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Global Food Security

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According to the current report on the Millennium Development Goals (UN 2015), the share of undernourished people living in the developing world has fallen from 23.3% in 1990-1992 to 12.9% in 2014-2016 (projection). Despite this progress towards global food security, about 795 million people worldwide (or 780 million people in developing regions) will remain undernourished in 2014-2016 (UN 2015). Put differently, more than 10% of the world population still suffers from chronic hunger (FAO et al. 2015). Moreover, globally, one in seven children under age five are projected to be underweight in 2015 and one in four were stunted in 2013, i.e. had inadequate height for their age (UN 2015) – not only causing current hardship and pain but also leading to adverse long-term effects (see Lehmann-Uschner 2015). Against this background, global food security will feature prominently in the emerging post-2015 development agenda, such as the Sustainable Development Goals (UN 2015). Food security is defined as a status in which "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996: Paragraph 1). The main challenges to global food security in the medium- to long-term range from a growing world population to more resource-intensive diets, bioenergy generation and climate change. Already today, these developments account at least partly for the current rise in agricultural commodity prices. In addition to the fight against poverty, proposed solutions to meet the challenges include a sustainable intensification of agricultural production, reductions in yield losses and food wastes, open trade regimes, emission-saving agricultural practices and shifts in consumer preferences towards more sustainable demand patterns.

The Challenges Ahead in the Agriculture and Food Sector

There is widespread agreement that food security is severely undermined by poverty (e.g., FAO 2009b). According to UN (2015), the worldwide share of people living below the World Bank's international poverty line of $1.25 per person per day – characterizing extreme poverty – amounts to 12% in 2015, i.e. 836 million extremely poor people. Globally, about 78% of the extremely poor live in rural areas and about 63% work in agriculture, mostly as smallholder farmers (Olinto et al. 2013).

In addition, global agriculture faces several major challenges in the medium- to long-term, which can become detrimental for food security. These challenges are related to both supply and demand.

First of all, global agriculture needs to feed a growing world population, projected to increase from the mid-2013 level of 7.2 billion people to about 9.6 billion by 2050 (UN 2013).

Second, it has to satisfy the changing diets of vast populations in emerging countries and urbanizing areas. In particular, the rising per-capita incomes in economies like China and Brazil have contributed to higher per-capita food consumption and shifts in demand patterns away from plant-based food towards animal-source food, such as meat and dairy products (FAO 2009a). From 1980 to 2005, for example, the annual per-capita meat consumption in China rose from 13.7 kilograms (kg) to 59.5 kg and that in Brazil from 41.0 kg to 80.8 kg, while the developed countries (excluding the former centrally planned economies) saw an increase from 82.4 kg to 95.8 kg (FAO 2009a: Chapter 2, Table 1). Globally, the per-capita consumption of animal products started to accelerate in the early 1990s, while the per-capita demand for vegetal products remained relatively unchanged (Bringezu et al. 2014: Figure 3.7). Since animal-source products require considerably more acreage per nutrition value due to the rather inefficient conversion of animal feed into human food (Pelletier and Tyedmers 2010), their increasing production raises the demand for agricultural land (Bringezu et al. 2014). A similar intensity in resources applies to the production of processed and prepared foods (von Witzke and Noleppa 2010), increasingly demanded by growing urban populations at the cost of basic staples (Rosegrant et al. 2001) – by 2050, 66% of the world population is projected to be urban, compared to 54% in 2014 (UN 2014).

Third, the expansion of bioenergy, such as biofuels for transport, cuts into the scarce resources used for food production, in particular land, water and nutrients (Bringezu et al. 2009, 2014). Over the 2000-2011 period, for example, biofuel production increased from 16 billion liters to more than 100 billion liters worldwide (Blanco et al. 2013). This has mostly been driven by government interventions. (For an overview of biofuel policies, see Sorda et al. (2010).) Biofuel production is projected to nearly double again by 2023 (OECD and FAO 2014). Since ethanol and biodiesel will still be mainly derived from food crops in 2023 (so-called first-generation biofuels, cp. Box), about 12%, 28% and 14% of the respective global supply of coarse grains, sugar cane and vegetable oil are expected to enter biofuel production in that year (OECD and FAO 2014).

> First-generation ethanol is mainly produced from cereals and sugar; first-generation biodiesel from vegetable oils, such as rape oil or palm oil (Blanco et al. 2013). Relying on food crops, first-generation biofuels directly compete with food production (Blanco et al. 2013). For this reason, the European Union (EU) discusses to limit their expansion (e.g., EC 2012).
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> Compared to first-generation biofuels, the competition for agricultural resources tends to be reduced or even eliminated for second-generation biofuels, which are mainly derived from agricultural by-products, woody biomass residues or non-food crops, and non-agricultural biofuels made from wastes of animal fats or algae (Blanco et al. 2013).

Box: Biofuels

Fourth, climate change will play an increasing role for agricultural production. On the one hand, agriculture contributes to climate change. Globally, for example, agricultural activities, without the land use, land-use change and forestry (LULUCF) sector, account for about 13% of all greenhouse-gas (GHG) emissions, mainly in the form of methane (CH_4) and nitrous-oxide (N_2O) emissions (cp. Ciais et al. 2013). Including the LULUCF sector, agriculture's contribution is reported to range from about 25% to 30-35% (see Tilman et al. 2011; Foley et al. 2011). Even in Germany, where the agricultural sector has a share of 1% in gross domestic product only (World Bank 2015), it is the source of 7-8% of all GHG emissions, excluding carbon dioxide (CO_2) from LULUCF (UBA 2013: Table 2). As a contributor to climate change, agriculture will have to cut its GHG emissions, such as those arising from livestock production (Dong et al. 2006) and fertilizer use (De Klein et al. 2006). EC (2014), for example, has proposed to include agriculture (and the LULUCF sector) into the EU's 2030 GHG reduction target. GHG mitigation will inevitably put constraints on the available agricultural production techniques. On the other hand, agriculture will be affected by climate change. While both positive and negative effects on crop production can possibly occur in northern latitudes, countries in low latitudes are expected to see declining yields – all against a general increase in the variability of crop yields worldwide (Porter et al. 2014).

Drivers of Food Prices

Since the beginning of the 2000s, the pressures on agriculture have already led to an upward trend in international agricultural commodity prices. (For the development of real prices of corn (maize), soybeans and wheat in the United States (US) from 1924 to 2012, for example, see Alston and Pardey (2014: Figure 4).) This suggests that the times of faster growth in agricultural supply than demand ('agricultural dreadmill') have come to an end (von Witzke 2012; Alston and Pardey 2014).

Empirically disentangling and even quantifying the specific factors that contribute to the recent rise in agricultural commodity prices, however, proves a difficult task. In addition to long-term drivers, such as population growth and rises in agricultural productivity, prices of agricultural commodities depend on short-term supply shocks, such as due to extreme weather events, and are influenced by substitution effects between agricultural commodities as well as storage-induced substitution between successive harvests (e.g., Wright 2014; Roberts and Schlenker 2013). Many studies focus on the food-price booms of 2006-2008 and 2010-2011 rather than on a long-term trend increase. Still, valuable insights can be gained from the following – non-exhaustive – list of analyses, in particular for the role of biofuels.

Analyzing international price developments of wheat, rice and corn from 1961 to 2012, Wright (2014) finds that the price jumps observed since 2005 are best explained by the growing – and persistent – demand for first-generation biofuels. While the relevance of biofuel generation for agricultural commodity prices is also stressed by many others, such as Mitchell (2008), Abbott et al. (2008; 2009), Headey and Fan (2008), Baffes and Haniotis (2010), Trostle et al. (2011), Hochman et al. (2011), Hausman et al. (2012) and Roberts and Schlenker (2013), they mainly disagree on the extent of the impact. Mitchell (2008), for example, concludes that increased biofuel production from food grains and oilseeds in the US and EU was the main driver of the food-commodity price increases between 2002 and 2008. Roberts and Schlenker (2013), in turn, find that the 2009 US ethanol mandate can be associated with a 20-30% increase in aggregated world prices of corn, wheat, rice and soybeans – where the range of price increases depends on the recovery of by-products from ethanol generation as livestock feed. Likewise, Hausman et al. (2012) associate 27% of the US corn price rise in 2006/2007 to increased corn ethanol production. However, while Trostle et al. (2011) acknowledge the role of biofuels for long-term food-commodity price increases, they see only a limited role of biofuels in the 2007-2008 price spikes. Likewise, Gilbert (2010), Baffes and Haniotis (2010) and Zilberman et al. (2013) are cautious about attributing much of the 2007-2008 food-commodity price spikes to biofuel production.

Not explicitly taking account of biofuel generation, Baffes and Dennis (2013) analyze stocks-to-use ratios, crude-oil prices, manufacturing prices, the US-dollar exchange rate, interest rates and income growth as determinants of long-term price trends of maize, wheat, rice, soybeans and palm oil, and attribute the food price rises over 1997-2004 to 2005-2012 mainly to crude oil prices, stocks-to-use ratios and the depreciation of the US dollar. Thereby, crude-oil prices are assumed to affect food prices via the supply side, i.e. as inputs into agricultural production; the stocks-to-use ratio is expected to capture income effects, biofuel production, weather shocks and interest-rate impacts; the depreciation of the US dollar is assumed to strengthen demand and weaken supply from the rest of the world (Baffes and Dennis 2013).

The importance of the US-dollar exchange rate in determining the prices of agricultural commodities as found by Baffes and Dennis (2013) is reiterated by Mitchell (2008), Abbott et al. (2008; 2009) and Gilbert (2010), for example. Likewise, the stocks-to-use ratio – combined with changes in global agricultural production and consumption – has also been found a crucial driver by, e.g., Abbott et al. (2008; 2009) and Hochman et al. (2011). Thereby, Hochman et al. (2011) see a particular role for income growth in emerging economies causing greater demand for food commodities; however, this is rejected by Baffes and Haniotis (2010), for example. Furthermore, while the view that high energy prices cause the costs of agricultural production to rise is supported by Mitchell (2008) and Headey and Fan (2008), Abbott et al. (2008) find that the price of crude oil rather works through changes in biofuel demand – following the link from higher crude-oil prices to higher fossil-fuel prices to higher biofuel prices to higher food-commodity prices. However, as detailed in Zilberman et al. (2013), the various prices are linked in many other ways, such that a rise in biofuel prices can both increase and decrease food-commodity prices. While there tends to be a long-term positive relation between fossil-energy prices and food-commodity prices, which has increased during the 2007/2008 boom (e.g., Gilbert 2010; Baffes and Haniotis 2010), Gilbert (2010) shows that crude-oil prices do not seem to have impacted food-commodity prices during 2007/2008. Note that a detailed review of the relation between crude-oil prices, biofuel prices and food-commodity prices is beyond the scope of this Roundup.

According to Martin and Anderson (2012), trade-policy interventions, such as export restrictions, implemented during the 2006-2008 agricultural-commodity price boom with the aim to shield domestic food prices from international price fluctuations significantly increased the world-market prices for rice and wheat. Likewise, von Braun and Torero (2009) and Headey and Fan (2008) list trade-policy interventions as one of the key factors explaining the food-commodity price spikes in 2008. For a recent theoretical formulation of the relation between crop failures, export tariffs and traded quantities/food prices in a stylized world grain market, see Baake and Huck (2013).

Finally, von Braun and Torero (2009), for example, stress financial speculation as a driver of the 2006-2008 food price spikes. Gilbert (2010), in turn, names index-based investment in agricultural futures markets rather than traditional speculation as the major channel for macroeconomic and monetary factors to have increased food commodity prices in 2007/2008. However, the financial-speculation argument is rejected by other authors, such as Wright (2014) and Headey and Fan (2008). While Baffes and Haniotis (2010) see some room for financial activity to influence short-term prices, in particular for index-fund activity in the 2008 price spike, they rule out that it has an effect on long-term price trends. For a detailed overview of the relation between financial speculation and commodity prices, see Hachula and Rieth (2015).

Possible Solutions

Notwithstanding any distributional issues affecting food security, there is consensus that global food production will have to increase considerably by 2050 to meet demand. Typical projections range from 60% (Alexandratos and Bruinsma 2012) to 100-110% (Tilman et al. 2011). In addition, global food security could be supported by a shift to sustainable demand patterns, such as reduced meat consumption (e.g., Ripple et al. 2014).

Starting with supply factors, there is a great variety of potential solutions to increase the production of agricultural commodities and in particular those of food crops. Since agricultural expansion is limited by the availability of suitable land as well as environmental and climatic constraints on further deforestation and conversion of grassland into cropland (e.g., Ramanakutty et al. 2002; Foley et al. 2011), it is widely agreed that a 'sustainable intensification' is required to increase agricultural production, i.e. an environmentally friendly rise in agricultural productivity on the given acreage (e.g., Royal Society 2009; FAO 2009b). The rate of agricultural productivity growth having tended to decline globally since the 1990s (Alston and Pardey 2014), one of the ingredients to sustainable intensification is agricultural research and development, both public and private (Alston and Pardey 2014; von Witzke 2012). Other factors include location-specific investments in agricultural inputs (e.g., enhanced seed and breed varieties), infrastructure (e.g., sophisticated irrigation systems) and institutions (e.g., better finance mechanisms and land rights) (Godfray et al. 2010; Foley et al. 2011); improved management practices targeted at greater water- and nutrient-use efficiency (Foley et al. 2011); knowledge and technology transfers to developing countries to close yield gaps and a general spread of high-tech agricultural production, like precision farming (von Witzke 2010). Thereby, yield gaps refer to the "difference between realized productivity and the best that can be achieved using current genetic material and available technologies and management" (Godfray et al. 2010: 813).

Further solutions include the reduction of yield losses and food wastes (Godfray et al. 2010; Foley et al. 2011), frequently occurring due to weeds, pests and diseases; poor production, harvesting and processing techniques; insufficient transport and storage facilities; or food waste at the retailing and consumption stages (e.g., Oerke 2005; Gustavsson et al. 2011; Kummu et al. 2012; Buzby and Hyman 2012).

Moreover, an open agricultural trade regime is regarded to raise food security (e.g., Matthews 2014; FAO 2009b; cp. the above-described role of trade policy for the food-price spikes in 2007/2008). While protectionist trade- and agricultural-policy measures have been reduced over time, market-distortive government interventions are still widespread (Anderson et al. 2013). Moreover, agricultural trade is governed by new developments, such as the rise in private food quality standards (e.g., OECD 2006). Implemented predominantly by retailers in developed countries (for an overview, see von Schlippenbach and Teichmann 2009), it is heavily discussed whether they constrain the market access of smallholders from developing countries (e.g., Grote 2014; OECD 2007), at the same time when a stronger smallholder involvement is regarded especially conducive to the goals of increasing agricultural output and food security along with reducing poverty (e.g., Godfray et al. 2011).

Finally, GHG emission reductions or carbon sequestration in the agricultural sector can be brought about by the adoption of recommended agricultural practices, such as no-till farming, cover crops and crop rotation (Lal 2008), or innovations like biochar. Thereby, the term biochar refers to a carbon-rich solid obtained from the heating of biomass in the (near) absence of oxygen, most commonly in a process known as pyrolysis. Being characterized by high carbon stability and a favorable nutrient-retention capacity, it is increasingly discussed to incorporate biochar in agricultural soils to sequester carbon and to improve soil fertility (e.g., Lehmann et al. 2006; Lehmann 2007; Sohi 2012). For further details on the climate-impact of biochar in agriculture, see Teichmann and Kemfert (2014).

Turning to demand factors, a shift in consumer preferences away from animal-based food – at least away from resource-intensive livestock varieties, such as cattle, to less resource-demanding animals, such as poultry – seems desirable from both a food-security and climate perspective (Ripple et al. 2014; Godfray et al. 2010; Foley et al. 2011). With this regard, it is discussed whether taxes on meat could be used as an instrument to reduce meat consumption (e.g., Säll and Gren 2015; Ripple et al. 2014; Wirsenius et al. 2011). However, as shown by Bonnet and Réquillart (2013) for the taxation of soft drinks, for example, the impact of policy interventions on consumer behavior strongly depends on the design of the tax, consumer substitution patterns and strategic firm behavior.

Conclusion

The challenges to global food security and their possible solutions reveal a strong interconnectedness of future developments in the agriculture and food sector with the provision of bioenergy and climate change. Moreover, consumer preferences and poverty play an important role. For this reason, progress towards global food security cannot be achieved by a single measure, but only by the combined consideration of all possible solutions. Furthermore, the improvement of global food security is a responsibility of all countries, both developed and developing. Ultimately, the challenges to food security cannot be solved in isolation, but need to be tackled together with the fight against poverty and climate change.

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