Trade in Technology: A Potential Solution to the Food Security Challenges of the 21st Century

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With the path of 20th century food prices now comfortably in the rearview mirror (*Figure 1*), the question of whether agricultural technological progress would be able to keep pace with growing population appears to have been put to rest. The global agricultural price index in the year 2000 was only one-quarter of its value in 1900, and just 40% of its average value at the end of the 1970s. This is clear evidence that, over the broad sweep of the 20th century, improvements in agricultural technology led to strong output growth, outpacing population growth. Of course, there were many commodity price spikes that arose during this time, with the most dramatic coming in the wake of the Russian crop failure during the early 1970s when this price index more than doubled. A later doubling occurred at the beginning of the 21st century, when a perfect storm of growing bioenergy demands, low commodity stocks and crop failures led to the index rising from less than 40 to more than 80 over a decade's time (Abbott, Hurt, and Tyner 2011). As with the earlier price spikes, this led to a flurry of concern about Malthusian scarcity scenarios, and a burst of investments in agricultural research and development (R&D). However, as with the earlier price booms, all indications are that this one is also on the wane, aided by the slowing rate of growth in global population (Baldos and Hertel 2016).

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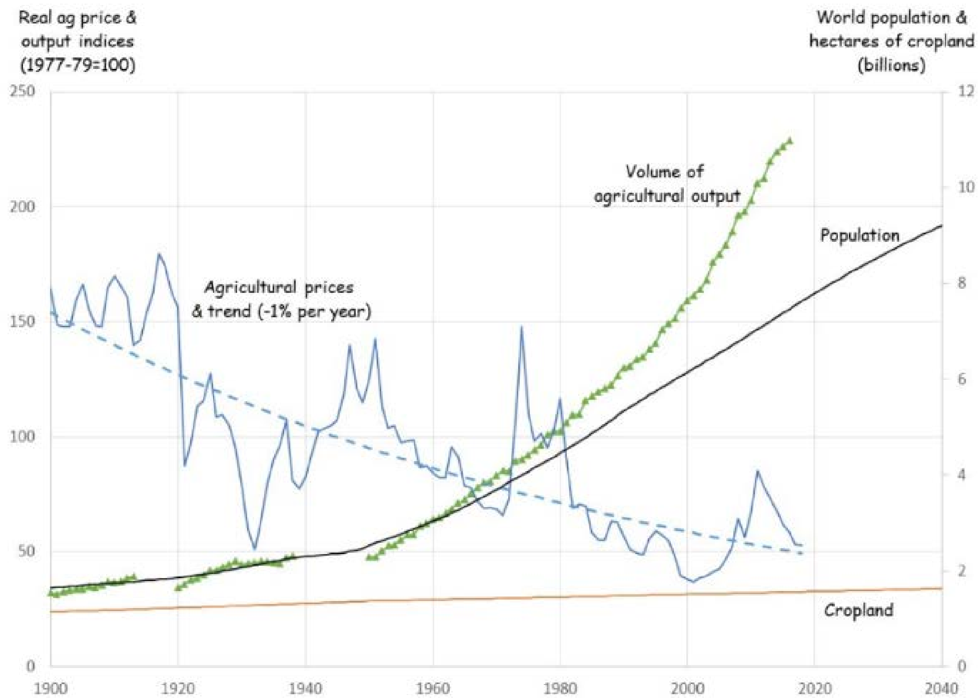

Figure 1. Evolution of global population, cropland, and real agricultural output and price indices since 1900. Source: Fuglie et al. (2019). The real agricultural price index is the Grilli-Yang price index of traded agricultural commodities divided by the US GDP price index.

While the outcome of the global footrace between food supply and demand seems no longer in doubt, this is not the case within particular regions – most notably Sub Saharan Africa (SSA), where virtually all of the world's net population growth between today and the end of this century is expected to arise (UN Population Division 2015). Indeed, the reluctant decline in fertility in this region has caused the United Nations Population Division to revise upward its global population forecasts. Niger is the poster child for this challenge, with a fertility rate of 7.5 children per woman (INS/Niger and International 2013). If productivity growth in agriculture was also proceeding at a record-breaking pace, this demographic anomaly would be of lesser concern. However, lack of investment in national agricultural research, poor dissemination of new technologies, weak institutions and civil unrest have resulted in below average rates of agricultural productivity growth in the region (Fuglie and Rada 2013). And this region is also one of the most threatened by climate change (IPCC 2014). This combination of high population growth and low productivity growth has allowed the Malthusian challenge to re-enter the debate in SSA. Indeed, since 2011, rates of undernutrition in this region have begun to rise, after more than a decade of steady decline (FAO et al. 2019).

Absent a dramatic shift on the demographic front, we must look to the technology side of this regional footrace for a solution. Greater investment in national agricultural research institutions in Africa is clearly an important part of picture. However, given the extremely long lag between public R&D investment in agriculture and improved productivity growth – historically in the United States it has taken two decades for R&D spending to achieve peak impact (Baldos et al. 2019) – such investments will likely not solve the near-term challenge. This brings us to the topic of trade – more specifically: trade in agricultural technology. In Hertel, Baldos and Fuglie (2020) we distinguish between two types of trade in technology. The first, dubbed *direct trade in technology*, focuses on the transfer of knowledge from overseas. Historically, direct transfer of agricultural technology has been hampered by the challenges of adapting solutions from one agro-ecosystem and economic environment to another. Technologies developed for irrigated Asian agriculture have generally proven ineffective in SSA (Pingali 2012), and the empirical evidence shows little in the way of 'technology spill-ins' from rich countries in temperate regions to tropical zones (Fuglie 2018; Hayami and Ruttan 1985). However, R&D in the emerging economies may prove more transferable to SSA given their closer environmental proximity. We focus on this type of technology spill-in as we consider the potential for direct trade in technology.

We have named the second type of trade in technology '*virtual technology trade*' as it is fully in the spirit of the growing literature on virtual water trade (Allan 1998; Yang and Zehnder 2007). This literature points out that water-intensive crops can be imported in lieu of growing them domestically – hence the idea that these countries are importing 'virtual water'. In the case of agricultural technology, we suggest that one piece of the solution to the Malthusian challenge in the SSA region is to import food from regions where technological improvements are outpacing population growth. Historically, virtual trade in technology has been limited by restrictive agricultural trade policies, motivated by self-sufficiency targets as well as concerns about food safety, genetically modified crops, and a host of other factors. Therefore, it is interesting to think about the potential for virtual technology trade to solve the Malthusian challenge in SSA if and when the region becomes more integrated into global agricultural markets.

While a number of studies have produced long-term projections of supply and demand balances in world agriculture (see von Lampe et al. 2014 for a summary and comparison of 10 of the more prominent ones), almost all have assumed exogenously determined rates of productivity growth. State-of-the-art analyses of R&D, however, take into account the substantial lag between R&D spending and changes in farm productivity. This lag is typically one or two decades, beyond which these productivity effects wear off due to R&D capital depreciation (Alston et al. 2010; Baldos et al. 2019). In Hertel, Baldos and Fuglie (2020), we extend this prior work by (i) projecting future growth in R&D capital stocks, taking into account past R&D spending patterns and allowing for R&D capital depreciation, (ii) accounting for differences in the quality and capacity of national agricultural R&D systems by allowing R&D elasticities to vary across global regions, based on a review of more than 40 econometric studies of past performance (Fuglie 2018); and (iii) incorporating the potential for international R&D spillovers – that productivity growth in one region depends not only on that region's R&D spending but also on technology transfer from other parts of the world.

To assess the relative contribution of each channel to food security in Africa, we employ a partial equilibrium, quantitative trade model, augmented by these dynamic relationships between R&D investments, knowledge capital and agricultural productivity. We begin by examining the relative importance of the three technology-food security linkages over the historical period: 1991-2011. Here, we see that *direct R&D investments in SSA have historically been the dominant vehicle for lowering food prices in Africa*. Looking forward in time to 2050, we find that if SSA researchers can successfully adapt technologies from the emerging market economies, technology 'spill-in' effects could rival in importance the region's own R&D investments. The relative importance of the three technology-food security linkages also varies depending on the extent of SSA integration into global markets. However, even with the current state of food trade friction, we find that *virtual technology trade will be the most important vehicle for reducing non-farm undernutrition in Africa between the present and 2050*.

Given the importance of agricultural output growth in the rest of the world for SSA's food security – via virtual trade in technology -- we also explore the consequences of more widespread adoption of the Northern European approach to the agriculture-environment interface. Rather than allowing farm productivity growth to be translated into increased food production, Northern Europe has used this opportunity to withdraw resources from agriculture, resulting in a relatively flat farm output profile since 1990 (Heisey and Fuglie 2018). *We examine the impact on 2050 non-farm undernutrition in SSA of strengthened environmental restrictions in the richest economies, as well as China and Latin America*, such that their production profile, between the present and mid-century, remains flat. This results in higher food prices in SSA (compared to the baseline) and a lesser reduction in non-farm undernutrition, as well as far greater rates of cropland conversion SSA. *Under this scenario, much of the environmental burden of feeding the world is shunted to Africa*.

While the world appears to be currently moving away from free trade in agriculture and other commodities, the forces encouraging globalization remain strong, with global supply chains continuing to play a key role in feeding the world – albeit with greater diversification of sources likely on the horizon. Therefore, it is important to understand the interplay between international trade in commodities and trade in technology. In our work, we also consider the role of technology trade when commodity markets are fully integrated (i.e., one world price for each agricultural crop). *We find a number of important advantages offered by integrated markets*. First and foremost, *this can ease the impact of uneven growth in population on the one hand, and productivity on the other, such as is projected for the SSA region to mid-century*. In addition, even under the scenario in which rich countries withdraw resources from agriculture, *integrated markets can facilitate price reductions in the SSA region, accompanied by reductions in non-farm undernourishment and well as reductions in cropland area, with associated environmental benefits*.

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