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Food Security, Agriculture and Policy Making: When Believing is Not Enough

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Abstract

Global population has grown from approximately one billion a hundred years ago to eight billion in 2022. To feed this rapidly expanding population has required sustained technological advances in agricultural production and food storage, transportation and processing. This technological progress is fostered by the application of science and engineering to mechanization, chemistry and genetics. While not everyone is well fed, most are. Feeding the additional two billion people expected by 2050 will require continued technological advances. Some countries, however, are in the process of eschewing the use of modern agricultural technology to return agricultural production to pre-modern methods. They do so at their peril and, in some cases, threaten the food security of their populations. The major mandated changes in production methods also have the potential to create barriers to international trade – again negatively impacting on food security. This paper reports on the results of three such experiments in Sri Lanka, Mexico and the European Union. The conclusion is that policy makers should take more care when making radical changes in agricultural policy pertaining to production methods.

Keywords: food security, policy making, production methods, regulation, trade disputes

Introduction

The world's population is expected to reach 10 billion by 2050, an additional 2 billion people to feed beyond today's 8 billion. Much of this population growth will be in Sub-Saharan Africa, South Asia, the Middle East and North Africa (OECD/FAO, 2019), places where food production is already in deficit and unlikely to be able to meet the increased demand.

Given natural resource endowments, modernization in the agriculture sector and levels of agricultural productivity, a small group of countries are able to produce surplus food commodities while most others remain in perpetual deficit[1] whether due to a lack of resource endowments or rapid consumption increases caused by population and/or income growth with which production cannot keep pace. Hence, an essential component of global food security[2] is international trade – the movement of food from areas of surplus production to those in deficit. Worldwide food security is not an issue of food shortages, it is ensuring access to food, which must move, often across borders, from areas of surplus production to ones in deficit, at prices that consumers, particularly low-income ones in developing countries, can afford. Imported food acts as a buffer against fluctuations in domestic food supply. Combined worldwide production of any given food commodity is far less variable than that of individual countries; hence, more trade integration through functioning international supply chains can stabilize food prices, improve farmer incomes and reduce the prices consumers face (Anderson, 2016; Yeung et al., 2017; Martin and Laborde-Debucquet, 2018; Laborde and Pineiro, 2020; Gillson and Fouad, 2015). As a result, nearly 20 percent of calories consumed worldwide are traded (Huang et al., 2018). As Sen stated in 1981: "Starvation is the characteristic of some people not having enough food to eat. It is not the characteristic of there not being enough food to eat" (Sen, 1981, p.1).

In 2020, at the outset of the Covid-19 pandemic lockdowns, attention was focused on domestic and global food supply chains which suffered demand and supply side shocks. Most governments moved the ensure these supply chains remained functional and access to food remained unimpeded (Barichello, 2020; Gray, 2020; Hobbs, 2020; Laborde and Pineiro, 2020; Lusk, 2020; Rude, 2020a; 2020b). The pandemic's logistical impacts on food supply chains continue to linger in 2022 (Vos et al., 2022), contributing to rising food prices worldwide.

The 2022 Russian invasion of Ukraine has also brought widespread attention to international food security as Ukraine, known as the breadbasket of Europe, is a major agri-food exporter supplying Europe and Africa amongst others with many commodities. Russia is a global exporter of wheat, energy and fertilizer, with exports of the latter two currently sanctioned by the global community in retaliation for the invasion. The region is a major world supplier and transport hub for wheat and fertilizers and the war is placing global food security at high risk. It has exacerbated a growing global food crisis, with prices for food, fertilizer and energy already surging. The head of the United Nations (UN) Food program calls the food crisis caused by war in Ukraine 'a catastrophe on top of a catastrophe' (CBC, 2022a). Food shortages are occurring in places where wheat is a staple food including the Sahel and Horn of Africa (CBC, 2022b). The Food and Agriculture Organization (FAO) reports that in 2022, hunger, malnutrition and food insecurity are rising worldwide, with poor and vulnerable populations most impacted (FAO, 2022). The risk of famine is growing, with Somalia, South Sudan, Nigeria, Ethiopia, Yemen, Afghanistan, Guatemala most at most risk (UN, 2022).

Food inflation is now a pressing concern in every country, whether developed or developing. For example, similar rates of average annual food inflation were presented in Canada (11.4 percent, Oct 2022), (CBC, 2022c), the US (11.2 percent, Sept 2022) (BLS, 2022) and the UK (11.6 percent) (Kollewe and Wearden, 2022). In the EU, the August 2022 inflation rate for food and non-alcoholic beverages was 15.4 percent (Clark, 2022). Thailand's September 2022 food inflation registered 9.82 percent (Trading Economics, 2022), Sri Lanka faced an 85 percent increase in Oct 2022 compared to Oct 2021 (CBSL, 2022), while in Turkey, food inflation is approaching 100 percent (Akman and Kandemir, 2022). Food and energy costs are the main drivers of overall global inflation (Barrett, 2022), reducing standards of living everywhere but the poor and vulnerable in all countries are the most affected. Overall food security is coming under increasing pressure worldwide.

These issues have highlighted global food security as it faces obvious risks, understandably drawing widespread attention amongst mainstream media and the general population. Governments' attempts to mitigate these risks are also garnering attention from wide audiences. There is, however, another looming threat to food security, one that is gradual and cumulative, whose reach generally goes unnoticed by most, much like a frog in a pot of simmering water, until it is too late.

Individual countries use a broad range of policy tools to achieve domestic priorities and goals but these will affect the international trade of goods and services, either in price, quantity or both. Each country will have unique approaches to implementing and enforcing their policies, resulting in international regulatory divergence. Regulatory divergence between countries means the rules and regulations will likely be different for the same product in each market, causing friction for any foreign firms wanting to export to multiple international markets (Yeung et al., 2017).

Regulatory misalignment and divergence are occurring due to overall declining international co-operation, resulting in asynchronous approvals and a lack of equivalence or harmonization. More countries are implementing individual regulatory regimes, particularly related to food safety, that do not align with other nations' policies, or international standards, convention or practices. There is a myriad of causes for this and the reasons why it is so difficult to address are equally numerous (Isaac, 2007; Yeung et al., 2017; Smyth et al., 2016). Decreasing international cooperation in policy decisions is also evidenced as more countries implement policies that may violate their WTO obligations.

An alarming trend in regulatory divergence is occurring where policy makers are pursuing agri-food policies that deviate away from science- or evidence-based decision making, disregarding facts, history and expert counsel. Policymakers and leaders strategize and envision goals but are more frequently failing to take into consideration the realities of what is biologically possible or available. By disregarding the knowledge and advice of scientific experts, their own agricultural agencies or agri-food practitioners, to use agricultural policy as a political tool or in support of ideology, a disconnect between policy decisions and reality is taking place, with severe lasting repercussions that needlessly threaten the supply of food and food security.

Increasing regulatory divergence creates greater friction in agri-food trade, increasing fulfillment costs, with the cumulative effect of thickening borders, segregating markets and gradually grinding trade movement to a halt. Exporting becomes riskier due to uncertainty and reduced transparency. The cumulative effect of incremental but increasingly divergent policy decisions around the world is the division and slowing of agri-food trade and the concurrently increasing threat to food security.

Three case studies where such policy making is occurring are presented, with their resultant or projected economic and social risks. The impact on global agri-food trade, emphasizing food security is discussed.

Case Studies

Sri Lanka

As part of its 2019 *Vistas of Prosperity and Splendor* policy framework, the government of Sri Lanka abruptly switched to 100 percent organic farming[3] in April 2021, banning all chemical fertilizers and pesticides with little warning or transition time for farmers, against the advice of agricultural experts. The government promised delivery of natural alternatives such as compost and manure as replacements (Malkanthi, 2021; Jayasinghe and Ghoshal, 2022; Beillard and Galappattige, 2021).

As predicted, yields in the immediate growing season following the decision (May – August 2021) fell between estimates of 20 to 70 percent, depending on the crop. The decline continued the following season (Sept 2021 – March 2022) with the rice crop, a staple of the Sri Lankan diet in which it had been self-sufficient, dropping between an estimated 40 – 50 percent from normal yields, a pattern also mimicked by other crops (Ghoshal and Jayasinghe, 2022; Rasheed and Kuruwita, 2022). The government quickly reversed the fertilizer ban within six months and provided compensation to farmers but these measures were insufficient to stem the disruption to production (Jayasinghe, 2021). Government efforts to import fertilizer were limited by lack of funds.

Anti-government protests began in March 2022 and grew. Widespread food shortages forced nine of ten families to skip meals or otherwise reduce food consumption. Many in the urban middle class resorted to using food banks and the country acknowledged the dire need for international aid as the risk of famine grew (Ghoshal, 2022; Francis and Kurtenbach, 2022; Krutika and Mallawarachi, 2022). Destitute farmers may have been able to grow sufficient food for their own families but lacked the resources to continue commercial farming. They and other members of the agricultural supply chain exited the sector. Yields are unlikely to rebound or may be lower for the next harvest season, providing little relief for food supply or prices (Jayasinghe 2021; 2022a; Ghoshal and Jayasinghe, 2022b). The policy has decimated the country's food security and plunged the entire economy into a self-induced crisis (Nordhaus and Shah, 2022; Jayasinghe and Ghoshal, 2022; The Economist 2021). The overall economy defaulted into bankruptcy (DW, 2022) pinning the country's economic viability on an IMF bailout. Protests became increasingly violent, ousting the heads of state, causing them to flee the country by the beginning of July 2022 (Francis, 2022; Jayasinghe, 2022c). Food inflation had reached nearly 94 percent in Sept 2022 (Jayasinghe, 2022d) when the IMF agreed to a provisional US$2.9 billion bailout (Jayasinghe, 2022b).

Many factors contributed to Sri Lanka's economic collapse. The combination of pandemic induced problems (supply chain issues, loss of tourism, reduced remittances, returning diaspora), years of economic mismanagement, corruption, high levels of external debt and poor domestic fiscal policies left it without sufficient resources to weather economic shocks. The fertilizer ban and consequent crop failures was the shock the economy could not absorb, triggering the economic downward spiral. Global inflation, loss of agricultural export earnings, lack of foreign exchange, currency devaluation, poor credit ratings and the war in Ukraine increased costs for a rapidly depleted national treasury that was unable to pay for imported necessities such as food, medicine, energy and fertilizer (Kuruwita, 2022; Kahn et al., 2022; Nordhaus and Shah, 2022; Bhowmick, 2022; Francis and Kurtenbach, 2022; Ghoshal and Pal, 2022).

A multitude of factors contribute to the fiscal viability and functioning of any economy. There are many other examples of countries with economic mismanagement, high food inflation, poor fiscal policy, high levels of debt and/or corruption, all trying to recover from the pandemic. These in any combination do not immediately threaten food security such as that experienced by Sri Lanka. Domestic crop failures combined with the inability to import from external sources, war/conflict and poor agricultural policy decisions do pose immediate threats to food security. Poor agricultural policy decisions can destroy an economy and the agricultural farming system, which will take years to recover. The probability and severity of such disruptions depends on a country's individual circumstances, its economic resilience, the weight and nature of the agricultural sector in the overall economy, and external global factors. In Sri Lanka's case, the fertilizer ban caused agricultural failure and hunger in one crop cycle with interlinked multiplier effects rippling through a vulnerable economy.

Whether the government was fully motivated by the agro-ecology ideology it espoused or merely sought to conserve funds by not subsidizing the cost of imported commercial fertilizer for farmers, the decision to replace conventional production and fertilizer with organic systems and natural alternatives ignored some essential facts. Sri Lanka could not produce or source sufficient organic alternatives to commercial fertilizer that would compensate for the yield differential and certainly not on short notice.[4] The government failed to deliver much of the promised natural alternatives to farmers (Jayasinghe and Ghoshal, 2022). Even if it were able to provide the alternatives, organic yields are lower than conventional production with higher variability, and organic productivity lags behind that of conventional production.[5] Organic production costs are higher than conventional crops, as are the overall distribution and supply chain costs due to smaller volumes and ingrained inefficiencies (FAO, n.d.). The misguided and rushed fertilizer ban in Sri Lanka caused agricultural collapse and food shortages. Fiscal problems reduced Sri Lanka's ability to import replacement food supplies, resulting in severe food insecurity.

Mexico

During his presidential campaign, Andrés Manuel López Obrador (AMLO) promised to improve rural wellbeing and increase the productivity of small agricultural producers in order to reach food self-sufficiency, invoking food sovereignty as a matter of national security and pride (de le Barrera et al., 2019). At the end of 2021, the Government of

Mexico issued a Presidential Decree to ban genetically modified (GM) corn and phase out the use of glyphosate, to be replaced by sustainable agro-ecology alternatives and practices appropriate for Mexico, on the justification of protecting its people's health, the environment and food sovereignty, as promised in the campaign. AMLO indicated he believes the safety information regarding GM products is insufficient. There has been much confusion and uncertainty about the decree ranging from implementation, regulatory structure, trade regulations, enforcement, process, administration, and oversight (Kuypers, 2021) as the government has not issued consistent guidance nor clarification regarding the decree. For example, nearly two years after the decree was issued, it remains unclear whether the ban applies to GM corn intended for food and/or feed, or to food products containing ingredients derived from GM corn (Garrison, 2022a; 2022b; Kuypers, 2021; Pratt 2021b).

Mexico is the world's second largest importer of yellow corn. It sources 95 percent of its yellow corn imports from the United States, roughly 15 million tonnes annually, of which 92 percent is GM corn (Pratt, 2021b). While it is self sufficient in growing white corn for human consumption, virtually all the yellow corn grown in and imported by Mexico is intended for livestock feed (a small proportion is used in food processing). Poultry for meat and eggs and dairy beef consume 57 percent of the feed produced in Mexico, producing the staples of the Mexican diet that constitutes much of the country's food security (Macall et al., 2022).

To compensate for the ban on GM corn, Mexico intends to replace 30 percent (5-6 million tonnes) of its total corn imports with increased domestic production. Achieving this increase is improbable for two reasons. Between 2000 and 2020, Mexico only produced sufficient yellow corn to meet 14 percent of its yellow maize demand. Its production trend has not increased, remaining relatively stable since 2015, averaging roughly 27.5 million tonnes annually (Pratt, 2021b; Macall et al., 2022). AMLO's push to increase self sufficiency has provided free fertilizers and expanded irrigation among other incentives, which has increased domestic corn production between 1-2 percent annually (Garrison and Barrera, 2022). Since Mexican farmers are banned from cultivating GM corn, the needed rapid yield and productivity improvements are unlikely (Pratt 2021b; Garcia 2021; de la Barrera et al., 2020; Alcántara-de la Cruz et al., 2021; Ventura 2021b).

Macall et al. (2022) found that at current average yields, to compensate for the loss of imported GM supplies, hectares planted to conventionally produced yellow corn would have to increase 512 percent to meet current domestic demand. However, as the decree intends to switch Mexico's agriculture to agro-ecology,[6] they calculated that hectares planted to maize would have to increase by 761 percent over current production to compensate. Despite these calculations, the Deputy Agriculture Minister stated "We do believe that we will achieve it" referring to increasing local corn production to 6 million tonnes (Garrison and Barrera, 2022).

The government plans to source the remaining 70 percent of its needed corn imports from non-GM corn suppliers. As most corn grown in the world is GM, it is unclear where the non-GM corn will be sourced from. Other large producers such as Brazil and Argentina have indicated they will not alter their GM production systems to supply Mexico (Garrison and Barrera, 2022; Pratt, 2021b). Even if they would, transportation costs would make their exports to Mexico uneconomical for feed processing. This would also be the case were Mexico to source non-GM corn from China. The government has announced it will seek direct agreements with farmers around the world to source non-GM corn supplies (Garrison and Barrera, 2022). It seems improbable that there would be sufficient growers globally willing to firstly, contract with any government directly given the risk exposure and secondly, produce the volume Mexico needs.

AMLO has been a vocal opponent to glyphosate and the Decree bans it by 2024, with the directive that agro-ecology suitable alternatives be found (AP, 2020). Mexico's National Agricultural Council states that the combined GM and glyphosate ban threatens to decrease the country's corn production by 30–45 percent, in sharp contrast to the government's plan to increase production by 30 percent (Alcántara-de la Cruz et al., 2021; Pratt 2021a; Garcia 2021). This is similar to the decrease modelled by Macall et al. (2022). Converting Mexico to the government's envisioned agro-ecology production system will require more farmland and resources, neither of which is readily available (de la Barrera et al., 2020; Ventura 2021b; Macall et al., 2022). Agricultural groups, farmers' groups and other agricultural stakeholders' efforts to stop the bans have been unsuccessful through most of 2021/22 (Garcia, 2021; Reuters, 2021). The GM and glyphosate ban is widely viewed as violating Mexico's obligations in the United States, Mexico and Canada Trade Agreement (USMCA) with both Canada and the US concerned about its impact on agri-food trade.

Most of the world's corn production is grown for livestock feed or industrial uses and is GM. Conventional and organic corn is mostly for human consumption. To switch from importing GM to non-GM corn for feed means Mexico requires a combination of organic and conventionally produced corn. The agro-ecology strategy will focus on organic production which is always more expensive than conventional (see endnote 5). Even if organic supplies were to be grown domestically as well as imported, there would not be enough. What would be available would be costly and it is improbable that Mexico's consumers and livestock producers could afford them. As a result, the GM ban/agro-ecology strategy will cause food prices to drastically increase, exacerbating existing inflationary pressures on consumers' food purchases, risking Mexico's overall food security (Garcia, 2021; Macall et al., 2022; de la barrera et al., 2020; Alcántara-de la Cruz et al., 2021). Analysts are predicting moderate starvation for Mexican livestock as a result of the GM corn ban and the improbability of finding non-GM supplies (Pratt, 2021b). Significant costs would be imposed on the Mexican economy.

WPI (2022) calculates in the first year of the ban, non-GM corn prices could rise 48 percent to US$8.14/bushel and Mexico's cost to import corn would increase by US$ 571 million. The ban would increase the average price for corn by 19 percent and Mexico's consumers would pay an average of 16 percent more for corn tortillas, a staple in their diet. More of their income would be spent on food, and they would suffer greater food insecurity. Corn based ingredients such as protein, fiber and oil used in thousands of processed foods would also incur price increases, further contributing to food inflation and food insecurity in Mexico. Mexican livestock production shrinks, declining an average of 1.2 percent annually. Mexican poultry production declines 17 percent while hog production would shrink 13 percent. Beef and dairy sectors suffer production decreases of 9 and 8 percent respectively. For Mexico's poorest populations, prices could rise to the point that eggs become a luxury item. For Mexico to administer the GM ban would require an additional US$1.056 billion related to testing, segregation and traceability, costs that would be passed onto consumers. Over ten years, the ban would increase Mexico's corn import costs by US$4.4 billion, shrink Mexico's GDP by $11.72 billion, reduce economic output by nearly $20 billion and over 55,000 jobs would be lost annually. Costs imposed upon Mexico's USMCA trade partners and their exporters were also calculated to be in the billions (WPI, 2022).

Macall et al. (2022) calculate losses in both Mexican surplus due to adoption of the agro-ecology strategy ranging from 12 to 18 percent over five years to 2029. Their conservative estimate is that the cost of 1 MT of yellow maize will increase 81 percent to a cost of at least US$3 billion annually.

There is a further concern that the ban will move beyond glyphosate to other chemicals used in agriculture and food production, which would make Mexico's regulatory environment the world's most stringent. A proposed chemicals ban would remove 60 percent of the pesticides used in Mexico for the sake of the precautionary principle and replace them with natural plant- or micro-organism derived alternatives that may or may not yet be available. Mexico's National Agriculture Council warned that this chemicals ban would reduce farmers' yields such that they would stop growing food, placing Mexico's food security at high risk (Garrison, 2022a).

Mexico has a comprehensive Biosafety Law governing the development, use and release of GM organisms (CIBIOGEM 2019) and has a history of GM approvals. It has long maintained a GM cultivation ban in corn to protect heritage varieties amid fears of mingling, environmental release and cross pollination but allows experimental field release for GM maize.[7] Cotton is the only GM crop planted in Mexico. Although other GM crops are not technically banned from cultivation, no new GM crops have been approved in Mexico since 2018 (Otero, 2021; de la Barrera et al., 2020; Macall et al., 2022; Ventura, 2021a; 2021b; 2021c). The ban intends to revoke existing GM approvals.

In November 2019, Mexico's Secretariat of the Environment unilaterally stopped approving import permits for the herbicide glyphosate, citing the precautionary principle and concerns about glyphosate and transgenic crops' effects on human health and the environment (Otero, 2021). COFEPRIS, the national health regulator, has not authorized new glyphosate resistant GM corn varieties since 2018, and indicated that the 2020 GM corn/glyphosate ban was based on "scientific evidence and risk assessments" which trade partners and agricultural groups dispute, citing lack of scientific basis (Garrison, 2022b). COFEPRIS did release an official document stating the rationale for revoking and banning of GM maize/glyphosate as (translated from Spanish): 1) Its right to protect against human health risks; 2) presence of glyphosate in final food products and in human samples; 3) irreversible risk (cytotoxic and genotoxic potential); 4) Human exposure (urban and rural occupational and non-occupational); 5) technologies that allow resistance to toxic substances increase their use due to the resistance generated in the pests they seek to control (COFEPRIS, 2020, page 35). The government's policy direction is hinted at by the statement in October 2022 to Reuters made by Mexico's Deputy Agriculture Secretary, Victor Suarez: "you give me the scientific evidence that they (pesticides and chemicals) don't do harm. The proof is on you, not me" (Garrison, 2022a).

Beyond this, Mexico has failed to provide scientific rationale or basis to justify the ban as well as the reversal of its own GM policies. The given reasoning contradicts the scientific evidence regarding the safety of GM crops.[8] Such actions are likely to contravene USMCA provisions, with US farm groups urging the US government to bring forth a trade challenge on this basis (Goodman, 2022; Reuters, 2022; Macall et al., 2022; Garrison, 2022b; Haag, 2022) as the ban also imposes significant economic costs and losses to the US and Canada (Reuters, 2022; WPI, 2022).

On October 26, 2022, the Ministry of Agriculture and Rural Development issued a statement that while it will comply with the Decree and does not promote glyphosate, currently, there are limited alternatives to glyphosate and many pesticides, which are also less effective and more expensive. It warns their immediate prohibition would impact Mexico's food security and cause food inflation (MARD, 2022). On November 22, 2022, media reported that AMLO was considering allowing US GM yellow corn imports for livestock (Martin et al., 2022) with discussions scheduled between AMLO and the US Secretary of Agriculture Tom Vilsack on November 28 (Madry, 2022). On December 7, 2022, Mexico offered to extend the deadline one year to 2025 and revise its ban (Barrera and Graham, 2022). The situation remains fluid at time of writing but appears promising that Mexico's policy makers may be heeding the warnings based on science and evidence.[9]

With food inflation already at 14 percent, a 22 year high in Mexico, the contradictions in the Presidential Decree are clear. While it claimed to contribute and enhance Mexico's food security, the food inflation it would cause would only erode food security. It also contradicted AMLO's own stated policies of food security and affordability for Mexico. AMLO may have recalled the 2007 Tortilla Crisis in which he, as a Presidential candidate, personally protested with fellow Mexicans against surging prices in tortillas and the damage done to the then President Calderon, his political opponent (Hamm, 2007). He may also have been advised of the situation in Sri Lanka where citizens were sufficiently food insecure to oust their heads of government.

European Union

The European Union (EU) has long been a proponent of the precautionary principle and social rationality in its policy making where the role of science is only one aspect to inform policy making (Smyth et al., 2011; 2013). Once a scientific assessment is concluded, non-scientific criteria are then assessed, which reduces overall regulatory transparency and certainty (Viju et al., 2012).

The EU's *Farm to Fork* (F2F) and *Biodiversity Strategies* propose a comprehensive agenda for sustainable, circular food production in the EU as part of its overall Green Deal policy. It proposes a 50 percent reduction in the use and risk of pesticides, a 20 percent cut in fertilizer use, increasing organic land from eight to 25 percent, country of origin labelling for certain products and emphasizing plant-based diets, among its 27 measures (EC, 2020a; 2020b; Pratt, 2021a; Morrison, 2020). The F2F strategy is a keystone of the EU's *Green Deal* and its targets are expected to become, in essence, mandatory policy objectives under the upcoming Common Agricultural Policy cycle of 2023-2027 (Wesseler, 2022).

The economic impacts of F2F have been measured by several studies looking at different components of the policy. Beckman et al. (2020) used the GTAP–AEZ (Global Trade Analysis Project –Agro Ecological Zone) multiregional, multisector, computable general equilibrium model to measure the impact of F2F while Noleppa and Cartsburg

(2021) used a multi-market model. Barreiro-Hurle et al. (2021) and Henning and Witzke (2021) both used the Common Agricultural Policy Regionalized Impact (CAPRI) model of the European Commission's Joint Research Center. Bremmer et al. (2021) used the partial equilibrium model AGMEMOD (Agricultural Member State Modeling). Baquedano et al. examined the impact on 77 low to middle income countries.

The 20 percent reduction in fertilizer use will reduce EU crop yields, the amount of which varies by crop and location. A shrinkage in production for 2030 of 92 billion Euros, a maximum of 20 percent food inflation and increased land usage of between two to three million hectares was calculated by Bremmer et al. (2021). The other studies report similar findings. They all found that the reduction in pesticide use would decrease the EU's overall agricultural productivity, with losses varying by crop and location. Increasing the proportion of land dedicated to organic agriculture will also shrink yields and productivity depending on the crop and region (see endnote 5) with significant variances between member states. Some also partially quantified the F2F impact on greenhouse gases and biodiversity (Barreiro-Hurle et al., 2021; Henning and Witzke, 2021). All studies found the F2F strategy will reduce the EU's overall agricultural production and EU consumers will bear the resultant food price increases, reducing their overall consumer surplus. While some producers experience increases in income, this is not distributed evenly through the agricultural supply chain. The studies concur that as EU agricultural production decreases, drastically in some commodities, the EU will reverse from its status as a global net exporter of food to a net importer. Further, a net overall welfare loss is experienced that will not be compensated for by the environmental gains (Beckman et al., 2020; Noleppa and Cartsburg, 2021; Barreiro-Hurle et al., 2021 and Henning and Witzke, (2021). In order for F2F to increase overall welfare, further technological innovation, such as supporting modern biotechnology as well as institutional reforms, are needed (Wesseler, 2022). Beckman et al. (2020) calculate F2F could make an additional 22 million people food insecure. Baquedano et al. (2022) found that the EU's F2F and biodiversity strategies would increase food insecurity for 30 million Europeans and 171 million people globally.

It is not only economists warning of the F2F impact on food security. EU farmers have warned that F2F's intention to increase organic food production at conventional food prices is unrealistic (Morrison, 2020). The EU's producer and agri-food associations have collectively warned the policy is "well intentioned" (Pratt, 2021a), but the current approach will threaten the "viability of European agri-business culture" (CropLife Europe, 2021) with environmental protection forcing the "outsourcing of European agriculture" (Barreiro et al., 2021). Beltran et al. (2021) assessed the F2F and *Green Deal* using an integrated approach incorporating environmental, economic, cultural, nutritional, legislative and societal considerations. They find that F2F is overly optimistic, and its viability will require significant support and policy tools as well as a redoubling of research, innovation, technology transfer, governance and changes in consumer consumption[10] if food security is to be maintained.

Further, EU policymakers are considering imposing trade barriers against agrifood products that do not comply with the *Farm to Fork* policy (Southey, 2021). To paraphrase Beltran et al. (2021), the EU's new sustainable policies will need to be supported by 'unsustainable imports', i.e. imports not produced to the EU's F2F environmental standards. The *Green Deal's* Carbon Border Adjustment Mechanism will force exporters to adjust their production practices to meet the EU's green standards in order to enter the EU market (EC, 2021; Paarlberg, 2022; Pratt 2021a; White 2021). There is considerable disconnect between the F2F policy that will greatly increase the EU's dependence on food imports and concurrent measures that make it much more difficult and costlier for the world's exporters to supply them. The risk to Europe's food security only increases in such a situation. Further, this reversal from a net food exporter to a net food importer means that the food the EU imports will consequently not be available for other, more import-dependent countries that also need it. Many of these countries' resource endowments are such that they have no choice but to be more reliant on food imports, rather than choosing to be as the EU is doing. The global pool of food available for export will be reduced in two ways as the EU will firstly no longer be contributing to the pool and secondly, will withdraw from the pool. This reduces worldwide food security as less is available for those that rely on imports.

The philosophical heart of the EU's *Green Deal* is the unproven concept of "growth without economic growth", to transform the EU into an equitable and prosperous society, with a modern, competitive and efficient economy where growth is decoupled from the use of resources for a sustainable future. It pursues alternatives to mainstream conceptions of economic growth that will require technological change with concurrent changes in consumption and social practices (EEA, n.d.). Pursuing and achieving such an evolutionary experiment requires time. While it undergoes this philosophical, societal, structural and economic transformation, it appears the science and data underpinning agriculture and food production will continue to only be considered one part of EU decision-making. Whether policy makers will provide sufficient transition times for what they have acknowledged as the necessary technological advances to be made, changes to governance and consumer behavior to occur, and research and innovation to advance (EEA, n.d.; Wesseler, 2021; Beltran et al., 2021) seems unlikely given the F2F timelines. Consider that current plant breeding techniques and commercialization can take years or even decades. Whether any eventual gains from research and innovation would be accepted by EU policy makers and consumers is also questionable given the EU's entrenched stance towards existing products of biotechnology (Viju et al., 2012; Smyth et al., 2011; 2013; 2016) and the current regulatory tone regarding new genomic advances (Paarlberg, 2022; Purnhagen and Wesseler, 2021). It is also unclear whether EU consumers are aware of, understand and will be accepting of the intended wholesale changes to their food security, costs of food and food consumption patterns.[11]

Given that food production will immediately be impacted by the F2F strategy while necessary structural institutional changes occur at a much slower pace, the EU is choosing to change itself from an area of surplus food production to a net deficit food production area and in the process, willingly place its food security at risk while it transforms. Recall that poor policy decisions destroyed Sri Lanka's agriculture sector in one crop cycle. While the EU makes its transition, Europeans will be caught between hunger and this grand experiment. The war in Ukraine has further exacerbated already soaring energy, food and heating costs[12] that are inflicting the worst affordability crises on European businesses and consumers in 50 years. They are faced with a cold, dark winter but could soon add hunger to their woes.

Conclusions

Food security is comprised of availability (i.e., physical supply of food at a local or national level), access (i.e., affordability of food in sufficient quantity), utilization (i.e., meeting of all nutritional needs), and stability (i.e., uninterrupted ability to meet food needs). It is generally understood amongst those involved in agriculture that policies affecting the use of agricultural inputs such as fertilizer and pesticides will reduce yields (i.e. availability), and raise the cost of food (i.e. reduce affordability and access). Global attention is being paid to food security due to the Covid-19 pandemic and the war in Ukraine. As the world emerges from the pandemic in the face of high food inflation and increased risk to food supplies, the looming need to increase global food production to feed 10 billion by 2050 lurks in the background, as does the threat of climate change. The world's governments and policymakers should be focusing on increasing agricultural productivity and overall production. Policy decisions should not impede or obstruct the ability to grow and produce food more than necessary.

Yet there is a growing trend amongst national governments to make food and agricultural policy decisions based upon ideology, beliefs or political motivations, particularly in the wholesale adoption of agro-ecology based food production.[13] Whatever the underlying motivation, by eschewing modern agricultural inputs such as fertilizer, pesticides and biotechnology in overall production, such policies will reduce agricultural yield and productivity that in turn, can have catastrophic food security results for consumers and producers, the impacts of which can take years to recover from. It has been described as using “a very old and unfeasible production system to feed the world.” (Garrison, 2022b).

Policy decisions should also not cause friction in the movement of food from surplus producing areas to ones in deficit. Reducing friction in agricultural trade requires regulatory cooperation and collaboration, the opposite of divergence. While critical to a functional trading system, it is eroding. It is the ability to import food from external sources that assists those suffering from disruptions to food production caused by conflict, crop failures or poor policy. It is the ability to import food from external sources that provides areas that cannot produce enough on their own with some measure of food security. Governments and policy makers should be working towards regulatory convergence in ongoing collaborative efforts to ensure trade in food occurs.

Global agrifood trade is becoming increasingly bifurcated between markets basing policy upon science and evidence, such as the US, Canada and Australia and those choosing the precautionary principle, such as the EU. Resilient global supply chains have thus far been able to accommodate these differences. When the regulatory burden becomes too complicated, individual firms will choose whether to supply a particular market or not.[14] When sufficient numbers of firms stop supplying a market, shortages, loss of choice and price increases result. Consumers with higher income levels, particularly in countries with sophisticated supply chains, tend not to notice such changes immediately as their incomes can absorb higher prices and substitutes are readily available. What might be noticed is that there is a temporary shortage of a particular item, say limes or romaine lettuce. Substitutes are usually available. When the line will be drawn, where supply chains are no longer able to provide at levels these consumers expect is unknown. It was hinted at during the beginning of the pandemic with the hoarding of toilet paper, pasta and tomato sauce. It is the lower income, marginalized and vulnerable in all countries that will suffer, first and more severely and for longer as they lack the cushion of afforded by surplus income.

A drastic policy change such as the EU’s Carbon Adjustment Mechanism may be sufficiently burdensome that a large cohort of global exporters choose to not supply the EU at a time when its own policy will radically reduce domestic food production. As a wealthy developed region, the EU possesses more fiscal resources to cushion the impact of food inflation than a smaller economy would but that is not sustainable for long as evidenced by its current attempts to mitigate energy inflation for its citizens. If its policies make it too difficult to supply, food will not be shipped to the EU, regardless of the funds available to purchase.

While much of recent agro-ecology policy making is being undertaken to address climate change and protect the environment, it must be tempered by the realities of biology and botany. Modern agricultural production is far from perfect, with its own set of problems beyond the scope of this paper. Efforts to address climate change in agriculture and food production are needed but must be based in science and evidence, taking into account transition times, cross sectoral linkages and multipliers. Decision makers without a background on science-centric issues should seek the counsel of recognized experts rather than following self-confirmed ideology and political belief.

Growing and producing food is governed and constrained by the irrefutable laws of biology, botany, and agronomy. It is a process that requires specific timing, seasonal cycles, inputs and processes that cannot be easily altered or stopped, especially on short notice. Agricultural inputs of sunlight, water, labor, soil, seeds, nutrients and chemicals will result in predictable outputs of crop yields and productivity, depending on the ratio of inputs, physical environment and seasonal biological lags. These physical requirements are governed by science and the laws of nature which have little regard for ideology, political agendas or bureaucratic schedules. Disruptions to growing food cannot be quickly corrected. At least one crop cycle will be lost, with additional time needed for the next to be successfully seeded and mature. It is often months if not a year, before food is once again successfully produced.

The current availability of food (or not) today was determined by producers' decisions made months or years ago, which in turn were based upon their planting and operational factors at that time, including the policy environment.[15] Policy decision making not based in science on issues grounded in physical science, or made without the appropriate transitions that accommodate physical science can have catastrophic consequences. The poor, the marginalized and those of lower incomes in all countries, regardless of developing or developed, will suffer first and the most severely for poor agricultural policy decisions. The middle class is also not insulated as food prices increase, availability and selection deteriorate. Food security and standards of living will fall for everyone.

Food security challenges were overcome in the past with advances in scientific innovation and developments in social protection (Barrett, 2021). In order to meet the forthcoming challenges of feeding 10 billion people and worldwide food security, policy makers should not discount the very tools that provided the solution in the past.

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Endnotes

[1] In 2018, the five countries of China, Korea, Japan, Russia and Saudi Arabia are responsible for roughly 40% of food net imports and seven countries (Argentina, Australia, Brazil, Canada, New Zealand, Thailand and USA) account for about 55% of total food net exports (Huang et al., 2018).

[2] Food security is considered to have been achieved when each of four interrelated components are met: availability (i.e., physical supply of food at a local or national level), access (i.e., affordability of food in sufficient quantity), utilization (i.e., meeting of all nutritional needs), and stability (i.e., uninterrupted ability to meet food needs) (Thome et al., 2019).

[3] In this discussion, organic practices and agro-ecology production systems are used interchangeably as organic practices are a large component of agro-ecology.

[4] The *Vistas of Splendor Strateg*y was supposed to transition to organic production over a 10-year period. While farmers found appeal in the idea of organic farming, many recognized that they required a transition period, and that a combination of organic and conventional farming was more feasible (Jayasinghe, 2021). Malkanthi (2021) found that the organic sector in Sri Lanka was in its infancy, requiring substantial investment in programming, extension, policy support, and in all aspects of the supply chain including production. It lacked the capacity to increase in scale or volume.

[5] The ranges of which are still debated but range between 8-30% less yield and 20-44% less productivity, depending on the specific crop, locality and region. The higher costs of organic

production are undisputed. Many studies have examined this issue – see FAO (n.d); Alvarez (2021); de Ponti et al. (2012); Lesure-Dumoulin et al. (2017) for example.
[6] In the US, organic production reduces maize yields by an average of 31 percent and this was used as a proxy for Mexico by Macall et al. (2022). Agro-ecology production in Mexico would occur in eroded soil conditions, where the crop would be nutrient deficient due to lack of fertilizer and under attack from pests which would not be controlled by pesticides. These conditions will decrease productivity and yield.
[7] Mexican public researchers have developed highly productive, drought resistant strains of local GM varieties of maize which under laboratory tests showed improved growth under scarce water conditions and at low temperatures compared with standard corn. This corn is limited to the lab and cannot be cultivated due to regulatory prohibition (Ventura, 2021c).
[8] National regulatory agencies in 72 countries have conducted 4,485 risk assessments, which include those for human health, all of which concluded that the risks from GM crops are no different to the risks from the production of non-GM crops and foods (ISAAA, 2019).
[9] It is important to note that the Presidential Decree did not have unanimous support with considerable internal division within the government as well as between government agencies and departments. While AMLO's supporters and a coalition within the government vocally supported his beliefs and the decree, including Deputy Agriculture Secretary Victor Suarez, others, including Agriculture Minister Victor Villalobos, were more measured.
[10] Including a significant reduction in the demand for animal protein by reducing supply and increasing price. An accompanying decrease in imported animal feed, of which the EU is one of the world's largest importers, is also prescribed (EC, 2020b).
[11] The F2F has goal of a protein transition away from meat and livestock by reducing their availability while increasing price. Plant-based diets are strongly emphasized with plans to increase the availability and sourcing of alternative foods and feeds including plant, microbial, marine and insect-based proteins and meat substitutes (Foote, 2020; EC, 2020b).
[12] From 1996 to 2017, the EU focused on decoupling greenhouse gas emissions (GHG) from economic growth and accelerated decoupling occurred with the launch of the EU's 2005 Energy Policy. While improvements in energy intensity and structure have been large drivers of EU's GHG emissions reductions, outsourcing its energy needs to non-EU countries also accounted for significant emissions reductions (Papiez et al., 2021). As it continues to shutter its fossil fuel and nuclear operations, the EU imports more than half of its energy supply. In 2021, the EU imported more than 40% of its total gas consumption, 27% of oil imports, and 46% of coal imports from Russia. The sustainability and strategic security of such outsourcing was immediately threatened by the Russian invasion of Ukraine in 2022. Europe is caught in a triple energy policy challenge – energy security, affordability, and addressing climate change (PRI, 2022). Given the expected economic outcomes of F2F, the EU will essentially outsource its food production as well. European food security could soon mirror its energy security.
[13]This is not to discount the contribution that organic production and agro-ecological practices can have on overall global food production. All modes of food production are welcomed and necessary but there are inherent limitations to organic production as discussed previously. It lacks the production capacity to increase yields and can only remain a niche production system for the very rich who can choose and afford it, or the production system used by subsistence farmers in developing countries who have no choice.
[14] Increasing regulatory burden has become an effective and pernicious policy tool for protectionist interests seeking market access barriers. See Isaac (2007), Kerr (2004), Hobbs (2007), Van den Belt (2003) for example.
[15] For example, US corn harvested in fall 2022 enters grain channels in 2023 and 2024 as the ability to store corn allows producers to choose more opportune times to sell their crop. In fall 2022, farmers booked their seed for the spring of 2023 for a crop that enters grain channels in 2024 and 2025 (Haag, 2022). Once corn has entered grain supply channels, more time passes before it is finally eaten or processed into a final food product for consumption.