Agriculture, Food, and Energy on Spaceship Earth

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AGRI-FOOD ECONOMIC SYSTEMS

The Issue

Emergency situations have a way of revealing essential relationships that lie otherwise hidden in the routine of the day to day, and similarly the bottlenecks that characterize these relationships are untested in a normal situation. The Covid-19 pandemic, and the associated collapse of demand for some products and simultaneous pulse of workplace absenteeism, followed by hoarding out of fear of scarcity, provided an illustration of how supply chain bottlenecks can suddenly appear and spill over into one another, in a cascading crisis.

The situation today of conflict in the Middle East, the disruption of trade flows in the energy-petrochemical complex, and destruction of infrastructure to extract, process, and distribute presents another illustration. We seem to learn daily of new supply chain relationships suddenly threatened and capacity destroyed that could impact consumption for some time to come, with an unequal distribution of effects across geographies and economic sectors. In response, we see a move of countries and the international community moving toward what Chatham House has described as “resource nationalism”.[1]

We don’t have an immediate framework at hand to interpret and assess these crises and their underlying relationships.[2] It forces reference to a type of closed-economy model that seems inconsistent with the familiarity of globalized, open trade. Writing sixty years ago, the economist Kenneth Boulding (1966) gave us the metaphor of “spaceship earth” to consider the environmental problems of the day.[3] On spaceship earth, there is no free space or free disposal, resources are finite, everything affects everything else- and everyone is aware of it. Boulding contrasted this “spaceman” economy with what he called the “cowboy” economy, where there is always a frontier of resources to exploit, and where messes can be dumped and left to apparently disappear.

Amid the daily dose of shocks, we suddenly discover the bottlenecks in specific resources and products, and are confronted by the fact that supplies are distributed across a highly concentrated set of nodes, each bound by their own capacity constraints. Assuming that the conflict ends soon (and there is no sign of this as of this writing) the damaged facilities could take multiple years to rebuild, if they are rebuilt. This presents the prospect of deep adjustments and realignments in the global economy, including the prospect of economic recessions, and agriculture and food will be intimately involved. Canada and its agri-food sector could be especially impacted.

This policy note helps develop a framework and provides an exploration.

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[1] “To secure critical minerals supply governments need to take a stake in industry”, Christopher Vandome, Chatham House, Mar 18, 2026

[2] The Arrow-Debreu model of general equilibrium with no free disposal does have some of these characteristics, and operates at a high level of abstraction. But it struggles to address large, sudden shocks

[3] Boulding, Kenneth E. (1966). “The Economics of the Coming Spaceship Earth”, In H. Jarrett (ed.) 1966. *Environmental Quality in a Growing Economy*, pp. 3-14. Baltimore, MD: Resources for the Future/Johns Hopkins University Press. http://arachnid.biosci.utexas.edu/courses/THOC/Readings/Boulding_SpaceshipEarth.pdf

A Calorie is a Calorie

Viewed independently, high global petroleum prices with simultaneously high food prices present serious affordability challenges for any society. But rather than being coincident, what if they were intrinsically linked, and not independent of one another? When viewed through the lens of calories (or joules)- with fossil fuels composed of *hydrocarbons*, and food composed of *carbohydrates*, protein, and fibre- they are linked by chemistry and energetics. Carbohydrates and hydrocarbons are both carbon chains, sources of energy, and are transformed back and forth regularly. As a result, they are also economically linked. It means that if we have a hydrocarbon problem, it will eventually translate into a carbohydrate problem, and vice versa.

Sunlight energy is converted into calories by plants through photosynthesis and is further transformed- into directly edible human carbohydrate calories by food crops; into carbohydrate calories inedible for humans but consumed by animals that in turn supply human edible protein and carbohydrate calories; and into calories from plant and animal sources used to make biofuels. In turn, fossil fuel energy is the residue of plant and animal growth from long ago. It both substitutes for calories originating from current sunlight and augments the calorie potential from solar-based components of the system- for example, through nitrogen fertilizers manufactured from natural gas; fuels used to power farm equipment, etc. Conversely, biofuels can substitute for fossil fuels.

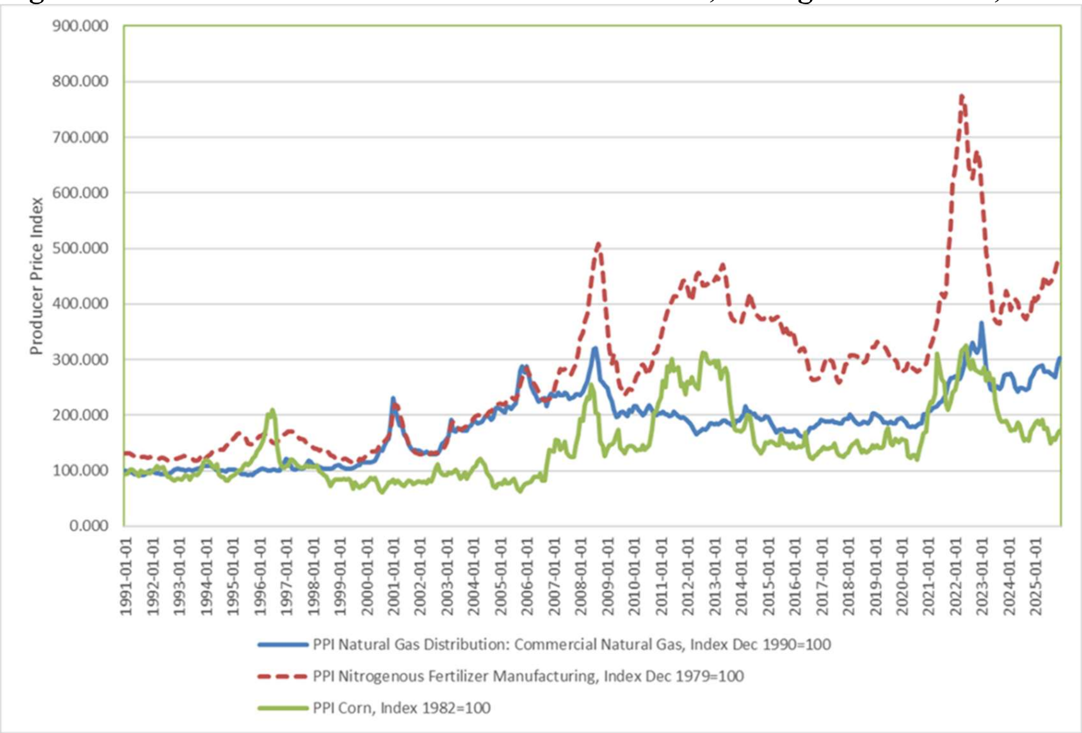
What binds this system, or closes the calorie economy, is the stock of greenhouse gases (GHGs), treated as CO_2 equivalents. Consumption of carbohydrates releases GHGs into the atmosphere (such as through respiration and enteric fermentation); extraction and consumption of hydrocarbons releases GHG emissions; plants fix atmospheric CO_2 as part of photosynthesis. The stock of atmospheric GHGs gives us the greenhouse effect that allows sufficient retention of solar energy and warmth for viable agricultural systems. Excessive warmth and severe weather from too large a greenhouse effect impairs plant growth and the functioning of agricultural systems.

Within this system, a calorie is a calorie- and when surpluses or shortages appear in one source of calories, there is a corresponding adjustment in others.

Everything Affects Everything Else

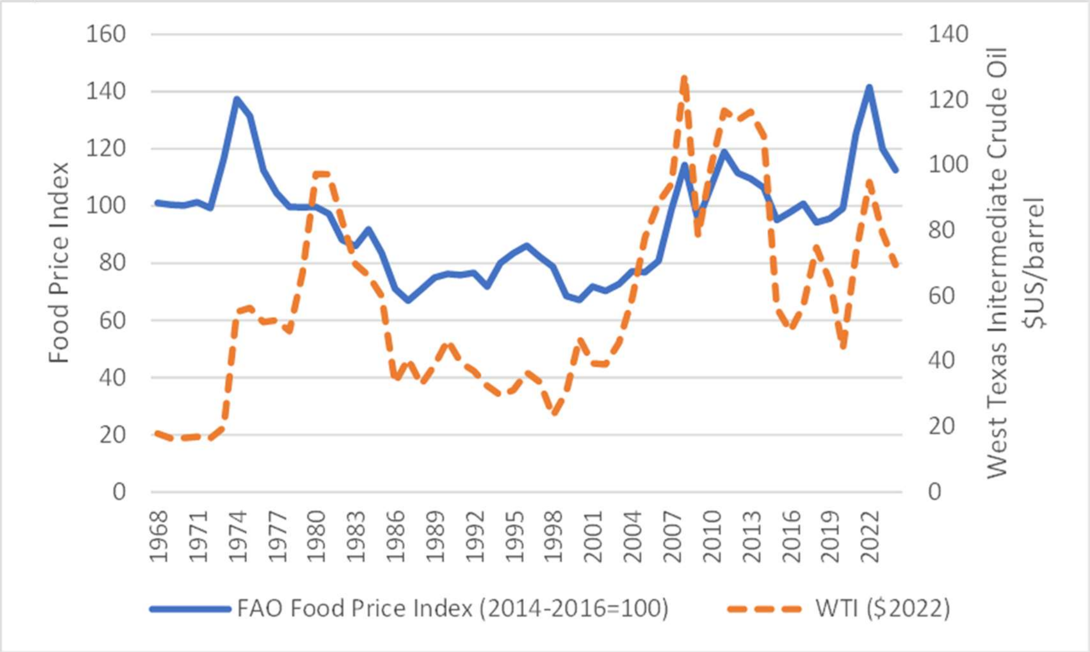
The energetics relationships between carbohydrate calories and hydrocarbon calories follow through into economic price relationships. Consider corn, natural gas, and nitrogen fertilizers illustrated in Figure 1 below. Natural gas is the foundational component of anhydrous ammonia under the Haber-Bosch process, and anhydrous ammonia is both a nitrogen fertilizer and a precursor to other nitrogen fertilizers, like urea. Corn, as well as wheat, rice and other staple grains, has a pronounced yield response to nitrogen, and in turn, corn acreage drives demand for nitrogen fertilizers. Figure 1 is consistent with nitrogen fertilizers priced according to the higher of the corn price and the natural gas price. Figure 2 provides some broader context. It plots the global food price index, adjusted for inflation, compiled by the UN Food and Agriculture Organization with the West Texas Intermediate Crude Oil price, also adjusted for inflation. The food price index is a global composite; WTI crude oil is a single commodity. However, the figure shows a remarkable correlation between the two series, with some deviations. Over time, the convergence between the two price indexes appears to be increasing.

Figure 1 US Producer Price Indices for Natural Gas, Nitrogen Fertilizers, and Corn



Source: Federal Reserve Bank of St. Louis

Figure 2 FAO Food Price Index vs WTI Crude Oil, 1968-2024

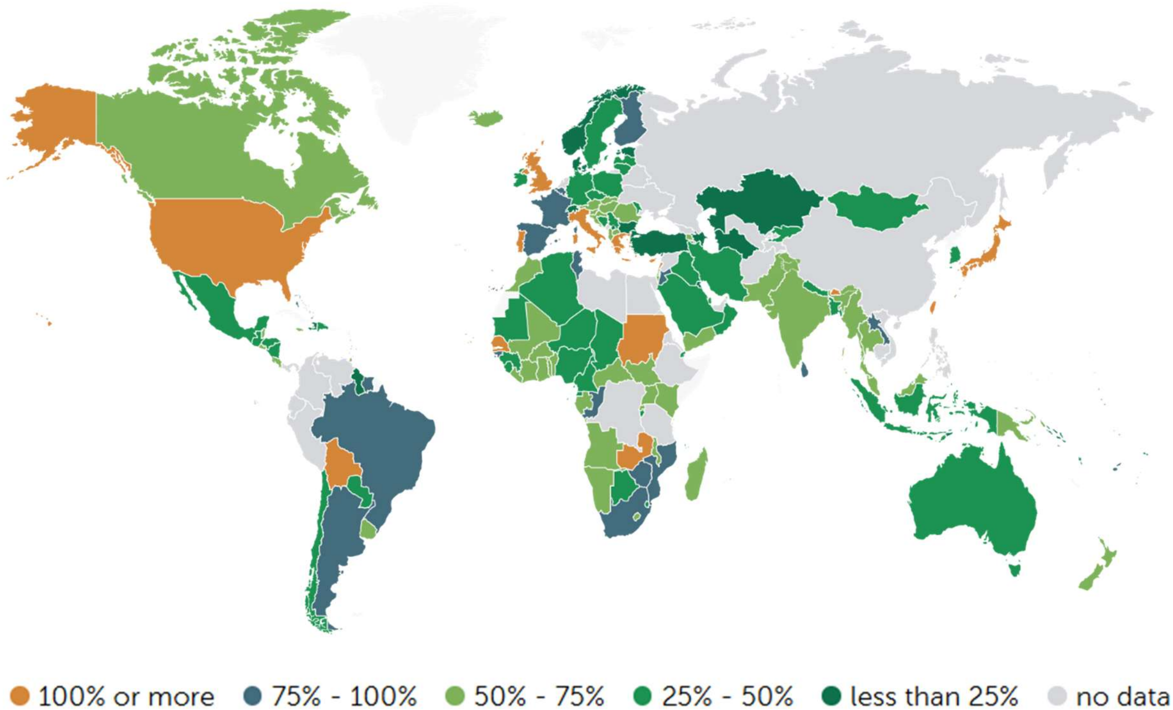


Source: UN-FAO and US Energy Information Administration

Harder to Kick Problems Down the Road

It will be increasingly difficult to blunt or defer the effect of availability and price shocks in calories rippling across products and geography through government policy actions. Many governments, especially in developed countries, have become heavily indebted relative to their GDP. This is illustrated in Figure 3 below, for 2024. A number of G7 countries have central government debt/GDP exceeding 50 percent, with several, including the US, the UK, and Japan, exceeding 100 percent. This limits government budgets and policy flexibility, and makes public finances sensitive to interest rates and government bond yields. New public spending, given existing high debt levels, will trigger increases in government bond yields, which will eventually translate into increasing interest rates- sharply increasing the cost of servicing the public debt. At the same time, central bank interest rate increases intended to combat consumer price inflation will collide with very high public debt levels creating much higher debt service costs, acting to undermine public finances. Increases in taxation are politically toxic.

Figure 4 Central Government Debt/GDP, 2024



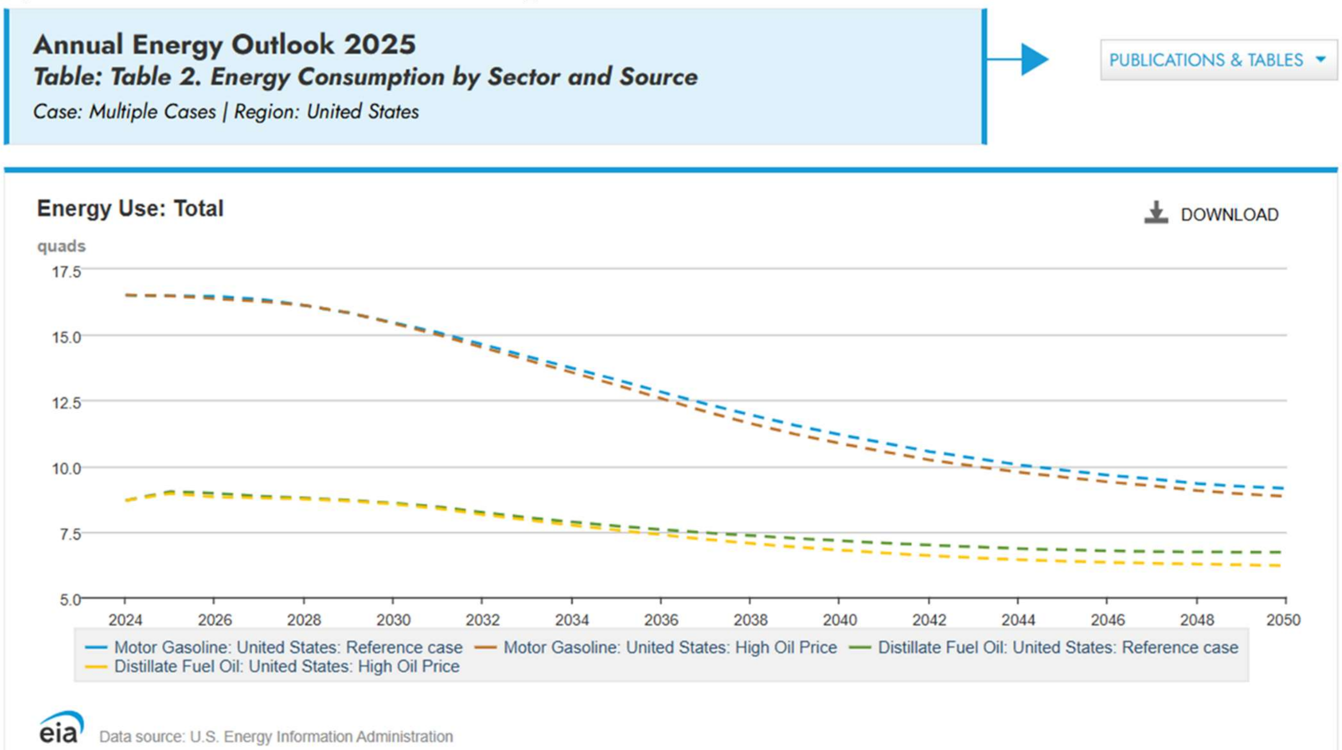
Source: International Monetary Fund

New and Complex Substitution Relationships

In a spaceship world, a sudden loss of supplies of hydrocarbon calories increases the opportunity cost of carbohydrate calories. This becomes borne out in pricing, and the tradeoff occurs in the current time frame as available public fiscal resource are scarce to cushion or defer the effect. But the effects are also complex, as we must confront existing trends in consumption and we experience a shift in relative prices (not just price levels) that induce secondary and further adjustment.

An important and illustrative example is the consumption of liquid fossil fuels. Before the conflict in Iran, it was anticipated that we would approach a peak in the consumption of liquid fossil fuels in the US and developed countries more broadly- peak gasoline within the next couple of years, and peak diesel fuel a couple of years deferred. Surely the spike in fuel prices, and the likelihood of sustained high prices, will accelerate that adjustment- through greater use of electric vehicles, more fuel-efficient vehicles, and fewer road miles driven. Figure 5 provides a US market outlook published in April 2025, under both a reference (status quo) scenario, and a high price ($US 150/barrel) scenario. Under either scenario, US gasoline consumption is immediately in decline, closely followed by distillate fuel (diesel fuel and heating oil) consumption.

Figure 5 Outlook for Total US Consumption of Gasoline and Distillate Fuels



Motor Gasoline includes ethanol blends; Distillate Fuels excludes renewable diesel fuel

In turn, in a higher priced hydrocarbon calorie environment, biofuels (ethanol and renewable diesel fuel) will be counted on to an ever-greater extent to substitute and extend hydrocarbon supplies, backed by policy instruments (mandates, tax credits, and subsidies) to direct supply.[4] But this is complex, and the broader demand for petroleum, especially in petrochemicals, is not envisaged as declining in the future- it will grow.

In the immediate term, fuel ethanol use is capped by a blending wall defined by the percentage of ethanol blended into gasoline covered under engine warranties- a maximum of 15 percent. Gasoline consumption that peaks and then falls implies reduced ethanol volumes, and ethanol expansion cannot provide respite to higher gasoline prices. The prospect of higher blends, perhaps up to 85 percent- which has been discussed but not broadly implemented, and could only currently work for a subset of engines- could suddenly become highly valuable. But new investment to expand fuel ethanol production faces what amounts to some tough math, effectively seeking to expand into a declining market. In Canada, the situation is different, as expanded ethanol production from new investment could substitute for imports.

Renewable diesel does not face a blending cap like ethanol; it just adds to the petroleum diesel fuel supply. But it shares the challenge of expanding into a declining market, despite the current supply shock. The feedstocks consumed in its manufacture are waste fats and oils from livestock processing, waste oils from food processing and food service, along with vegetable oils-principally soybean oil in the US and canola oil in Canada. The waste fats and oils are essentially fixed in supply; in order to increase renewable diesel supply, the feedstock increases come from increased use of soybean and canola oils. But crushing oilseeds also originates protein meals- valuable in livestock feeds, but the demand is price inelastic. It presents the prospect that demand for greater volumes of renewable diesel will drive much higher levels of oilseed crushing, and that it will be accompanied by higher volumes of much lower priced meals.

What will become of the protein meal, originated from oilseed crushing, to supply renewable diesel manufacturing? The developing markets for plant protein foods offer important opportunities[5] but the bulk of the market remains in feed. There is the prospect of reorienting livestock feed rations toward greater inclusion of soymeal, in place of feed grains.

The changing price relatives between feedstuffs pave the way for this; soymeal and corn provide an illustration. Figure 5 plots global corn and soymeal prices since 2003; corn has mostly ranged around US$200/tonne, with significant upward deviations to $US 300/tonne or more in 2007/08, 2011/12, and 2022/23. Soymeal has mostly ranged between $US 300-400/tonne, with major upward deviations in price in 2011/12 and in 2022/23. Prior to about 2012 there was no obvious trend in the soymeal/corn price ratio; however, since then there has been a declining trend, with recent lows, and the absolute price spread between soymeal and corn has narrowed considerably. Figure 6 relates the soymeal/corn price ratio to the US soybean crush. The US soybean crush ranged between 40-50 million tonnes between 2003 and 2014 with no apparent trend. Starting in about 2015 the crush began to increase, and has increased most recently to in excess of 70 million tonnes. This is consistent with increased soymeal supply, and a decreasing price versus other feedstuffs, notably corn.

[4] This is consistent with the recent increase in Renewable Volume Obligations Announced by the US EPA which increase mandated volumes for ethanol and (especially) renewable diesel fuel https://www.renewableenergymagazine.com/biofuels/epa-finalizes-new-renewable-fuel-standards-20260330

[5] See *Toward an Oilseed Strategy*, Independent Agri-Food Policy Note October, 2025 https://www.agrifoodecon.ca/uploads/userfiles/files/concepts%20in%20an%20oilseed%20strategy%20oct-25.pdf

Figure 5 Global Corn and Soymeal Prices, and Soymeal/Corn Price Ratio

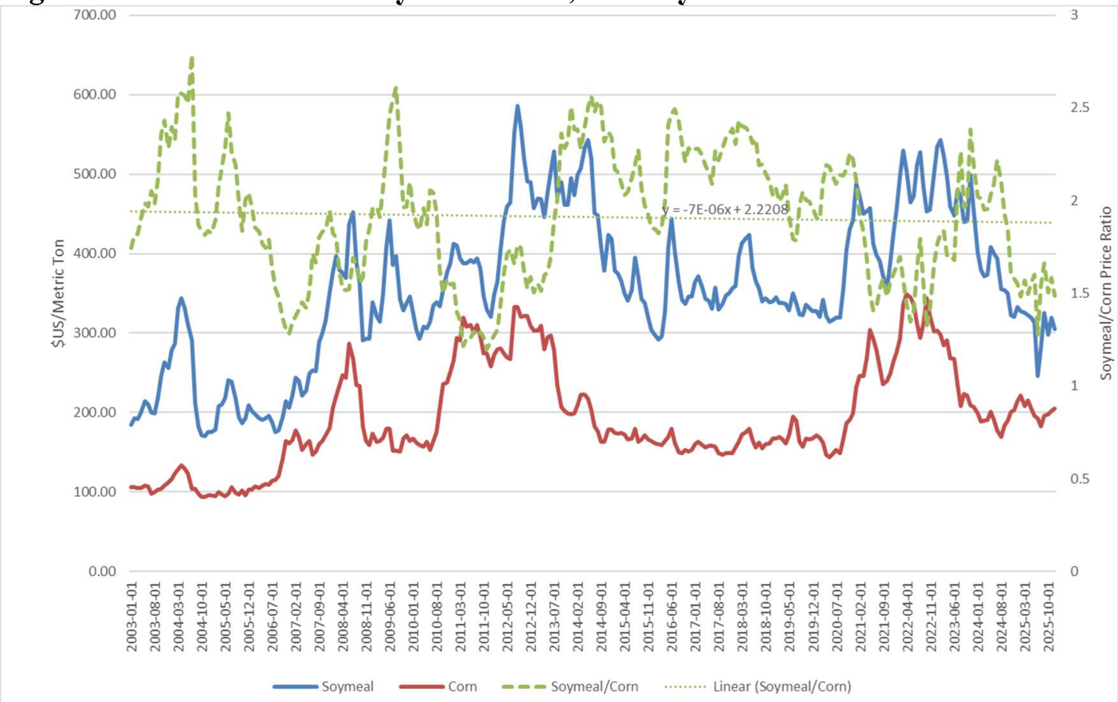
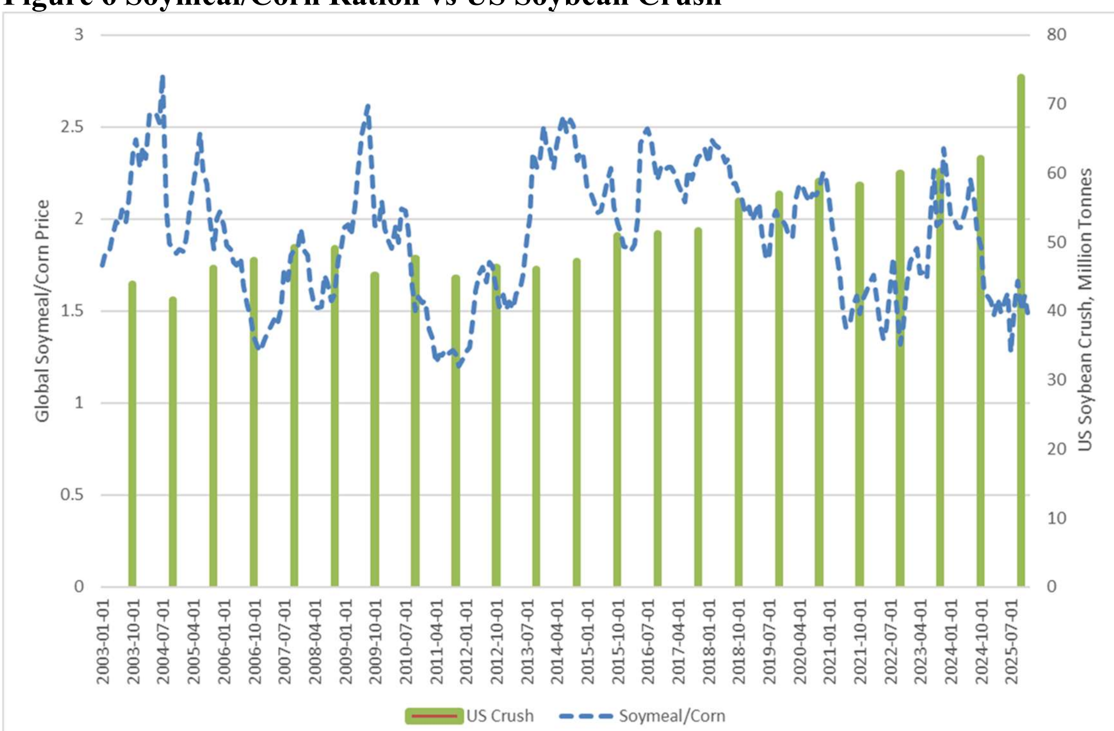


Figure 6 Soymeal/Corn Ration vs US Soybean Crush



Source: Federal Reserve Bank of St Louis and USDA-WAOB

If lower pricing of soymeal induces changes in livestock diets toward higher inclusion of protein meals like soymeal, and correspondingly reduces inclusion of feed grains like corn, what associated reorientation of crop acreage will result? What alternative markets for traditional feed grains like corn will retain historical acreage in these crops?

Conclusions

In a spaceship earth world, conflicts immediately impact and reflect resource scarcity, and can indeed be driven by resource nationalism. The proximate issue is energy; energy is calories; and calories are ultimately interchangeable between current photosynthetic sources in carbohydrates, and historical photosynthetic sources in the form of hydrocarbons. But the substitution relationships between them confront complex chemistries, environmental impacts, economics, and volatile trade policy and geopolitics among nations and groups of nations.

Because of the inherent complexity, there is a serious risk that the analysis of events and conclusions drawn will fall into the simplistic or reductionist. So far, the public discourse has mapped from “Straight of Hormuz closed, petroleum infrastructure damaged, expensive oil and gas” to “nitrogen fertilizer expensive, farmers will grow less nitrogen using crops” and “food could get expensive”.

But the situation is very fluid, and some desperate measures are being taken by countries, especially in Asia, ranging from partial driving bans, fixed fuel allotments for households and businesses, work from home orders, and school closures. Coal-powered electricity is making a sudden comeback. Surely this is only the beginning of adjustment if the conflict is sustained, if the damage to infrastructure in the Gulf takes some time to repair (if it is indeed repaired). The range of time scales of effect and adjustment are especially difficult to assess, as there are urgent issues- food security in parts of Asia for the current crop year- and longer term issues- as countries seek greater independence in calories (carbohydrates and hydrocarbons) and are prepared to invest out of fear of being cut off by expanding or future conflicts. There will thus be an ongoing need for detailed monitoring and analysis as the situation develops, we learn more, and the avenues open to adjustment- and the losses- become evident. This will be how we determine whether the damage to an LNG plant in Qatar in 2026 really impacts what a hog in Iowa or a steer in Alberta eats in 2027 and beyond, and how we gauge the risk of bread riots and social unrest in the Middle East, north Africa, and elsewhere in the future.

Pivots between carbohydrate calories and hydrocarbon calories have relied heavily on motivating policy, and it has been broadly less costly to originate calories for transportation and heating from hydrocarbons. But programming that facilitates substitution cannot occur independent of the public finance realities facing many western countries that are so indebted that they neither have the balance sheet to fund programming, nor can they borrow the money, nor can they print the money- and increased taxation appears politically out of the question. The immense costs going into the military exacerbate the situation. A technological breakthrough that materially decreases the costs of calorie conversion would be very welcome at the moment, as would be incentives for greater private capital investment that can somehow overcome the growing into a shrinking market problem.

In a spaceship world in which resource nationalism is taking hold, Canada emerges as a major power in calories- with extensive capacity beyond its own needs to share its hydrocarbons and carbohydrates with friendly like-minded nations. In this fluid situation, Canada’s positioning in foreign affairs and trade policy, and its available fiscal capacity to support infrastructure, should adjust accordingly.