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**Global agricultural market trends  
revisited:  
The roles of energy prices and  
biofuel production**

**WORKING PAPER**



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# **Global agricultural market trends revisited: The roles of energy prices and biofuel production**

**Harald von Witzke, Steffen Noleppa and Gerald Schwarz  
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This paper has benefited greatly from a discussion of an earlier version with the participants of the first Humboldt Forum for Food and Agriculture in Davos, Switzerland in March 2009. Research has been made possible in part by a research grant from BASF SE – The Chemical Company. The first two sections of the paper draw on von Witzke et al. (2008) who provide a detailed discussion of the Agricultural Treadmill and its end.

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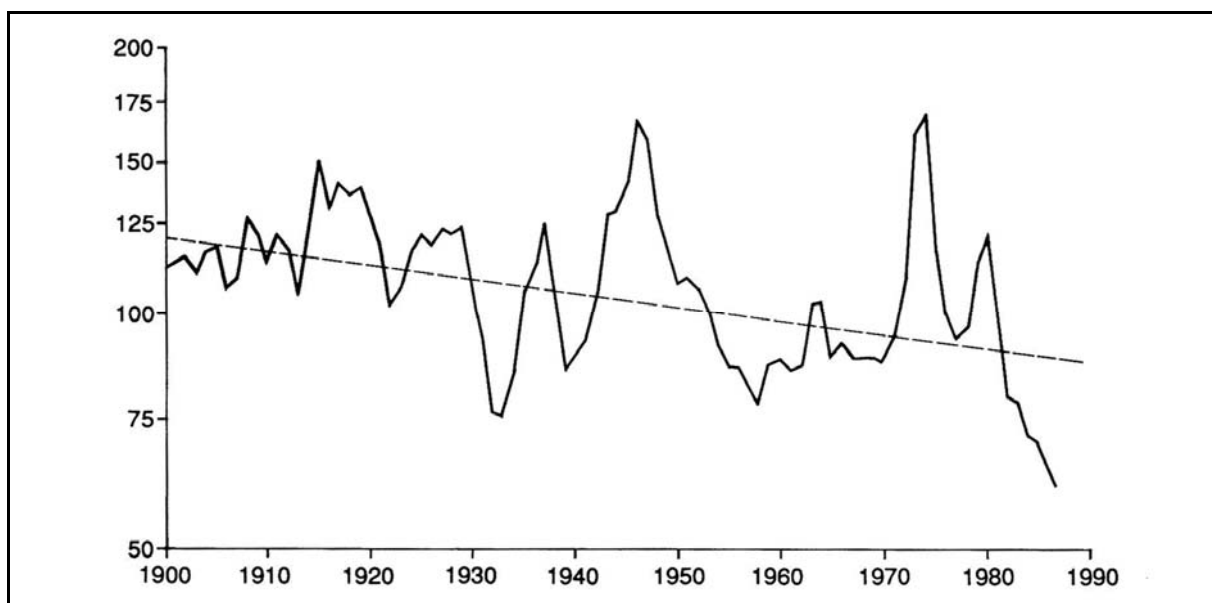
## 1. Introduction: The end of the Agricultural Treadmill

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 20<sup>th</sup> 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 (figure 1) 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.

**Figure 1: The Agricultural Treadmill: Real agricultural commodity prices, 1900-1990\***



\*Index of agricultural market prices, deflated (1977-1979=100).

Source: 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. In the remainder of this paper, we will first argue that the tendency towards higher prices than in the past may be expected to continue for the next few decades. In particular, we will analyze the role 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. 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.

## 2. Determinants of global food supply and demand growth

In the first half of the 21<sup>st</sup> 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). 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 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).

**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 of them 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 per cent 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 per cent of global production growth was the result of productivity growth and only around 20 per cent 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, 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, 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 per cent 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).

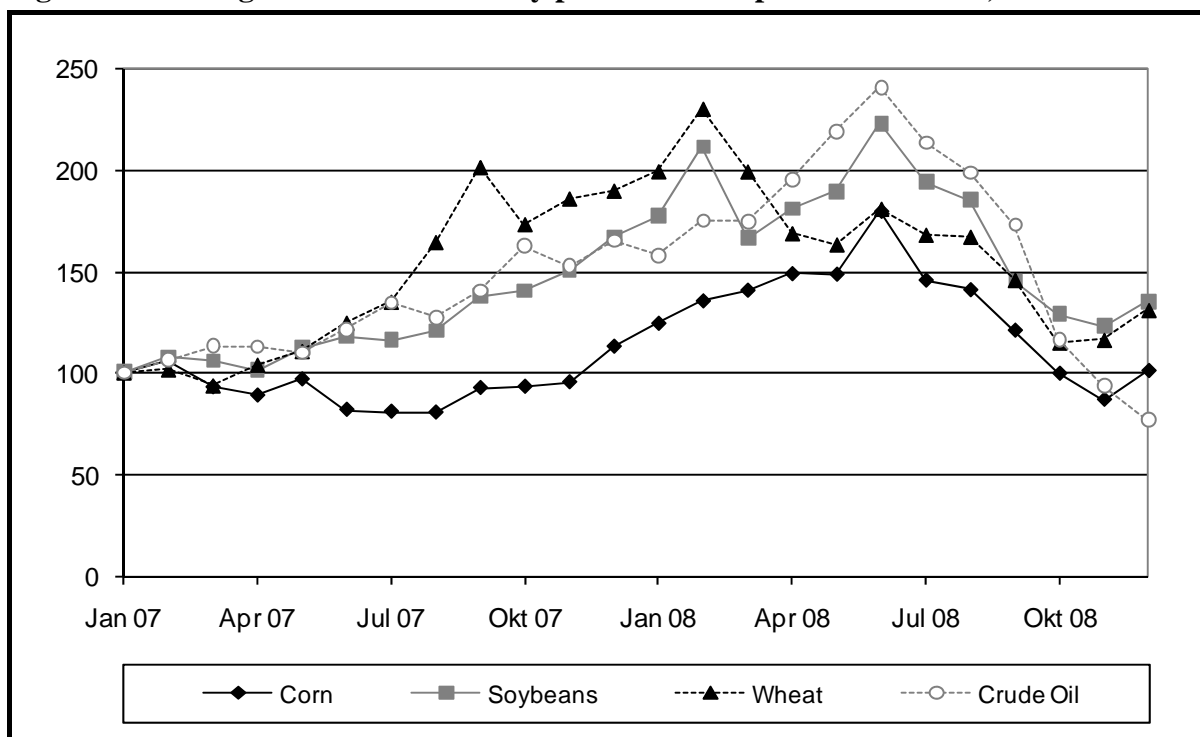
Furthermore, global warming will affect agriculture significantly. On balance, global production is expected to decline, all other things being equal. The tragedy in this regard is that the poorest countries of the world tend to be located in agro-climatic zones which will be most negatively affected 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 per cent (Doane, 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 2.

**Figure 2: Agricultural commodity prices and the price of crude oil, 2007-2008**



Source: CRB (2009).

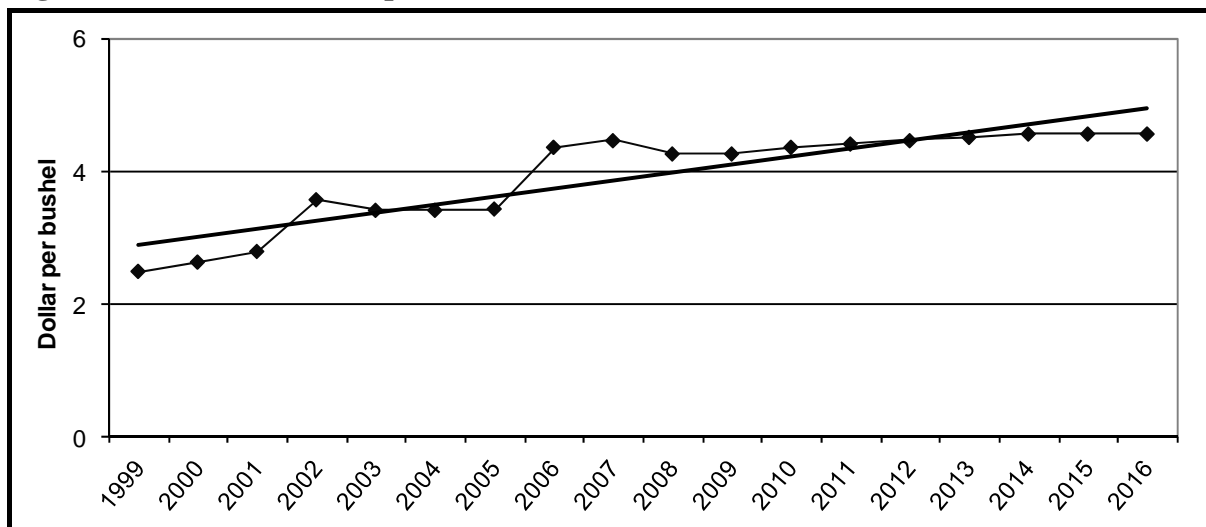
Agricultural commodity and energy prices have become cointegrated for another reason as well and that is the production of biofuels. Increasing energy prices increase production of biofuels. Government programs which aim at increasing biofuel production by means of subsidies, mandates or other instruments 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 bioenergy production may be less pronounced than it is sometimes argued. More than 95 percent of the global bioenergy 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 in 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 question is, to what extent are prices likely to rise?

### 3. International Agricultural Markets 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 3 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.

**Figure 3: The market price of wheat (1999-2016)**



Source: USDA (2007) and own computations.

Von Witzke et al. (2008) have developed a five region multi-market model of international agricultural trade. They analyzed international agricultural markets of selected commodities for the time period 2003/05 to 2013/15. The results of their analyses 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	Per cent 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 the model developed in our earlier study (von Witzke et al., 2008). This is a partial equilibrium model with interconnected markets and regions based on Jechlitschka et al. (2007). In this model each market in each region is characterized by a supply and demand function. Each market is linked with other markets through a set of cross-price elasticities. 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. 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 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 per cent.

**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	2015/17 in per cent of 2003/05
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 per cent 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, 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	233	492	398	394
Sugar	250	493	326	405

Source: Own calculations.

## Conclusions

In this paper we have analysed the determinants of the global demand for and supply of food. 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 21<sup>st</sup> 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 per cent 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.

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.

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