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**Domestic support
measures in the context of
adaptation and mitigation
to climate change**

Background paper for
The State of Agricultural Commodity
Markets (SOCO) 2018

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Acronyms

CSA	Climate Smart Agriculture
WTO	World Trade Organization
CO₂	Carbon Dioxide
AMS	Aggregate Measurement of Support
AFOLU	Agriculture, Forestry and Other Land Use
AoA	Agreement on Agriculture
GHG	Greenhouse Gas
R&D	Research & Development
IBLI	Index-Based Livestock Insurance
UNCTAD	United Nations Conference on Trade & Support
CRP	Conservation Reserve Program
ACEP	Agricultural Conservation Easement Program

Abstract

Climate Smart Agriculture (CSA) has been promoted as a key approach in addressing the effects of climate change. First launched in 2009, CSA refers to agricultural technologies that are well suited to increase farmer livelihoods in the face of a changing climate by 1) raising agricultural productivity; 2) building resilience of livelihoods and farming systems; and 3) reducing carbon emissions. While government implementation of mitigation and adaptation policies may be an effective means to help address climate change, concerns arise, if CSA policies run counter to international trade disciplines.

In particular, CSA policies could come into direct conflict with WTO trade rules, if these policies serve to insulate domestic producers from competition. Thus, they could potentially distort production and trade. This paper examines CSA policies in the context of the WTO agreements, including domestic support disciplines under the WTO Agreement on Agriculture.

1. Introduction

Climate change will likely have significant impacts on agricultural production, particularly in developing countries highly dependent on rainfed-agriculture (McCarthy, Lipper and Zilberman, 2018). Findings of the fifth assessment report of the Intergovernmental Panel on Climate Change conclude that “all aspects of food security are potentially affected by climate change including food access, utilization, and price stability” (Porter *et al.*, 2014, p. 488). Thus, the potential impacts of climate change will further complicate the goal of meeting food and nutrition demands for a growing global population and growing consumer incomes, as laid out in the United Nations Sustainable Development Goals (UN, 2015).

Climate Smart Agriculture (CSA) is an approach developed by the Food and Agriculture Organization of the United Nations (FAO) to develop the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change (FAO, 2013). The CSA approach has three main pillars: 1) sustainably increasing agricultural productivity and incomes; 2) adapting and building resilience to climate change; and 3) reducing and/or removing greenhouse gas emissions, where possible. CSA aims to improve food security, help communities adapt to climate change and contribute to climate change mitigation by adopting appropriate practices, developing enabling policies and institutions and mobilizing needed finances (FAO, 2013).

Trade can help mitigate the effects of climate change on food security by providing a buffer against short term disruptions in supplies, caused by droughts, floods or other extreme weather events, events which are projected to be more likely as global temperatures rise (Lantz, Baldos and Hertel, 2015). The importance of trade has increased in recent years, as larger shares of global consumption are supplied by imports. These trends are projected to continue over the next ten years (OECD-FAO, 2017; O’Donoghue and Hansen, 2017). Over the longer term, trade will become even more critical, as changing climates cause food production to shift geographically and more highly variable weather increases price volatility.

While government implementation of mitigation and adaptation policies may be an effective means to help address climate change, concerns arise if CSA policies run counter to international trade disciplines. In particular, CSA policies could come into direct conflict with WTO trade rules, if those policies distort production and trade.

This paper considers how CSA policies may affect production and trade; and as such, comport with existing WTO rules. Section 2 discusses agriculture’s contribution to global greenhouse gas (GHG) emissions. In Section 3, recent trends in international trade are reviewed and the impacts of GHG emissions on international trade are discussed, including how trade can potentially help achieve sustainable agricultural development for food security under climate change. WTO disciplines affecting domestic support policies are analyzed in more detail in Section 4. Section 5 focuses on how CSA policies may potentially

conflict with WTO trade rules, including the Agreement on Agriculture, and the Agreement on Subsidies and Countervailing Measures. Section 6 offers recommendations on how CSA policies can be best designed to ensure compatibility with WTO rules or how WTO rules could be modified to accommodate CSA policies, without creating large trade distortions. Concluding comments are offered in Section 7.

2. Agriculture's contribution to global GHG emissions

Agriculture is a major contributor to global greenhouse gases through crop and livestock production, as well as through land conversion. Agriculture contributes to climate change directly by emitting methane (CH₄) and nitrous oxide (N₂O) in crop and livestock production, and indirectly by affecting net CO₂ emissions through its impact on soil, forests and other land uses. Agriculture can also serve to sequester atmospheric carbon, through soil management practices and planting of perennial crops and trees.

Agriculture is an emissions-intensive sector, which typically emits a far greater share of GHG gases than it produces in economic activity. The World Bank (2017) estimates, that agriculture accounts for about 3.8 percent of total GDP in 2015, compared to 24 percent of global GHG emissions. In the United States, agriculture accounts for about 10 percent of total GHG emissions while the agricultural sector accounts for only 1 percent of GDP (USDA and ERS, 2017).

Estimation by Smith *et al.* (2014) showed, that total direct and indirect GHG contributions from agriculture, forestry and other land uses (AFOLU) in 2010, was the second largest source of GHG emissions (after fossil fuel use), accounting for 24 percent of total global anthropogenic emissions. Based on FAOSTAT data, Blandford and Hassapoyannes (2017) estimated, that direct emissions from agriculture account for about 10–12 percent of global GHG emissions in 2012–2014. Agriculture is the largest contributor to non-CO₂ GHG emissions, accounting for 56 percent of emissions. Livestock are estimated to account for 80 percent of the direct emissions, largely in the form of CH₄. Ruminants account for more than 80 percent of total livestock-related GHG emissions (Havlik *et al.*, 2014).

Land use generates CO₂ emissions by changing the carbon stock in forest land (soil and biomass), and in the soil of cropland, grassland, and wetlands (peatlands and flooded land). Gibbs *et al.* (2010) estimate, that between 1980 and 2000, 83 percent of agricultural land expansion in the tropics occurred, because of deforestation, much of which was done to increase livestock production. Blandford and Hassapoyannes (2017) estimated, that deforestation accounted for 59 percent of global land use emissions in 2012–2014.

Agriculture is also an energy intensive sector, using fossil fuels for a number of production activities, including fuel for trucks and machinery, natural gas and electricity to power pumps, and provide heating and cooling for livestock operations. Agriculture utilizes fertilizers and pesticides that are produced in an energy-intensive manner.

While emissions from energy use are not accounted for under the AFOLU sector, they account for almost one percent of global GHG emissions (Blandford and Hassapoyannes, 2017). Also omitted in those calculations are emissions from further downstream processing, for example food production and distribution.

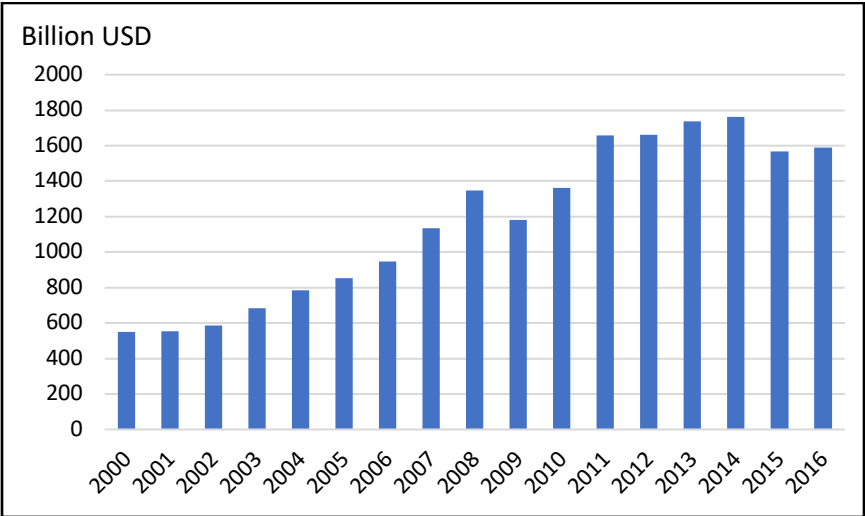
Blanco *et al.* (2014) estimated, that between 1970 and 2010, GHG emissions from AFOLU increased by 20 percent, although the net change since 1990 has been minimal, due in part to decrease in land use emissions. Blandford and Hassapoyannes (2017) estimated, that during the period 1990-2014 emissions from deforestation and other land uses dropped by nearly 25 percent. Yet, while land use emissions have trended downward, their decline has been offset by increases in agricultural emissions. Over the period 1990 to 2010, agriculture’s direct emissions increased by 15 percent, due to an increase in the use of synthetic fertilizers and increased livestock numbers(Blandford and Hassapoyannes,2017).

With food demand projected to increase by as much as 60 percent between 2010 and 2050 (FAO, 2017), agricultural GHG emissions are likely to increase proportionately, unless there are significant offsets either through decreased land use emissions or increased emission efficiencies in agricultural production.

3. The effects of climate change on global trade

Climate change will potentially have significant effects on international trade in agricultural products, as the relative comparative advantage of countries changes with shifts in production. Trade can help mitigate the impacts of climate change by helping to balance shifts in supply and demand. But as we have seen in the past, market distortions caused by government policies, can interfere with trade and exacerbate price volatility.

Figure 1: Growth in world agricultural exports 2000–2015

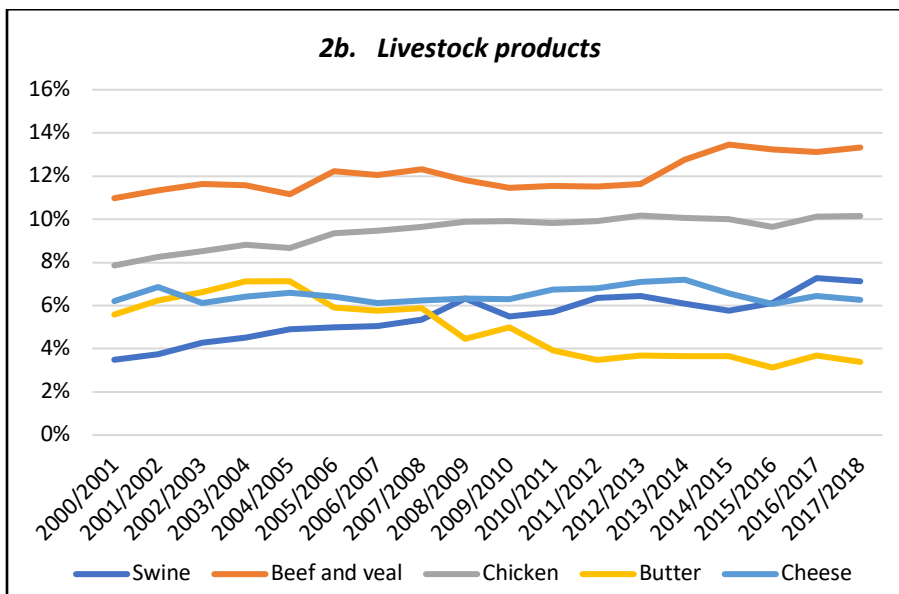
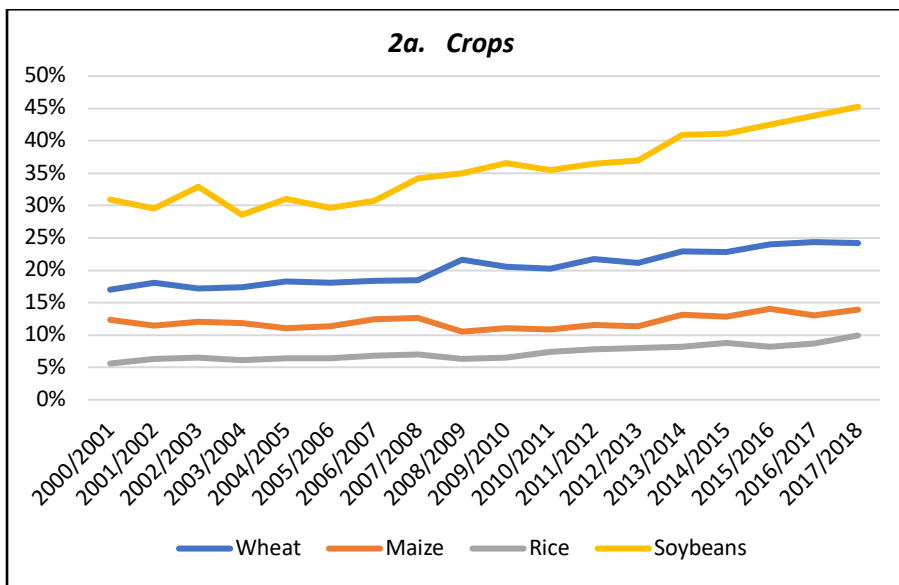


Source: WTO Statistics Database 2017

Agricultural trade has increased more than 200 percent since 2000 (Figure 1). Higher income growth, increased population and more open markets brought on in part by completion of the Uruguay Round, which brought agriculture under multilateral trade rules and disciplines that have all contributed to its growth in both volume and value.

Since 2000, imports account for a larger share of total consumption for many commodities. For example, soybeans imports now account for almost 43 percent of total global consumption compared to only 31 percent in 2000 (Figure 2a). Wheat imports –as a share of total consumption– have increased from 17 percent to 24 percent over the same period. Meat imports have increased as well (Figure 2b).

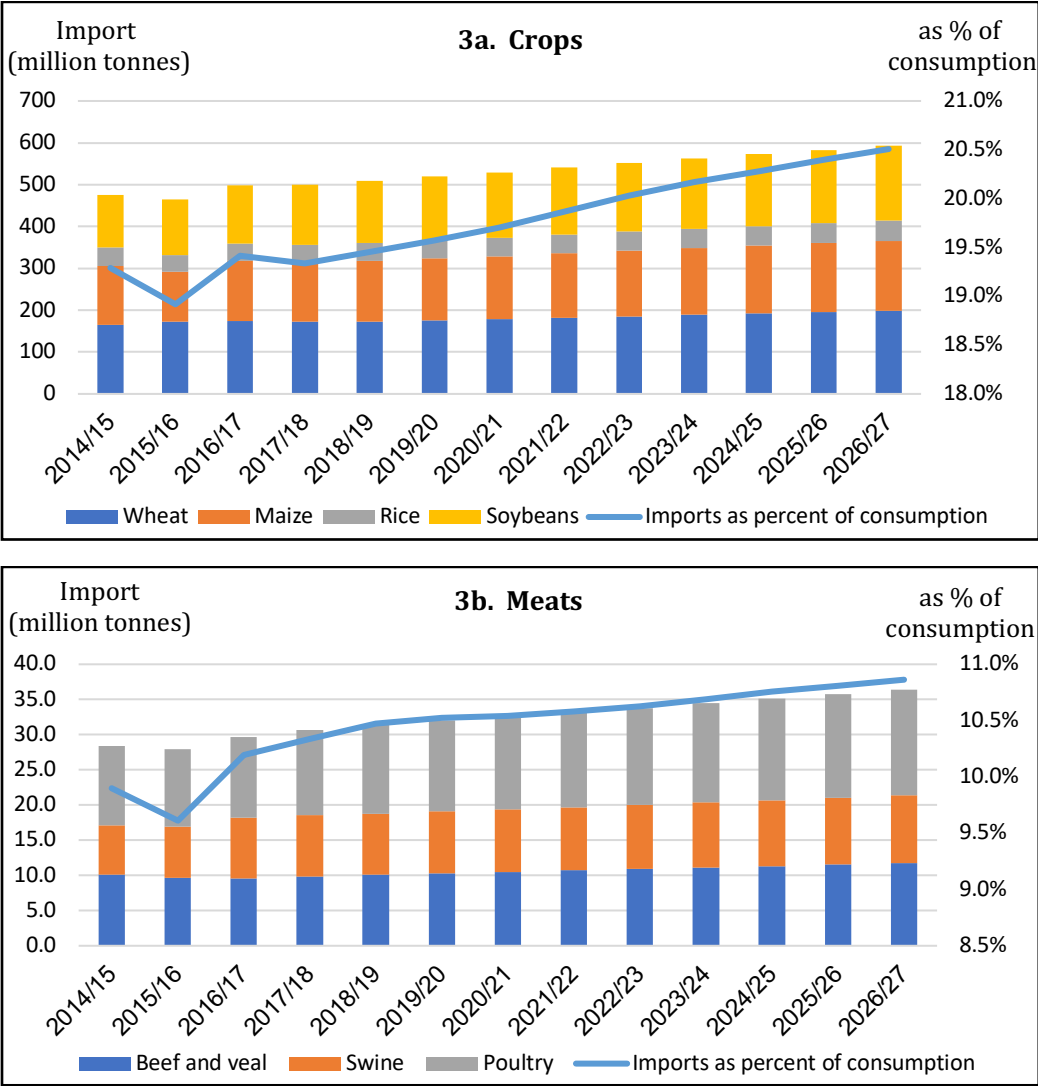
Figures 2a & 2b: Imports as percent of global consumption of (a) Crops and (b) Livestock products



Source: USDA Foreign Agricultural Service

Baseline forecasts by the US Department of Agriculture (O’Donoghue and Hansen, 2017) and OECD-FAO (2017) suggest, that these trends are likely to continue over the next ten years. Figures 3a and 3b show projected imports as percent of total global consumption for major grains and meat products. All years, show modest increases in import penetration (defined as the share of imports in consumption). Neither the USDA baseline nor OECD-FAO baseline explicitly take into account the impacts of climate change on production.

Figure 3: Projected imports as percent of consumption of crops and meats

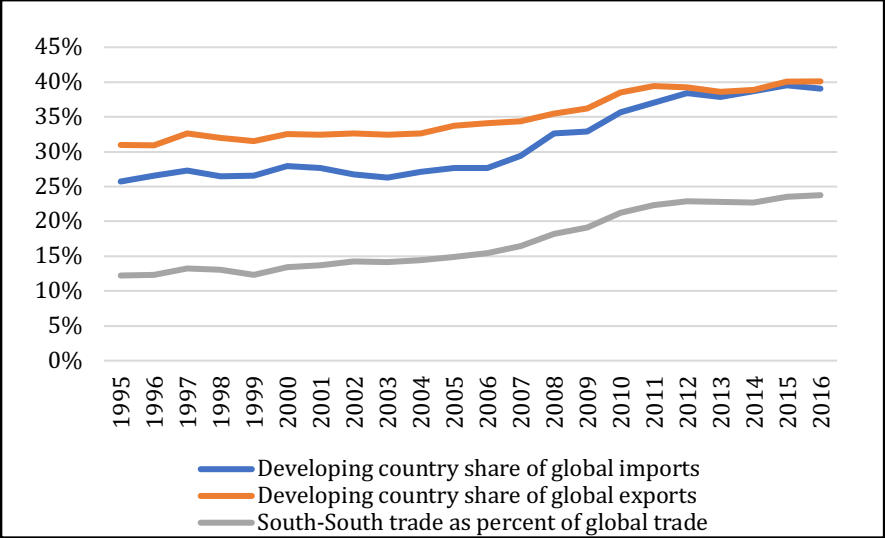


Source: USDA ERS International Baseline Data

Since 2005 there have also been significant changes in the composition of trade. In particular, we have seen the growing importance of developing countries, both in terms of their growing share of global imports and their growing share of global exports (Figure 4). For example, Brazil has become the number one soybean exporter, surpassing the United States since 2011. Expansion of maize area, particularly doubled cropped area, has boosted Brazil’s share of maize exports as well. The Black Sea region of the Former Soviet Union

(Kazakhstan, Russia and Ukraine) now accounts for almost 30 percent of world wheat exports and has become a significant exporter of maize and other coarse grains, as well as soybeans.

Figure 4: Growth of South-South trade



Source: UNCTAD Stat

On the import side, about two-thirds of soybeans traded globally are imported by China, and that share continues to grow. China has become a growing market for maize and other coarse grains, as well as swine and poultry (Gale, Hansen and Jewison, 2016). Africa has become a large and growing market for rice exporters such as India, Pakistan, Vietnam and Thailand (Nigatu *et al.*, 2017). South-South trade – as a share of total agricultural trade – has grown from 13 percent in 2000 to almost 25 percent in 2014 (UNCTAD, 2017). That translates to about one quarter of the growth over the past 15 years, due to South-South trade.

How climate change will affect future trade patterns is less certain, although it will alter the comparative advantage of some regions over others (Huang *et al.*, 2011). It is important to recognize, that a country’s comparative advantage in producing a crop is not static, but changes with relative changes in regional yields, costs, and other factors (Leamer, 1984). Work by Nelson *et al* (2010) suggests, that while trade may not be able to fully offset the impacts of climate change, it can partially mitigate its impact by balancing supply and demand across regions. Similar results have been confirmed in more recent analysis by Martinez *et al.* (2017), who concluded, that while regional yields will be adversely affected, consumption is more modestly affected, because of trade.

In addition to potentially altering regional crop and livestock production, climate change will likely result in more variable weather, which will exacerbate yield volatility and increase vulnerability to insects and other pests, some of which may be exacerbated by propagation of invasive species through trade (FAO 2013; Westphal *et al.*, 2008).

Trade helps mitigate regional production shortfalls, though as was seen in the food price spikes of 2007/08 and 2010/11, concerns arise, that trade may expose exporting countries to increased price volatility in domestic markets. Research by Minot (2014) and Ceballos *et al.* (2017) found little evidence, that international price volatility was transmitted to domestic markets except in those cases, when exports were large relative to domestic consumption. However, trade integration in many developing countries is likely limited due to high transportation and other transactions costs, which limit trade flows (Bouët, Cosnard and Laborde, 2017).

Concerns over heightened international price volatility in 2007/08 and 2010/11 prompted numerous countries to impose export restrictions or other insular policies (Demeke, Pangrazio and Maetz, 2009). Many of those policies – while potentially dampening price increases in domestic markets – only served to increase prices and price volatility in international markets. Moreover, such beggar-thy-neighbor policies resulted in other countries adopting similar policies, further exacerbating price volatility and hurting net importing countries (Anderson, Ivanic and Martin, 2014).

4. WTO disciplines affecting domestic support policies

Since completion of the Uruguay Round in 1994 and creation of the World Trade Organization the following year, agriculture has been brought into a system of multilateral rules and disciplines, including market access, export competition and disciplines governing agricultural support (Josling, Tangerman and Wharley, 1996). Agricultural policies designed to address climate change would be subject to those and many other rules. As the focus of the paper is primarily on CSA policies, a brief description of the domestic support provisions of the Uruguay Round Agreement on Agriculture follows. A more detailed legal analysis can be found in Häberli (2018).¹

4.1 Support measures and the Agreement on Agriculture

Domestic support disciplines under the WTO Agreement on Agriculture (AoA) distinguish between programs that are viewed as non- or minimally-trade distorting (so-called Green Box subsidies) and those that are not (Amber Box subsidies). Green Box subsidies are judged to have no, or at most, minimal trade - distorting effects and are exempt from reduction under the AoA. To be included in the Green Box, programs must not be tied to current production or current market prices, and must meet specific policy criteria spelled out in Annex 2 of the AoA.

Amber Box subsidies are judged to have more than minimal trade - distorting effects, and are capped under the terms of the AoA. Amber Box support includes payments to

¹ Border measures are discussed in Blandford (2017).

producers that are tied to current production levels, market price support programs, and other policies that make payments based on current output and current market prices such as countercyclical income support programs. These subsidies are converted into an aggregate measurement of support (AMS) using a methodology set out in Annex 3 and Annex 4 of the AoA (Effland, 2011). Under the AoA, each country which reported non-exempt domestic support during the 1986-88 base period committed to bind its total AMS at average levels calculated over the base period and then reduce it by a prescribed percentage (for developed countries, by 20 percent over 6 years; for developing countries, by 13 percent over 10 years).

Amber Box subsidies are further classified into two groups—product-specific and non-product-specific support—and both categories are subject to *de minimis* tests that exempt support below a specific share of the current value of production from the reported AMS. For developed countries, if the estimated level of support is less than 5 percent of the value of current production, support is considered *de minimis* and excluded from calculations of the total current AMS. The *de minimis* threshold for developing countries is 10 percent of the value of current production.²

WTO members who had larger subsidies than the *de minimis* levels at the beginning of the post-Uruguay Round reform period were committed to reduce these subsidies in aggregate (by 20 percent for developed countries and 10 percent for developing countries). Countries without domestic support reduction commitments are effectively bound by *de minimis* levels.

A third category of trade-distorting support, called Blue Box support, is addressed in Article 6.5 of the AoA. Any subsidies and other forms of income transfers that would normally be included in the Amber Box are placed in the Blue Box if the program under which those income transfers occur also requires farmers to limit production and base payments on fixed area and yields or made on 85 percent or less of a base level of production, or, in the case of livestock, such payments are based on a fixed number of head. Under the AoA, Blue Box expenditures are not capped and, therefore, not subject to any limitation or reduction commitments.

There are also exemptions for developing countries (sometimes called a “Special and Differential (S&D) Box”), covered under provisions in Article 6.2 of the AoA. These exemptions include government measures of assistance to encourage agriculture and rural development, generally available investment subsidies, and agricultural input subsidies generally available to low-income or resource-poor farmers.

Lastly, as demonstrated in the *US-Upland Cotton* dispute, non-Green Box support measures may be challenged under the WTO Agreement on Subsidies and Countervailing Measures, if those measures were shown to cause serious prejudice to another member’s interest, for

² As a condition of its accession to the WTO, the *de minimis* threshold for China is set at 8.5 percent of the value of production.

example, by displacing exports to third-country markets, significant price suppression in world markets or increased market share by the subsidizing country.

4.2 Defining Green Box subsidies

Exempt policies under the Green Box must meet specific criteria laid out in Annex 2 of the AoA. To qualify, Green Box subsidies must not distort production or trade, or at most cause minimal distortion (Annex 2, Paragraph 1). Subsidies must be government-funded (not through indirect support such as higher consumer prices) and must not involve price support. In addition, as reflected in Table 1, Paragraphs 2 through 13 of Annex 2 detail specific categories for government service programs.

Table 1: Green Box Categories

Paragraph	Description
2	Provision of general services that provide benefits to agriculture or the rural community such as research and extension, pest and disease control, inspection services, marketing and promotion services and infrastructural services
3	Public stockholding programs for food security purposes
4	Domestic food aid programs
6	Decoupled income support to producers
7	Government financial participation in income insurance and income safety-net programs
8	Payments (made either directly or by way of government financial participation in crop insurance schemes) for relief from natural disasters
9	Structural adjustment assistance provided through producer retirement programs
10	Structural adjustment assistance provided through resource retirement programs
11	Structural adjustment assistance provided through investment aids
12	Programs for environmental programs
13	Payments to producers in disadvantaged regions under regional investment programs

In 2013, Members agreed as part of the Bali package to add the following activities to general services programs to promote rural development, food security and poverty alleviation, particularly in developing countries. Included were programs relating to land reform and rural livelihood security, such as: land rehabilitation; soil conservation and resource management; drought management and flood control; rural employment programs; issuance of property titles; and farmer settlement programs.

5. The potential impact of international trading rules on climate policies

Under the UN Climate Agreement concluded in Paris in November 2015, countries agreed to take actions to keep the rise in global average temperature this century from pre-industrial levels to below 2°C (UN Framework Convention on Climate Change, 2017). With AFOLU emissions accounting for 24 percent of total global GHG emissions, policymakers will need to address the projected growth in AFOLU emissions, if the

objectives of the Paris Agreement are to be met. Moreover, reductions must take place, while meeting Sustainable Development Goals of eliminating hunger by 2030.

There are basically three policy approaches to reduce net GHG emissions: 1) taxing GHG emissions directly; 2) subsidizing practices that would reduce GHG emissions or sequester CO₂; and 3) reducing GHG emissions or sequestering CO₂ through regulation. In addition, there are policies that are targeted at mitigating the financial impacts of climate change, such as agricultural insurance. This section examines such policies in the context of how they might impact production and potentially be viewed by WTO agreements, including the AoA.

5.1 Taxing GHG emissions

In economics, an externality is the cost or benefit that affects a party, who did not choose to incur that cost or benefit. Unregulated markets with significant negative externalities are considered inefficient in that, market prices do not reflect the true (societal) cost of that good or service. Because the cost of the negative externality is not included, producers produce more (and consumers consume more), than they would had, had the cost of the externality been reflected in the price. Taxing the producer for the cost of the externality would, in theory, “internalize” the externality, so that costs and benefits will affect mainly parties, who choose to incur them.

Carbon taxes have been proposed to address the societal externalities caused by GHG emissions through global warming. A carbon tax applied to agricultural emissions, would have a number of consequences. The immediate effect would be to raise prices of agricultural products. Table 2 shows the effects of a USD 20/tonnes CO₂^e price on effective carbon taxes for grains (wheat), rice, beef and chicken for selected countries. The data on GHG emissions were drawn from recent work by Blandford and Hassapoyannes (2017) that derives direct GHG emissions per tonne of product produced for various countries, using FAOSTAT data. The taxes were then compared to average annual commodity prices for 2016 (World Bank Group, 2017) to demonstrate their relative magnitudes.

Table 2—Effects of a USD 20/tonnes carbon tax on selected agricultural prices for selected countries

Country	Wheat	Rice	Beef	Sheep meat	Chicken
Australia	3.0%	3.4%	11.0%	13.4%	0.2%
Brazil	2.2%	2.5%	16.5%	16.7%	0.2%
China	2.6%	4.0%	12.5%	5.9%	0.6%
Ethiopia	1.2%	7.1%	71.5%	25.2%	2.8%
European Union	2.4%	13.1%	8.2%	10.1%	0.2%
India	3.6%	3.5%	54.4%	22.4%	0.5%
Indonesia	2.4%	5.6%	22.6%	22.3%	2.9%
New Zealand	2.4%	---	8.9%	8.1%	0.2%
United States of America	2.4%	5.6%	6.0%	---	0.2%

Source: Blandford and Hassapoyannes 2017, World Bank Group 2017

Because of the relative GHG-inefficiency of extensive livestock production, beef prices would rise relative to grains and poultry, likely shifting consumption towards beef substitutes. Note, that price impacts would be less severe for countries where agricultural production is more efficient vis-à-vis GHG emissions. In the example here, the impact of a USD 20/tonnes CO₂ e carbon tax would have a proportionate greater price impact on grass- and range-fed beef producers (India, Indonesia, Ethiopia), than in countries where confined feeding was more prevalent (EU and U.S.).

While Table 2 is useful for illustrative purposes, in practice, a carbon tax would be much more difficult to implement, since GHG emissions depend on numerous factors, including practice, crop and region (Eve *et al.*, 2014). Any estimates derived for a carbon tax would be fraught with uncertainty, since emissions are often from non-point sources and this is the reason why they are difficult to measure. A more likely approach would be for countries to impose a more targeted tax on a specific sector, such as fossil fuel production that would then have indirect impacts in energy-intensive sectors such as agriculture. Alternatively, cap and trade schemes could be introduced that limit the total amount of emissions and allow trading of emission permits. Cap and trade schemes would penalize higher emitting products and services, while providing incentives for adaption of more efficient technologies. But cap and trade schemes would still be challenging for agriculture, due to the high costs of monitoring, necessary to ensure the integrity of the trading scheme.

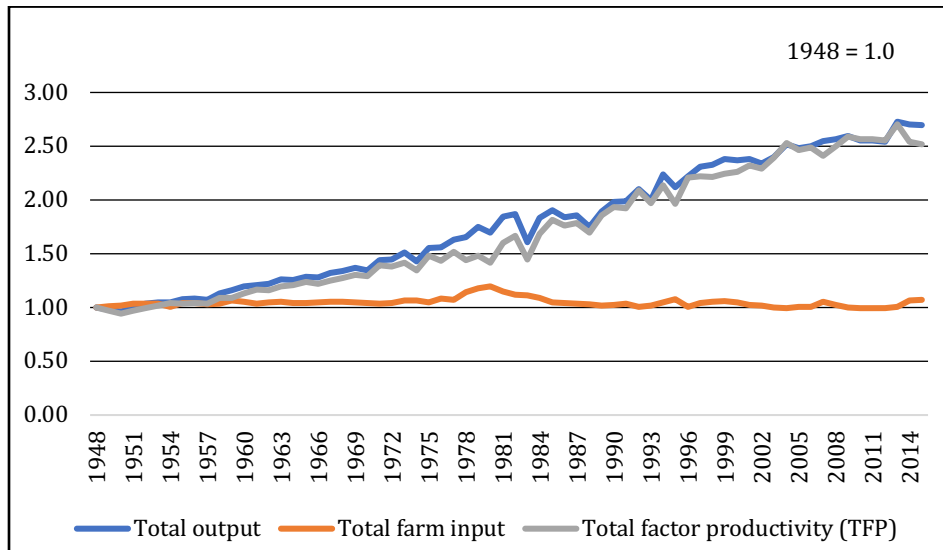
Domestic taxes are typically not covered under international agreements since they are likely to depress, rather than enhance output. Nonetheless, as Blandford (2013) points out, exempting sectors like agriculture from emissions caps, could raise the issue of implicit subsidization by allowing exempt sectors to sell emissions credits. Like a carbon tax, the value of carbon offsets would be subject to similar uncertainty in measurement, as well as monitoring and enforcement issues. Offsets could also present food security concerns, for example, if cropland were taken out of production for carbon sequestration purposes.

5.2 Providing subsidies to increase GHG efficiency in production

Under the CSA approach, mitigation measures for climate change are promoted that are in line with the “food security first” objective. One approach is to improve efficiency by decoupling production growth from emissions growth. This involves reducing emissions per kilogram of food output – included in this calculation are the effects of emissions from reduced deforestation per kilogram of food. The second way is to increase resource efficiency by increasing productivity.

Publicly funded research is another way governments can help mitigate the impacts of climate change, through increasing the productivity and GHG-efficiency of plant and animal production. Public financing of agricultural research and development has led to large and sustained agricultural productivity gains (Alston *et al.*, 2010; Alston and Pardey, 2014). Figure 5 shows US agricultural productivity since 1948. While productivity has increased over 150 percent since 1948, input use has remained more or less constant.

Figure 5: U.S. Total Factor Productivity



Source: USDA and Economic Research Service

Fuglie (2017) argues, that the public-goods nature of knowledge capital, namely the non-excludability of free riders in enjoying the benefits of Research and Development (R&D); and the small-holder structure of farming, have implied a major role of government in investing in agricultural R&D. And while private investment in R&D has grown, as recently as 2011, public institutions accounted for about three-quarters of total global spending on agricultural research (Fuglie, 2017).

Research by Baldos and Hertel (2014) points to the role of total factor productivity growth in mitigating GHG emissions by increasing carbon efficiency (amount of production per GHG emission). Work by Wise *et al.* (2009) shows, that if production technologies were frozen at 2005 levels, land-use change carbon emissions (assuming no mitigation strategies) would be more than 70 billion tons CO₂ e higher over the 21st century, because greater amounts of land would have been necessary to produce the same amount of food. However, due to the so-called rebound effect, some of the productivity gains may be partially offset by increased production, at least at the national level, due to improved profitability. At the global level, rebound impacts are likely smaller, since demand elasticities and most productivity gains will be passed through in terms of lower prices.

Public expenditures for CSA Research and Development would likely be consistent with Paragraph 2 of Annex 2 of the AoA. Other examples of general services policies would be technical assistance programs aimed at helping crop and livestock producers develop and implement nutrient management plans; and research activities, that promote soil health and reduce GHG emissions from cropland and livestock. These policies do not involve direct payments to producers or processors, nor are these activities funded by transfers from consumers. But if they do, these policies would be considered amber and subject to discipline.

Input subsidies to encourage adoption of new GHG technologies would generally be considered Amber Box programs, since they are tied to production or the input itself. The exception would be for resource poor or low income farmers in developing countries, who could claim these measures under Article 6.2 of the AoA.

5.3 Providing subsidies to reduce GHG emissions or sequester carbon

Climate smart policies that provide producers financial incentives to adopt policies which reduce GHG emissions or increase carbon sequestration, must meet specific criteria to be considered “Green Box” under the AoA and this is why they are exempt from WTO discipline. For example, consider a climate smart policy that would pay livestock producers to install anaerobic digesters to capture GHG emissions. To qualify as an environmental program consistent with paragraph 12 of Annex 2 of the AoA, the amount of the payment must be limited to the “extra costs or loss of income involved with complying with the government programme” (Paragraph 12(b)). To the extent that such policies also provide an incentive component to encourage adaptation, this may make them ineligible for Green Box protection. Cost-share programs for establishing conservation practices on agricultural land have supported implementation of farming practices and structures that reduce loss of fertility through soil erosion; facilitate improved drainage, water storage, and more efficient irrigation; and provide manure storage and assistance with meeting nutrient management regulations (Claassen, Duquette and Horowitz, 2013). In the United States of America, programs like the Environmental Quality Incentives Program and the Conservation Stewardship Program – that help cover input costs and income foregone for environmentally friendly practices – may reduce productivity or take some years to achieve full production capacity.

The production effects of cost–share programs are difficult to calculate for two reasons. First, the additionality of such programs is often uncertain, which means that some producers would have adopted such practices without incentive payments or cost–share (McFarland, 2011; Claassen, Duquette and Horowitz, 2013; Mezzatesta, Newburn and Woodward, 2013). Should subsidies be provided for all producers, who use a practice or for just those, who newly adopt such a practice? In the former case, the “additionality” gained by the subsidy may be small, in which case, the marginal cost of adoption is quite high. If the subsidy is restricted to just those, who newly adopt a practice, producers who had previously adopted the practice may have incentives now to discontinue the practice, if they believe they will be paid for re–enrolling in the program.

Second, although the impact of some of these practices on crop yields may be beneficial over the long run by improving soil fertility, planting conditions, and water availability – that could potentially lead to increased production and lower prices– in the short run the impacts are likely minor and, for some practices, productivity will remain below conventional practices.

CSA policies to encourage carbon sequestration include putting cropland into long term set asides. For example, the United States has operated the Conservation Reserve Program (CRP) since 1986. Under the CRP, producers are paid a yearly rental payment in exchange for removing environmentally sensitive land from agricultural production and planting species that will improve environmental quality. CRP contracts are competitively awarded on the basis of environmental benefits and typically extend for 10 to 15 years. Since its first year of operation in 1986, the CRP has idled on average 12.6 million hectares (ha) annually, but in recent high-price years, contracts matured and many farmers opted to bring land out of retirement. The 2014 farm bill restricts the enrollment of land in the CRP to 10.1 million hectares (ha) – equivalent to 25 million acres–, and as of September 2017, only 9.5 million hectares (ha) were enrolled in the CRP, down from 13 million hectares (ha) at its peak.

The reduction in land use intensity, provided by the CRP, can provide multiple environmental benefits, including substantial GHG mitigation,= that occurs as carbon is sequestered in soils or vegetation (USDA, 2016). Recent efforts by the US Department of Agriculture to augment benefits under the CRP, have included enrolling lands into permanent or long-term easements within the Agricultural Conservation Easement Program (ACEP), with State Easement Programs under the Conservation Reserve Enhancement Program, and with private partners. Other efforts include targeting eligible lands to enroll additional riparian buffers, wetlands, and other conservation practices with large GHG mitigation benefits into CRP and enrolling organic soils – a highly concentrated source of GHG emissions – into CRP or ACEP.

Two concerns arise with land set aside programs. First, idling cropland could potentially exacerbate food security. Baker *et al.* (2010) consider the impact of a carbon offset program that pays producers to convert cropland to forestland. Assuming a carbon price of USD 50/tonnes CO₂ e, they found that producers would afforest as much cropland as 15.8 million hectares (ha). While farm incomes would rise, consumers would lose.

Second, afforesting cropland may encourage indirect land use effects elsewhere. To the degree that retiring cropland reduces supply, the resulting price increases may encourage production (rebound effect), particularly in countries where crop production may be less GHG-efficient or where expansion of production occurs through deforestation or pasture conversion.

To the degree possible, carbon sequestration efforts via afforestation of cropland should be targeted towards cropland with the poorest and least efficient yields from a GHG perspective.

5.4 Measures to increase resilience to producers to the effects of climate change

Under the AoA, the Green Box accommodates a number of mitigation measures that can help producers adjust to increased weather volatility that will likely accompany climate

change. Agricultural insurance is available in over 100 countries (Mahul and Stutley, 2010). Annex 2 of the AoA also accommodates public reserve programs that can help buffer the impacts of production shortfalls to meet food security needs. For producers, whose livelihoods are adversely affected by climate change, Annex 2 allows structural adjustment programs, such as producer retirement programs to transition producers, to more economically viable livelihoods. And, through the Bali Decision, Annex 2 was extended to include activities to promote rural development and land reform, such as land rehabilitation; soil conservation and resource management; drought management and flood control; rural employment programmes; issuance of property titles; and farmer settlement programmes.

5.4.1 Agricultural insurance and disaster assistance

Agricultural insurance and disaster assistance programs can potentially mitigate the effects of increased climate variability due to climate change (Skees and Enkh-Amgala, 2002; FAO, 2013). Disaster programs are typically payment programs that compensate producers for losses incurred due to a natural disaster. Such programs often are initiated *ex post*, which means, that a producer may have no guarantee of receiving such a payment at time of planting. Insurance, by contrast, guarantees, *ex ante* (typically prior to planting) a payment contingent on a qualified loss. In return, the producer typically pays a premium for such protection, though the premium is often times subsidized by the government.³

In developed economies such as the United States, Japan, Canada, and Europe, agricultural insurance is generally characterized by indemnity-based programs that provide crop and livestock coverage against named perils, multiple perils, and, more recently, price and revenue risks. Individual-based coverage is expensive, because of the high cost of administering contracts and adjusting losses. Moreover, individual-based policies are prone to moral hazard and adverse selection problems, which add to the monitoring costs⁴ (Kalra, 2013). Because these costs are generally high relative to other risk management strategies – such as crop diversification, futures markets, or off-farm income–, demand for agricultural insurance products, in the absence of subsidies, tends to be low. This explains why private unsubsidized markets for multiple peril insurance have generally failed (Wright and Hewitt, 1994; Goodwin and Smith, 1995) and why the larger insurance programs in the United States, Canada, and Japan are generally highly subsidized. In their comprehensive review of agricultural insurance programs, Mahul and Stutley (2010) found, that almost two-thirds of the countries surveyed, reported that they subsidized premium costs. These countries accounted for more than 90 percent of total premiums, at an average subsidy rate of 47 percent. For example, the public costs of the US program, which are estimated at about one-third of 2014 total global premium volume, are projected

³ Not all disaster assistance programs are *ex post*. Some countries offer producers *ex ante* disaster protection. In such a case they operate effectively like a fully subsidized insurance program (Glauber, 2004).

⁴ Moral hazard problems arise when insured producers alter their behavior after purchasing insurance to affect their likelihood of collecting an indemnity. Adverse selection problems arise when risks vary across insurance buyers and buyers know more about the risks they face than does the insurer who sets the rates (Hirshleifer and Riley, 1992).

to exceed USD 8 billion annually over the next 10 years, an expenditure of almost 90 cents for every USD 1 premium written (CBO, 2017).

With such high program costs, it is little wonder, that the larger agricultural insurance programs are generally found in developed countries, or increasingly, in large emerging economies, like India and China. The high costs of contracting with large numbers of dispersed smallholders– when there are fixed costs to contracting and poorly developed legal institutions for enforcing contracts– have led many to conclude, that conventional, indemnity–based insurance does not work for smallholder farmers in developing countries (Hazell, 1992). To address these concerns, index–based insurance products based on specific perils or events (for example, regional yield loss, drought, or flood) and recorded at a regional level (for example, by regional weather stations) have been promoted. Examples of such products include area–yield insurance, where premiums and indemnities are based on the average yield in a region, or weather–based indices, such as rainfall insurance, where producers receive a payment if rainfall in the region falls below a designated level (Skees, Hazell, and Miranda, 1999; Carter, 2012). Such contracts typically minimize moral hazard and adverse selection issues (Miranda, 1991) and can be provided at lower costs, because loss adjustment and monitoring costs are so much lower (Skees, Black and Barnett, 1997).

Index insurance schemes have been piloted in a number of developing countries, with somewhat limited success (Miranda and Farrin, 2012; Carter *et al.*, 2014). Participation in pilot programs has been generally limited (Binswanger-Mkhize, 2012). Smith (2016) points out, that small–holder farmers already have ways of mitigating risk, including informal community–based initiatives, enterprise diversification, and off–farm employment. Another drawback is the existence of basis risk; that is, the degree to which the regional yield or weather variable is correlated with the individual farm yield. Producers, whose yields are poorly correlated with the aggregate index may find such insurance offers to be insufficient risk protection; thus, basis risk can act to limit demand. One exception is India’s Weather Based Crop Insurance Scheme, an index–based insurance program that has grown considerably since its introduction in 2007 to include more than 9 million Indian producers in 2010–11, with a combined commercial premium volume of about USD 260 million (Clarke *et al.*, 2012; Mahul, Verma, and Clarke, 2012). However, the program is heavily subsidized, and participation is mandatory, if producers participate in government credit programs. Recent work by Bertram-Huemmer and Kroehnert (2018) of livestock index insurance in Mongolia concludes, that insurance mitigated the impacts of drought for producers, who participated in the pilot.

Some believe, that the potential market for weather–based insurance products is more likely limited to insuring relatively large groups of farmers, either directly or indirectly through aggregators, such as input providers, credit providers, or buyers in contract farming situations (Binswanger-Mkhize, 2012; Smith, 2016). Another potential use of weather–based contracts would be by national governments to mitigate wide–spread emergencies like droughts (Miranda and Farrin, 2012).

Agricultural insurance has witnessed dramatic growth since the launch of the Uruguay Round, largely the result of substantial government support measures. The levels of support for many programs have raised concerns, that in addition to providing risk mitigation, subsidies may be distorting production and trade.

When crop insurance is available and priced, so that the farm can acquire coverage, risk averse farms produce more. But the pure subsidy impact also matters. Recent papers by Babcock (2015) and Du, Feng and Hennessy (2017) point out, that if producers are participating in the crop insurance program primarily to “harvest” subsidies, they are not acting optimally. This means, that they are not choosing optimal levels of coverage to maximize subsidies. Their studies conclude, that farmers’ decisions about how much crop insurance to buy, are not generally consistent with either expected profit or simple models taking risk aversion into account. Farmers do not pick coverage levels that maximize expected subsidy nor do they demand full insurance coverage. However, over time, producers have tended to sign up for higher coverage levels, where the per unit subsidies tend to be higher. Glauber (2013) shows, that in the United States of America the average coverage levels for most row crops have grown significantly and continuously since the late 1990s, when subsidies were increased for higher coverage levels.

Measurement of impacts of the US crop insurance program have focused on planted area and the effects of insurance on input use. Goodwin, Vandever, and Deal (2004) examined Midwestern corn and soybean producers and wheat and barley producers in the Northern Plains and found, that a 30 percent decrease in premium costs were likely to increase barley acreage by about 1.1 percent and corn acreage by less than 0.5 percent. Soybean and wheat acreage showed no statistically significant impact. Ligon (2012) analyzed the impact of crop insurance on specialty crops and concluded, that the introduction of crop insurance had a large and positive impact on tree crops, but a negligible impact on non-tree crops. Goodwin and Smith (2012) have questioned, whether the results of earlier studies continue to be relevant, given that subsidy levels are much higher now than when earlier research was conducted and revenue policies have largely replaced yield coverages. For example, the Goodwin, Vandever, and Deal study examined the effects of insurance subsidies over the period 1986–1993, prior to enactment of major legislation in 1994 and 2000, that dramatically increased subsidy levels, and prior to the introduction of revenue insurance (Glauber, 2004). More recently, Yu, Smith and Sumner (2018) found, that increased crop insurance subsidy rates have had significantly positive impacts on production of major field crops, but the magnitude of the overall production increases have been small as a share of total production.

The aforementioned studies have mostly indicated, that crop insurance subsidies have had small impacts on production overall in areas, where insurance is broadly available across crops. Crop insurance likely has larger impacts on crop choice when insured crops compete against uninsured crops, or when crops – where revenue insurance is available– compete against crops, where only yield insurance is available (Wu and Adams, 2001).

Glauber (2017) pointed out, that meeting the strict criteria in paragraph 7 (income insurance) or paragraph 8 (natural disaster and crop insurance) of Annex 2 of the AoA may

make it difficult to report insurance programs in the Green Box. For example, both Paragraphs 7 and 8, limit coverage to 70 percent of expected income or yield and establish guarantees based on 5 years or less of historical data. Most area-based yield programs or weather-based derivative products tend to offer higher coverage levels and coverage levels tend to be based on expected yield or income outcomes, which may differ from averages of past outcomes. Moreover, the 70 percent coverage limit is arguably overly stringent for index products, since index volatility is typically substantially less than volatility for individual yield or revenue-based coverage. Glauber (2017) noted, that because of the variance with Annex 2 criteria, most countries – that notify insurance programs to the WTO – notify them as Amber Box programs.

Increased yield variability due to climate change will increase the costs of insuring these risks, as premium costs will rise. This may reduce the attractiveness of agricultural insurance as a mitigation option, unless governments continue to subsidize a large share of the premium costs. And insurance companies may be less willing to underwrite risks without large public support in the form of reinsurance (Glauber, 2004).

5.4.2 Public stockholding programs

Like trade, stocks serve to mitigate the impact of production shortfalls (Williams and Wright, 1991). Private stockholders typically hold inventories when expected speculative profits are non-negative. This happens, when expected prices equal or exceed the cost of purchasing and storing the commodity. When supplies are abundant and prices are low, stockholders tend to purchase and hold more stocks. During periods of scarcity, when prices are high, stockholders release stocks onto the market and inventory levels fall. Stocks, much like trade, tend to buffer the impacts of supply. Unlike trade, which may be negative (imports) or positive (exports), stocks are limited in that, one can store for future shortfalls, but cannot borrow from the future to mitigate current shortfalls.

Public stockholding programs date back at least two thousand years (Sumner, Alston and Glauber, 2010). For example, in the Biblical story Joseph tells the Pharaoh to store grain during times of abundance to forestall shortages during times of drought (Genesis 41:53–57). Chen (1974) described stockholding schemes in China in the first century BCE. More recently, the United States of America introduced government stockpiling programs in the 1930s (Glauber and Effland, 2017) and the European Union introduced price intervention schemes under its Common Agricultural Policy in the 1960s (Josling, 1974). Subsequent reforms in the United States of America and the European Union have greatly diminished the role of those public stockholding programs, but large national reserve programs exist in many developing countries such as China and India (G20, 2011).

Large-scale public stockholding programs have been criticized for a number of reasons (Wright and Prakash, 2011). First, they tend to be costly, both in terms of costs of procurement and the costs of storage. Second, stockholding programs often operate on pre-announced procurement prices that when set high relative to current market prices can lead to large stock acquisitions and distort production decisions. The experience of the

European Union, United States of America and more recently, China, has been that such policies can lead to burdensome government stockpile levels. Those stocks can further distort markets when governments decide to draw down public stocks by dumping them on world markets. Lastly, public stockholding programs often operate in a manner that discourages private stockpiling, which reduces the effectiveness in stabilizing market prices.

Unlike large scale buffer stock schemes, small public reserves for purposes of meeting short-term emergency food needs can help mitigate production shortfalls, particularly in countries, where transportation costs may limit or delay imports of needed supplies. In addition, their operation is less likely to disrupt stockholding by merchants, and other private sector market participants. One such example is the World Food Programme's (WFP) Forward Purchasing program that aims to achieve more rapid and cost-effective food delivery to beneficiaries across countries in various regions (WFP, 2010).

The AoA allows for certain publicly-funded government programs with no (or at most minimal) trade distorting effects or effects on production, to be exempted from domestic support reduction commitments, provided they also meet policy specific criteria that are laid out in paragraph 3 of Annex 2 of the AoA. Of particular concern is, how countries procure grain or other foodstuffs for the reserve. If procurement is based on pre-announced statutory prices that exceed base-period reference prices, then countries must report these measures as Amber Box (and if the support for those commodities exceed *de minimis* levels). The provisions in paragraph 3 have been controversial in the WTO with some developing countries seeking to relax criteria in the provisions to allow for public stockholding programs in developing countries. The changes have been strongly opposed by a number of developed countries and exporting developing countries, which expressed concern, that if administered prices are set high enough, they would distort producer production decisions, potentially leading to surpluses that could depress global market prices.

5.4.3 Structural adjustment payments

Climate change could have severe adverse implications for producers in affected regions. In cases where climate change has dramatically affected crops or livestock production, structural adjustment programs could help countries mitigate those impacts by providing aid to build regional infrastructure to support alternative crops, or even by taking land out of crop or livestock production, or in more extreme cases by assisting producers who leave agriculture altogether.

Structural measures that are designed to assist permanently disadvantaged producers or regions, are covered in Annex 2 of the AoA under Paragraph 9 (producer retirement programs), Paragraph 10 (resource retirement programs), Paragraph 11 (regional investment aids) and Paragraph 13 (regional adjustment programs). Due to the costs of such programs, the measures – covered under Paragraphs 9, 10, 11 and 13 – have been

largely used by developed members, such as the European Union and the United States of America. International funding will likely be necessary to assist poorer countries in making large structural adjustments of this kind.

5.5 Regulatory policies to address climate change

In addition to subsidies and taxes, climate change mitigation can also be imposed through regulation. Restrictions could be placed on certain practices to reduce GHG emissions (for example, regulating how manure is managed) or by regulations that mandate the production of products that are more GHG efficient.

Biofuel mandates have been touted as climate smart policies, though they remain controversial, because of their potential impact on GHG emissions, when agricultural production practices and direct and indirect land use effects are considered (USDA, 2016). United States of America biofuel policies have stimulated demand for biofuels and their feedstocks. From 2005 to 2011, US production of corn-based ethanol increased from 3.9 billion gallons to 13.9 billion gallons, at an annual growth rate of almost 24 percent per year. Corn use for ethanol grew by about 3.4 billion bushels, accounting for more than 40 percent of total corn use in 2011/12. United States of America biodiesel production rose from just 90 million gallons in 2005 to more than 1.2 billion gallons by 2014. About 25 percent of soybean oil use goes to biodiesel production; other important feedstocks include animal fats and other vegetable oils.

As Babcock and Fabiosa (2011) point out, a number of other factors were critical for ethanol's growth. First, the phase-out of Methyl Tertiary Butyl Ester (MTBE) as a gasoline additive in 2004 and 2005 boosted demand for ethanol as its replacement in oxygenated fuel markets. This growth in ethanol demand combined with existing demand subsidies and a limited supply of ethanol to greatly increase ethanol prices, led to the wide processing margins in 2006 and 2007. Large margins further spurred investment in ethanol production capacity. Second, the rapid rise in oil prices beginning in 2006 encouraged discretionary blending of ethanol as a substitute for gasoline.

The rapid rise in corn and other commodity prices in 2007–2008 prompted concerns about the impact of ethanol on food prices both in the United States of America and abroad. Many critics, like Wright (2014), blamed biofuel production for increased prices and volatility. Condon, Klemick and Wolverton (2015) reviewed a wide range of studies that considered the impact of ethanol production on corn prices during the period 2007–2010. Their meta-analysis concludes that about one-third of the price increase in corn prices over the period was likely due to increased ethanol production.

Since 2011, United States of America corn ethanol production has remained relatively flat at about 14 to 15 billion gallons, reflecting automobile performance constraints that limit ethanol penetration in motor fuel use at 10 percent (the so-called blend wall). Today, the blender tax credits for ethanol have been eliminated as have the high supplemental duties

on ethanol imports. The Renewable Fuel Standard (RFS) mandates established under the Energy Independence Security Act of 2007 have been relaxed reflecting the blend wall constraint. As a result, corn use for ethanol remains at about 5.1 billion bushels per year and is not projected to grow much over the next 10 years (O'Donoghue and Hansen, 2017).

The RFS's impact on current corn prices is likely small. Ethanol is currently price competitive as an octane enhancer in gasoline production (Irwin and Good, 2015). As a result, even with lower oil prices, ethanol production margins remain competitive and ethanol production levels have remained above mandates under the RFS. Thus, elimination of the mandates would likely have little impact on ethanol production and hence corn use and prices, at least in the short run. Over the long run, its competitiveness would largely be driven by the relative price difference between corn and petroleum absent consumption mandates.

By contrast, United States of America biodiesel production is heavily dependent on the mandates and the current US biodiesel tax credit, which provides USD 1/gallon credit for blenders of biodiesel fuel. Under the recent RFS for 2016, mandates for biodiesel were set at 1.9 billion gallons. In the absence of the mandates and tax credits it is unlikely that biodiesel production would be more than one-third of current levels, as a number of states and municipalities mandate biodiesel use.

Lastly, concerns have been raised about the impact of biofuel policies on indirect land use change (Searchinger *et al.*, 2017). The modest GHG emissions reduction due to first generation biofuel (such as maize) use may be largely offset by the impact of higher prices on world production, particularly if production expansion is a result of deforestation or pasture conversion.

WTO domestic support issues are potentially raised, when subsidies are used to encourage biofuel production or consumption, which, in turn, has potential impacts on feedstock production (for example, corn for ethanol production, soybeans for soybean oil-based biodiesel production). As such, biofuel policies distort feedstock production and this is the reason why they are amber in nature. For example, under its Biomass Crop Assistance Program (BCAP) the United States of America provides financial assistance to owners and operators of agricultural and non-industrial private forest land who wish to establish, produce, and deliver biomass feedstocks. The United States of America has notified BCAP expenditures as Amber Box.

6. Designing WTO-compatible CSA policies

Climate Smart Agriculture aims to achieve sustainable agricultural development for food security under climate change. For the most part, those goals are compatible with the WTO goals of free and open trade. Indeed, as was discussed in Section 3, international trade is itself a mitigating strategy in meeting the food security challenges of climate change. An

open trading system will best serve the potential needs of balancing future supply and demand regardless of how those factors will be affected by climate change. To this end, further progress in lowering tariffs and other border measures and eliminating trade-distorting domestic support will help facilitate timely and appropriate exports to meet food security concerns over the long run and more importantly, during times of distress caused by climate-induced crop failures. In addition, progress should be made towards eliminating the use of export restrictions and other distortions.

Ideally, the externalities caused by GHG emissions would be fully incorporated in market prices; in practice, this will likely never be the case. Nonetheless, CSA policies aimed at reducing GHG emissions, or sequestering CO₂, or mitigating the effects of climate change itself, should not be back door ways of promoting protectionism or distorting domestic production. Such policies, while attractive from a narrow domestic perspective, will likely have more consequential adverse impacts in international markets, particularly for developing countries who will be less likely to afford such support measures. In this sense, CSA policies should be compatible with the overarching conditions of the Green Box of providing minimal trade- or production-distorting support.

That is not to say that reforms to the provisions in Annex 2 should not be considered. As Glauber (2017) points out, the Annex 2 provision governing insurance are not well adapted to current insurance programs, particularly index insurance and weather derivatives, which are increasingly being used in developing countries (Miranda and Farrin, 2012). That said, heavily subsidized insurance programs, particularly those that provide price and revenue protection, can distort production since they are directly coupled to actual production.

Increasing productivity, particularly in developing countries where yield gaps are often greatest, should be a priority of any CSA policy. More public R&D should be directed towards climate resilient varieties and towards an aim of increasing GHG efficiency. While Article 6.2 of the AoA allows for subsidized input use to increase productivity in resource poor developing countries, input subsidies for developing countries that promote less GHG-efficient production technologies should be viewed with more caution.

Resource retirement programs may offer significant opportunities for carbon sequestration through afforestation. However, the impact of sequestered carbon on GHG emissions must be analyzed in a global context in terms of indirect land use as well as food security concerns. Likewise, biofuel mandates should be limited to non-food and non-feed feedstocks, though land use effects of converting potential cropland to biofuel use remain an issue of concern.

7. Conclusions

Addressing climate change in a way that ensures meeting the UN Sustainable Development Goals will pose significant challenges in the years ahead. Of broader consideration is whether the exigencies of climate change require rethinking rules underlying the global trading system, particularly those governing domestic support. Should measures that encourage the adoption of GHG-efficient policies be encouraged, even if they increase production and trade? Such policies may be efficient from a global perspective, yet could lead to adverse consequences for producers at the regional or country level—particularly penalizing developing countries whose resources may be insufficient to match that of more developed countries.

Climate Smart Agriculture is an important tool to help mitigate agriculture's contribution to GHG emissions as well as help producers and communities better adapt to the conditions brought on by climate change. Free and open trade should be seen as an integral part of any CSA strategy. Efforts at further liberalization through reductions in tariff and non-tariff barriers, trade-distorting domestic support, and export subsidies and restrictions should be vigorously pursued.

References

- Ahmed, K., Wang, G., You, L., Anyah, R., Zhang, C., & Burnicki, A.** 2017. Projecting regional climate and cropland changes using a linked biogeophysical–socioeconomic modeling framework: 2. Transient dynamics. *Journal of Advances in Modeling Earth Systems* 9(1): 377.
- Alston, J., M. Andersen, J. James, and P. Pardey.** 2010. Persistence Pays: US Agricultural Productivity Growth and the Benefits from Public R&D Spending. New York: Springer.
- Alston, J.M., Pardey, P.G.,** 2014. “Agriculture in the Global Economy”. *J. Econ. Persp.* 28 (1): 121–146.
- Anderson, K., Ivanic, M. & Martin, W.J.** 2014. Food price spikes, price insulation, and poverty. In J.P. Chavas, D. Hummels & B.D. Wright, eds. *The Economics of Food Price Volatility*, pp. 311–339. Chicago, USA, University of Chicago Press.
- Antle, J.M.** 2015. Climate change vulnerability and food insecurity. *Choices* 30(2).
- Babcock, B.** 2015. Using Cumulative Prospect Theory to Explain Anomalous Crop Insurance Coverage Choice. *American Journal of Agricultural Economics* 97: 1317–1384.
- Babcock, B. & Fabiosa, J.** 2011. The Impact of Ethanol and Ethanol Subsidies on Corn Prices: Revisiting History. *CARD Policy Briefs* 1 Ames, IA, US: Iowa State University, Center for Agricultural and Rural Development.
- Baker, J., McCarl, B., Murray, B., Rose, S., Alig, R., Adams, D., Latta, G., Beach, R., & Daigneault, A.** 2010. Net Farm Income and Land Use under a U.S. Greenhouse Gas Cap and Trade. *Policy Issues*. PI7. <http://www.choicesmagazine.org/UserFiles/file/PI7.pdf>
- Baldos, U. & Hertel, T.W.** 2014. Global food security in 2050: The role of agricultural productivity and climate change. *Australian Journal of Agricultural and Resource Economics* 58: 1–18. (also available at <https://doi.org/10.1111/1467-8489.12048>).
- Bertram–Huemmer, V. & Kraehnert K.** 2018. Does Index Insurance Help Households Recover from Disaster? Evidence from Index–Based Livestock Insurance (IBLI) Mongolia. *American Journal of Agricultural Economics*, 100(3): 145–171.
- Binswanger–Mkhize, H.** 2012. Is There Too Much Hype about Index–based Agricultural Insurance? *Journal of Development Studies* 48(2):187–200.
- Blanco, G., Gerlagh, R., Suh, S., Barrett, J., de Coninck, H. C., Diaz Morejon, C. F., Mathur, R., Nakicenovic, N., Ofosu Ahenkora, A., Pan, J., Pathak, H., Rice, J., Richels, R., Smith, S. J., Stern, D. I., Toth, F. L. & Zhou, P.** 2014. Drivers, Trends and Mitigation. In O. Edenhofer, R. Pichs–Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I.

Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel & J.C. Minx, eds. *Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York, USA, Cambridge University Press.

Blandford, D. 2013. *International Trade Disciplines and Policy Measures to Address Climate Change Mitigation and Adaptation in Agriculture*. Paper produced under E15 Initiative. Geneva, International Centre for Trade and Sustainable Development (ICTSD) and World Economic Forum 2014. (also available at: www.e15initiative.org/).

Blandford, D. & Josling, T. 2009. *Greenhouse Gas Reduction Policies and Agriculture: Implications for Production Incentives and International Trade Disciplines*. International Centre for Trade and Sustainable Development (ICTSD)– International Food & Agricultural Trade Policy Council (IPC) Platform on Climate Change, Agriculture and Trade, Issue Brief No.1, ICTSD, Geneva, Switzerland and International Food & Agricultural Trade Policy Council, Washington DC, USA.

Blandford, D. & Hassapoyannes, K. 2017. *Agriculture's Role in Global GHG Mitigation Towards the Below 2°C Warming Objective: Potential, Means and Economic Implications*. Paris: OECD Consultant Report. COM/TAD/CA/ENV/EPOC (2017)11.

Bouët, A., Cosnard, L. & Laborde, D. 2017. *Measuring Trade Integration in Africa*. (International Food Policy Research Institute) IFPRI Discussion Paper 01667. Washington, DC. <http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/131365>

Brown, M.E., Carr, E.R., Grace, K.L., Wiebe, K., Funk, C.C., Attavanich, W., Backlund, P. & Buja L. 2017. Do markets and trade help or hurt the global food system adapt to climate change? *Food Policy* 68: 154–159. <http://www.sciencedirect.com/science/article/pii/S030691921630481X>

Burney, J., Davis, S. & Lobell, D. 2010. Greenhouse gas mitigation by agricultural intensification. *Proceedings of the National Academy of Sciences (PNAS)* 107(26): 12052– 12057.

Campbell, B., Thornton, P., Zougmore, R., van Asten, P. & Lipper L. 2014. Sustainable intensification: What is its role in climate smart agriculture? *Current Opinion in Environmental Sustainability* 8: 39–43.

Carter, M. 2012. *Designed for Development Impact: Next Generation Approaches to Index Insurance for Smallholder Farmers*. Munich, MunichRe Microinsurance Compendium 2.

Carter, M., de Janvry, A., Sadoulet, E. & Sarris, A. 2014. *Index-Based Weather Insurance for Developing Countries: A Review of Evidence and a Set of Propositions for Up-scaling*. La Fondation pour les Études et Recherches sur le Développement International. http://www.ferdi.fr/sites/www.ferdi.fr/files/evenements/presentations/wp_ferdi_working_paper_on_index_insurance_june_19_kl.pdf

Ceballos, F., Hernandez, M. A., Minot, N. & Robles, M. 2017. Grain price and volatility Transmission from International to Domestic Markets in Developing Countries, June 2017, *World Development* 94: 305–320.

Chen, H. 1974. *The Economic Principles of Confucius and His School*. New York, USA, Gordon Press.

Claassen, R., Duquette, E. & Horowitz, J. 2013. Additionality in agricultural conservation payment programs. *Journal of Soil and Water Conservation* 68 (3): 74A–78A.

Clarke, D., Mahul O., Rao, K. & Verma, N. 2012. Weather Based Crop Insurance in India. Policy Research Working Paper 5985. World Bank. Washington, DC.

Condon, N., Klemick, H. & Wolverton, A. 2015. Impacts of Ethanol Policy on Corn Prices: A Review and Meta-analysis of Recent Evidence. Washington, DC. *Food Policy* 51: 63–73.

Congressional Budget Office (CBO). 2017. Baseline for Farm Programs.

Demeke, M., Pangrazio, G. & Maetz, M. 2009. Country responses to the food security crisis: nature and preliminary implications of the policies pursued. Initiative on soaring prices. Rome, FAO.

De Pinto, A. & Ulimwengu, J. M., eds. 2017. A thriving agricultural sector in a changing climate: Meeting Malabo Declaration goals through climate-smart agriculture. ReSAKSS Annual Trends and Outlook Report 2016. Washington, D.C., International Food Policy Research Institute (IFPRI). <http://dx.doi.org/10.2499/9780896292949>

Du, X., H. Feng, and D. Hennessy. 2017. Rationality of Choices in Subsidized Crop Insurance Markets. *American Journal of Agricultural Economics* 99(3):732–756.

Earley, J. 2009. U.S. Trade Policies on Biofuels and Sustainable Development. Programme on Agricultural Trade and Sustainable Development, Issue Paper No.18. Geneva, Switzerland. International Centre for Trade and Sustainable Development.

Effland, A. 2011. Classifying and Measuring Agricultural Support: Identifying Differences between the WTO and OECD Systems. Economic Information Bulletin No. 74. Economic Research Service, US Department of Agriculture.

Eve, M., Pape, D., Flugge, M., Steele, R., Man, D., Riley-Gilbert, M. & Biggar, S., eds. 2014. Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. July 2014, Technical Bulletin Number 1939. Office of the Chief Economist, United States Department of Agriculture, Washington, DC. 606 pp.

FAO. 2010. *Climate Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation*. Rome

- FAO.** 2013. *Climate Smart Agriculture: Sourcebook*. Rome.
(also available at <http://www.fao.org/docrep/018/i3325e/i3325e.pdf>).
- Fuglie, K.** 2017. “R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture.” *Applied Economic Perspectives and Policy* 40(3): 421–444.
- Keith, F.** 2018. R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture, *Applied Economic Perspectives and Policy* 40(3), 421–444.
<https://doi.org/10.1093/aep/px045>
- G20.** 2011. “Price Volatility in Food and Agricultural Markets: Policy Responses” Policy Report including contributions by FAO, IFAD, IMF, OECD, UNCTAD, WFP, the World Bank, the WTO, IFPRI and the UN HLTF. <http://www.oecd.org/tad/agricultural-trade/48152638.pdf>.
- Gale, F., Hansen, J. & Jewison, M.** 2016. China’s Growing Demand for Agricultural Imports. Economic Information Bulletin No. 136, Economic Research Service, U.S. Department of Agriculture.
- Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N. & Foley, J. A.** 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences* 107(38): 16732– 6737.
- Glauber, J. W.** 2004. Crop Insurance Reconsidered. *American Journal of Agricultural Economics* 86 (5): 1179–1195.
- Glauber, J.W.** 2013. The Growth of the Federal Crop Insurance Program, 1990–2011. *American Journal of Agricultural Economics* 95(2): 482–488.
- Glauber, J.W.** 2017. Agricultural insurance and the WTO. In A. Bouët & D. Laborde Debucquet, eds. *Agriculture, development and the global trading system: 2000– 2015*. Chapter 10. 325–364. Washington, DC, International Food Policy Research Institute (IFPRI). https://doi.org/10.2499/9780896292499_10
- Glauber, J. & Effland, A.** 2017. U.S. Agricultural Policy in *Handbook of International Food and Agricultural Policies, Volume 1, Policies for Agricultural Markets and Rural Economic Activity*. In T. Josling, W. Meyers, T. Johnson, eds. World Scientific Publishing.
- Godfray, H. C. J.** 2015. The debate over sustainable intensification. *Food Security* 7: 199– 208.
- Golub, A., Henderson, B., Hertel, T., Rose, S. & Avetisyan, M.** 2010. Effects of GHG Mitigation Policies on Livestock Policies. Paper presented at the 13th Annual Conference on Global Economic Analysis. Penang, Malaysia.

- Goodwin, B. & Smith, V.** 1995. *The Economics of Crop Insurance and Disaster Relief*. Washington, DC, AEI Press.
- Goodwin, B. & Smith, V.** 2012. What Harm Is Done by Subsidizing Crop Insurance? *American Journal of Agricultural Economics* 95 (2): 489–497.
- Goodwin, B., Vandever, M. & Deal, J.** 2004. An Empirical Analysis of Acreage Effects of Participation in the Federal Crop Insurance Program. *American Journal of Agricultural Economics* 86 (4): 1058–1077.
- Häberli, Christian.** 2018. Potential conflicts between agricultural trade rules and climate change treaty commitments. *The State of Agricultural Commodity Markets (SOCO) 2018: Background paper*. Rome, FAO, 2018. 50 pages.
- Haile, B., Azzarri, C., Koo, J. & De Pinto, A.** 2017. Trade, climate change, and climate-smart agriculture. In A. De Pinto & J.M. Ulimwengu, eds. *A thriving agricultural sector in a changing climate: Meeting Malabo Declaration goals through climate-smart agriculture*, Chapter 5, pp. 54–68. Washington, D.C., International Food Policy Research Institute (IFPRI). http://dx.doi.org/10.2499/9780896292949_05
- Havlík, P., Valin, H., Herrero, M., Obersteiner, M., Schmid, E., Rufino, M., Mosnier, A. et al.** 2014. Climate change mitigation through livestock system transitions, *Proceedings of National Academy of Sciences* 111(10): 3709–3714, Washington, DC.
- Hazell, P.** 1992. The Appropriate Role of Agricultural Insurance in Developing Countries. *Journal of International Development* 4: 567–581.
- Hirshleifer, J. & Riley, J.G.** 1992. *The Analytics of Uncertainty and Information*. New York, Cambridge University Press.
- Herrero M., Henderson, B., Thornton, P. K., Conant, R. T., Smith, P., Wiersenius, S., Hristov, A.N., et al.** 2016. Greenhouse gas mitigation potentials in the livestock sector. *Nature Climate Change* 6: 452–461, Springer Nature, London. <http://dx.doi.org/10.1038/NCLIMATE2925>.
- Huang, H., M. von Lampe and F. von Tongeron.** 2011. “Climate change and trade in agriculture.” *Food Policy* 36: S9-S13.
- Hussein, Z., Hertel, T. & Golub, A.** 2013. Climate change mitigation policies and poverty in developing countries. *Environmental Research Letters* 8: 035009. <http://iopscience.iop.org/article/10.1088/1748-9326/8/3/035009/meta>
- Irwin, S. & Good, D.** 2015. Further Evidence on the Competitiveness of Ethanol in Gasoline Blends. *farmdoc daily* (5): 17. Department of Agricultural and Consumer Economics, University of Illinois at Urbana–Champaign, January 30.

Josling, T. 1974. Agricultural Policies in Developed Countries: A Review. *Journal of Agricultural Economics* 25(3): 229–264.

Josling, T., Tangermann, S. & Warley, T. 1996. *Agriculture in the GATT*. London, MacMillan Press.

Josling, T. & Blandford, D. 2009. Biofuel Subsidies and the Green Box. In R. Melendez-Ortiz, C. Bellman & J. Hepburn, eds. *Agricultural Subsidies in the WTO Green Box*. pp. 530–568. Cambridge, UK, Cambridge University Press.

Kalra, A. 2013. Partnering for Food Security in Emerging Markets. Sigma 1. Geneva. SwissRe. http://media.swissre.com/documents/sigma1_2013_en.pdf.

Lantz, U., Baldos, C. & Hertel, T. 2015. The role of international trade in managing food security risks from climate change. *Food Security* 7: 275–290.

Leamer, E. 1984. *Sources of International Comparative Advantage: Theory and Evidence*. Cambridge, Massachusetts, MIT Press.

Lendle, A. & Schaus, M. 2010. Sustainability Criteria in the EU Renewable Energy Directive: Consistent with WTO Rules? International Centre for Trade and Sustainable Development (ICTSD), Information Note No. 2. Geneva, Switzerland, ICTSD.

Ligon, E. 2012. “Supply and Effects of Specialty Crop Insurance.” In *The Intended and Unintended Effects of U.S. Agricultural and Biotechnology Policies*, edited by J. Graff Zivin and J. Perloff, 113–142. Chicago: University of Chicago Press.

Lybbert, T.J. & Sumner, D.A. 2012. Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. *Food Policy* 37: 114–123. <http://dx.doi.org/10.1016/j.foodpol.2011.11.001>.

Mahul, O. & Stutley, C. 2010. Government Support to Agricultural Insurance: Challenges and Opportunities for Developing Countries. Washington, DC, World Bank.

Mahul, O., Verma, N. & Clarke, D. 2012. Improving Farmers’ Access to Agricultural Insurance in India. Policy Research Working Paper No. 5987. Washington, DC, World Bank.

Martinez, P., Blanco, M., Van Doorslaer, B., Ramos, F. & Ceglar, A. 2017. What role will climate change play in EU agricultural markets? An integrated assessment taking into account carbon fertilization effects. *Spanish Journal of Agricultural Research* 15(3): e0115.

McCarthy, N., Lipper, L. & Zilberman, D. 2017. Economics of Climate Smart Agriculture: An Overview. In N. Lipper, N. McCarthy, D. Zilberman, D. Asfaw & S. Branca, eds. *Climate Smart Agriculture*. Springer Verlag.

- McFarland, B.** 2011. Carbon Reduction Projects and the Concept of Additionality. *Sustainable Development Law & Policy* 11 (2):15–18.
- Mezzatesta, M., Newburn, D. & Woodward, R.** 2013. Additionality and the Adoption of Farm Conservation Practices. *Land Economics* 89 (4): 722–742.
- Minot, N.** 2014. “Food price volatility in sub-Saharan Africa: Has it really increased?” *Food Policy* 45: 45-56.
- Miranda, M.** 1991. Area–Yield Crop Insurance Reconsidered. *American Journal of Agricultural Economics* 73: 233–242.
- Miranda, M. & Farrin, K.** 2012. Index Insurance for Developing Countries. *Applied Economic Perspectives and Policy* 34(3): 391–427.
- Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R. D., Tokgoz, S., Zhu, T., Sulser, T. B., Ringler, C., Msangi, S., & You, L.** 2010. Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options. Washington, DC, International Food Policy Research Institute.
- Nigatu, G., Hansen, J., Childs, N. & Seeley, R.** 2017. Sub–Saharan Africa Is Projected To Be the Leader in Global Rice Imports. Amber Waves. Economic Research Service US Department of Agriculture. October 2. <https://www.ers.usda.gov/amber-waves/2017/october/sub-saharan-africa-is-projected-to-be-the-leader-in-global-rice-imports/>
- O’Donoghue, E. & Hansen, J.** 2017. USDA Agricultural Projections to 2026. US Department of Agriculture (USDA), *Agricultural Projections* No. (OCE–2017–1) 106 pp. <https://www.ers.usda.gov/publications/pub-details/?pubid=82538>
- OECD & FAO.** 2017. OECD–FAO Agricultural Outlook 2017–2026. <http://www.oecd.org/publications/oecd-fao-agricultural-outlook-19991142.htm>
- Pape, D., Lewandrowski, J., Steele, R., Man, D., Riley–Gilbert, M., Moffroid, K. & Kolansky, S.** 2016. Managing Agricultural Land for Greenhouse Gas Mitigation within the United States. Report prepared by ICF International under USDA Contract No. AG–3144–D–14–0292. July 2016. https://www.usda.gov/oce/climate_change/mitigation_technologies/ICFMitgationReportWEB.pdf
- Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B. & Travasso, M.I.** 2014: Food security and food production systems. In C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea & L.L. White, eds. *Climate Change 2014: Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects*, pp. 485–533. Contribution of Working Group II to the Fifth Assessment

Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, Cambridge University Press and New York, NY, U.S.

Searchinger, T., Edwards, R., Mulligan, D., Heimlich, R. & Plevin, R. 2017. Do biofuel policies seek to cut emissions by cutting food? *Science* 347 (6229): 1420–1422.

Skees, J., Hazell, P. & Miranda, M. 1999. New Approaches to Crop Yield Insurance in Developing Countries. Environment and Production Technology Division (EPTD) Discussion Paper 55. Washington, DC, International Food Policy Research Institute.

Skees, J.R., Black, J.R. & Barnett, B.J. 1997. A Designing and Rating an Area Yield Crop Insurance Contract. *American Journal of Agricultural Economics* 79(2): 430–438.

Skees, J.R. & Enkh-Amgala, A. 2002. Examining the feasibility of livestock insurance in Mongolia. Policy Research Working Paper 2886. Washington, DC, World Bank.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B. et al. 2007. Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. *Agriculture, Ecosystems and Environment* 118: 6–28. Elsevier, Amsterdam.

Smith P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E.A., Haberl, H., Harper, R., House, J., Jafari, M., Masera, O., Mbow, C., Ravindranath, N.H., Rice, C.W., Robledo Abad, C., Romanovskaya, A., Sperling, F. & Tubiello F. 2014. Agriculture, Forestry and Other Land Use (AFOLU). In: O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel & J.C. Minx, eds. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, U.S.

Smith, V. 2016. Producer Insurance and Risk Management Options for Smallholder Farmers. *The World Bank Research Observer* 31(2): 271–289.

Sumner, D., Alston, J. & Glauber, J. 2010. Evolution of the Economics of Agricultural Policy. *American Journal of Agricultural Economics* 92(2): 403–423.

Tian, H., Lu, C., Ciais, P., Michalak, A.M., Canadell, J.G., Saikawa, E., Huntzinger, D.N. et al. 2016. The terrestrial biosphere as a net source of greenhouse gases to the atmosphere. *Nature* 531(7593): 225–232, Springer Nature, London.

Tubiello, F., Salvatore, M., Córdor Golec, R., Ferrara, A., Rossi, S., Biancalani, R., Federici, S., Jacobs, H. & Flammini, A. 2014. Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks: 1990–2011 Analysis. Working Paper ESS/14–02, Rome, FAO.

United Nations Conference on Trade and Development (UNCTAD). 2017. UNCTADStat. <http://unctadstat.unctad.org/EN/>

United Nations Framework Convention on Climate Change. 2017. The Paris Agreement. http://unfccc.int/paris_agreement/items/9485.php

United Nations Global Compact. 2016. UN Global Compact Calls on Companies to Set USD 100 Minimum Internal Price on Carbon. 22 April, 2016. <https://www.unglobalcompact.org/news/3381-04-22-2016>.

United Nations. 2015. UN Sustainable Development Goals. <http://www.un.org/sustainabledevelopment/sustainable-development-goals/>

US Department of Agriculture. 2016. USDA Building Blocks for Climate Smart Agriculture and Forestry. Washington, DC. [Cited 6 June 2017]. <https://www.usda.gov/sites/default/files/documents/building-blocks-implementation-plan-progress-report.pdf>

US Department of Agriculture & Economic Research Service. 2017. Agriculture and Climate Change. <https://www.ers.usda.gov/topics/natural-resources-environment/climate-change/agriculture-and-climate-change/>

Vermeulen, S.J., Campbell, B.M. & Ingram, J.S.I. 2012. Climate change and food systems. *Annual Review of Environment and Resources* 37: 195–222, Annual Reviews, Palo Alto

Wang, G., Ahmed, K. F., You, L., Yu, M., Pal, J. & Ji Z. 2017. Projecting regional climate and cropland changes using a linked biogeophysical–socioeconomic modeling framework: 1. Model description and an equilibrium application over West Africa, *Journal of Advances in Modeling Earth Systems* 9: 354–376, <https://doi.org/10.1002/2016MS000712>

Westphal, M.I., Browne, M., MacKinnon, K. & Noble, I. 2008. The link between international trade and the global distribution of invasive alien species. *Biological Invasions* 10: 391.

Wiebe, K., Lotze–Campen, H., Sands, R., Tabeau, A., van der Mensbrugge, D., Biewald, A., Bodirsky, B., Islam, S., Kavallari, A., Mason–D’Croz, D. et al. 2015. Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios. *Environmental Research Letters* 10: 85010. <https://doi.org/10.1088/1748-9326/10/8/085010>

Williams, J. C. & Wright, B. D. 1991. *Storage and Commodity Markets*. New York, Cambridge University Press.

Wright, B. 2014. Global Biofuels: Key to the Puzzle of Grain Market Behavior. *Journal of Economic Perspectives* 28 (1): 73–98.

Wright, B. & Hewitt, J. 1994. All-Risk Crop Insurance: Lessons from Theory and Experience. In D. L. Hueth & W. H. Furtan, eds. *Economics of Agricultural Crop Insurance: Theory and Evidence*, pp. 73–114. Boston, Kluwer Academic Publishers.

Wright, B. & Prakash, A. 2011. The fallacy of price interventions: a note on price bands and managed tariffs. In A. Prakash, ed. *Safeguarding Food Security in Volatile Global Markets*, pp. 231–254.

World Bank Group & ECOFYS. 2016. Carbon Pricing Watch 2016. Washington, DC. <https://openknowledge.worldbank.org/bitstream/handle/10986/24288/CarbonPricingWatch2016.pdf?sequence=4&isAllowed=y>

World Bank Group. 2017. The World Bank National Accounts data and OECD National Accounts data files. [Cited 2 November 2017]. <https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS>.

World Food Programme (WFP). 2010. Review of the Working Capital Financing Facility. World Food Programme, Rome.

Wu, J. & Adams, R. 2001. Production risk, acreage decisions and implications for revenue insurance programs. *Canadian Journal of Agricultural Economics* 49(1): 19–35.

Yu, J., Smith, A. & Sumner, D. A. 2018. Effects of Crop Insurance Premium Subsidies on Crop Acreage. *American Journal of Agricultural Economics* 100 (1): 91-114 <https://doi.org/10.1093/ajae/aax058>

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D.B., Huang, Yao, Huang, M. et al. 2017. Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences* 114 (35): 9326–9331. <https://doi.org/10.1073/pnas.1701762114>

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