No. 46 March 2010

RIS Policy Briefs

The Advent of Corn-based Ethanol: A Re-examination of the Competition for Grains

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 and characterised the world's use of grains after the World War II.[1] The last few years have witnessed a large scale diversion of corn in the US to feed the ethanol distilleries. While the corn used for ethanol grew by around 60 per cent in the 1990s, the annual diversion of corn for ethanol production in 2008-09 was roughly six times 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.

While concerns over climate change and the urge to reduce carbon emissions have served as a motivation to replace gasoline with bio-fuels, the surge in crude oil prices in the current decade has also played its role in this transition. The history of the evolution of bio-fuels production points strongly towards the primacy of the role played by the oil prices.[3] There has always been a strong urge to reduce dependence on crude oil and directed the energy of policymakers to search for alternative and economically viable energy sources. The recent trend of ethanol production from corn in the US since 1980 reveals the linkages that crude oil prices have with bio-fuel production are currently stronger than ever.

In this context, it is worthwhile to investigate the impact of large scale grain-based fuel production on the overall grain-use equilibrium, particularly in developed nations. This has widespread implications for the entire world and in particular, the global south where hunger is an everyday reality of life even today. The global food crisis in 2006-08 also 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. This brief primarily makes an effort to comprehend the theoretical tenets of the food-feed-fuel competition which has emerged following the emergence of grain-based bio-fuel production, an occurrence almost exclusive to the US economy.

The Contours of Grain Competition

In a sense, the use of grains for ethanol production 'externalizes' 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. Given this new facet in the utilization of cereals, it would be useful to revisit the theoretical foundations of the grain-use equilibrium. In a seminal article written in 1985, Yotopoulous 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 the growth in incomes as the two sources of rising demand for grains in the world. This is expressed by the following relation:

$$\bar{D}=\bar{N}+e\bar{y} \quad \text{.....(i)}^{4}$$

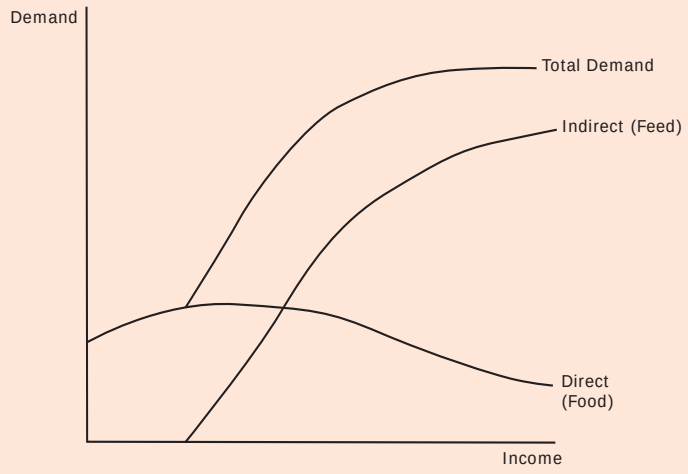
where $\bar{D}$, $\bar{N}$ and $\bar{y}$ are the growth rates of the total demand for grains, population and per capita income over time. *'e'* is the elasticity of food demand with respect to income. The elasticity of demand for food with respect to population was assumed to be unity. Figure 1 aptly illustrates the relation of food and feed demand with income.

There are two basic tenets of the Yotopoulos hypothesis. First, the elasticity of demand for food by the middle income classes is higher than that of the lower classes due to the high indirect consumption of grains in the form of animal products by the

RIS Policy Briefs are prepared to communicate results of RIS research on specific policy issues to the policy makers.

This Policy Brief has been prepared by Dr. Arindam Banerjee, Consultant , RIS.

Figure 1: The Food-Feed Competition



Source: Yotopoulos, 1985.

former. As income rises, the middle income classes consume more diary products and meat leading to a much higher demand for grains given the poor conversion ratios between grains and animal products.[5] The demand is even higher when people graduate into the middle income classes with rising income. The income elasticity of food demand for the middle income classes is even higher than the richer classes. This is so as with 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 behaviour of different income classes with the rise in income was cited by Yotopoulos to explain the very high per capita consumption of grains in the developed countries with high per capita incomes. The higher the average income in a country and larger the size of the middle and rich income classes, the higher is the demand for grains, indirectly as feed in the form of animal products. As a result, the total demand for grains, both directly and indirectly, is much higher in the high income countries compared to the rest.[6]

The other major theoretical aspect of the competition for grains is the linkage that operates between food and feed markets and the ensuing food-feed competition. The food-feed competition essentially operates through an adjustment of prices and can have different outcomes under varying circumstances. In high income countries, where animal products formed a significantly large component in the average diet and correspondingly the livestock herd was also large, it was observed that the livestock herd played the role of a cushion which could absorb minor or major shocks arising due to grain production shortfalls in the short run. This cut-back in livestock feeding releases grains supply for direct consumption as food, which is important for the low-income classes. In the early 1970s when feed prices abruptly increased, steep reductions in livestock feeding were observed in the US.

However, along with this, there is another phenomenon that occurs over the long run. A competition among food and feed emerges in an income differentiated society with time. If the income of the middle-classes rise at a fast rate over a period and consequently the demand for animal products also increases, there is a rise in the prices of feed grains. As a result, the prices of soft grains normally used for direct consumption, also rises in the long run due to the linkage between the food and feed grain markets (as soft grains are also fed to livestock and there is an increased diversion of these grains for livestock production). This increase in food prices deflate the real income of the poorer classes relatively more than the middle and richer classes as the poorer classes consume larger proportions of grain directly compared to the others.

This leads to the onset of the food-feed competition and 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', according to Yotopoulos) depends on the relative income elasticities of food and feed consumption of the different classes. The extent of the rise in food price depends on the income elasticity of feed grains demand on the middle and richer classes. In case 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 elasticity of feed demand is low in the economy. In such cases, a much greater price increase is required to release feed grain for food use so that any production shortfall in grains can be mitigated. In the process, this has 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 food-feed competition can be envisaged to be occurring within the boundaries of a country as well as in the world as a whole.

Emergence of Food-Feed-Fuel Competition

Let us now come to the changes that occur when

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 in large parts of the world, post WW-II, caused the genesis of the modern-day food-feed competition (Warnock, John W. 1987. *The Politics of Hunger: The Global Food System*. Methuen, Toronto).

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).

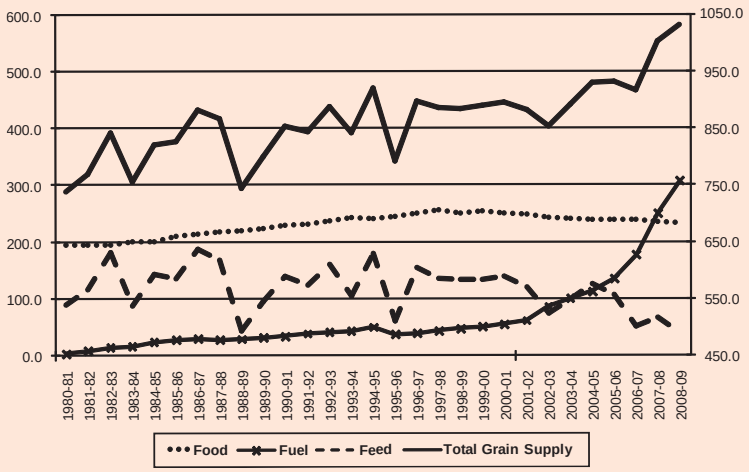
3 Both Brazil and the United States, the leaders in ethanol production, had triggered their initiatives for ethanol production in the second half of the 1970s after the oil shock (Brown, Lester R. 1980. Food or Fuel: New Competition for the World's Cropland. *Worldwatch Paper 35*. March).

grains are also used for producing bio-fuels. Our study reveals that in the subsequent period between 1980-81 and 2000-01, the feed component of grain-use has played the important role of adjusting with the fluctuations in the overall supply of grains. Figure 2 exhibits these trends in the per capita grain-use in the US along with the different components. This is observed for other high income regions like the EU also. 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 in the subsequent two decades. The elasticity for food demand was 0.3 during this period much higher than that for feed (0.01)[7].

This was due to a number of reasons. The period which Yotopoulos studied was one characterized by a high growth of world cereal output. The annual growth rate of total grain output in 1966-80 was 2.9 per cent which was much higher than the 1.3 per cent in 1980-81 to 2000-01. For the US, these figures were 3.3 and 0.9 per cent respectively for the two periods.[8] This, along with the introduction of subsidized production of ethanol from corn meant that there was much lesser space for feed demand to grow without jeopardizing the demand for food in an absolute sense. The use of corn for ethanol production grew at an annual rate of 8.7 per cent during this period. There has also been some effect of the substitution of animal products by processed cereals/foods in the average diet in the US since the mid-seventies.[9] However, what is important from our point of view is the fact that feed demand continued to play the role of a cushion adjusting to changes in the supply of grains and preventing any decline in the demand for food.

The more dramatic fallout of corn-based ethanol production for grain-use competition is witnessed in the current decade with the surge in crude oil prices. Between 1980 and 2001, the production of ethanol was mainly sustained by the subsidy provided by the US government. The price of production of an energy-equivalent litre of ethanol was higher than the retail price of one litre of gasoline when the Federal and State taxes on the latter are removed.[10] Ethanol production moved into the competitive zone once the crude oil prices crossed the $55 per barrel mark in the current decade. While the demand for ethanol increased at a fast rate in the earlier period, as evident from the high growth rate of corn use for feeding ethanol distilleries, there was an incomparable and brisk increase in ethanol demand in the current decade when it emerged as a cheaper alternative to gasoline. The corresponding annual growth rate of fuel-feed use of corn between 2000-01 and 2008-09 was a staggering 24.5 per cent.

Figure 2: USA Per Capita Domestic Grain Use: 1980-81 to 2008-09



Source: Calculated by the author using WASDE data on grain use (various years) and FAO Population figures (various years)

Note: The food and fuel use variables are plotted on the LHS while the Feed and total domestic grain supply are plotted on the RHS. The unit of measurement for all variables is kg.

This brings us to the impact of bio-fuels on the grain-use equilibrium. There is a crucial transformation that occurs in the character of competition for grains. The food-feed competition that existed hitherto was based on the changes in dietary patterns which occurred along with rise in incomes. This meant that the pace of growth in the demand for animal products and hence for feed was linked to the growth rates of income. This growth in feed demand does not occur overnight as it takes time for the middle classes to expand and change their food consumption patterns. Even for fast growing economies, this transition may take a couple of decades to occur. In other words, the use of grains as feed is largely constrained by the demand for it.

This is clearly not the case with the fuel-use of grains. The immense demand for fuels is already present in the economy even before the production of bio-fuels starts. No change in consumption pattern of any income class is required for generating demand for ethanol. It is just a matter of substitution of gasoline with ethanol when the latter is a cheaper alternative. Therefore, once oil prices cross the threshold price at which ethanol becomes competitive, there is immediately a massive demand for ethanol and hence an enormous fuel-use demand for grains. This enormous demand virtually appears overnight. Unlike feed use, the actual *ex post* use of grains as fuel is actually constrained by supply and not demand. The supply-constraint character is vindicated by the fact that even after more than five-fold increase in ethanol production in the US between 2000 and 2008,

[4] See Yotopoulos, Pan A. 1985. Middle-Income Classes and Food Crises: The "New" Food-Feed Competition, *Economic Development and Cultural Change,* 33(3): 463-83 for a detailed derivation of this relation.

[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 (Yotopoulos, 1985).

[6] 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).

it barely accounted for 6 per cent of the total motor fuel use (i.e. ethanol plus gasoline use) in the economy. In highly motorized countries like the US, where the per capita per day gasoline use was as high as 4890 litres in 2002 (precisely the time when the surge in ethanol production started), there seems to exist an endless demand for ethanol.[11] 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.

This transformation has a couple of important implications for the competition for grains. First, the transition from food-feed to food-feed-fuel competition establishes a strong demand-side linkage between the grain markets and the oil market. This linkage comes into operation once oil prices rise above the threshold level rendering ethanol production as a competitive option. Although, the government subsidies or concessions to ethanol production perform the same role of making the latter a viable energy source, there are fiscal limits to which such a support can be extended. Hence, we witness that the rise in ethanol use, when it is supported by tax exemptions, is not as fast as when there is a surge in the oil prices.

What this means for the grain market is that from now on the food and feed prices will increase even without any production shortfalls, either due to a fall in output or a sudden rise in income levels and demand, but due to 'external' developments like price surges in the oil markets. Oil prices, which earlier 'pushed' grain prices upwards from the cost or the supply side only, will henceforth, also 'pull' grain prices to higher levels from the demand side. This is exactly what occurred during the recent food crisis where the oil prices have had an amplified impact on food prices. The result has been the increase in the number of hungry people on the globe even as the per capita grain supplies have increased since 2002-03.

The second implication is more critical in nature. In the competition between food and feed, when feed prices and meat prices rise, grains are released for consumption directly as food in accordance with the income elasticity of feed demand. Feed plays the role of a cushion in the manner we described earlier and maintains food consumption in case of occasional supply shortfalls. This is facilitated by the fact that animal products can be substituted by direct consumption of grains in the human diet. The case with fuel-use of grains is clearly not similar. Even if corn prices rise driving up the ethanol prices in turn, direct consumption of grains is not a substitute for ethanol in the diet of the vehicles. Hence, grains are not released for food or animal-feed use through a reduction of fuel-feed consumption unless the price of ethanol exceeds that of gasoline.

In that sense, fuel does not play any cushioning role like feed. Also, the share of fuel-use in total grain supplies increase and correspondingly the share of feed decreases. The share of fuel-feed in total use of grains in the US in 2008-09 was already 29.9 per cent. This again undermines the capacity of feed grains to play the role of a shock absorber in case of any decline in supplies. In fact, our analyses reveal that both the food-use and feed-use declined between 2000-01 and 2008-09, by average annual rates of 0.78 and 1.7 percent respectively. Feed-use is actually less adversely affected when we consider the fact that a part of the grain used in ethanol distilleries comes back as animal feed in the form Dried Distillers Grain (DDG).[12] However, even after adjusting for DDG, the *ex post* feed-use still declined by 0.08 percent annually.

Both these implications follow from the fact that factors outside the grain market and the domain of the dynamics of human diet are playing an important role in determining the contours of the competition for grains. The movement of crude oil prices as well as the dynamics and trends in the automobile markets have emerged as crucial factors in determining grain prices and demand. This is what we can term as the 'externalization' of the grain-use equilibrium. The voracious demand for fuel-use of grains that appears, actually crowded out both the food and feed use in the current decade in the US. While a developed country like the US with low levels of hunger and under-nutrition can afford such experiments, a similar development at the global level will prove to be ominous for the poor, particularly in the developing nations. The low-income classes will increasingly lose access to their subsistence food requirements in the wake of dramatic increases in food prices caused by competition from empty gas tanks of automobiles.

*****

7 We have estimated the growth rates of real per capita income (at 1980 prices) for the US between 1980 and 2000 by using income data from the *World Development Indicators* (WDI) database maintained by the World Bank. The growth rates of per capita food, feed and fuel use in the US can also be estimated from our data on disaggregated grain use. Using these growth rates in relation I, we have estimated the income elasticity of food, feed and fuel demand for the period. The data for corn-use as fuel feed has been taken from the Feedgrains database, Economic Research Service available at (http://www.ers.usda.gov/Data/FeedGrains/

8 All growth rates of grain production are calculated based on USDA's WASDE estimates.

9 See 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 for the dietary transition.

10 One gallon of ethanol provides roughly two-third the energy provided by a gallon of gasoline.

11 Worldwatch Institute. 2007. *Biofuels for Transport: global potential and implications for sustainable energy and agriculture*. Earthscan. London

12 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 (based on information on ethanol co-products from the National Corn Growers Association (NCGA), US).