RIS
Research and Information System for Developing Countries

Core IV-B, Fourth Floor, India Habitat Centre, Lodhi Road, New Delhi-110 003, India.
Ph. 91-11-2468 2177-80, Fax: 91-11-2468 2173-74-75, Email: publication@ris.org.in
Website: http://www.ris.org.in, http://www.newasiaforum.org

RIS Discussion Papers

The Food-Feed-Fuel Triangle: Implications of Corn-based Ethanol for Grain-Use Competition

Arindam Banerjee

Discussion Paper # 167

RIS
Research and Information System for Developing Countries

The Food-Feed-Fuel Triangle: Implications of Corn-based Ethanol for Grain-Use Competition

Arindam Banerjee

RIS-DP # 167

August 2010

RIS
Research and Information System for Developing Countries

Core IV-B, Fourth Floor, India Habitat Centre
Lodhi Road, New Delhi – 110 003 (India)
Tel: +91-11-2468 2177/2180; Fax: +91-11-2468 2173/74
Email: publication@ris.org.in

The Food-Feed-Fuel Triangle: Implications of Corn-based Ethanol for Grain-Use Competition

Arindam Banerjee*

Abstract: The contemporary world is witnessing certain critical changes in the domain of grain utilization. With the ongoing efforts to substitute fossil fuels with bio-fuels, there has been a rise in the importance of fuel-use of cereals. This adds a new dimension to the food-feed competition that emerged in the 20th century. Revisiting Yotopoulos' food-feed competition model in the context of the large scale corn-ethanol production in the US, this paper attempts to draw out the new theoretical tenets of grain-use dynamics that have emerged with the new food-feed-fuel competition. The crude oil prices appear to play a more important role in the competition for grains between the various end-uses. Along with this, the equilibrating role that animal-feed has played in the grain-use dynamics in developed countries, with large middle-classes, is jeopardized with the advent of grain-based bio-fuels like corn-ethanol. The examination of the issue reveals that the US bio-fuels targets can have more serious implications for food security in the future that what meets the eye.

The contemporary world is witnessing critical changes in the domain of grain-utilization. With the ongoing efforts to substitute fossil fuels with bio-fuels, there has been a rise in the importance of fuel-use of cereals. This adds a new dimension to the modern-day food-feed competition that emerged in the 20th century and particularly characterised the world's use of grains after the World War II.[1] The last few years have seen a large scale diversion of corn, the bulk of it in the United States (US) to feed the ethanol distilleries. While the corn used for ethanol grew by around 60 per cent in the decade of the 1990s, the annual diversion of corn for ethanol production in 2008-09 was roughly six times (a 600 per cent rise) that in 2000-01 (calculations based on data from the *FeedGrains Database,* USDA). The corn-ethanol industry has also undergone a massive expansion during the same time period.[2] This phenomenal expansion of corn-based ethanol production in the current decade probably has more dramatic implications than what meets the eye.

* Consultant, RIS, New Delhi, India. Email: arindam@ris.org.in

Apparently, it seems that concerns over climate change and the urge to reduce carbon emissions have boosted the production of bio-fuels and bio-diesels in quite a few countries in recent times. The effort to substitute gasoline by bio-fuels, however, dates back to the mid-1970s when Brazil first adopted the strategy to replace gasoline by ethanol, manufactured from sugarcane.[3] Brazil was shortly followed by the United States when it started supporting the production of ethanol from corn through enactment of the 1978 Energy Act.[4] Several other countries like New Zealand, Australia and Austria among the developed world and a few like South Africa, Sudan and Thailand among the developing nations started exploring the feasibility of bio-fuel production in the 1980s. At that juncture, more than environmental concerns, it was the oil-shock of 1970s that intensified the urge to reduce dependence on crude oil and directed the energy of policy-makers to search for alternative, economically viable energy sources.

Interestingly, the trajectory in which ethanol production from corn in the US has developed since 1980 reveals that the linkages crude oil prices have with bio-fuel production are currently stronger than ever. Whether the substitution of fossil fuels by bio-fuels serves the purpose of reducing Greenhouse Gas (GHG) emissions or not is a contentious issue but that is not the primary concern of this paper. Our central focus is to investigate the impact of large-scale grain-based fuel production on the overall grain-use equilibrium, particularly in developed nations. This also has widespread implications for the entire world and, in particular, the global south where hunger is an everyday reality of life.

This paper primarily makes an effort to comprehend the theoretical tenets of the food-feed-fuel competition with an empirical analysis of grain-use in US since 1980. The discussion also touches upon the recent global food crisis, which stands testimony to the fact that the integration of oil and grain prices has been reinvigorated in recent times with the emergence of the 'new' demand linkages. Finally in summary, some possible spatial and temporal ramifications of expanding grain-based bio-fuels production are briefly dealt with from a broader and futuristic point of view.

The Contours of Food-Feed Competition:

In a sense, the use of grains for ethanol production 'externalizes' (more on this term later) the grain-use equilibrium that had evolved over the last century. The transition from a food-feed to food-feed-fuel competition for grains implies that the grain-use equilibrium comes to be intricately linked with the movement of oil prices. In this context, it would be useful to revisit the theoretical foundations of the grain-use equilibrium before we explore the more recent developments. In a seminal article written in 1985, Yotopoulos had theorized the relationship between the food-use and feed-use of grains and how it unfolds with rising incomes and the graduation of people from the lower to the higher income classes.

He identified the growth of population and growth in incomes as the two sources of rising demand for grains in the world. This is expressed by the following relation-

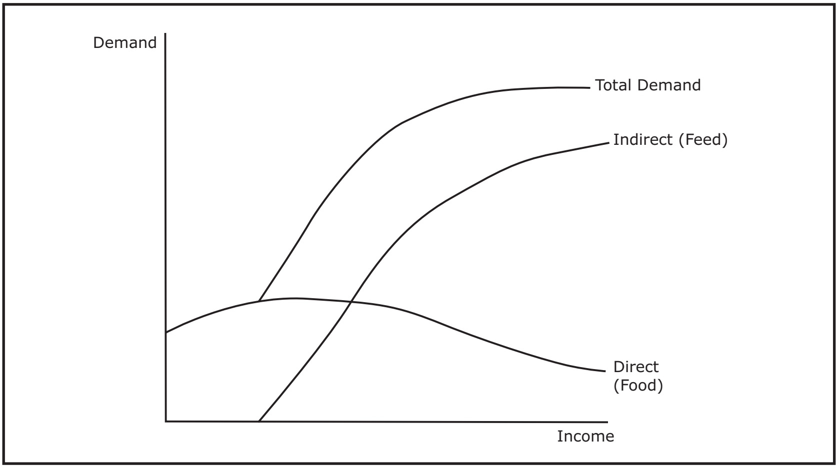
$$\dot{D} = \dot{N} + e.\dot{y} \quad \ldots\ldots \quad (I)$$

where $\dot{D}$, $\dot{N}$ and $\dot{y}$ are the growth rates of the total demand for grains, population and per capita income over time. In relation I, 'e' is the elasticity of food demand with respect to income. The elasticity of demand for food with respect to population was assumed to be unity. There are two basic tenets of the Yotopoulos hypothesis.

First, the elasticity of demand for the middle income classes is higher than the lower classes due to the high indirect consumption of grains in the form of animal products by the former. As income rises, the middle income classes consume more meat and diary products leading to a much higher demand for grains (indirectly as feed) given the poor conversion ratios between grains and animal products.[5] The demand is even higher when people graduate into the expanding middle income classes with rising income. The income elasticity of feed demand for the middle income classes is also higher than the richer classes. At very high levels of income and food consumption, the uppermost classes in the society increase their expenditure on food consumption relatively much lesser with any rise of income. The consumption on non-food items and savings increase much faster for these classes with rising incomes. This differential rise in demand for food with growing incomes was demonstrated by the 1974-5 food consumption data of Tunisia.[6]

The combination of direct and indirect consumption of grains constitutes the total demand for grains in any single economy or for the world as a whole. Figure 1 represents this demand curve for grains as incomes levels rise. The changes in dietary patterns of different income classes with increases in income explained the very high per-capita consumption of grains in the developed countries with high per-capita incomes. With higher incomes and larger middle- and rich-income classes, the total demand for grains, both direct and indirect, is much higher in the developed countries compared to the rest.[7]

Figure 1: The Food-Feed Competition



Source: Yotopoulos, 1985.

The elasticities computed by Yotopoulos for the period 1966-80 also revealed that feed elasticities were higher than the food elasticities in all regions including for some of the less developed regions.

The other major theoretical aspect is the food-feed competition that occurs in the dynamic setting. The competition for grains is based on the linkage between the food and feed markets that exist as soft grains are also fed to animals for livestock production. The demand for meat products rise with increasing income and pushes up the meat prices over time. A consequent increase in livestock production demands more animal feed, which increases feed grain prices, and grains are diverted from food-use to feed-use. In a situation where feed-grains supply is insufficient to meet the rising demand, soft grains like wheat or corn are also used as animal feed leading to a rise in the food prices also. This increase in food prices deflates the real income of the poorer classes relatively more than the middle and richer classes as the former consumes larger proportions of grain directly compared to the others. Thus, a redistribution of grain consumption across different income classes is accomplished in the process with the richer classes cornering a greater share of grains through their *indirect* consumption. By what dimension the food and feed prices actually rise and to what extent this redistribution takes place will depend on the respective elasticities of food and feed demand with respect to income for the different classes. The food-feed competition essentially operates through an adjustment of prices and can have different outcomes under varying combination of demand elasticities. This can be envisaged to be occurring within the boundaries of a country as well as in the world as a whole.

Interestingly, there are two countervailing processes that are intrinsic to the food-feed competition. This was observed in case of any short-run grain supply shortfall, particularly in high income countries, where animal products form a significantly large component in the average diet and the corresponding livestock herd in the economy is also substantial. The livestock herd played the role of a cushion which could absorb minor or major shocks arising due to grain production shortfalls. A fall in production and supply of grains, especially coarse cereals used as animal feed, caused an increase in feed-grain prices. This led to a rise in meat prices and a fall in the demand for meat. This happens more significantly in economies with a fairly large and expanding middle class whose income elasticity for feed demand is high. Any consequent cut-back in livestock feeding released large volumes of grains for direct consumption as food. In the early 1970s, steep reductions in livestock feeding were observed in the US (Yotopoulos, 1985: 478).

However, along with this, the food-feed competition described above occurs more gradually over the long run. The prices of soft grains escalate in the long run due to the linkage between the food and feed grain markets with an expanding middle income class. The emerging levels of food and feed consumption in the economy depends on the respective price changes and respective demand elasticities of the different income classes. Whether the consumption of the poorer classes are actually depressed (or 'crowded out', the term used by Yotopoulos) as a result of this process depends on the relative income elasticities of food and feed consumption of the different classes.

The extent of the food price rise depends on the income elasticity of feed grains demand on the middle and richer classes. When the middle classes are not very large in size and the bulk of the demand for feed mainly originates from the rich elite classes, the overall income elasticity of feed demand is low in the economy. In such cases, a much greater price increase (and a larger fall in real incomes) is required to release feed grains for food use such that the supply shortfall in grains can be mitigated. In the process, there is a more adverse effect on the real incomes of the poorer classes, who may end up finding it difficult to maintain their subsistence level grain consumption. This will be typical of a less developed country with considerably large income inequalities.

This occurrence of 'crowding out' of food demand was observed for Africa by Yotopoulos in the lates 1960s and 1970s. The total demand for grains was declining and that for direct consumption of food was stagnated in this period even as the income elasticities for feed demand were the highest in Africa in the entire less-developed world. The demand for food may be declining or stagnated in a different scenario as well. In countries with high per capita grain consumption and more than required calorie intakes, a fall in the demand for food can occur due to a shift towards animal products by large sections of the population for the purpose of improving their nutritional status. This was happening in the centrally planned economies between 1966 and 1980 as a result of the conscious government policy of large meat subsidies aimed to improve the quality of diets of their population on an egalitarian basis (ibid: 469-71). This was accompanied by the fastest rise in demand for grains in these countries among the world during this period. Poor countries like those in Africa with declining average per capita total demand for grains, of course did not enjoy this luxury.

We have outlined the hypothesis by Yotopoulos and his findings for the period between 1966 and 1980 in some detail as it is useful to appreciate the historical nature and trends of the competition for grain-use. This will enable us to record the new developments and transformations that have occurred in this domain since 1980. The transition from food-feed to food-feed-fuel competition can be best comprehended when we contrast the features and dynamics of the 'new' competition of grains with that which had evolved in the post World War II period.

The Transition from Food-Feed to Food-Feed-Fuel

The competition to food from bio-fuels can occur at multiple levels. First, it can be observed in the domain of production. A bio-fuel like ethanol, which is chemically a hydro-carbon, can be produced from any crop that contains sugar. While ethanol can be produced from cereals like wheat or corn, it can also be extracted from sugarcane and its by-products, sugar beets or sweet sorghum. A higher price for bio-fuels can generate a competition for arable lands, natural resources and even money capital and investments and displace the production of food crops in favour of the non-cereal crops that are used as feedstocks in bio-fuel distilleries. On the other hand, expansion of bio-fuels demand can lead to environmental concerns regarding degradation of natural habitat and loss of forests and embedded resources. Such concerns are already a reality in the Brazilian natural forests in Cerrado, home to some of the rarest and endangered species in this world or the South-East Asian rainforests, which runs the risk of being destroyed, along with its mega-fauna, by the rapidly expanding palm oil plantations (Worldwatch, 2007). The destruction of natural habitat can also adversely affect the food security of ethnic communities dependent for their livelihood on forest resources.

The above nature of competition that generates from bio-fuels or bio-diesels for natural resources, including arable land, is of serious concern and warrants careful studies and assessments. However, in this paper, we focus on the third and more direct competition for cereals that bio-fuels cause, i.e. at the level of grain consumption or use. In a situation where there is no apparent reduction in food crop production, there is still an intensified competition for grains between food, feed and fuel. When grains are used for fuel-use, new contours emerge in the erstwhile food-feed competition. Various changes can be located in the nature of the competition as well as new factors surface as the drivers of this competition.

The study mainly focuses on the US economy for the reason that the bulk of the production of grain-based ethanol is presently located in that economy (Table 1). US produced nearly half (49.6 per cent) of the world ethanol in 2007. The only other country that produces significant amount of ethanol is Brazil (38.3 per cent), where it is not manufactured from grains but sugarcane. Among the other countries producing ethanol, a few like China, Canada, Australia and the European Union (EU) use grains as feedstocks. China used part of its grain stocks, which had become unsuitable for human consumption, to produce ethanol between 2003 and 2005, but driven by concerns over food prices, suspended the use of corns for bio-fuels production in 2007 (Keyzer *et al.,* 2008). In the overall scenario, all the economies sans the US, which produce some kind of grain-based ethanol, constitute less than one-tenth of the total world production of grain-based ethanol.

Table 1: World Fuel Ethanol Production by Country or Region, 2007 (Millions of gallons, all grades)

Country	**2007**	**Per centage Shares**
U.S.	6,498.6	49.60
Brazil	5,019.2	38.31
European Union	570.3	4.35
China	486.0	3.71
Canada	211.3	1.61
Thailand	79.2	0.60
Colombia	74.9	0.57
India	52.8	0.40
Central America	39.6	0.30
Australia	26.4	0.20
Turkey	15.8	0.12
Pakistan	9.2	0.07
Peru	7.9	0.06
Argentina	5.2	0.04
Paraguay	4.7	0.04
Total	**13,101.1**	**100.0**

Source: Renewable Fuels Association, Industry Statistics.

The emergence of corn as the predominant feed-stocks for ethanol distilleries in the US is purely based on the economics of production. The ethanol yield of sugarcane, which Brazil has used as feedstock for their ethanol industry, has always been greater than corn (Table 2). However, the yield of sugarcane is high under tropical conditions and not so under the temperate conditions that prevail in the US. Among cereals, corn has the highest yield of ethanol and given that corn was already being grown in the US on a large scale primarily for feed in the livestock industry, it readily emerged as the leading feedstock for ethanol distilleries.

Table 2: Ethanol Yield (litres per hectare) of Sugarcane (Brazil) and Corn (US)

Feedstock	1977	2002
Sugarcane (Brazil)	3630	6500
Corn (US)	2200	3100

Source: Brown (1980) for the 1977 figures and Worldwatch (2007) for 2002 figures.

Let us now look at the developments in the domain of grain-use in the era of corn-based ethanol. We can segregate the history of the ethanol industry in the US into two phases that are characteristically different, namely the *subsidy phase* and the *crude oil driven phase*. The production of ethanol between 1980 and 2000 was mainly facilitated by subsidies from the US government. The use of corn for ethanol production grew at an annual trend rate of 10.1 per cent during these two decades.[8] The tax and subsidy structure of the US government played a major role in rendering economic viability to the ethanol industry. Unlike sugarcane ethanol in Brazil, it is the combination of taxes on gasoline and subsidized production of ethanol that made the latter a viable substitute for gasoline. This is also true for the ethanol produced from wheat by the EU. The price of production of an energy-equivalent litre of ethanol was higher than the retail price of one litre of gasoline in US when the Federal and State taxes on the latter are deducted.[9] The costs of production figures for 2004 in Table 3 illustrate the economics of substituting gasoline by ethanol.

Table 3: Production Costs of Ethanol and Gasoline: Major Ethanol Producing Countries, 2004

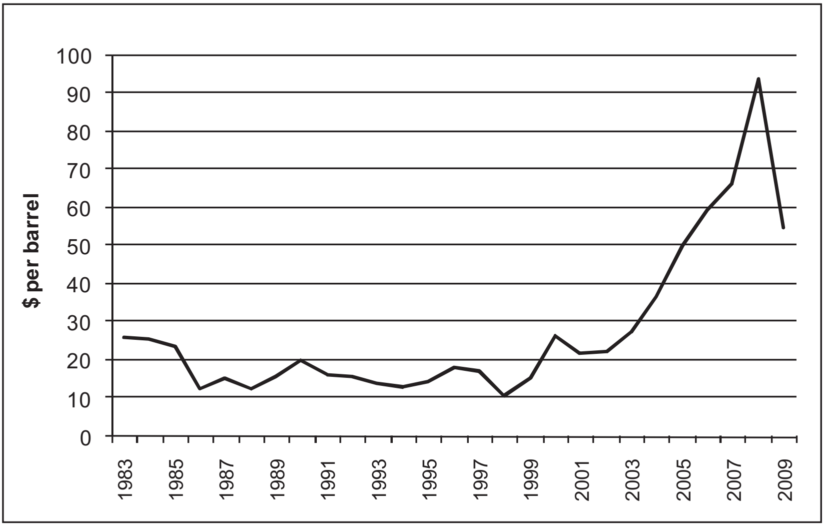
Country	Ethanol (€/ltr)	Gasoline (€/ltr)
US	€ 0.36 (corn)	€ 0.45 (with tax) € 0.32 (without tax)
EU	€ 0.70 (Wheat)	€ 1.09 (with tax) € 0.34 (without tax)
Brazil	€ 0.27 (sugarcane)	€ 0.69 (with tax) € 0.33 (without tax)

Source: Worldwatch (2007).

Currently, there are about 200 subsidies on ethanol production in the US, of which the major subsidy is the Volumetric Ethanol Excise Tax Credit (VEETC), which provides a subsidy of $ 0.45 per gallon and goes directly to companies blending ethanol into gasoline (Koplow, 2009). The Renewable Fuels Standards (RFS) and the 2007 Energy Independence Security Act (EISA) mandate pre-specified blending volumes for ethanol within specific time periods. The EISA now requires that by 2022, 36 billion gallons of bio-fuels must be blended with gasoline of which 15 billion gallons are expected to be produced from corn. According to estimates, this target will require an accumulated subsidy of $420 billion between 2008 and 2022. The 2008 level of $9.5 billion subsidy to the ethanol industry is expected to rise to $60 billion by 2022 (ibid).

In reality, the actual subsidies required to fulfil the EISA targets may be lesser if the crude oil prices continue to rule at high levels. The reasons for that can be located in the second period of our analysis, from 2001 to 2009, where ethanol production is driven by high crude oil prices. Ethanol production moved into the competitive zone once the crude prices crossed the $55 per barrel mark in 2005-6 (Figure 2). The period after 2001 when oil prices started surging, ethanol production became more competitive and started expending briskly, given the gasoline taxes and carbon credits to bio-fuels that were already in place. The corresponding annual trend growth rate of corn-use for ethanol production between 2001-2 and 2008-9 was a staggering 25.7 per cent.[10] The crash in the oil prices, post the financial crisis, caused considerable stress on the margins of the ethanol industry but that situation eased out as the oil prices started rising in the later months of 2009. The overall production of ethanol has exponentially multiplied in the current decade, driven primarily by surging crude oil prices, which made the substitution of gasoline by gasohol (gasoline blended with ethanol) profitable. We shall now look at the varying impact of ethanol use on the competition for grains in these two periods in the light of the modern food-feed competition, outlined in the previous section.

Figure 2: Crude Oil Prices (Domestic First Purchase) in USA: 1983 to 2009

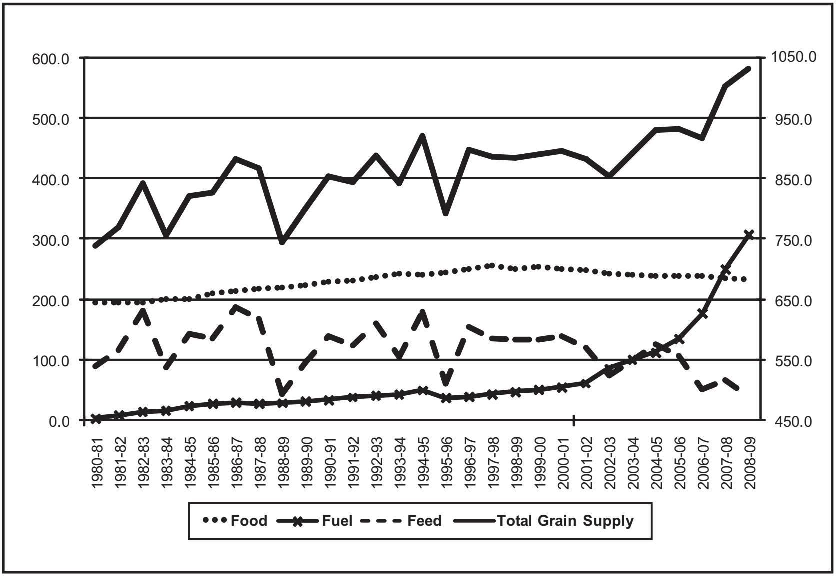


Source: US Energy Information Administration.

The Subsidy Phase

The US per capita domestic grain-use since 1980-1 and the trends in the different use categories is represented by Figure 3. The total grain-use is also equivalent to the total domestic grain supply that we derive after subtracting *net exports* and *net addition to stocks* from *total domestic grain production*. The vertical line marks the two phases of bio-fuel growth that we have identified.

Figure 3: USA Per Capita Domestic Grain Use: 1980-81 to 2008-09



Source: Calculated by author using WASDE data on grain-use and FAO Population figures.

Note: The food and fuel use variables are plotted on the LHA while feed and total domestic grain-use are plotted on the RHA. All variables are in kg.

We can observe that between 1980-1 and 2000-1, the feed component of grain-use has played the important role of adjusting with the fluctuations in the overall supply of grains. The lines representing the per capita domestic grain supply and the per capita feed use are nearly identical in the figure during the two decades indicating the centrality of the short run adjustments by the 'cushion' of livestock herd in the overall grain-use equilibrium. Yotopoulos identified this as a normal phenomenon in the high income developed countries with large middle classes. This adjustment, which favours the low-income classes and helps them to maintain their direct food consumption in the wake of supply shortages, was a reality for the US in this period.

However, unlike what Yotopoulos estimated for market developed countries in the period 1966-80, the elasticity for feed demand was lower than that for food in the US. We have estimated the growth rates of real per capita income (at 1980 prices) for the US between 1980 and 2000, using income data from the *World Development Indicators* (WDI) database maintained by World Bank. The growth rates of per capita food, feed and fuel use in the US can also be computed from our data on disaggregated grain use. Using these growth rates in relation I, we obtain the income elasticity of food, feed and fuel demand for the period. The elasticity for food demand was 0.3, much higher than that for feed (Table 4). On the other hand, the elasticity of grain demand for bio-fuels was quite high at 1.68. Backed by the lucrative government subsidies, the demand for feedstock for ethanol distilleries were rising at a faster rate than real per capita income.

Table 4: Income Elasticity of Food, Feed and Fuel Demand in USA: 1980-81 to 2000-2001

Use category	Income Elasticity
Food	0.30
Feed	0.01
Fuel	1.68
Total cereals	0.14

Source: Estimated by the author using WASDE and WDI database.

This reveals quite a dissimilar picture from what Yotopoulos had observed between 1966 and 1980.[11] This reversal of the situation with regard to food and feed elasticities warrant some explanation on the basis of the developments that were occurring in the US food economy. However, before that discussion, we shall briefly clarify some specificity of our data for the sake of precision. The food demand component that we use for our analysis has been residually derived by deducting feed- and fuel-use from the total cereal demand. Apart from food-use, this residual component also includes seed, waste and other uses (like non-food processing uses like manufacture of oil for soap). The WASDE dataset does not supply data separately for these categories.

On the other hand, the FAO Food Balance Sheets (FBS) provides information for these categories separately. However, the drawback with the FBS is twofold. First, the time series data is available only till 2005-6 and secondly, the FBS does not provide any information on the use of grains for bio-fuels manufacture separately as of now, unlike the WASDE. To resolve this conundrum, we have alternatively also used the FBS data and superimposed the information on fuel-use of grains available from the WASDE on that for a re-examination. The FBS data gives a category called 'processing' which includes all food and non-food (mainly fuel) processing. Deducting the WASDE data on corn-use for ethanol from this category, we can obtain the residual food-processing component.

Our calculations using the FBS dataset reveal that the category of seed and other utilization (includes waste) together constituted a mere 4.4 per cent of total grain-use on average during the entire period between 1980-1 and 2005-6. Food-use alone constituted 12.5 per cent and 'food along with food-processing' comprised 22.5 per cent of total grain-use. When we recalculate the income elasticity for food demand after excluding seed and other utilization between 1980-1 and 2000-1, it is 0.35 (only food) and 0.38 (for food plus food-processing), i.e. there is no major change from our earlier estimation using WASDE data. The non-exclusion of seed and other utilization does not pose any major problem due to the minor share of these use categories.

Let us now return to the issue why the income elasticity of food is higher than that for feed, quite unlike the experience between 1966 and 1980. There are at least three reasons behind the stagnancy exhibited by feed-use demand for grains after 1980. First, the period which Yotopoulos studied was one characterized by a high growth of cereal output. The annual growth rate of total grain output in the world in 1966-80 was 2.9 per cent which was much higher than the 1.3 per cent in 1980-1 to 2000-1. For the US, these figures were 3.3 and 0.9 per cent respectively for the two periods.[12] Naturally this slower growth in cereals output put a constraint on feed supplies and prevented fast increases in animal product consumption like in the sixties and seventies. The second reason lies in the introduction of subsidized production of ethanol from corn. There was much lesser space for feed demand to grow without jeopardizing the demand for food in an absolute sense. The per capita corn-use for ethanol production grew at an annual rate of 8.7 per cent during this period. The large ethanol subsidies successfully redirected a substantial share of grains that were earlier used as animal feed to the ethanol distilleries in the US.

Finally, we must also recognise the dietary changes that have been occurring in the US since the 1980s. The nutritional history of the US reveals that the intake of meat and poultry were declining between 1909 and 1939, roughly the period between the World Wars. Since the 1940s, this trend turned positive and animal product intakes by the US consumer increased rapidly till the 1970s (Page and Friend, 1978). However, there has been considerable substitution of animal products by processed cereals/foods in the average diet in the US since 1976-7. It was pointed out as early as 1993 that the US diet was shifting in favour of a low-fat medium-fat grain and pasta dishes from medium-fat high-fat meat and fish during 1970s and 1980s (Popkin, 1993). Using the 1977-8 and 1987-8 National Food Consumption Survey data of the US, Popkin identified significant increases in the consumption of low-fat pasta dishes, low-fat poultry and high-fat grain and pasta dishes between 1977 and 1987. These food items displaced the consumption of medium and high-fat red meat. A later study by Popkin *et al.* in 1996 confirmed that there has been significant reduction of consumption of high-fat red meat for both high and low socio-economic classes among the white as well as the black population in the US.[13] The consumption of other food items like bacon and low-fat red meat had also declined. Such changes in dietary patterns in the US are also responsible for the relatively low increase in feed demand that we witness after 1980.

However, what is important from our interest is that during this period, feed demand continued to play the role of a cushion adjusting to changes in the grains supply in the short-run. This allowed the low-income classes to maintain their direct consumption of grains and not get crowded out by the food-feed competition, at least in the short-run. In the next section, we shall trace the more fundamental changes that have emerged in the grain-use equilibrium after 2001 when ethanol production in the US is driven by the high and surging crude oil prices.

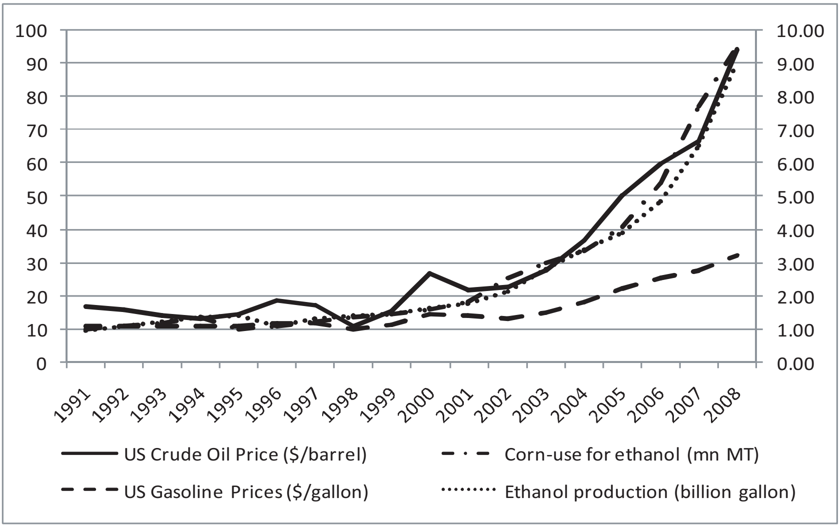
The Crude Oil Driven Phase

The current decade is witness to the remarkable fallout of corn-based ethanol production with the surge in crude oil prices. The high oil prices raised ethanol prices and caused a rapid expansion of ethanol output. Between 1980 and 2001, the production of ethanol was mainly sustained by the subsidy provided by the US government. Although these subsidies also rendered ethanol as an economically viable replacement for gasoline, its production did not surge like in the current decade, as any increase in production also meant a concomitant increase in the government subsidy. Since the latter is constrained by several factors and essentially an external policy decision, the ethanol industry expanded exactly by that extent to which the government wanted it to through its quantum of subsidy.

This situation changes when the crude oil prices and correspondingly the gasoline prices start increasing to a level where ethanol emerges as a cheaper option to run cars even without a single cent of government subsidy. This situation was reached when the crude oil prices crossed the $55 per barrel mark in 2005. However, with subsidies in place, the ethanol production started surging from the moment the oil prices start moving northwards. The expansion of ethanol production from corn exactly corresponds to the surge in the crude oil prices which is portrayed by Figure 4. The demand for ethanol, which increased at a fast rate in the earlier period, exploded in the era of high crude prices. The annual growth rate of per capita corn-use for ethanol production between 2000-1 and 2008-9 was unbelievably high at 24.5 per cent.

Let us now approach the intrinsic changes that have occurred with regard to grain-use in the US. Looking back at Figure 3, we observe that the total per capita consumption of grains is rising at a faster pace compared to the earlier period.[14] Also among the three component of grain use, only fuel-use has a positive slope while food and animal feed show a decline. This disjunction of trends of animal feed-use from the total grain use is something unique to the experience that developed countries like the US has hitherto had. The disjunction is also captured by the income elasticities of different use categories (Table 5). The elasticity results are intriguing.

Figure 4: Crude Oil Prices. Gasoline Prices, Ethanol Output and Corn Use for Ethanol in US: 1991 to 2008



Source: US Energy Information Administration, Renewable Fuels Association, USA and WASDE, USDA.

Note: The Crude Oil Prices and the corn-use for ethanol are measured on the LHA while the remaining two variables are measured on the RHA.

While food and feed both show a falling demand with respect to income, the fuel-use has a phenomenal income elasticity of 5.48, i.e. for every one per cent increase in per capita real income, the per capita demand for fuel-use of corn rose by nearly five and a half per cent!

Table 5: Income Elasticity of Food, Feed and Fuel Demand in USA: 2001-2002 to 2008-2009

Use category	Income Elasticity
Food	-0.17
Feed	-0.38
Fuel	5.48
Total cereals	0.54

Source: Estimated by the author using WASDE and WDI database.

What can be the source of such high and unnatural demand for fuel-use of grains? The answer to that question actually leads us to explore the new paradigms of grain competition that have emerged as a result of using grains for bio-fuel production. It is evident from the elasticity results that there has to be an additional factor which generates demand for grains apart from population and income like we have considered till now. The crucial transformation that occurs in the character of competition for grains is its new linkage with crude oil prices. The food-feed competition that existed in the post WW-II period was based on the changes in dietary patterns which occurred along with rise in incomes. In the present situation, the demand for corn as ethanol feed is not generated primarily by rising income but by the rise in crude oil prices. As ethanol is a substitute for crude oil, the corn-use demand, derived from ethanol demand, has positive cross-price elasticity with oil prices. As oil prices increase, the demand for corn as fuel-feed will increase to an extent as determined by this cross-price elasticity. Thus, the contemporary demand for grains is determined additionally by oil prices, which is captured by the new demand function for grains (relation 2)

$$D = D(N, y, p) \qquad \text{.........(2)}$$

where 'D' is the demand for grains, 'p' is crude oil price and 'N' and 'y' are population and per capita income respectively. The earlier grain demand function (relation I) modifies as crude oil price comes in to the scenario with the use of grains as fuel-feed. The oil price elasticity of corn demand for ethanol is the new critical variable that has to be taken into account from now on when one tries to explain the rates at which the demand for fuel-feed will increase.

At the initial point from where Yotopoulos started his analysis, we have

$$D = N.q \qquad \text{.........(3)}$$

where 'N' is the population and 'q' is the per capita demand for food

Now, in the fuel-feed era, instead of $q = f(y)$, we have

$$q = g(y, p) \qquad \text{.........(4)}$$

Consequently, the change in per capita demand for food (q) over time is

$$\frac{\delta q}{\delta t}.\frac{1}{q} = \frac{\delta q}{\delta y}.\frac{y}{q} . \frac{\delta y}{\delta t}.\frac{1}{y} + \frac{\delta q}{\delta p}.\frac{p}{q} . \frac{\delta p}{\delta t}.\frac{1}{p} \quad ....(5)$$

Taking the time derivative of total demand for food (***D = N.q***), we

$$\dot{D} = \dot{N} + e_y.\dot{y} + e_p.\dot{p} \quad .... (6)$$

where $e_y = \frac{\delta q}{\delta y}.\frac{y}{q}$ and $e_p = \frac{\delta q}{\delta p}.\frac{p}{q}$.

'e_y' and 'e_p' are the income elasticity and oil price elasticity for per capita food demand. $e_y , e_p \geq 0$.

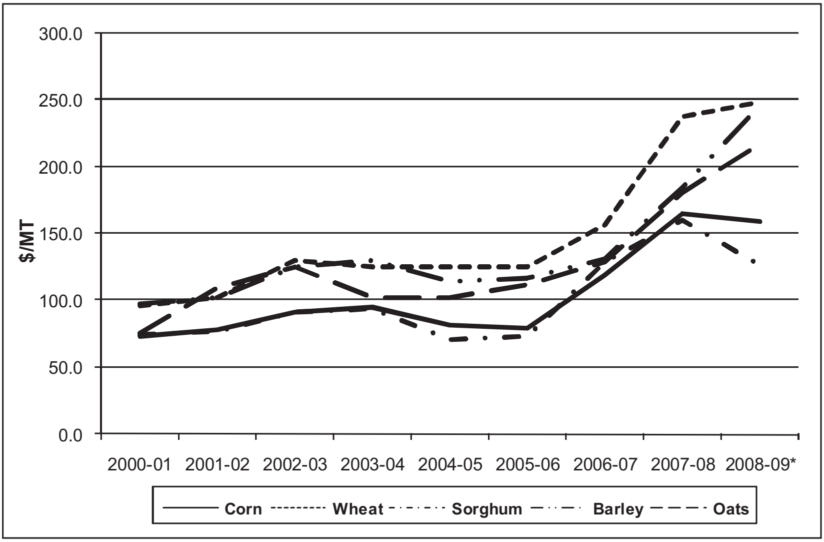
$$\dot{D} = \frac{\delta Nq}{\delta t}.\frac{1}{Nq}, \quad \dot{N} = \frac{\delta N}{\delta t}.\frac{1}{N}, \quad \dot{y} = \frac{\delta y}{\delta t}.\frac{1}{y} \quad \text{and } \dot{p} = \frac{\delta p}{\delta t}.\frac{1}{p}.$$

$\dot{D}$, $\dot{N}$, $\dot{y}$ and $\dot{p}$ are the time growth rates of total demand for grains, population, per capita real income and crude oil prices.

Relation 6 represents the new situation where demand for grains is also dependent on oil prices. The grain demand can now increase even when population and income are both constant. Even if $\dot{N}$ and $\dot{y}$ are both zero, the total demand for grains will still increase if $\dot{p}$ is positive and the extent of this increase is determined by the cross-price elasticity e_p. The US crude prices increased by 330.6 per cent between 2001-2 and 2008-9 while the demand for corn by the ethanol industry rose by 276.7 per cent. The increase in the demand for corn feed is also influenced by a rise in income which in turn raises the number of vehicles in the economy. However, we can safely conclude that a bulk of the increase in fuel-feed demand was due to rise in crude oil prices and not due to increase in the number of vehicles, which rose by a meagre 8.69 per cent in this period.

In the grain market from now on, the food and feed prices will increase even without any rise in demand via growth in population or income levels,

Figure 5: Average Farm Prices ($/MT) for different grains in US: 2000-01 to 2008-09



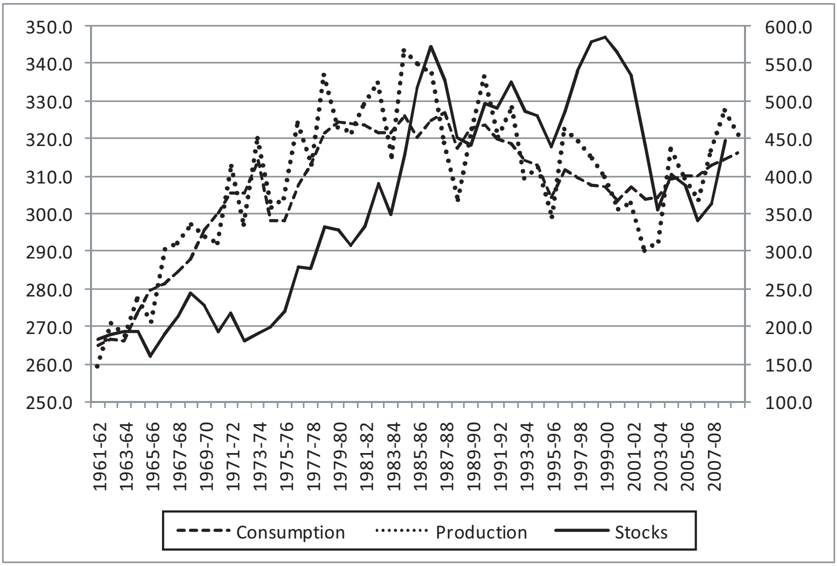
Source: WASDE, USDA.

but due to 'external' developments like price surges in the oil markets. Thus, there is a distinct 'externalisation' of the grain-use equilibrium. Oil prices, which earlier 'pushed' grain prices upwards from the input-cost side only, will henceforth, also 'pull' grain prices to higher levels from the demand side. The role of bio-fuels in the recent global food crisis has been earlier pointed out by several authors (Rosegrant, 2008; Mitchell, 2008; Keyzer *et al,* 2008). That the corn prices acted as the leader among the different grain prices during this crisis is evident from Figure 5.[15] The average farm prices for wheat and sorghum moved exactly in tandem with the corn prices while barley and oats prices were also pushed up by the surging corn prices.

On the other hand, when oil prices slide, the food prices will also need to come down in order to maintain the viability of the ethanol industry. When crude prices crashed near the end of 2008 with the financial meltdown, the food prices were also immediately pushed downwards or their upward trends were arrested. In a sense, the oil prices act as an iron roof to which the food prices stick to like a magnet when the former is rising and which presses the food prices down when it is collapsing.

Does that imply that income has no role in generating demand for fuel-use of grains like it has for food and animal feed? As mentioned earlier, income will become a causal factor in the fuel-use demand, when due to incremental earnings, more people purchase cars or run their cars for more miles. This is, however, subject to the condition that oil prices are significantly high for gasohol to be used as fuel. Income levels will essentially play a secondary role as prices have the potential to change much more sharply than income. This growth in animal feed demand occurs gradually as it takes time for the middle classes to expand and change their food consumption patterns. Even for fast growing countries, these changes may take a couple of decades to occur.

Figure 6: Per capita World Food Consumption, Production and Stocks: 1961-2 to 2008-9 (in Kgs)



Source: Calculated by author using WASDE data on grain-use and FAO Population figures.

Note: Production and Consumption are measured on the LHA while stocks on the RHA.

The growth rate of grain-use as animal feed and the overall cereal-use has been generally constrained by demand. Although in the short run, in a couple of years when cereal production may be poor, the cereal-use can face a supply constraint but in the longer run, it will mostly be bound by the demand for grains. This is largely corroborated by the historical experience of the food economy post WW-II. Since the late 1960s when food consumption was rising fast, the world per capita food stocks have also been growing significantly (Figure 6) as production was rising faster than consumption. When cereal production started declining since mid-1980s (illustrated by the dip in grain stocks in the mid-1980s), the situation was salvaged by a corresponding decline in per capita consumption of grains (since 1985 to 2000) brought about by mass-deflationary policies, particularly in the global south. The normative food stocks were broadly maintained at a high level through declining consumption till the turn of the century. It is only since 2000 that world food stocks exhibit a more consistent depleting trend.

The dynamics of grain competition is clearly different in the case of fuel-use of grains. An immense demand for gasoline is already present in the economy even before the production of bio-fuels starts. This is all the more true for a motorized economy like the US.[16] No alteration in consumption pattern of any income class is required for generating demand for ethanol. It is simply a matter of substitution of gasoline with ethanol or gasohol when the latter is a cheaper alternative. Therefore, once oil prices cross the threshold price at which gasohol becomes competitive, there is immediately a massive demand for ethanol and hence a vast fuel-use demand for grains. This enormous demand virtually appears overnight. Unlike the earlier food-feed equilibrium regime, the actual *ex post* use of grains in the era of grain-based bio-fuels is immediately constrained by supply and not demand. This is precisely the reason why the world per head grain stocks is declining in the current decade.

One can argue that that world consumption of grains may be rising due to other reasons located across the world and question the rationale of attributing the declining stocks primarily to rising corn-use for ethanol in US. The apprehension does not hold ground if we look at the increase in per capita cereal-use for the US, the World and the World minus USA between 2001-2 and 2008-9. The figures respectively stand at 149.9 kg, 8.9 kg and 2.8 kg (WASDE, USDA). Notably, the per capita corn-use for ethanol in the US rose by an even higher 245.9 kg in this period.

The supply-constraint character is also vindicated by the fact that even after the more than five-fold increase in ethanol production in the US between 2000 and 2008, it barely accounted for 6 per cent of the total motor fuel consumed (i.e. ethanol plus gasoline use) in the economy. In countries like the US, where the per capita per day gasoline use was astronomically high at 4890 litres in 2002 (precisely the time when the surge in ethanol production started), there seem to exist an endless demand for ethanol as a gasoline-substitute. This reasserts the point that the arrival of fuel-use of grains relegates the linkages of grain competition with income levels to a secondary sphere and gives primacy to the linkages with the oil prices.

Apart from the enhanced role of oil prices in determining food prices, the advent of corn-based ethanol leads to a number of transformations in the grain-use equilibrium. As already elaborated, the transition from food-feed to food-feed-fuel competition establishes a strong demand-side linkage between the grain markets and the oil market, oil prices emerge as the key factor in grain-use adjustments and the use of grains essentially becomes supply-constraint due to drastic short-run changes and the incessant demand for ethanol. Apart from these changes, there is critical change that occurs in the internal dynamics of the grain-use equilibrium. With the drastic rise in fuel-feed demand, the long run dynamics of food and feed demand based on income distribution among the population gets completely jeopardized. Even with increase in per capita income, the food and feed demand walk in the opposite direction. This is of crucial significance for the low-income classes of the population.

We have earlier seen how in the short-run, the animal feed component of grain demand and the large livestock herd acted as a cushion and helped maintaining direct food intakes (relatively larger for the poor) in case of occasional grain supply shortfalls. This adjustment process is technically possible as animal products can be substituted by direct consumption of grains in the human diet. The same is not true for fuel-use of grains. Even if corn prices rise and drive up the ethanol prices, there is no cut-back in ethanol and fuel-feed consumption till the price of ethanol exceeds that of gasoline. This occurs as direct consumption of grains is not a technical substitute for ethanol in the diet of the vehicles.

In that sense, fuel-use does not play any cushioning role like animal-feed. Not only that, as the share of fuel-use in total grain-utilization increase and correspondingly the share of feed decreases, it also undermines the capacity of feed to act as a shock-absorber in case of supply shortfalls. The share of fuel-feed in total grain-use in US in 2008-9 was already 29.9 per cent. Correspondingly, the share of feed-use declined from 65.7 per cent in 2000-1 to 47.6 per cent in 2008-9. In fact, our analyses reveal that both the food-use and feed-use declined between 2000-1 and 2008-9, by average annual rates of 0.8 and 1.7 per cent respectively. In reality, feed-use is less adversely affected as a part of the grain used in ethanol distilleries recycles back as animal feed in the form of Dried Distillers Grain (DDG).[17] After adjusting for DDG, the *ex post* feed-use still declined by 0.1 per cent annually. Thus, the voracious demand for fuel-use of grains that appears mainly crowds out food-use in US in the current decade.

The use of grains as animal feed has not declined by much when we account for the *double-use* of grains, i.e. first as fuel-feed and then the DDG used as animal feed. The middle income classes which consume significant amounts of grain indirectly in the form of animal products are hit to a lesser extent in that sense. However, there is a clear reversal of the increasing trends in food-use (or direct consumption) of grains that was witnessed between 1980 and 2000. The low-income classes are bound to be adversely hit as a result of this process.

There is some diverse opinion as to whether there is any hunger-incidence currently in US.[18] In case the lowest decile of the US population is food-insecure as some commentators point out, the crowding out of food-use has definitely been aggravating that situation and must have pushed more people into vulnerability in times of rising grain output. On the other hand, we cannot exonerate the use of grains as fuel-feed even if we accept that by international monitoring standards, the incidence of hunger in the US is negligible. Even in such a situation, the negative trend of food-use of grains must have derailed the nutritional transition that the Americans have been experiencing for over a couple of decades. The shift towards grain and pasta diets by the average American consumer, driven by concerns over a healthy diet and lifestyle diseases is now seriously constrained by the demand for grains by cars or car-owners.

Summary

We have traced the multiple dimensions of the transformation in the grain-use equilibrium and its implications for the different income classes in the US. There are still some concerns that remain with regards to the effect of these developments on the rest of the world. The other crucial issue is the future trajectory of the bio-fuel industry and what that implies for development at large. It would be useful to briefly touch upon these two issues by way of summary.

It is clear enough that any replication of the US corn-based ethanol industry in other parts of the world, particularly in developing countries, which continuously grapples with under-nutrition, will be disastrous. However, even in the absence of such replications, corn-based ethanol production in the US still has serious ramifications for developing countries given her near monopoly over global corn exports. The US share of global corn exports in the current decade has been 60.3 per cent. Although this is lower than the 68.7 per cent share that she had in the 1990s, it is substantial to strongly impact the world corn markets. When corn price shoot up in the US, the world export prices for corn will inevitably go up preventing poor and middle income corn-importing nations to procure their required corn supplies via trade. This was well-illustrated by the Mexican political instability and crisis in 2007, the central issue of which were the highly priced corn imports from the US (Bello and Baviera, 2009).

The gradual thinning of US corn exports is already visible. The per capita US corn export has declined from the decadal average of 190.2 kg in the 1980s to 171.3 kg in the 1990s and 166.8 kg in the current decade. The decline in the current decade would have been even larger had it not been for a surge in corn output that the US could successfully engineer through the introduction of transgenic corn in the Mid-western provinces. While the historical rate of growth of US corn production over half a century (between 1961-2 and 2009-10) has been 2.4 per cent, the annual trend growth rate of corn output was an exceptional 4.1 per cent between 2002-3 and 2008-9. Lucrative prices and new technology led to an increase in both acreage (by 13 per cent) and yield (by 19 percent in this period.

The important question that arises is whether such a surge in production is sutainable over a longer period, given the constraints that remain on indefinite expansion of corn acreage and also the historically observed uncertain and short-lived nature of transgenic technology. Without such a phenomenal increase in corn production, the ethanol industry with its current trajectory is bound to deplete US corn exports significantly in the future. This connects us to other issue of sustainability of ethanol production from corn in the future. During the financial crisis, when oil prices crashed, the ethanol industry witnessed serious pressures on their margins. This raises the question as to whether the corn-ethanol industry is a sustainable option in the long-run or more of a passing phenomenon.

The turnaround of the crude prices in late 2009 has restored back viability in ethanol production. Given the present situation, the basic condition for an expansion of the industry without the assistance of larger subsidies is that in future, the oil prices should rule above the threshold price which renders competitiveness to the industry. Even if there is no reduction in the unit cost of ethanol production due to technological developments, the industry will still expand if the nominal crude prices rise faster than the rate at which the price of production in the ethanol industry rises, driven by inflation in the economy. In other words, the real crude prices has to increase over time. The US Energy Information Administration forecasts indicate that real crude prices (at 2008 dollars) will increase from their current 2009 levels and stabilize at more than $105 per barrel after 2020. If crude prices stick to this predicted path, unhindered expansion of US ethanol industry in future is a distinct possibility.

This raises the more serious question, which policymakers in the US and the world over has to tackle in future. Even if we assume that ethanol production expands no more than the prescribed US targets, there can emerge enormous grain deficits in the US; an ominous development both for the US and the world. The draft US Biofuels Security Act (BSA), 2007 had sought to set strenuous targets of producing 30 billion gallons of ethanol by 2020 and 60 billion gallons by 2030. In case the US attempts to meet these targets only from corn feedstocks, they would have to deal with large grain deficits. Assuming that grain supplies and population continue to grow at the observed historical rates, the per capita food and feed consumption is maintained at the 2008-09 level and technology remains unchanged in the ethanol industry, the US will face a large deficit of 94 million tonnes of grains in 2020 and a staggering one of 285.6 million tonnes in 2030.[19]

The US policymakers were well aware of these future ramification which is why this bill probably never became a law. The EISA, 2007 suitably modified the targets to avoid this catastrophic situation and mandates that of the 36 billion gallon production target by 2022, at least 21 billion gallons has to be produced from non-corn feedstocks. This congressional mandate is hinged on the delicate expectation that the technology for economically producing ethanol from cellulosic material like grass and wood will be in commercial operation, sometime between 2012 and 2015. Success in this avenue can significantly ease the supply constraint for the ethanol industry although there are valid concerns even then regarding the impact of cellulosic ethanol production on natural resources like habitat and water.

Frankly, there is very little leverage in this regard. If the cellulosic technology does not get operational by 2015 or is not environmentally sustainable, the biofuels targets can lead to precarious situations. Any attempt to meet the targets from corn-based ethanol can seriously destabilize the food and livestock economy across the globe, given the enormous grain deficits that will emerge. In such a situation, it would be more prudent for the US to suspend or abort the declared ethanol targets, thereby preventing any man-made social and economic disaster in the future.

What can still drive the US to chase the ethanol targets even if the cellulosic technology does not work is the political economy of high consumption of fossil fuels. The pressure within the US establishment for a shift towards bio-energy generates from the urge to strategically reduce one's dependence on fossil fuels and a whole range of economic, political and environmental issues are attached with this. The massive consumption of fuel associated with high level of motorization in the US (in the larger sense, the high-value consumption baskets that capitalism has encouraged for decades now) has reached us to a phase where competition for resources has become more intense than ever.

The food-feed-fuel regime is marked by the antagonism between vehicle-owners and the rest of the population. While the high motorization in the US means that car-owners are a sizable group in the population, at the global level, they form a minority. Portentously, this minority corners larger shares of grains that otherwise could have provided nutrition to the billions of hungry and under-nourished in this globe. It is therefore impending on the world civilization, and in particular the developed nations, to restrict the motorization of their economies and even reduce it through developing extensive public transport networks with high man-vehicle ratios. Other useful policies are the Vehicle Quota System, which pre-empts the number of new vehicles each year or the Electronic Road Pricing that discourages private vehicles to use roads during peak hours; policies that Singapore has effectively used for decades. From the global point of view, any sustainable path of development where the world's poor are not 'crowded out' in terms of food intake will have to account for developing feasible norms of lifestyle.

Appendix:

Estimation of hypothetical grain deficits in US in 2020 and 2030:

Assumption 1: Grain supply and population will grow at historical growth rates witnessed between 1980 and 2008.

Assumption 2: Per capita consumption of food and feed for the average US consumers will remain fixed at the 2008-9 level and not experience any decline from that level.

Assumption 3: Technology remains unchanged in the corn-based ethanol industry over time.

The parameters used in our estimation are given in Table A1. All the calculations are based on the WASDE data.

Table A1: Parameters used in the Estimation of US Grain Deficits in 2020 and 2030

Parameter	Unit	Value
Historical Annual Population Growth rate	%	1.06
Historical Annual Grain Supply Growth rate	%	1.81
Pegged level of Food-use per capita	Kg/year	233.1
Pegged level of Feed-use per capita	Kg/year	491.0

Table A2: Estimated US Grain Deficits in 2020 and 2030

Targets	Population	Grain Supply	Grain Requirement					Deficit
			Food	Feed	Fuel	Total	Total adjusted for DDG	
	Projected	Projected	Pegged	Pegged	Targeted			
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii= vii-ii)
2020:30 billion gallons of ethanol	350.9	396.0	81.8	172.3	317.7	571.8	490.0	94.0
2030:60 billion gallons of ethanol	385.7	465.5	89.9	189.4	635.3	914.6	751.1	285.6

All grain supply and demand are in million tons while population is in million. We have used the BSA, 2007 proposed targets of 30 billion gallons in 2020 and 60 billion gallons in 2030 and used the current corn-ethanol conversion ratio to estimate the amount of corn (in metric tons) required to meet these targets. The pegged levels of per capita food and feed consumption and population figures of 2020 and 2030 has been used to arrive at the amount of grains required for these two categories. We have also adjusted the total requirement for the Dried Distillers Grain (DDG) that comes in the animal feed markets from the ethanol distilleries. See Note 17 for the conversion factor of DDG. The last column in Table A2 gives the possible grain deficits.

Endnotes

1. While the cultivation of livestock products and its consumption has been existent for a long time, large scale operations in this sector first emerged in the 20th century. The horizontal and vertical integration in agriculture, the emergence of large Transnational Food Corporations in the second half of the 20th century and the faster growth of income and demand for animal products in the developed world, post WW-II, caused the genesis of the modern-day food-feed competition (Yotopoulos, 1985, Warnock, 1987).
2. The production of ethanol in the US, which barely doubled in whole of the 1990s, surged in the current decade. The annual ethanol output in 2007 was more than five times that in 2000 (based on data from the Renewable Fuels Association, USA).
3. Brazil launched an alcohol fuel program based on sugarcane feedstocks in 1975 with an estimate of $5 billion subsidy to support the National Alcohol Program over the next ten years (Brown, 1980).
4. The Energy Act of 1978 exempted every gallon of gasohol (gasoline blended with ethanol) from the Federal gasoline tax of 4 cents. This in effect provided a subsidy of 40 cents on each gallon of ethanol blended with nine gallons of gasoline (10 per cent blending). Following this, by early 1980s, sixteen states exempted gasohol from the state taxes (ibid).
5. The calorie equivalent grain-meat conversion ratios for poultry in 2:1 i.e. 2 kg of grain has to be fed to the chicken to produce poultry meat that provides the same amount of energy as 1 kg of grain when directly consumed. For beef, this ratio is high as 7:1.
6. See Yotopoulos, 1985: 474-5.
7. The per capita consumption of food grains in a developing region like South Asia was roughly 166 kg in 1980. In the same year, the same figure in the USA was nearly 739 kg and in the European Union (EU-15) was around 485 kg of food grains (based on World Agricultural Supply and Demand Estimates (WASDE), published by the USDA).
8. Calculated on the basis of WASDE data, also available at the http://www.ers.usda.gov/data/feedgrains/
9. One gallon of ethanol provides roughly two-third the energy provided by a gallon of gasoline.
10. Same as endnote 8
11. Yotopoulos (1985) had estimated the income elasticities for market Developed Countries, i.e. mainly the countries in North America and Western Europe, as a whole and observed that the respective figures for food and feed to be 0.03 and 0.14.
12. All growth rates of grain production are calculated based on USDA's WASDE estimates.
13. The consumption of high-fat red meat between 1965 and 1989-91 for the low socio-economic status whites declined by 71 per cent and by 89 per cent each for the low socio-economic status blacks and the high socio-economic status whites. For the changes in consumption of other food items, see Popkin, Seiga-Riz and Haines, 1996.
14. The trend annual growth rate of per capita grain consumption in the US between 1980-1 and 2000-1 is 0.73 per cent while the same is 2.4 per cent between 2001-2 and 2008-9 (estimated from USDA WASDE dataset).
15. The prices has been converted from $/bushel to $/metric ton using the relevant coefficients. The conversion factors from bushel to metric ton for the different feed-grains are as follows. Corn and Sorghum: 0.025401; Barley: 0.021772; Oats: 0.014515 and Wheat: 0.027216.
16. Taking passenger and heavy vehicles in account, the vehicle to man ratio in the US in 2007-8 was 0.81, increasing from 0.68 in 1980-1. This ratio, which we estimated based on the US Department of Transportation (USDOT) data, is the highest in the world.
17. A ton of corn used for ethanol production returns around 286 kg of DDG, of which roughly 90 per cent are used in the US domestic feed market as high protein concentrates (based on

information on ethanol co-products from the National Corn Growers Association (NCGA), US). There are other reusable by-products of ethanol production when wet-milling is used but nearly all ethanol distilleries in the US use the dry-milling process.

18 Although international estimates and monitoring of hunger classifies USA as a hunger-free country, there are observers who have pointed out that even USA, the richest nation in the world has 36 million people (12 per cent of population) living in hunger and food insecurity (Magdoff and Tokar, 2009).

19 The estimation methodology is given in details with the results in the Appendix.

References:

Bello, Walden and Mara Baviera. 2009. "Food Wars." *Monthly Review*, 61(3): 17-31.

Brown, Lester R. 1980. "Food or Fuel: New Competition for the World's Cropland." *Worldwatch Paper 35*. March

FAO. 2008. *Food Balance Sheet: A Handbook*. Rome

GoUS. 2007. *Energy Independence and Security Act, 2007.*

Keyzer, Michiel, Max Merbis, Maarten Nubé and Lia van Wesenbeeck. 2008. Food, Feed and Fuel: When Competition Starts to Bite. *Brief*. Centre for World Food Studies (SOW-VU), Amsterdam.

Koplow, Doug. 2009. *A Boon to Bad Biofuels*. Friends of the Earth and Earth Track. April

Magdoff, Fred and Brian Tokar. 2009. "Agriculture and Food in Crisis: An Overview." *Monthly Review*, 61(3): 1-16.

Mitchell, Donald. 2008. A Note on Rising Food Prices. *Policy Research Working Paper No. 4682*. Development Prospects Group, The World Bank, April.

Page, Louise and Berta Friend. 1976. "The Changing United States Diet." *BioScience,* 28(1): 192-7.

Popkin, Barry M. 1993. "Nutritional Patterns and Transitions." *Population and Development Review*, 19(1): 138-57.

Popkin, Barry M., Anna Maria Seiga-Riz and Pamela S. Haines. 1996. "A Comparison of Dietary Trends among Racial and Socioeconomic Groups in the United States." *The New England Journal of Medicine*, 335(10): 716-22.

Rosegrant, Mark W. 2008. "Bio-Fuels and Grain Prices: Impacts and Policy Responses." Testimony for the U.S. Senate Committee on Homeland Security and Governmental Affairs (May 7). http://www.ifpri.org/publication/biofuels-and-grain-prices (accessed on 10 July 2009).

USDA. *World Agricultural Supply and Demand Estimates*. Various years

_______ Feedgrains database, Economic Research Service, http://www.ers.usda.gov/Data/FeedGrains/ (accessed on 18 June 2009)

Warnock, John W. 1987. *The Politics of Hunger: The Global Food System*. Toronto: Methuen.

Worldwatch Institute. 2007. *Biofuels for Transport: Global Potential and Implications for Sustainable Energy and Agriculture*. London: Earthscan.

Yotopoulos, Pan A. 1985. Middle-Income Classes and Food Crises: The "New" Food-Feed Competition. *Economic Development and Cultural Change,* 33(3): 463-83.

RIS Discussion Papers

Available at http://www.ris.org.in/risdiscussion_papers.html

DP#166-2010 *Global Financial Crisis: Implications for Trade and Industrial Restructuring in India* by Prabir De and Chiranjib Neogi

DP#165-2010 *Are Trade Openness and Financial Development Complementary?* by Ram Upendra Das and Meenakshi Rishi

DP#164-2010 *Does Governance Matter for Enhancing Trade?: Empirical Evidence from Asia* by Prabir De

DP#163-2010 *Rules of Origin under Regional Trade Agreements* by Ram Upendra Das

DP#162-2010 *Geographical Indications at the WTO: An Unfinished Agenda* by Kasturi Das

DP#161-2010 *Revision of India Nepal Treaty of Trade and its Implications for Strengthening Bilateral Trade and Investment Linkages* by Indra Nath Mukherji

DP#160-2009 *Regional Cooperation for Regional Infrastructure Development: Challenges and Policy Options for South Asia* by Prabir De

DP#159-2009 *India's Trade in Drugs and Pharmaceuticals: Emerging Trends, Opportunities and Challenges* by Reji K Joseph

DP#158-2009 *On Managing Risks Facing the Indian Economy: Towards a Better Balance between Public and Private Sectors* by Ramgopal Agarwala

DP#157-2009 *Regional Economic Integration in South Asia: Prospects and Challenges* by Ram Upendra Das

DP#156-2009 *The European Union's Proposed Carbon Equalization System: Can it be WTO Compatible?* by Biswajit Dhar and Kasturi Das

DP#155-2009 *Addressing the Defaults of Globalization*

by Prof. Jan Pronk

DP#154-2009 *Trade Facilitation, Information Technology and SMEs: Emerging Evidences from India* by Sachin Chaturvedi

DP#153-2009 *Climate Change, Technology Transfer and Intellectual Property Rights* by K. Ravi Srinivas

DP#152-2009 *The Limited Promise of Agricultural Trade Liberalization* by Timothy A. Wise