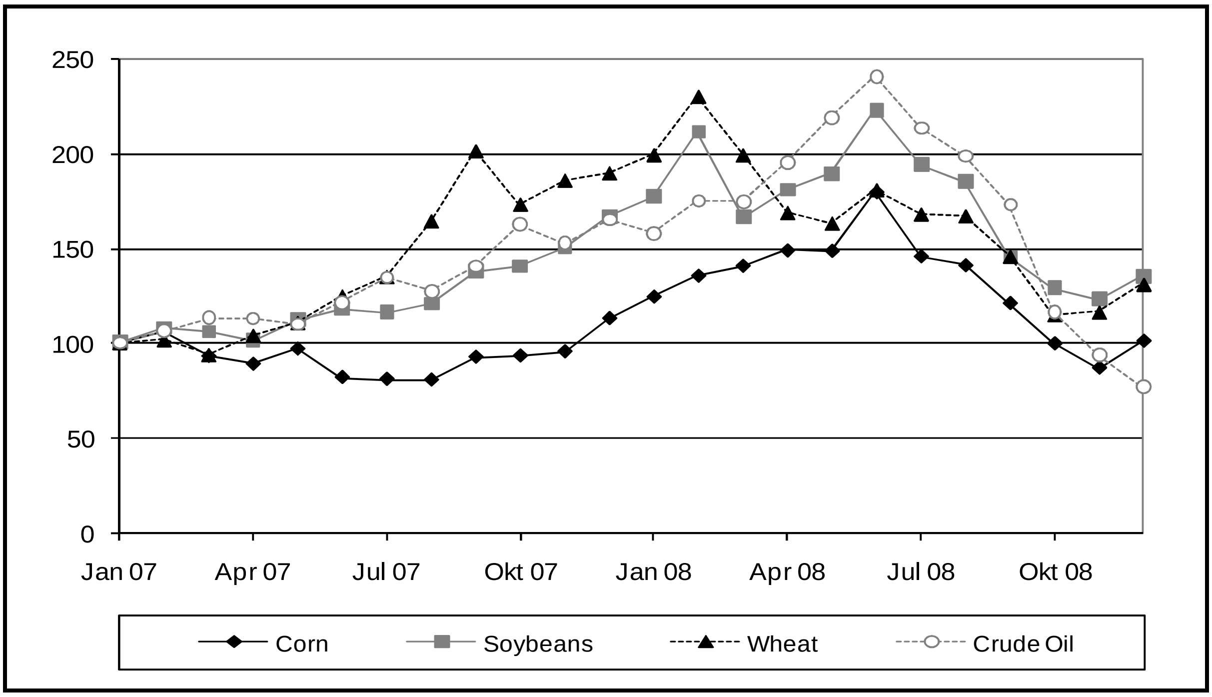
However, a sufficiently high productivity growth will be difficult to achieve. Since the times of the Green Revolution agricultural productivity growth has been declining. From the 1960s to the 1980s annual productivity growth in world agriculture averaged around four percent. This number is now down 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

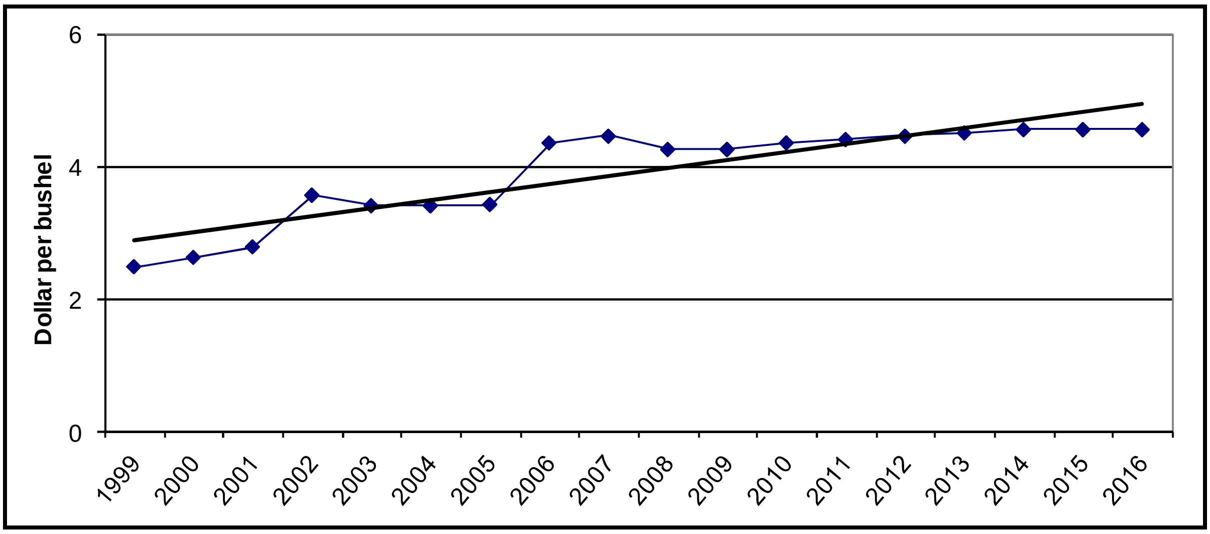
Energy markets have changed significantly in the past few years. Despite the recent decline, the expectation is for generally higher energy prices in the future (U. S. Energy Information Administration 2009). Higher energy prices, thus, result in significantly higher cost of production which acts to 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 and to what extent will potential future developments of energy prices and biofuel production contribute to higher prices. The following analysis presents the projection of world market prices of selected agricultural commodities for 2015/17 and the impacts on key crop markets in the EU-27.

International Agricultural Market Prices in 2015/17

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.

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.

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).

In the following, we will present the result of an analysis which is based on the model developed in our earlier study (von Witzke et al. 2008). 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 19986; 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).

As before, the base period of our analysis is 2003/05. However, prices are now projected to 2015/17 rather than 2013/15. Moreover, the sugar market is now included in the analysis. New assumptions concerning bioenergy demand have been derived based on data from the OECD-FAO Agricultural Outlook 2008 – 2017 (OECD and FAO 2008). 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 from US$ 45 per barrel in 2003/05 to UD$ 102 per barrel in 2015/17 (EC 2008).

Table 4 exhibits the world market prices of selected agricultural commodities for the base period and for 2015/17 under the new base scenario which will be referred to as the '2015/17 base scenario'. As is evident, capturing the swift growth in bioenergy production and assuming a significant increase in the price of energy dramatically alters the results. Rather than going up modestly, prices under the new scenario rise by between around 50 to 110 percent.

Table 4. Real world market prices of selected agricultural commodities, 2003/2005 – 2015/17

Market	2003/05 (US$/mt)	2015/17 (US$/mt) base scenario	Change (in percent)
Wheat	158	272	72
Corn	106	219	107
Other grains	91	137	51
Oilseeds	288	492	71
Sugar	250	493	97

Source: Own calculations.

For the calculations in table 5 the 2015/17 base scenario was modified to include all determinants of the supply of and demand for the selected commodities except that either the price of energy or the extent of biofuel production was held constant at their respective 2003/05 levels. As can be seen, with the price of energy held at the 2003/05 level, the price increase is significantly lower. For instance, in the price of wheat would increase only by about 18 percent during the time period analyzed here when the price of energy is held constant at its 2003/05 level.

Assuming a constant biofuel production and an increasing price of energy contributes significantly to the increase in agricultural commodity prices for wheat, other grains and sugar, this clearly demonstrates that the price of energy will be a major determinant of the price of food in the decades to come.

Table 5. Real world market prices under alternative scenarios (US$ per metric ton)

Market	**2003/05**	**2015/17 base scenario**	**2015/17 with 2003/05 energy price**	**2015/17 with 2003/05 biofuel production**
Wheat	158	272	186	237
Corn	106	219	157	158
Other grains	91	137	104	129
Oilseeds	288	492	398	394
Sugar	250	493	326	405

Source: Own calculations.

European Union crop markets in 2015/17

It is now interesting to explore changes in demand, supply and trade under the projected market situations for these crops in the EU in 2015/17. It is evident from table 6 that demand can be expected to increase on most markets reflecting a growing population, demand for animal feeds due to changing food preferences and a rise of demand for bioenergy.

The increase in demand is particularly large for oilseeds. This is the result of a continuing expansion of the acreage planted with biofuel crops to meet an increasing domestic bioenergy demand, while the demand for food and animal feeds decreases on the oilseeds market. Increases in demand for wheat and corn are considerably smaller than on the oilseeds market. Food and feed demand does not increase to a very large extent on both markets. In fact, demand for animal feeds even decreases on the corn market due to an increase in the relative price of corn compared to other feed crops. The increase in total demand for wheat and corn is mainly a result of significant growth in the demand for bioenergy, which reflects both the fairly low demand in the reference period and the considerable growth in demand during the time period analysed here. The sugar market shows a different picture. The total demand for sugar in the EU declines sharply, driven by a fall in non-energy use of sugar. The decrease in sugar demand mainly reflects the increase in the relative price of sugar compared to other crop markets such as wheat and other grains.

Table 6. Changes in Demand (EU-27) between 2003/05 and 2015/17

Market	2003/05 (k tons)	2015/17 (k tons) base scenario	Change (in percent)
Wheat: total demand	**121947**	**127331**	**4.42**
food demand	63133	64066	1.48
feed demand	58213	59824	2.77
energy demand	600	3441	473.50
Corn: total demand	**60155**	**65737**	**9.28**
food demand	12833	14864	15.82
feed demand	47021	46766	-0.54
energy demand	300	4107	1269.00
Oilseeds: total demand	**35351**	**64776**	**83.24**
food demand	7416	6080	-18.02
feed demand	22735	17798	-21.71
energy demand	5200	40897	686.49
Other grains: total demand	**88301**	**102434**	**16.01**
food demand	23474	29372	25.12
feed demand	64594	71299	10.38
energy demand	233	1764	656.00
Sugar: total demand	**18723**	**12310**	**-34.25**
non-energy demand	18707	11958	-36.08
energy demand	16	352	2100.00

Source: Own calculations

The lower prices under the alternative scenario with the price of energy held constant at the 2003/05 level results in bigger demand increases compared to the base scenario 2015/17 (table 7). Wheat demand can be expected to increase by nearly 12 percent while sugar demand only decreases by 14.5 percent. Assuming a constant biofuel production at the 2003/05 level and an increasing price of energy still leads to an increase in wheat and other grains demand reflecting population growth and changes in consumer preferences from the base period 2003/05 until 2015/17. Relative changes in total corn demand are the same in both alternative scenarios. However, with the energy price held constant the increase in demand for corn is caused by higher bioenergy use, while with constant biofuel production the rise in corn demand is caused by an increase in food consumption.

Table 7. Changes in Total Demand (EU-27) under Alternative Scenarios

Market	2015/17 base scenario (in percent)	2015/17 with 2003/05 energy price (in percent)	2015/17 with 2003/05 biofuel production (in percent)
Wheat	4.42	11.81	2.76
Corn	9.28	10.74	10.74
Oilseeds	83.24	89.62	-4.85
Other grains	16.01	17.39	12.06
Sugar	-34.25	-14.51	-27.33

Source: Own calculations

The demand on the oilseeds market is particular sensitive to the implemented assumptions emphasising the importance of future biofuel production levels for the oilseeds market.

Without an increase in biofuel production demand for oilseeds can be expected to decline, also reflecting the minor role of oilseeds in food and feed consumption in the EU compared to other regions.

The changes in European Union supply are shown in table 8. Higher costs of energy use in crop production leads to a decline in the supply of wheat, other grains and sugar. 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 other grains.

Table 8. Changes in Supply (EU-27) between 2003/05 and 2015/17

Market	2003/05 (k tons)	2015/17 (k tons) base scenario	Change (in percent)
Wheat	130215	129524	-0.53
Corn	58488	68948	17.88
Oilseeds	20790	30350	45.98
Other grains	89998	86689	-3.68
Sugar	21060	18083	-14.13

Source: Own calculations

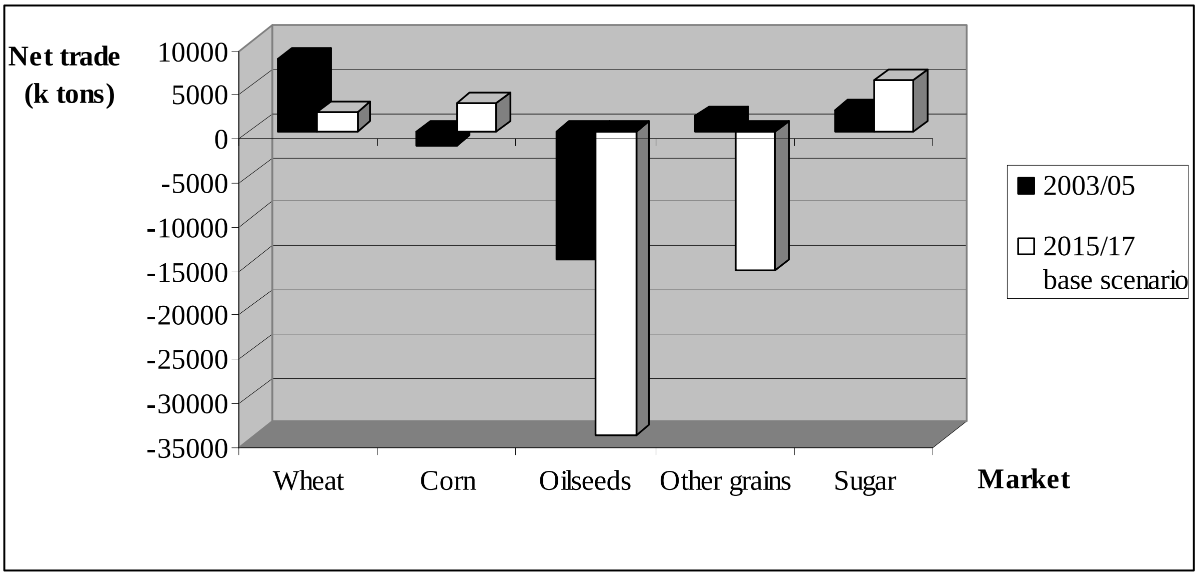
Table 9 confirms the impact of higher energy costs for crop production in the EU. With a constant price of energy at 2003/05 level production on all covered crop markets would increase. On the other hand, the important role of biofuel production is particular evident for the corn and oilseeds market. Without an increase in biofuel production corn production would decline, while the increase in oilseeds production would be considerably smaller.

Table 9. Changes in Supply (EU-27) under Alternative Scenarios

Market	2015/17 base scenario (in percent)	2015/17 with 2003/05 energy price (in percent)	2015/17 with 2003/05 biofuel production (in percent)
Wheat	-0.53	9.34	-4.22
Corn	17.88	32.13	-4.17
Oilseeds	45.98	54.43	22.69
Other grains	-3.68	5.48	-0.32
Sugar	-14.13	7.42	-16.93

Source: Own calculations

However, 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. Figure 3 compares the net trade position in 2003/05 and 2015/17.

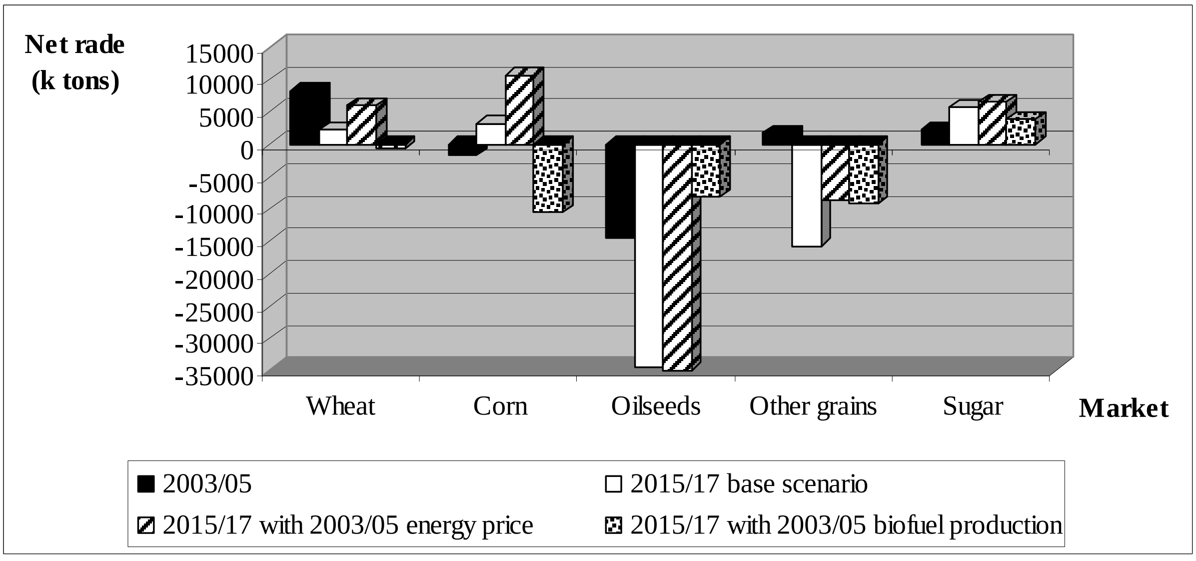


Source: Own calculations

Figure 3. Net trade position (EU-27), 2003/03 and 2015/17

Consistent with the findings for demand and supply changes, the net trade position will deteriorate for wheat, oilseeds and other grains while it will improve for corn and sugar. Net exports on the wheat market decrease by over 70 percent, while net imports of oilseeds increase by 135 percent. The net trade position for other grains changes from a net export to a net import situation. Overall, the European Union will switch from a net exporting to a net importing position for grains (sum of wheat, corn, and other grains).

Adding the alternative scenarios to the analysis, figure 4 highlights increased net imports of oilseeds due to rising biofuel production and the negative impacts of higher energy costs on net trade on wheat and corn markets in the EU.



Source: Own calculations

Figure 4. Net trade position (EU-27) under alternative scenarios

A central reason for the deterioration of the net trade position on the oilseeds market is the significant growth in domestic demand for bioenergy production. Higher costs of energy use –

and to a lesser extent increased domestic demand for bioenergy - cause the change in the net trade position for grains. This suggests that there will be an increased need for imports to balance domestic European Union supply and demand in the future, in particular if land and other inputs are increasingly diverted from domestic food or feed to bioenergy production.

If the European Union wishes to maintain its present level of self-sufficiency in food and feed crops for food security reasons, agricultural land productivity will have to increase. As agricultural land reserves are limited, yields would have to be increased even further. Table 10 provides an estimation of approximate yield increases necessary to maintain the net-trade position of the reference period in 2015/17.

Table 10. Required Yield Increases to Maintain EU-27 Net Trade Position of 2003/05 in 2015/17

Key crop	**Increase (in percent)**
Wheat	13.7
Oilseeds	97.6
Other grains	28.3

Source: Own calculations

In wheat the yield would have to be further increased by nearly 1.4 percent annually compared to the reference period; in other grains it would have to increase by 2.8 percent per annum. In oilseeds the yield increase would have to be an extraordinary 10 percent annually.

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 and agricultural trade in the EU. 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 by between about 50 to 100 percent between 2003/05 and 2015/17. 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.

At the first World Food Summit in 1996 the Food and Agriculture Organization of the United Nations formulated the goal of cutting in half by 2015 the number of malnourished humans living on this planet in 1995. This goal is clearly out of reach. On the contrary, the number of malnourished is growing. Most estimates suggest that the number of malnourished humans was around 920 million before prices started to rise in 2006. The high food prices in 2008 added another 44 million to this number (e. g. World Bank 2008).

Continuing price rises would increase the number of malnourished humans even further. This would not just be a major humanitarian issue. It would also have the potential to trigger widespread violence and significant migration away from food insecure countries with all the attendant social cost. The food riots in poor countries in 2008 and the ethnic tensions in some of these countries most likely would be dwarfed by events triggered by a prolonged period of high food prices.

The results of our analysis also show that the potential of developed countries and regions such as the EU to contribute to food security in developing countries might decline in the future. Rising biofuel production and in particular higher energy costs of crop production can be expected to result in a reduction of crop supply for food and feed uses in the EU. Taking into account key drivers of agricultural markets the results predict that the EU turns into a net importing region of grains. In addition, EU net imports of oilseeds will rise substantially. The increased need for imports to balance domestic European Union supply and demand would further add pressure on world markets and compete with food needs of developing countries. Significant increases in productivity would be required in order to maintain the present level of self-sufficiency on crop markets in the EU.

Given that the world's natural resources for food production, including land, water and fossil energy are limited, 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.

Agricultural productivity growth does not fall from heaven like manna. Rather it is the result of investment in agricultural research and education. 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).

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.

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.

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.

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.

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

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., 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.

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.

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.

World Bank. 2008. Rising Food and Fuel Prices: Addressing the Risks to Future Generations. Washington, DC: World Bank, 2008.