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Climate change and trade in agriculture ☆,☆☆

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ABSTRACT

Agricultural productivity in both developing and developed countries will have to improve to achieve substantial increases in food production by 2050 while land and water resources become less abundant and the effects of climate change introduce much uncertainty. Already less resilient production areas will suffer the most, as temperatures will rise further in tropical and semi-tropical latitudes and water-scarce regions will face even drier conditions. International trade plays an important role in compensating, albeit partially, for regional changes in productivity that are induced by climate change. While a well-functioning international trade system can support the adaptation to climate change-related challenges, trade policies as such are imperfect instruments to induce less emissions globally. A well-functioning international trading system can support the adaptation to climate change-related challenges. Hence welfare gains from reforms to trade policies may be greater than normally measured if they also reduce GHG emissions globally.

Driving forces in agricultural markets: where does climate change come in?

According to some estimates global food production will have to increase by 70% until 2050 (relative to 2007), to meet the demands of a growing population (OECD, 2009, based on FAO, 2006, and Bruinsma, 2009). Agricultural productivity in both developing and developed countries will have to improve to achieve this, while land and water resources become less abundant and the effects of climate change introduce much uncertainty. International trade will become increasingly important in connecting food surplus with food deficit areas.

Climate change potentially affects key drivers of international trade in agricultural products. Trade theory has traditionally emphasized differences in technology (Ricardo) and differences in endowments of production factors (Heckscher–Ohlin–Samuelson) as determinants of international trade. According to this body of literature, countries will tend to specialize in exports of those goods that use intensively the relatively abundant factor of production.

Through its effects on productivity and yields, climate change impacts on the technology dimension behind trade patterns. Through its impact on the amounts of arable land and water, it impacts on the endowments dimension. Changes in the returns to factors of production employed in agriculture are driving the potential changes in patterns of geographical specialisation of production. While climate change has a direct bearing on those relative returns, international trade will tend to reinforce those changes, as trade in goods is ultimately an exchange of the services of those production factors incorporated in the traded goods. If a production factor is specific to the production of one good, such as land being (almost) specific to agriculture, the specific factor model (Ricardo–Viner) shows that trade will increase the returns of the specific factor used in the export good.

On the input side to agricultural production a number of major factors have a direct link to climate change. (for a more comprehensive review see e.g. FAO (2003, 2006), This particularly concerns developments in energy markets, the availability and use of water and land resources, and agriculture's potential to both emit and sequester GHGs.

Energy prices have long been an important factor in agricultural production costs. Both fuel and other energy-rich inputs to agriculture represent considerable shares in variable costs differing across agricultural commodities and production regions. Increasingly, sugar and grain crops are also used for transport fuel production, while other forms of bioenergy use biomass are competing with food and feed production for land and other resources, hence strengthening the link between energy markets and agricultural markets. While most of the biofuel and bioenergy chains depend

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strongly on government subsidies, higher energy prices in general (as well as growing concerns about climate change) also result in increased interest in these forms of renewable energy deemed (though not always justifiably so) to significantly contribute to GHG emission savings (OECD, 2008).

Land use for agricultural production is expanding notably in Latin America and parts of Africa, but global agricultural area has been largely constant over the past 15 years following losses due to competing land use (urbanization, industrialization, etc.) and environmental pressures. Bringing significant new areas of land under production has a wide variety of social implications, resource and environmental consequences, including on deforestation and forest degradation in developing countries, an important issue under climate change negotiations. Deforestation, mainly to convert land for agricultural use is responsible for some 17% of current global GHG emissions.

Agriculture uses some 70% of global freshwater withdrawals, mostly in irrigation systems which are responsible for a substantial share in the growth of average yields, as well as for making output less volatile. With water basins being increasingly overused in an increasing number of countries and regions, and polluted and/or salinated in others, water shortages are likely to increasingly limit the growth of agricultural production.

Next to those drivers on the supply side, the developments of population and consumer demand play a key role in shaping international trade flows. The most dynamic development in food and feed demand in recent years has occurred in the developing world, and especially in Asia (OECD/FAO, 2010). While an increasing proportion of agricultural output is being traded (Anderson, 2010), most growth takes place in processed products and market differentiation is increasingly important. Essentially all growth of the world population until 2050 is expected to materialize in the developing world (UN, 2008). This not only translates to growth in volume of food demand in those regions, but in combination with increasing incomes is expected to lead to a more animal protein-rich diet, with obvious consequences for trade in animal feed and livestock products.

Finally, there is the dimension of policy interventions that change relative prices facing producers and consumers, and hence alter their production and consumption decisions. Agriculture particularly in a number of OECD countries is known to benefit from substantial transfers from both tax payers and consumers (OECD, 2010). Much of that support remains coupled to production and hence keeps distorting markets and trade. In a similar way, unaccounted negative (or positive) external effects of agricultural production, such as the emission (or sequestration) can be seen as an implicit support (or tax) to agricultural production, coupled to output to the degree these external effects are directly linked to production. Just as tariffs or payments can distort production decisions and trade, lacking internalization of external effects can have direct implications on agricultural markets and trade flows.

A new set of climate-change related policies adds to this set of interventions and affects the incentives that producers and consumers are facing. Policies such as carbon taxes, border carbon adjustments and carbon footprint standards alter the relative prices of commodities according to their carbon content and thus may hamper or foster trade flows, depending on the nature of their implementation. The challenge is to design policies that are addressing climate change while being least trade restrictive.

To assess how exactly those impacts translate into changes in factor returns, production and trade patterns, including specialisation within the agricultural sector and between agriculture and other sectors, large scale models are needed that incorporate huge amounts of data. Even with well developed data to support future projections with empirical observation, the assessment remains somewhat speculative as their exist many uncertainties, particularly regarding the impacts of climate change on productivity of crops and livestock. A part of that uncertainty stems from still inconclusive scientific results on the future evolution of climate change, another part stems from the inherent unpredictability of developments in new technologies and techniques to adapt to changing climatic circumstances.

Climate change and impact on agriculture

Climate change projections vary and there are different views about the extent of likely effects of climate change on agriculture. Despite those differences, the consensus is that already less resilient production areas will suffer the most, as temperatures will raise further in lower latitudes (tropical and semi-tropical) and water-scarce regions will face even drier conditions. Heat-related and water borne-diseases related to rising temperatures and more flooding may also increase food safety risks.

There is a large body of literature on the impacts of climate change on agricultural production, but generally individual studies are only focusing on a particular country or region. The vast majority of studies are on crops, and only a few on livestock. The Intergovernmental Panel on Climate Change (IPCC, 2007), in its latest assessment (Fourth Assessment Report, AR4),[2] summarizes the global agricultural situation as follows:

- Climate change will lead to higher average global temperatures over the time scale of several decades. The global distribution of temperature change is quite variable – locally this may translate into more extremes of warm and cold.
- Implications for crop yields are generally positive for temperature increases up to 3 °C (longer growing season and CO_2 fertilization), after which increasing heat stress implies a trend to decreases in crop yields. While there is much uncertainty around these estimates, whatever the net effect globally, the expectation is that farm productivity may be higher in temperate rain-fed regions and lower in the tropics. The negative impacts on yield may be partly overcome through adoption of appropriate varieties, but requires investment into basic research and development as well as into deployment of new varieties and extension.
- Higher temperatures lead to greater evapotranspiration, and therefore faster cycling of water through the system, although the global quantity available may not change significantly. Patterns of precipitation are very likely to change. Floods and droughts may become more frequent; however, there is a high degree of uncertainty on the causal relationships between climate change and frequency of extreme events. While this has implications for rain-fed crops, irrigated crops may also face issues with water scarcity.

Model-based projections of the global agricultural system depend to a large extent on the assumed changes in agricultural productivity, but the effects of climate change on agricultural productivity and hence on trade flows are highly uncertain, particularly at a regional level. Many studies highlight the importance of assumptions for crop yields under increasing levels of CO_2 concentration in the atmosphere (CO_2 fertilization). While laboratory trials under optimal conditions have demonstrated crop yield increases, few results are available under real world conditions. Reilly et al. (2007) analyse the counter-argument that increased respiration of ozone may off-set the positive yield effects of CO_2 fertilization. Moreover, as already noted, as the severity of climate

[2] The process for the next update, AR5, is currently in preparation and the final report is scheduled for 2013.

change increases, other factors having a negative impact on yield are likely to dominate.

The body of literature on the wider economic impacts of climate change, particularly those including quantitative estimates spanning most sectors, is relatively small. Tol (2009) finds that only 14 estimates of the total damage cost of climate change have been published (includes all sectors), but notes that "the number of authors is lower and can be grouped into a UCL group and a Yale one". Generally, the studies find that the impacts of a doubling of atmospheric concentration of GHG on the current economy are relatively small. He also notes that more recent studies tend to come up with smaller estimates, due in part because earlier studies excluded reaction by farmers, thereby overstating some of the costs.

The recognition that economic agents would adapt to climate change in ways that reduce negative impacts and take advantage of positive impacts is one of the most important advances in newer studies. However, as Antle (2008) points out, while aggregate impacts are often estimated to be relatively small, important local impacts may be expected, particularly in the poorest and most vulnerable regions of the tropics. He argues that to the extent change is gradual, farmers with access to resources (i.e. in developed countries) will be able to adapt through changes in crop management/selection and appropriate capital investments. In developing countries on the other hand there is a compelling case for increased investment in public research, outreach and infrastructure.

Wreford et al. (2010) review the recently growing body of literature on the costs of adaptation to climate change. They also note that many of the large-scale global cost estimates "mask the distributional impacts of adaptation and do not provide sufficient information for decision-making at a local or national level".

In summary, existing studies seem to be in general consensus that the economic impacts of climate change on agriculture are modest in the aggregate. However, the analysis so far has been strongly influenced by rather simplistic assumptions about future crop yields, and therefore do not provide a satisfying answer and are surrounded by much uncertainty. Most analytical frameworks also completely ignore the potentially very important impacts of increasing frequency of extreme events. Significant additional research will be required in many other areas, not least to recognize the location specific impacts of climate change at more disaggregated levels. Thus the impact of climate changes on the global distribution of agriculture production, and therefore on trade patterns, remains uncertain.

Carbon balances: agriculture is part of the problem and solution to GHG emissions

In 2004 agriculture directly contributed about 14% of global anthropogenic greenhouse gas (GHG) emissions according to IPCC. Land use, land use change and forestry account for a further 17%, much of which is deforestation to convert into agricultural land. Thus globally agriculture contributes approximately one third of total anthropogenic emissions.

In addition to the emissions consequences of land use change, changes in land cover can also be important contributors to climate change and variability, particularly at the local level. There is a growing body of literature on the complex relationships between changes in land cover and local climate (Pielke, 2005; Stone, 2009). These links include the radiation (both solar and longwave) balance of the land surface, the exchange of sensible heat between the land surface and the atmosphere, and the roughness of the land surface and its uptake of momentum from the atmosphere.

In contrast to other sectors, agricultural activities not only produce greenhouse gas emissions, but can also remove carbon from the atmosphere. This is achieved through management practices that increase soil organic carbon, which according to Smith et al. (2007), accounts for most of the technical potential (89%). The economic potential will be lower; however agricultural mitigation options are found to be cost competitive with a number of non-agricultural options in achieving long-term (i.e., 2100) climate objectives.

Given the significant potential contribution it will be important to develop an appropriate framework that provides incentives for these activities. A comprehensive framework for a full accounting of terrestrial carbon continues to be the subject of intense multilateral negotiations at the UNFCCC.

Linkages between climate change, agriculture and trade

Climate change affects the supply side of agriculture primarily through its impacts on productivity, yields, and the availability of arable land and water. These changes in technology and endowments in turn alter the returns to factors of production employed in agriculture and are driving the potential changes in patterns of geographical specialisation of production.

Climate change is expected to lead to important changes in the geographical distribution of agricultural production potential, with increases in mid- to high-latitudes and a decrease in low latitudes. This shift in production potential will have to coincide with higher trade flows of mid- to high-latitude products such as cereals and livestock to low latitudes. For example, Fischer et al. (2002) estimate that by 2080 cereal imports by developing countries would rise by 10–40%.

Policy actions that countries take to mitigate the effects of climate change also have an impact on trade flows in agriculture. Golub et al. (2010) show that given higher emission intensities of livestock industries in many developing compared to developed countries and of ruminant meat compared to other livestock sectors, and given large differences in abatement costs across livestock sectors and regions, a global carbon tax, together with a sequestration subsidy in forestry, would hurt livestock production in developing countries particularly strongly, resulting in increased net imports to Sub-Saharan Africa and reduced exports from South America. Such a scenario, however, may not be very likely, given food security considerations in developing countries. Sparing developing (non-Annex 1) countries from the carbon tax would reduce those pressures, even though much of the reduced crop and livestock output in South America is found to be linked to reduced deforestation and increased re-forestation due to the sequestration subsidy.

The production and use of biofuels, such as ethanol and biodiesel, are also supported by public policies in many countries, with the aim of mitigating climate change as one of the main arguments. Studies, including recent work by OECD (2008), have shown that the actual GHG savings from most biofuels along the whole life cycle are relatively small and come at high public costs. The implications of biofuel policies for agricultural commodity and food prices are subject to intense debate. Cereal and oilseed prices are increased through the induced additional use of these crops in the ethanol and biodiesel chains, and the OECD (2008) estimates that international grain prices are increased by between 5% and 7% in the medium term (i.e. around 2015) through the policies in place in 2007 – the more recent changes in US and EU legislations are likely to further increase this effect.

Among the existing policies fostering northern hemisphere biofuel markets, tariffs on ethanol imports appear to be particularly problematic. Their removal would result in a more efficient supply of biofuels globally. At the same time, given the much superior energy and GHG performance of cane-based ethanol relative to its grain-based counterparts, reducing these trade barriers would also increase the positive impact of biofuels on climate change.

But international trade itself has direct and indirect influences on climate change (OECD, 1994, 2000). Trade directly impacts on emissions through the use of fossil fuels in transportation. More indirect impacts are stemming from trade as an important determinant of the distribution, structure and scale of the global production and its associated GHG emissions. But trade also influences the choice and development of technologies. It is impossible to determine beforehand the net impact on GHG emissions of all those factors combined.

This can be illustrated with the much publicized debate on "Food-Miles". While *a priori*, the expectation is that the further food is transported, the greater the GHG emissions, the total impact on emissions is crucially dependent on the method of transport (air, land, or sea). Moreover, the emissions from the production process also depend crucially on natural endowments (including weather) and technology. A complete life-cycle assessment, from extraction of raw materials, to production, processing and transport to the final consumer may result in a higher or lower carbon footprint for imported goods compared to the domestically produced equivalent. Thus the important message is that trade can have both positive and negative effects for climate change – the impact cannot be known *a priori*, and will depend on the exact way in which carbon content is measured and how much GHG emissions are taxed.

Trade will thus have a role to play in accommodating climate change-induced changes in production by enabling the flow of agricultural products from surplus to deficit, and from lower cost (inclusive of GHG emissions) to higher cost regions. Climate change mitigation policies in agriculture will have an impact on trade flows by influencing the relative production costs of different agricultural products. At the same time, the activity of trade itself has complex influences on emissions.

Trade is part of the solution to climate change challenges

Summarizing the state of knowledge around the turn of the millennium, the IPCC AR4 report noted that the climate-induced shift in production potential is expected to result in higher trade flows of mid- to high-latitude products such as cereals and livestock to low latitudes where yields are expected to fall. Indeed, international trade is regarded as an important factor to compensate for falling yields in tropical and semi-tropical latitudes.

However, more recent work indicates that trade may only partially compensate for falling yields. Nelson et al. (2009) estimate that developing country imports of grain will increase substantially, but imports do not compensate fully for the reduced productivity following from climate change. As a result, this work predicts increased malnutrition in developing countries.

Since GHG emissions are trans-boundary, and the resulting climate change problems are truly global commons issues, policy coordination between countries is intrinsically difficult to achieve, especially in view of unequal distribution of costs and benefits of mitigating actions. The question then is whether trade policies would be an appropriate instrument to induce globally less GHG intensive production methods. Reductions in one country or region could be off-set by additional emissions elsewhere through "carbon leakage". Because countries undertaking commitments to reduce emissions put domestic industry at a cost disadvantage, proponents argue that a compensating carbon tariff on imports proportional to the carbon emitted in the manufacture of those goods could be applied. However the actual consequences of carbon leakage may not be very significant. Recent research (Matoo et al., 2009; OECD, 2009, Winchester et al., 2010) finds that as the coalition of countries acting domestically to reduce energy intensity increases, the leakage rate falls rapidly. The global economic welfare effects of border carbon adjustments are overwhelmingly found to be negative and the net effects on emissions are very small. Better targeted domestic policies to improve energy efficiency in non-coalition countries do a far better job.

Another set of trade policies relates to the use climate-change related standards, such as carbon footprint standards. There is much activity in many countries on development of private and government standards on energy efficiency in products such as cars and electrical appliances and carbon accounting and labelling on food items by supermarket chains. (OECD, 2010). Climate-related standards are already in use on some agricultural products and biofuels and are likely to become increasingly important in the future (Hebebrand, 2009). In order not to act as trade barriers that discriminate between domestic and foreign products both the WTO Agreement on Technical Barriers to Trade (TBT) and the Sanitary and Phytosanitary (SPS) Measure agreement encourage the use of relevant international standards in domestic regulation. A likely area of further debate is whether climate-related standards should only refer to the characteristics of the final product, or whether standards applicable to so-called non-product related production and processing methods' are permissible under WTO rules. The latter would enable countries to control the imports of products based on their production methods, including on their alleged 'climate friendliness'. Clearly, the development and application of internationally more or less harmonised standards can have profound implications for trade flows and regional specialisation of agricultural production, and hence international coordination of what constitutes a climate-related standard and which body or bodies should be charged with international standards setting warrants close attention from policy makers.

Concluding remarks

Available research indicates that climate change is expected to lead to important changes in the geographical distribution of agricultural production potential, with increases in mid- to high-latitudes and a decrease in low latitudes. International trade plays an important role in compensating, albeit partially, for regional changes in productivity that are induced by climate change. Together with productivity changes, changes in endowments of arable land and usable water, developments in energy markets, population growth and government policies, both existing agricultural policies and newly conceived climate-related policies, all drive the patterns of regional specilisation and of international trade. Considerable uncertainty surrounds the model-based long-term projections, particularly regarding the impacts of climate change on productivity of crops and livestock. This uncertainty stems both from still inconclusive scientific results on the future evolution of climate change, and from unknown developments in new technologies and techniques to adapt to changing climatic circumstances.

The ability to realize the compensating potential of international trade depends on a well-functioning international trade architecture. Imposing import restrictions, perhaps motivated by the desire to increase domestic production in the face of declining yields, and hence confounding food security with food self-sufficiency, is clearly not a sustainable solution. Likewise imposing export restrictions in surplus regions, as witnessed during food price spikes in 2007/2008 and motivated by the objective to keep domestic prices low relative to world prices, creates problems for food importing countries and undermines the trust in the functioning of the global trade system. Concluding the Doha Development

Agenda round of trade negotiations as soon as possible would make a very important contribution to tightening international disciplines on trade policy measures and to improving the stability of the trade system. Welfare gains from reforms to trade policies may be greater than normally measured if they also reduce GHG emissions globally.

There is general agreement on the need to internalize the externality of GHG emissions through a carbon pricing mechanism, but there is little consensus on how to achieve this at a global level as evidenced by the recent failure to reach a multilateral agreement at the UNFCCC Negotiations in Copenhagen. Thus we are in a world of second best solutions (or third, fourth, etc.). However, direct border policies, such as import tariffs based on the carbon content of the imported product are found to be ineffective instruments to reduce GHG emissions. Besides, there is no consensus on how to calculate the direct and indirect carbon content, and internationally agreed methods are lacking. Indirect trade policies stemming from behind-the-border measures, such as climate-related standards, have a bearing on trade flows, but neither are all their impacts fully understood nor is there a clearly defined international coordination mechanism to set and enforce international standards.

While a well-functioning international trade system can (and is indeed crucial to) support the adaptation to climate change-related challenges trade policies in isolation are imperfect instruments to induce less emissions globally.

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