Feeding the World in 2050: The Role of Agricultural trade, Natural Resources and Environmental Agreements (A Gravity Approach)

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Abstract

International agricultural trade has grown significantly during the last two decades. Many countries rely on imports to ensure adequate food supplies. A few are becoming food baskets of the world. This process highly affects agricultrual production systems and thus implies environmental impacts in large exporting nations. In a world of growing populations and fast adjusting global dietary habits, this tendency is likely to intensify. This study analyses the effects of increasing trade on natural resource exploitation in six Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico and Peru) using the concept of virtual water trade and external land footprints. Within a gravity model setting, drivers of agricultural commodity trade between Latin America and its most important trading partners are identified. This paper attempts to assess a causal relationship between natural resource endowments (land and water) and agricultural commodity exports. A special emphasis will also lie on identifying the role of international environmental regulations on ensuring sustainable agricultural trade flows. It results that differences in land endowments explain trade flows and that water scarcity drive agricultural commodity imports. Partly positive and partly negative coefficients of different Multilateral Environmental Agreements (MEA) confirm both the Porter's hypothesis and pollution haven hypothesis. Since coefficients are very low for all MEAs, the influence on trade is marginal. These are promising results: First, because trade seems to foster global food

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production efficiency, meaning that countries with more abundant resources specialise in resource–intensive goods. Second, because our modelling results suggest that the expansion of trade, and the income growth that comes with it, may favour government's willingness to sign MEAs.

Keywords: gravity, multilateral environmental agreements (MEA), virtual water trade, natural resources, agricultural commodity trade

1 Introduction

Currently, the world is in a state of rapid transition strongly affecting agricultural markets. Population is expected to grow to about nine billion people in 2050 and urbanisation along with income growth has induced dietary changes towards higher global meat consumption. As a reaction to climate change, biofuel policies were put in place leading to growing energy crops cultivation, competing with food crops. All these factors drive global food demand, and along with liberalising agricultural commodity markets, this leads to increasing trade which is expected to continue in the future (Conforti, 2011; Godfray et al., 2010). This poses large challenges to sustainable food supply. Particular attention has been paid to a possible overexploitation of water and land resources as a limiting factor to agricultural production(Smith et al., 2010; Liu et al. 2008; Liu and Savenije, 2008, Yang). In a scenario of a globalised world, it has been argued that a possible solution to mitigate scarcity tensions in water-short countries is the concept of virtual water trade (Allan, 1998; Falkenmark and Lannerstea, 2010).

Virtual water is defined as the water used to produce a commodity, good or service, that is traded internationally (Allan, 1998; Wichelns, 2004). The concept of virtual water trade defines one possible demand-side adaptation opportunity for water-short nations by purchasing a portion of its food requirements in international markets, rather than using scarce water resources to produce all food crops themselves. Wilchelns (2010) claims however that, although the notion of virtual water trade has been effective in encouraging analysts and politicians to look at water issues, it lacks a conceptual underlying framework. Asink (2010) states that the concept of virtual water has been used incorrectly used to make claims that are not in line with empirical facts and standard economic theory. In the same vein, the fact that observed trade flows cannot be explained by the virtual water perspective has been posed by Kumar and Singh (2005) to conclude that trading strategies based on its postulates will not mitigate water scarcity. In analogy to this concept stands the concept of virtual land trade or rather known as the land footprint. It expresses how many hectares of land were used for agricultural production (invers yield relationship) for the export market. Using graphical analyses of nations, Wilchelns (ibid.) concludes that arable land in per capita terms is a better predictor of trade flows than water endowment, even though he concedes that even land scarcity is not sufficient to explain trade flows.

Even though the concept of virtual water and land trade seem to favour on average global natural resource use effeciency, increasing trade between countries and continents raises the question of sustainable water and land use in the world's leading agricultural exporting countries. The social and environmental costs that are often associated with an excessive natural resource use remain in exporting nations. Environmental hotspots can be created in countries that do not have the capacity or the political willingness to curtail powerful exporting sectors on the basis of environmental constraints. This raises the question of whether environmentally-based trade regulations possibly implemented by the WTO could contribute to solving regional water problems by shifting trade flows in an optimal way. According to Hoekstra (2010), binding multilateral rules should be established to remedy the market failure of not-internalized external effects of production of traded goods. In other words, one can ask whether there is rationale for implementing international environmental regulations in order to bring negative environmental consequences of agricultural commodity trade to a minimum.

Taking into account the concept of virtual water and land trade, this study quantifies the impacts of agricultural trade on limited natural resources in a set of large Latin American trading nations (Argentina, Brazil, Chile, Colombia, Mexico and Peru). Especially in light of a growing world population and an augmenting middle class, we reflect on the explanatory power of land and water endowments per capita in driving trade flows. Growing global dependency, both economically and environmentally, increases the need for coherence and coordination in trade and environmental policies. In order to answer the question of whether internationally binding agreements help to achieve higher environmental standards, without sacrificing economic development in developing and threshold countries, the paper attempts to estimate the overall impact of major Multilateral Environmental Agreements (MEA) on agricultural export flows in a gravity setting.

This paper is organized as follows. The next paragraph offers an overview of the evolution of historical and future trends in agricultural commodity trade with its impacts on natural resources in six Latin American exporting nations. Already existing international environmental regulations that aim at combating negative environmental effects of human activity are described as a possible solution towards more sustainability. Section three discusses the issues within the theoretical framework of the Heckscher-Ohlin(H-O) theory versus Linder's theory and the Polluter's haven theory versus Porter's theory. On this basis, hypotheses about the role of natural resources and environmental regulations on trade are formulated. Section four describes the methods and data used for the empirical analysis. Section five presents the model results and discusses the special case of Latin America and the future challenges to feed the world in a sustainable way. The paper finalises with some concluding remarks, highlighting policy implications.

2 Global and Latin American agriculture in a changing environment

FAO's (2006) baseline projections show that by 2050 the world's average daily calorie availability will probably rise to 3.130 kcal per capita. This would still leave four percent of developing countries' popultion cronically undernourished in 2050. This, together with expected population growth, would result in a need to increase agricultural production by 70% in 2050 compared to production in 2005/2007 (Conforti, 2011). Increased food production will either result from increased yields due to technological change and expanding irrigated agriculture or from expansion of agricultural land. As yield increases have slowed down over the last decade (Conforti, 2010, Freibauer, 2011), competition for agricultural land will play a role in the future. According to FAO projections, arable land would need to expand by some 70 million ha. These numbers consist a 120 million ha expansion in developing countries which is offset by a decline of 50 million ha in developed countries. According to agro-ecological modelling results almost all of the land conversion would take place in in Sub-Saharan Africa and South America (Fischer et al., 2002). Taking into account future biofuel demand, this number is likely to be corrected upwards. Much of this land would have lower productivity, most would come from forest and savannah, and its conversion would involve significant negative climatic and biodiversity effects (Bruinsma, 2009). According to Rockström et al. (2009), for humanity to stay within the so called "planetary boundaries", no more than 15% of the global ice-free land surface should be converted into agricultural land. Besides rainfed agricultural land expansion, the projected expansion of irrigated land is at about 32 million ha. A major question concerning the future is whether there will be sufficient freshwater to satisfy the growing needs of agricultural and non-agricultural users. At a global level, irrigation water withdrawal is expected to grow by about 11% until 2050, with an increase in developing countries of 14% being offset by a decline in developed countries of more than 2%. Thus, cropland needs to be allocated to the most productive areas, and processes that lead to the loss of productive land, such as land degradation, loss of irrigation water, and competition with land uses such as urban development or biofuel production, needs to be controlled.

Due to the above mentioned pressure on the demand side versus a globally uneven potential to produce more, trade plays an increasingly role in achieving sustainable food security. As large areas in Latin America have comparative advantages in agricultural production due to their still rich natural resource endowment, agricultural commodity trade with LAC is likely to further increase.

We analyse six important agricultural importers and exporters in Latin America. Brazil and Argentina are categorised as very large exporting nations supplying the world with staple food products. Due to its natural resource endowments, Mexico has become a very large importing nation, whereas Chile, Colombia and Peru are both importer and exporter with an increasing exporting tendency of high value products. Table 1 reports the percentage of world agricultural exports and imports of the six countries. Altogether, these countries totalled almost 12% of world food exports in 2010, up from 9% en 2001, whereas its imports have remained stable at a level of 3.6%. The percentage of world exports has grown mainly in Brazil, but also Argentina and Chile have increased their participation in agricultural commodity exports. Colombia has slightly decreased its export share while Peru and Mexico have slightly increased their shares in agricultural export activities. An increasing development of the agricultural sector in Argentina and Brazil has led to a decreasing share of imports in those countries. Chile and Mexico on the contrary, increased their import shares while import shares on world agricultural trade are stable in Columbia and Peru (Niemeyer and Garrido, 2011). From a natural resource endowment perspective these market developments make sense reflecting an agricultural specialization effect in resource rich countries (e.g. Argentina, Brazil) and an increase in agricultural imports in resource constraint countries (e.g. Mexico and Chile).

2.1 Virtual water and land trade

This upward trend in agricultural trading activity in absolute and relative terms has had and will have important implications for water and land resources in the region. Hoekstra and Chapagain (2008) were the first authors to establish a linkage between globalisation and water issues, and obtained the first evaluations of virtual water trade. They distinguish between green and blue water, where green water describes the rainwater stored in the soil as soil moisture whereas blue water is defined as total renewable water resources. Siebert and Döll, (2010) estimated consumptive green and blue

Table 1: Percentage of world agricultural exports and imports (evaluated in dollar values) of Argentina, Brazil, Chile, Colombia, Mexico and Peru (1995-2010)

trade share	*X/M*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
Argentina	X	2.20%	2.28%	2.45%	2.18%	2.17%	2.21%	2.07%	2.21%	2.18%	2.26%	2.26%	2.54%	2.78%	2.38%	2.54%
	M	0.25%	0.33%	0.33%	0.28%	0.28%	0.25%	0.10%	0.13%	0.14%	0.14%	0.14%	0.19%	0.23%	0.16%	0.15%
Brazil	X	2.72%	3.03%	2.86%	2.81%	2.82%	3.34%	3.47%	4.14%	4.52%	4.48%	4.66%	5.12%	5.40%	4.28%	5.81%
	M	1.26%	1.15%	1.13%	0.85%	0.81%	0.66%	0.65%	0.67%	0.57%	0.52%	0.61%	0.74%	0.82%	0.58%	0.89%
Chile	X	0.95%	0.96%	0.98%	1.08%	1.16%	1.26%	1.12%	1.09%	1.17%	1.19%	1.22%	1.24%	1.11%	1.23%	1.14%
	M	0.22%	0.23%	0.24%	0.23%	0.24%	0.23%	0.22%	0.23%	0.23%	0.24%	0.27%	0.29%	0.33%	0.27%	0.31%
Colombia	X	0.57%	0.72%	0.70%	0.62%	0.56%	0.52%	0.50%	0.44%	0.46%	0.54%	0.52%	0.52%	0.50%	0.51%	0.42%
	M	0.31%	0.32%	0.33%	0.28%	0.29%	0.30%	0.29%	0.26%	0.26%	0.24%	0.28%	0.29%	0.32%	0.31%	0.31%
Mexico	X	1.20%	1.32%	1.44%	1.49%	1.65%	1.59%	1.53%	1.44%	1.42%	1.48%	1.53%	1.37%	1.27%	1.40%	1.38%
	M	1.33%	1.41%	1.58%	1.64%	1.85%	2.04%	2.03%	1.90%	1.84%	1.83%	1.88%	1.86%	1.84%	1.67%	1.65%
Perú	X	0.30%	0.39%	0.24%	0.29%	0.35%	0.34%	0.34%	0.29%	0.34%	0.37%	0.40%	0.37%	0.39%	0.41%	0.43%
	M	0.22%	0.21%	0.25%	0.20%	0.17%	0.19%	0.18%	0.17%	0.18%	0.18%	0.18%	0.21%	0.24%	0.22%	0.25%
Total	X	7.93%	8.69%	8.68%	8.47%	8.71%	9.26%	9.03%	9.62%	10.09%	10.33%	10.60%	11.15%	11.45%	10.21%	11.72%
(6 countries)	M	3.60%	3.65%	3.87%	3.47%	3.63%	3.67%	3.48%	3.35%	3.21%	3.16%	3.36%	3.59%	3.79%	3.22%	3.57%

Source: WTO (2011)

water uses of 18 major crops on a global scale with a spatial resolution of 30 arc-minutes, and virtual water trade of these crops at the national level. They concluded that around 94% of the world crop-related virtual water trade has its origin in green water. Hanasaki et al. (2010) found that virtual water trade in just five commodities and three livestock products are equivalent to 545 km^3/yr. Of the total virtual water exports, 61 km^3/yr (11%) are blue water (i.e., irrigation water) and 26 km^3/yr, (5%) are non-renewable and nonlocal blue water. From an environmental perspective, it is crucial to establish whether the water used originates from rainwater evaporated during the production process (green water) or from surface and/or groundwater sources evaporated as a result of the production of the product (blue water). Traditionally, emphasis has been given to the concept of blue water through the "miracle" of irrigation (Aldaya et al. 2010). However, for the analysis of sustainability aspects of international agricultural commodity trade, the green water component plays a crucial role (Niemeyer and Garrido, 2011). Green water differs from blue water in its scope of application and is generally associated with lower opportunity costs than blue water (Albersen et al. 2003). Green water cannot be automatically reallocated to uses other than natural vegetation or alternative rainfed crops, whereas blue water can be used for irrigating crops as well as for urban, agricultural and industrial water uses (Garrido et al. 2010). Furthermore, excessive irrigation can cause severe salinisation, water logging and soil degradation, which are evident in many areas of the world (Tilman et al., 2001). Following the notion of opportunity costs, trading green virtual water is overall more efficient than trading blue virtual water, holding other factors constant (Yang et al. 2006). It has been argued that the use of green water in crop production is considered more sustainable than blue water use, although this is not necessarily the case if either blue water resources are not over-exploited (Garrido et al. 2010) or expanding rainfed agriculture is associated with massive land use changes. The latter phonomenon can be observed in Argentina and Brazil, being countries experiencing high environmental opportunity costs of land use change (see Figure 3). In order to depict the impact of trade on national water resources we investigated on green and blue virtual water exports in our six countries of investigation (see Figure 1 and Figure 2).

There is an upward trend of both, green and blue virtual water exports in all six trading nations. Mexico depicts the only exception with a decreasing trend of green virtual water exports. This development makes sense since trade offers the opportunity to capitalise comparative advantages leading to a shift away from rainfed agriculture in Mexico. In Argentina and Brazil green virtual water exports is much more pronounced than blue virtual water ex-

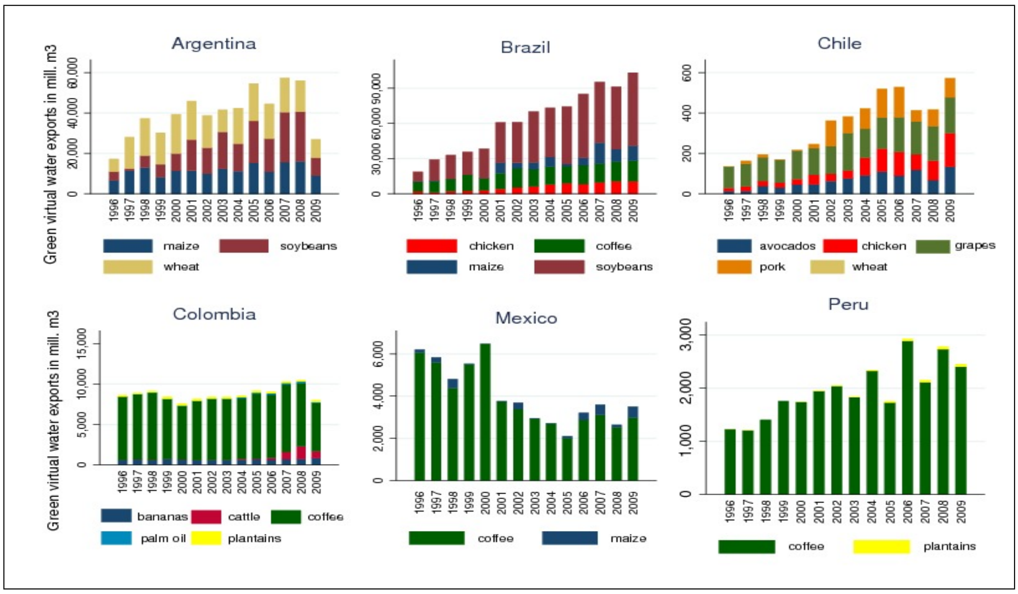

Figure 1: Trends of green virtual water exports in million m^3 (1996 - 2009) Source: own elaboration, data Mekonnen and Hoekstra. (2010) and FAOSTAT (2011)

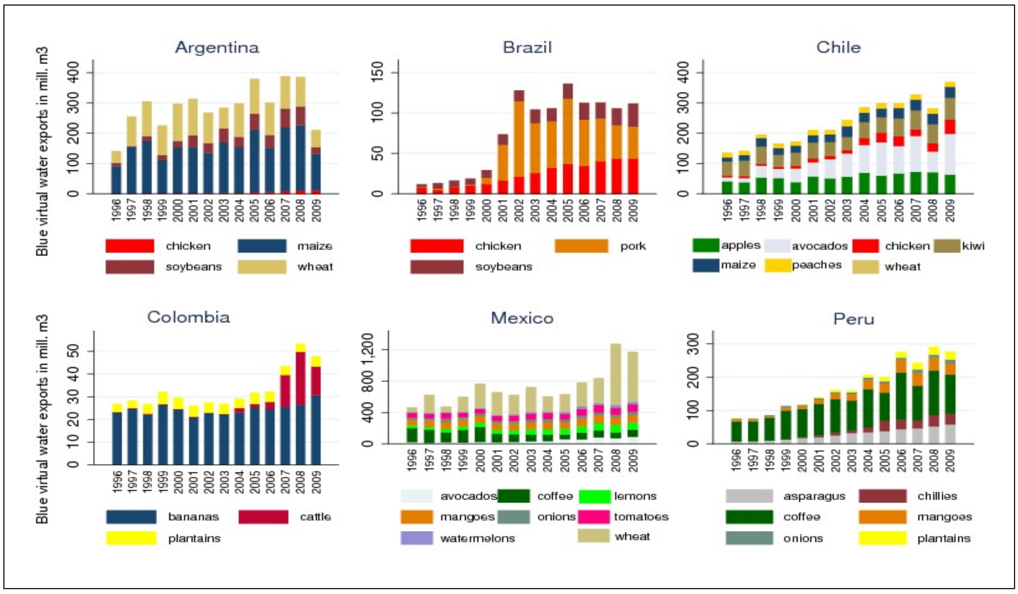

Figure 2: Trends of blue virtual water exports in million m^3 (1996 - 2009) Source: own elaboration, data Mekonnen and Hoekstra. (2010) and FAOSTAT (2011)

ports which in turn reflect their comparative advantage in rainfed agriculture.

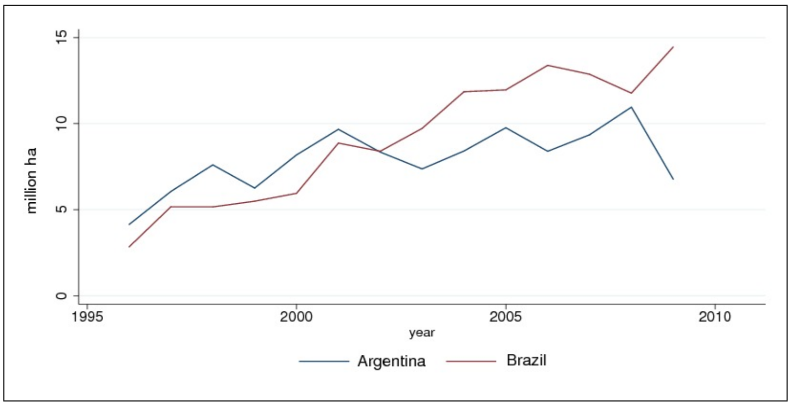

Figure 3: Land footprint of crop exports in million hectares (1996 - 2009)
Source: own elaboration, data FAOSTAT (2011)

The escalation of soybean production as Argentina's and Brazil's main export crop has resulted from a massive expansion of farm land (see Figure 3). In both countries the area harvested has more than doubled in the period of 1996-2009, whereas yields in soybean production have not been significantly growing. This development reflects the increasing international demand for high protein feedstuff to satisfy accelerated meat consumption preferences (Niemeyer and Garrido, 2011). In contrast, in Chile, Mexico and Peru the share of blue virtual water exports is much higher. Especially in Mexico there is a shift away from coffee and maize exports, being produced under rainfed conditions, towards exporting irrigated high value fruits and vegetables. Also Chile and Peru satisfy their staple food needs more and more by importing those crops and instead have been using their scarce land and water resources for the production of higher value export products such as fruits, vegetables and livestock. This production shift has led to a situation with much higher irrigation water needs, while area harvested and the land footprint of export crops have been stable in those countries. Colombia's share of green water exports is higher than its blue water exports, however relatively stable over the period of investigation. Due to more and more cattle exports, Colombia's blue water exports have only recently increased by almost 100% compared to 1996, reflecting the recent global demand increase. In summary, in Argentina and Brazil environmental concerns mainly arise from land use changes while Chile, Colombia, Mexico and Peru might face regional water over exploitation. With projected increasing agricultural producion and exports in LAC, this environmental pressure is also likely to increase without appropriate environmental regulations.

The following countries are among the main trading partners of Latin

American agricultural products in Dollar value terms: Belgium, Brazil, Canada, Chile China, France, Germany, Guatemala, Iran, Italy, Japan, Mexico, the Netherlands, the Russian Federation, Spain, United Kingdom, the USA and Venezuela (Comtrade, 2012). Figure 4 illustrates green and blue virtual water exports of Argentina, Brazil, Chile, Colombia, Mexico and Peru, green arrows indicating a large share of green virtual water flows and blue arrows indicate large volumes of blue water embedded in export products. The bulk of green virtual water flows from Argentina, Brazil and Colombia to China, Japan, Europe, the USA and Venezuela. Blue virtual water from Latin America originates to a very large extend in Mexico and has its main destination in the United States (and to some extend Algeria). Chile and Peru play a smaller role, but mainly export fruits and vegetables produced with blue water to Europe, the United States, Mexico and China. To what extent changing natural resource endowments per capita in the countries of origin and destination play a role in explaining these trade directions will be discussed in section 5. However, as shown in Figure 1 and Figure 2 virtual water exports have increased in all five countries, regardless of their own natural resource endowments. Due to this increasing environmental pressure from accelerating global demand it is therefore crucial to understand the plethora of agricultural trade drivers in order to formulate effective policies for more environmental sustainability.

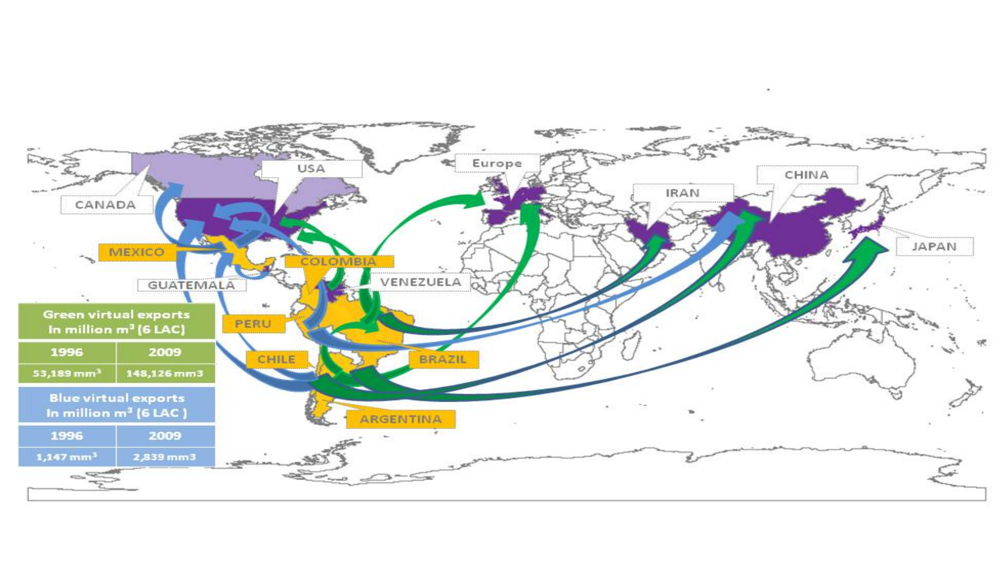

Figure 4: Green and blue virtual water exports in Argentina, Brazil, Chile, Mexico and Peru with important trading partners (2009)
Source: own elaboration, data Mekonnen and Hoekstra (2010) and FAOSTAT (2011)

2.2 Global environmental governance

As mentioned above, agricultural production and consumption patterns are contributing to manifold environmental concerns, not only at local but also at regional and international scale. The transitions required to an economy which sustainably uses scarce natural resources can not only be successfull through technological breakthroughs, changing consumer behaviour and market reforms, but also requires effective operation of multilateral governance that is able to promote consultation and cooperation between countries. The questions arise as to who will lead these transitions and who will take decisions. Despite long standing acceptance of the need for sustainable development, both of these questions remain unclear. The WTO still has much to do to with harmonising international trade and the 2009 Copenhagen climate summit also did not succeed in concluding a global agreement. The recent phenomenon of "land grabbing" in Africa points to the priority of the political dimension in international resource policies, and seems to suggest that the protection of national interests rather than global resource conservation is prime concern (Freibauer, 2011). This apparent focus on defending national security of resource supply is occurring at a time when globalisation has increased mutual dependencies between nations. However, several attempts have been made over the years by negotiating and signing various international multilateral environmental agreements (MEA). Their goal has been the establishment of an equitable foundation for international cooperation in environmental concerns, thus helping to foster sustainable development on a regional and global scale (United Nations, 2010). In order to improve existing and future policies and to give incentives to overcome national concerns about sacrificing economic development in favour of environmental regulations, it is crucial to understand the effect of already existing policies. Especially the effects of MEAs on the increasingly pofitable agricultural export sector is crucial for successful global cooperation in the future.

The Stockholm Conference in 1972 marked the starting point for a series of international environmental agreements. In the 1980s, these agreements were converted into full-fledged multilateral conventions with a view to protecting each country's globally-beneficial environmental goods and services. One of the major institutional outcomes of this conference was the creation of the United Nations Environment Programme (UNEP), whose purpose is to develop and strengthen environmental management capabilities within the United Nations' system and to facilitate the negotiation of multilateral environmental accords. The 1992 United Nations Conference on Environment and Development was a landmark event because it produced agreements that afforded more comprehensive treatment of global environmental issues by focusing on the goal of sustainable development. The five Rio agreements[1] represented the most universal and coordinated political step taken in the early 1990s towards establishing an international system of cooperation for mainstreaming the environmental dimension into development. Complementarily the Global Environment Facility (GEF) was created, which provides financing for the activities and policies agreed upon at multilateral conferences dealing with such global issues as climate change, biodiversity, international waters, preservation of the ozone layer and, more recently, actions taken to combat soil degradation, desertification and persistent organic pollutants (United Nations, 2010).

Under the umbrella of the United Nations, we identified six MEAs as relevant for our study: the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocoll to the UNFCCC, Convention on Biological Diversity, United Nations Convention to Combat Desertification in those Countries Experiencing serious Droughts and/or Desertification and the Tropical Timber Agreement having as a goal the international trade of tropical timber from sustainably managed forests.

Additionally, we analyse the Convention on Wetlands (Ramsar, Iran, 1971). It is an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their wetlands of international importance and to plan for the sustainable use of all of the wetlands in their territories. Unlike the other global environmental conventions, Ramsar is not affiliated with the United Nations system of Multilateral Environmental Agreements, but it works very closely with the other MEAs and is a full partner among the "biodiversity-related cluster" of treaties and agreements.

Table 2 gives an overview of those agreements.

[1] The five Rio agreements are: the Rio Declaration on Environment and Development; Agenda 21; the Non-legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests; the United Nations Framework Convention on Climate Change; and the Convention on Convention on Biological Diversity. After the summit, agreement was reached on other major multilateral instruments, such as the United Nations Convention to Combat Desertification, the Kyoto Protocol, the Cartagena Protocol on Biosafety, the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Stockholm Agreement on Persistent Organic Pollutants.

Table 2: Relevant MEA for agricultural production and trade in Latin America

MEA	Entry into force	Members 1986	Members 2011	Argentina	Brazil	Chile	Colombia	Mexico	Peru
UNFCCC[a]	1994-03-21	0	195	1994	1994	1995	1995	1994	1994
Kyoto[b]	1996-12-26	0	193	1997	1997	1998	1999	1996	1996
CBD[c]	1993-12-29	0	193	1995	1994	1994	1995	1993	1993
CCDD[d]	1996-12-26	0	193	1997	1997	1998	1999	1996	1996
TT'83c[e]	1985-04-01	39	0	X	1985	X	1990	X	1985
TT'94	1996-12-31	0	61	X	1996	X	1999	2004	1997
TT'06	2011-12-07	0	63	X	X	X	X	2011	2011
GEF[f]	1994-07-07	0	182	1994	1994	1994	1994	1994	1994
RAMSAR c[g]	1975-12-21	39	159	1992	1993	1981	1998	1986	1992

Note: X if country has not signed or ratified MEA

Source: International Environmental Agreements Database Project (2012)

[a] UNFCCC: United Nations Framework Convention on Climate Change
[b] Kyoto: Kyoto Protocoll to the UNFCCC, aimed at fighting global warming.
[c] CBD: Convention on Biological Diversity
[d] CCDD: United Nations Convention to Combat Desertification in those Countries Experiencing serious Droughts and/or Desertification
[e] TT: International Tropical Timber Agreement
[f] GEF: Instrument For The Establishment Of The Restructured Global Environment Facility
[g] RAMSAR: Convention of Wetlands of International Importance Especially as Waterfowl Habitat

3 Theoretical background

On the basis of the above described interdependencies between world agricultural markets, per capita resource endowments and the pressing need for function global environmental governance, we want to base our analysis on some theoretical grounds.

3.1 Heckscher Ohlin versus Linder – the role of natural resource endowments

The factors embedded in trade or the factor-content approach was first employed by Leontief (1953) in his well–known test of the H-O theorem. The H–O theorem posits that the pattern of trade between countries will be based on the characteristics of the countries. That is, countries will produce and export goods that use the factors of production with which they are well endowed. For example, the H–O theorem predicts that capital–abundant countries will create and export capital–intensive goods while labour–abundant countries will export labour–intensive goods. Without trade, each nation would produce goods for their own consumption and the price of the capital–intensive good in the capital–abundant country would be low due to over–supply relative to the price of that good in a labour–surplus country. An analogous process takes place in the labour–abundant country. Thus, trade allows profit-seeking firms to move their products to the markets that temporarily have the higher price and trade flows will rise until the price of both goods are equalised in the two markets. It follows that free trade also tends to equalise relative factor prices across national borders (the factor price equalisation theorem). With natural resources being factors of agricultural production, the H–O theorem, therefore,demonstrates that differences in resource endowments are one driver of international trade. The traditional implication of the H–O theory is that water and land abundance determines which agricultural commodities are exported and which are imported, depending on their natural resource use in the production process (Rogers and Ramirez-Vallejo, 2011). Following the H–O theorem, not only absolute, but also relative endowments determine whether or not a country has comparative advantages agricultural production or rather manufactured production. In other words, countries trade more the larger their difference in factor endowments are.

Deviating from the supply-side explanations of the pattern of trade, an alternate explanation of the pattern of trade was offered in 1964 by a Staffan Linder (Linder and Cohen, 1961). Linder argued that the more similar the demand structures of countries, the more they will trade with one another. Further, international trade will still occur between two countries having identical preferences and factor endowments. In terms of the above interpretation of trade, it is demand and not supply that comes to the center stage as an explanation of trade. Especially in times of growing international demand for agricultural products and globally converging dietary preferences, it is worth testing whether relative natural resource scarcity increasingly determines agricultural trade patterns.

3.2 Pollution haven versus Porter - the role of environmental agreements

While there is a broad empirical literature on the impacts of trade on the environment, the empirical literature on the impact of environmental regulations on trade flows is relatively scarce (De Santis, 2011). According to economic theory, the environmental regulations are not neutral to trade flows. In fact, the environmental rules, modifying the production cost curve, would determine a change in comparative advantages. It is worth underlining, however, that the interaction between international trade and environmental policies could determine opposite effects on trade flows.

In the theoretical literature, most widely discussed is the "pollution haven — race to the bottom" hypothesis, which poses that countries that are open to international trade will adopt looser standards of environmental regulation, out of fear of a loss in international competitiveness. This hypothesis was initially formulated in the context of local competition for investments and jobs within Federal States, where the decentralised environmental responsibilities gave each state its own independence in setting environmental standards in line with their priorities. Most critics argue that increased competition for trade and foreign direct investment could lead to a lowering of environmental standards and regulations.

On the contrary, there is the Porter hypothesis that state that stringent environmental regulation does not necessarily deteriorate the industrial competitiveness of a country (Ambec and Barla, 2002). Rather, stringent environmental policies —under the condition that they are efficiently designed and employed— can further strengthen a nation's international competitiveness by means of innovation, investment and technological change.

In light of the discussed importance of global environmental governance, it is worth testing the pollution haven hypothesis versus Porter's hypothesis, because it might provide a good basis for future policy formulation and decision–making.

4 Methods and data

The aim of our empirical analysis is to estimate whether and how increasing demand pressure from demographic changes emphasise the role of natural resource endowments on driving agricultural trade flows. Further we reflect on the role of MEAs in exerting a significant impact on Latin American agricultural exports. After formulating the general model with its variables, we will develop hypotheses on a sound theoretical basis about each variable.

4.1 The gravity model with its microeconomic foundation

Fifty years ago, Jan Tinbergen (1962) used an analogy with Newton's universal law of gravitation to describe the patterns of bilateral aggregate trade flows between two countries i and j as "proportional to the gross national products of those countries and inversely proportional to the distance between them",

$$X_{ij}\alpha = \frac{(GDP_i)^{\alpha}(GDP_j)^{\beta}}{(dist_{ij})^{\zeta}} \tag{1}$$

with $\alpha, \beta, \zeta \approx 1$. The so called "gravity equation" in international trade has proven surprisingly stable over time and across different samples of countries and methodologies (Chaney, 2011). Generally, across many applications, the estimated coefficients on the mass variables cluster close to 1 and the distance coefficients cluster close to -1 while the estimated equation fits the data well: most data points cluster close to the fitted line in the sense that 80 - 90% of the variation in the flows is captured by the fitted relationship. The fit of traditional gravity improved when supplemented with other proxies for trade frictions, such as the effect of political borders, common language, colonialization information or existing regional free trade agreements (RTA) (Anderson, 2011).

The gravity equation can be derived from many different trade frameworks. In 1979, James Anderson proposed a theoretical explanation of the gravity equation based on a demand function with constant elasticity of substitution (CES) á la Armington (1969), where each country produces and sells goods on the international market that are differentiated from those produced in every other country. Later work has included the Armington structure of consumer preferences in (i) monopolistic competition frameworks (Krugman 1980; Bergstrand 1985), (ii) H–O models (Deardorff, 1998), or (iii) Ricardian models (Eaton and Kortum 2002). Given the plethora of models available, the emphasis is now on ensuring that any empirical test of the gravity equation is very well defined on theoretical grounds and that it can be linked to one of the available theoretical frameworks. In this context, two broad sets of key issues have been identified. A first important range of contributions is related to the multilateral dimension of the gravity model. Anderson and van Wincoop (2003) showed that the flow of bilateral trade is influenced by both the trade obstacles that exist at the bilateral level (Bilateral Resistance) and by the relative weight of these obstacles with respect to all other countries (multilateral resistance term). Thus, the omission of a multilateral resistance term is considered a serious source of bias and needs to be taken into account (De Benedictis and Taglioni, 2011).

The second main area of methodological concern is related to the the fact that not all exporting firms export to all foreign markets as they are generally active only in a subset of countries. The critical implication for modeling the gravity equation is that the matrix of bilateral trade flows might not be full, meaning that cells have a zero entries. The existence of trade flows which have a bilateral value equal to zero is full of implications for the gravity equation because it may signal a selection problem. If the zero entries are the result of the firm choice of not selling specific goods to specific markets, the standard OLS estimation of the gravity equation would be inappropriate: it would deliver biased results (De Benedictis and Taglioni, 2011; Chaney 2008; Helpman et al. 2008). Several approaches have been applied or suggested in the literature to address the problem of zero flows (see Martin and Pham, 2008). The most common solution in the literature confines the sample to non-zero observations to avoid the estimation problems related to zero flows. Alternatively, zero values may be substituted by a small constant, so that the double-log model can be estimated without throwing these country pairs out of the sample. Examples in the literature that followed this approach are Van Bergeijk and Oldersma (1990), Wang and Winters (1992) and Raballand (2003). Alternatively the standard Tobit model and the Heckman selection model (Heckman, 1979) have been used to deal with zero trade flows [2].

4.2 Model formulation

The generalised gravity model of trade states that trade volumes between country pairs, X_{ij}, is a function of their size (expressed as GDP and/or populations), their distance (proxy for transportation costs) and a set of (dummy) variables either facilitating or restricting bilateral trade flows.

Thus size is included as a mass variable which is expressed by multiplying GDP of i and GDP of j. Using per capita income instead of population al-

[2] For details see Linders and Groot (2006)

lows us to include the state of development of a country, assuming that higher developed countries participate more in trade than less developed countries. In order to make the model consistent with microeconomic foundations, a multilateral trade resistence term is needed which can be included by taking relative prices into account. However, agricultural price variables are not available for all countries and years, so we used the general consumer price index of each country. We also include dummy variables containing country specific information: common border, common language, colonial ralationship, common legal roots. Furthermore there are dummies included that give information about countries that benefit from generalized system of preferences (GSP), WTO memebership and if there is a RTA between two trading nations. Exchange rates, export taxes as well as import tariffs are also taken into account as they influence absolute and relative prices of agricultural commodities. Further, we include a dummy variable reflecting the food price crisis of 2007,2008 and 2011.

In order to test the H-O theory with respect to differences in capital endowments we create a similarity index of the two trading partners' GDP which is built as:

$$Simil = \ln\left(1 - \left(\frac{GDP_{it}}{GDP_{it} + GDP_{jt}}\right)^2 - \left(\frac{GDP_{jt}}{GDP_{it} + GDP_{jt}}\right)^2\right)$$

In order to test the H-O theorem with respect to natural resource we create a variable that gives the absolute difference in relative natural resource endowments (land and water per capita) between country pairs which is built as:

$$factor_r = \left|\ln\left(\frac{Resource_{rit}}{Pop_{it}}\right) - \ln\left(\frac{Resource_{rjt}}{Pop_{jt}}\right)\right|$$

To reflect on the role of natural resource endowments in light of population growth, we include agricultural land per capita and and total renewable water resources per capita in our regression. Also dummies indicating whether two trading parters have both ratified a MEA are included.

We operate with panel data using data from 1986 until 2011. We could not go beyond this time period because export values were not reported consistently until 1986 in all countries.

Before constructing the model equation, we analyse all variables for multicollinarity[3] by means of a pairwise correlation matrix. It results that there

[3]When two or more exogenous observation series are highly correlated or have the same

are problems of multicollinearity between “development“ and “mass“ (0.73) being statistically significant ($p \leq 0.05$). Furthermore, the variable “$fact_{land}$“ behaves colinear (0.72) at a significance level of $p \leq 0.05$ with endowments of agricultural land per capita in the country of origin. Thus, we only keep the variable for agricultural land per capita in the model and do not look at differences between two trading partners. The same holds for “$fact_{water}$“ so that we eliminate this variable. Among the MEAs the agreement “UNFCCC“ is correlated with many other MEAs leading to estimation problems. Therefore we delete this agreement from our analysis.

Following these results, we can formulate the following dynamic model equation in log-linear form:

$$\begin{aligned} lnX_{ijt} = \alpha_1 + \alpha_2 lnX_{ijt-1} + \alpha_3 lnDev_{ijt} + \alpha_4 lnDist_{ijt} + \alpha_5 lnCPI_{ijt} + \alpha_6 RTA_{ijt} \\ + \alpha_7 lnXR_{it} + \alpha_8 lnXR_{jt} + \alpha_9 lnTar_{jt} + \alpha_{10} lnXTax_{it} + \alpha_{d,11} Z_{ijt} + \alpha_{12} lnSimil_{ijt} \\ + \alpha_{13} lnAgLand_{it} + \alpha_{14} lnAgLand_{jt} + \alpha_{15} lnH2O_{it} + \alpha_{16} lnH2O_{jt} \\ + \alpha_{17} GATT_{ijt} + \alpha_{18} Crisis_t + \alpha_{m,19} lnMEA_{ijt} + \varepsilon_{ijt} \end{aligned} \quad (2)$$

where:

ln	=	natural logarithm,
i	=	exporting country i,
j	=	importing country j,
d	=	type of time invariant individual country characteristic j,
m	=	type of MEA,
X	=	export value of agricultural commodities,
$Dist$	=	great circle distance between i and j,
CPI	=	cosumer price index in i over CPI in j,
RTA	=	country i and j are both members of the same RTA,
XR	=	official Dollar exchange rate of country i and j,
Tar	=	weighted average applied tariff on primary products in j,
$XTax$	=	export taxes as share of total government revenue in i,
Z	=	vector of time invariant bilateral characteristics,
$Simil$	=	similarity index of capital endowment,
$AgLand$	=	agricultural land area per capita,
$H2O$	=	total renewable water resources per capita,
$GATT$	=	variable = 1 if both trading partners are a member of the WTO,
$Crisis$	=	food price crisis (years 2008, 2009 and 2011,
MEA	=	vector of MEAs (1 = both nations have ratified treaty).

predictive power with respect to the endogenous variable they are called multicollinear which means that both vectors are perfectly linearly dependent (Greene, 2003).

4.3 Estimation method

Before estimating equation 2 we delete observations which have zero trade flows. As already mentioned in 4.1 this is a common procedure to deal with zeros in the trade matrix. In our case this approach is justified, because in our estimations we operate with total agricultural export values on an aggregated level, implying that there are relatively few zeros in the dataset.

In order to choose the most reliable estimation technique we run various regressions using different estimators. In our estimation we use unbalanced panel data with individual effects being included in the regression. If individual effects are correlated with the regressors, OLS estimates omitting individual effects will be biased. Therefore we use panel data methodology for our empirical gravity model of trade. We have to decide whether the individual effects are treated as fixed or as random effects. For the regression results of the panel estimation, we get the result of the Hausman specification test $\chi^2(12) = 268.79$ being statistically significant ($p = 0.00$). This result suggest using a pairwise fixed effects model because the individual effects are correlated with the explanatory variables. However, a fixed effects model absobs all time invariant regressors which leads to a much more limited model specification than our original equation 2. For our analysis, eliminating such variables is not much of a problem though, because our variables of interest do change over time. Through using a pairwise fixed effects model, we can even proxy the trade resistence term as suggested in the literature. Feenstra (2004) shows that the inclusion of country pair dummies generates about the same effect than following Anderson and Van Wincoop (2003) who suggest using relative price differences.

After the fixed effects regression we conduct the modified Wald test for groupwise heteroscedasticity. It tests the hypothesis of homoscedasticity, which assumes constant variances of the error term across units. With a result of $\chi^2(46) = 4111.57$ being statistically significant ($p = 0.00$) we reject homoscedasticity. We also implement a test for serial correlation in the idiosyncratic errors of our linear panel–data model discussed by Wooldridge (2002). Under the null hypothesis of no serial correlation, the residuals from the regression of the first–differenced variables should have an autocorrelation of -.5. This implies that the coefficient on the lagged residuals in a regression of the lagged residuals on the current residuals should be -.5. Following the test results ($F(1, 45) = 81.99$) we reject the null ($p = 0.00$) and assume autocorrelation in the error term.

To account for the findings of the previous section, we use the Feasible

Generalised Least Squares (FGLS) estimation technique in which we combine a heteroscedastic error structure —allowing for country specific variance , defined as $E(\epsilon_{i,t}^2) = \sigma_{i,t}$— with across–panel correlations defined as $E(\epsilon_{i,t}\epsilon_{j,t}) = \sigma_{i,t}$, and with an first–order autoregressive AR(1) process, defined as $\epsilon_{i,t} = \rho_i \epsilon_{i,t-1} + \upsilon_{i,t}$. The correlation parameter ρ_i is allowed to be unique for each country and the regression equation contains a single intercept, slope coefficients are constant over time.

Another option is a Prais–Winsten regression model with panel–corrected standard errors (PCSE). The Prais–Winsten regression transforms the model to account for an AR1 process analogue to what was described for the FGLS method. The standard errors are calculated from a variance–covariance matrix that corrects for heteroscedasticity and correlation in the residuals across countries. This results in unbiased coefficients and consistent panel–corrected standard errors (Beck and Katz, 1995, 1996). The estimated standard errors are generally more conservative than those resulting from a FGLS regression (Beck and Katz, 1995). Our final estimates are reported in table and table in the section 5 showing that the coefficients are quite robust to changes in model specifications.

As a robustness check we also include the model results of the OLS regression to test whether or not the coefficients are quite stable.

After eliminating various variables due to insignificance, we obtain the following final model equation:

$$\begin{aligned} lnX_{ijt} = \alpha_1 + \alpha_2 lnX_{ijt-1} + \alpha_3 lnDev_{ijt} + \alpha_4 lnAgLand_{it} + \alpha_5 lnAgLand_{jt} \\ + \alpha_6 lnH2O_{it} + \alpha_7 lnH2O_{jt} + \alpha_8 GATT_{ijt} + \alpha_9 Crisis_t + \alpha_{10} lnKyoto_{ijt} \\ + \alpha_{11} lnTimber_{ijt} + \alpha_{12} lnGEF_{ijt} + \alpha_{13} lnRamsar_{ijt} + \varepsilon_{ijt} \quad (3) \end{aligned}$$

One could formulate a hypothesis about each variable included in the model. However, we are particularily interested in the role of natural resource endowments in a world that is becoming richer and more populated. Further the influence of certain MEAs are interesting for policy formulation. Thus we limit ourselves to formulating some key hypotheses about the main variables following the theoretical foundations discussed above:

H_{0A} = Latin American exports are *positively* influenced by:

1. the development variable, indicating that increasing economic development lead to more trade,

2. Agricultural land and water endowments in *exporting* country, because

more natural resources lead to absolute and comparative advantages in agricultural production.

H_{0B} = Latin American exports are *negatively* influenced by:

1. Agricultural land and water endowments in *importing* country, because more natural resources lead to absolute and comparative advantages in agricultural production making imports of the same product less favourable.

We have no priori on:

1. the signs of the MEAs: a negative sign favours the polluton haven hypothesis. On the contrary, a positive sign supports Porter's hypothesis.

4.4 Data

Our analysis includes data from 1986 until 2011 for all data that is used in the gravity model. For the descriptive analysis of disaggregated virtual water trade flows, we have used data from 1996 until 2009.

- Export quantities in tons for most important agricutltural commodities per country: Data source is FAOSTAT (2011) and available until the year 2009. The selected commodities make up at least 80% of the total agricultural export amount in each country.

- Virtual water content per product for each country of production: data source is Mekonnen and Hoekstra (2010). The data is available as an average of the years 1996-2005. For the years 2006-2009 we assume the same water content than for previous years.

- The land footprint per country is the sum of the land footprint of the most important traded products in each country. The data is is taken for the years 1996-2005 and stems from FAOSTAT(2011).

- Aggreated agricultural trade values: Data is downloaded from the UN Comtrade database for the years 1986-2011. Only those trading partners that make up at least %50 of the total trade value within the category are taken into account. We followed the SITC Rev.2 classification for primary food products which is defined as the Standard International Trade Classification (SITC) Revision 2, a statistical classification of the commodities entering external trade, designed to provide the commodity aggregates for purposes of economic analysis and to facilitate international comparisons of trade-by-commodity data.

- current GDP data: Data is downloaded from the World Bankd Development Indicators (WBDI) for all years.
- Import tariffs: Weighted mean applied tariff is the average of effectively applied rates weighted by the product import shares corresponding to each partner country. Data come form the WBDI.
- Taxes on exports (% of tax revenue): Data source is WBDI.
- MEAs: Data soure is the Internaional Environmental Agreement (IEA) Database Project: http://iea.uoregon.edu/ page.php?file=home.htmquery=static
- Land endowements: Data source is FAOSTAT
- Water endowments: Data source is Aquastat
- Population Data comes from WBDI
- All other data comes from the CEPII–database: http://www.cepii.fr/welcome.asp

5 Results and discussion

Table 4 illustrates the estimation results of equation 3 described in section 4.3. Due to the fact that the coefficients of each model only vary slightly over the three models, the results can be taken as robust. All variables have the expected signs.

We chose a dynamic model structure and included the export value lagged by one year on the RHS of the equation. The coefficients are as expected positive in all three models, expressing that export values in year t depend on the export value between two countries of the year before. Including this variable simply elimates part of the trend and accounts for autocorrelation.

The *development* variable is as expected positive, but shows an unexpected low coefficient. With an increase of 1% of country size, exports from Latin America only increase between 0.07% to 0.1% depending on the model. Thus, with an increasing development status of the two trading partners, there are higher agricultural trade flows. On the one hand, this can be explained by their higher financial ability to engange in trade. Only countries with sufficient amounts of foreign currency reserves can participate in large trade actions. On the other hand, this positive relationship between economic development and engagement in agricultural trade reflects a high demand for agricultural commodities in order to satify high quality dietary needs. Thus, with a strengthening middle class and lower poverty rates especially in threshold countries, agricultural commodity trade will further increase.

The low coefficient can be explained by the selection of the countries included in the regression. We only include Latin American exporters and many already highly developed importers. Therefore the future trend of fast development in threshold countries with its implications for trade is only marginally included in the results. For example China has only recently caught up in the statistics of being among the most important trading nations especially in value terms. Since our panel starts in 1986, the coefficient of development might be underestimated if using the model for future projections.

The dummy variable for the food price crisis also shows the expected positive coefficient and is statistically significant in all three models. This variable allows us to account for the price spike on the international commodity market in our regression.

With respect to capital endowments we can neither confirm nor reject the H–O theory. The same holds for Linder's theory, because the "*Simil*" variable was taken out of the regression due to insignificance in all three models.

5.1 Natural resources as trade drivers

Following the H–O theory, countries generally trade more, the less similar they are in terms of relative factor endowments. Since we had to take out the "fact" variables of land and water due to multicollinearity problems, so we cannot directly test the H–O versus Linder's theory. However we included agricultural land endowments per capita in exporting as well as importing countries. The results from all models indicates that two countries trade more the less equal they are in terms of land endowments (H–O is confirmed). More per capita agricultural area in a Latin American country leads to more exports to the rest of the world, especially if the importing nation has less agricultural area per capita. In other words, nations increase their agricultural trading activity if (i) the exporting country is rich in land endowments and/or (ii) the importing nation is particularly scarce in land endowments. With coefficients between 0,7 and 1,2 (depending on the model) the positive effect of land endowment in country i is especially pronounced. The negative coefficient of land endowment in country j varies between 0,8 and 1,0 at statistically significant levels ($p \leq 0.01$). Since the variable is expressed in per capita terms, this relationship will probably intensify in the future as population is expected to grow in many regions of the world (and with it per capita land goes down). Since Latin America also belongs to one of the fast developing regions with an increasing population, it is possible that their land per capita endowments in the future will shrink. This would imply less ability for them to supply the world market as they need to feed more and richer people themselves. This holds true at least if we follow the concept of "sustainable intensification" of agriculture which suggests not converting more natural land into agricultural land. This concept implies that more food needs to be produced on the same area of land while reducing the environmental impacts (Freibauer et al., 2011). Our model results confirm that up to now, agricultural land expansion possibilities still drive profitable agricultural exports significantly. Keeping in mind the planetary (and regional) boundaries we are facing, the focus must however lie on yield improvements instead. Withour a major technological breakthrough and keeping in mind our model results, it is questionable though if land conservation will come first.

With respect to water endowments per capita this relationship is less clear. We can neither confirm the H–O theory nor Linder's hypothesis. The variable total renewable resources per capita in the country of origin is not significant in any model. We can state however that per capita water scarcity in the coutry of destination does drive agricultural trade flows. In water short nations and under a scenario of growing pressure on the demand side, water short countries seem to consider agricultural imports as a solution to overcome the scarcity problem.

In summary, we can state that there is an increasing food supply dependency for land and water scarce countries on land rich countries. With increasing demand, this dependency is likely to grow more in the future making natural resource scarce countries rely on trade. The estimation results show that especially land availability drives agricultural commodity exports in Latin America. Since the coefficient for $Ag.Land/capita$ is negative for importing and positve for exporting nations, agricultural commodities do flow from land abundant to land scarce nations. Therefore, globally trade seems to be in favour of environmental sustainability rather than harming it. However, this does not mean that exporting nations do not overexploit their natural resources. It is crucial to operate within environmental limits, not only at a global scale but also at a local scale. Whether or not virtual water really flows from water rich to water scarce countries cannot be confirmed in our analysis. It can only be confirmed from our regression results that water scarce countries import more, especially with an increasing population.

5.2 International environmental regulations as trade drivers

Since our results confirm a causal relationship between trade and natural resources and keeping in mind the adverse environmental effects of agricultural production, the role of environmental policies is important in order to guarantee sustainable trade flows. Three to four of the six selected MEAs were significant depending on the model. The dummy variables contain information about when and where the agreements became legally binding in each country. The ratification of the Kyoto protocoll and signing the GEF have positive and significant coefficients, rejecting the hypothesis of polluton haven. In fact, signing one of the MEAs has increased agricultural commodity exports from Latin America, supporting Porter's hypothesis. It can be partly explained by a possible trade diversion effect with respect to countries that did not ratify MEAs, and a corresponding trade creation effect among members of the environmental agreement. We also find a positive and significant relationship between WTO memeberships and bilateral exports. Our six LAC exported between 28% and 38% more to countries that had also belonged to the WTO. This result makes sense as countries joining the WTO negotiations should have benefited from declining trade barriers. The combination of the positive coefficient of ratifying the Kyoto protocoll and entering the GEF as well as being a member of the WTO reflects the mutual supportiveness between those countries in harmonizing trade and environmental rules in international negotiations.

In contrary, the ratification of the Ramsar and Tropical Timber agreement support the pollution haven theory with coefficients being negative. The two agreements directly influence comparative advantages in agricultural production and thus hamper exports. One goal of the tropical Timber Agreement for example is the conservation of tropical rain forests. As we saw, in Brazil for instance, agricultural production is directly related to land use change. As especially soybean and cattle production directly or indirectly cause deforestation in Brazil (Willaarts et al., 2011), it is reasonable that the conservation of this area causes a limitation of agricultural production for export markets.

Therefore, we cannot give a general answer whether or not MEAs shift agricultural trade flows to countries with less strict environmental regulations. It seems to depend on the content and design of the treaty and needs to be evaluated case by case. However the coefficients of all MEAs, regardless of their sign, are very low. Therefore, we can state that agricultural trade is neither excessively negatively nor positively influenced.

The results demonstrate the importance of adequate environmental regulations that are internationally binding in order to guarantee sustainable agricultural trade flows. A fast growing world population with changing diets will continue to increase global demand for agricultural products from land and water abundant countries. Looking at virtual water exports in Latin American countries, we confirm an already high pressure from agricultural production for export markets. Thus, it become more and more important to adequately regulate trade, taking into account environmental concers, following the example of already existing MEAs. However, our modelling results indicate different results for different MEAs. Therefore, the design of internationally binding regulations is crucial in order to be effective. A one "policy fits all solution" does not seem to be appropriate in handeling such complex causal relationships.

Table 4: Estimation results, dependent variable = value of agricultural commodity exports (X_{ijt})

	OLS		FGLS		Prais–Winsten	
	Elasticity	Stand. error	Elasticity	Stand. error	Elasticity	Stand. error
$X_{i,t-1}$	0.656***	0.031	0.668***	0.018	0.648***	0.026
$Crisis$	0.089***	0.033	0.113***	0.027	0.108***	0.039
$Development$	0.096***	0.036	0.072***	0.024	0.065**	0.03
$Ag.land/cap_i$	1.156***	0.413	0.691***	0.250	1.007***	0.261
$Ag.land/cap_j$	-0.868***	0.27	-0.815***	0.189	-0.971***	0.204
$Water/cap_i$	-0.624	0.559	-0.494	0.340	-0.556	0.427
$Water/cap_j$	-0.491	0.353	-0.609**	0.255	-0.631**	0.299
$Gatt$	0.283**	0.134	0.376***	0.086	0.297***	0.089
$Ramsar$	-0.129***	0.049	-0.116***	0.027	-0.121***	0.025
$Timber$	-0.032	0.04	-0.075***	0.027	-0.051	0.032
$Kyoto$	0.108***	0.037	0.093***	0.027	0.133***	0.033
GEF	0.124**	0.055	0.078**	0.031	0.144***	0.042
$Constant$	-5.376	4.416	-7.343**	2.892	-6.901*	3.856

Legend: * $p \leq .1$, ** $p \leq .05$ and *** $p \leq .01$

Source: own estimation

6 Conclusion and policy implications

This paper looks at agricultural trade flows from six important Latin American countries. The concepts of virtual water trade and external land footprint reveal large impacts on natural resource uses, stemming from increasing agricultural production for export markets. Within a gravity model setting, the study gives a more holistic view on trade drivers of agricultural export commodities from Latin America. Standard gravity models' hypotheses are supported, namely, larger countries in terms of GDP per capita trade proportionally more with each other. The time invariant *distance* variable was absorbed by the pairwise fixed effects model and cannot be estimated.

We show that per capita natural endowments also explain observed trade flows from and out of our six Latin American countries. To the extent that countries with more land per capita export more, there seems to be some kind of specialisation in food production operating in observed trade trends in these countries. It would thus seem that the world may benefit, in terms of food production efficiency, that countries with more abundant resources specialise in resource–intensive goods.

Observed trade trends in Latin America may precede an expansion in food production in Africa which is also well endowed with natural resources. The results confirm a growing land dependency in order to meet changing dietary habits. One example of this phenomenon is China, becoming one of the main importers of agricultural commodities. Land and water scarcity in importing nations with high demands as a main trade driver may partly explain, though not justify on moral or political grounds, the recent phenomenon of *Land Grab* in Africa.

We also tested whether signing Multilateral Environmental Agreements (MEA) had an impact on observed trade flows, with a view to test whether trade confirms the pollution haven or the Porter's hypothesis. Our data partly supports the Porter's hypothesis and partly the pollution haven hypothesis. Since the coefficients are very low of all MEAs though, we can rather state that environmental agreements do not influence agricultural trade very much. This is an encouraging result, and suggests that the expansion of trade, and the income growth that comes with it, may favour government's willingness to sign MEAs. Although the direction of causality is difficult to be established, we conjecture, leave to further work, that the expansion of trade precedes or prompts political inclination to sign MEAs against the opposite hypothesis which would state that MEAs may be a prerequisite for releasing the potential for producing and exporting resource-intensive goods.

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