GMO Regulations, International Trade and the Imperialism of Standards

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GMO Regulations, International Trade and the Imperialism of Standards

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Abstract

This paper deals with the quantification of GMO regulations on bilateral trade flows. A composite index of the 'complexity' of such regulations for sixty countries based on 'objective' scores assigned to six GMO regulatory sub-dimensions has been developed. Using a gravity model, we show how bilateral 'similarity' in GMO regulations, affect trade flows for the composite index and its components. Results show that bilateral distance in GMO regulations negatively affect trade flows, especially as an effect of labeling policies, approval process and traceability systems. Interesting, the trade enhancement effect induced by GMO standards similarity increase by a factor of four when GMO regulations is treated as endogenous to trade flows. This pattern is consistent with an international environment where large importing countries 'dictate' the rules of the game to developing countries.

JEL: F13, F14, Q13, Q18, Q17
Keywords: GMO standards, Harmonization, Trade Flow, Gravity Model, Endogeneity

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1. Introduction

The stark polarization of public and private policies on genetically modified organisms (GMOs) represents one of the main issues of modern international agri-food supply chain. GMO standards differ strongly across countries and regions, resulting in a market fragmentation that currently challenges the international trading regime (Isaac et al. 2004).

Several authors have pointed out that the stringency of the GMO regulations of big agri-food importers, like the European Union (EU) and Japan, in contraposition with the 'soft' regulations of GMO producers, like the US and Argentina, could represent a serious problem for the developing country' strategy concerning GMO production and regulations (see, e.g., Tothova and Oehmke, 2004; Anderson and Jackson, 2004). Indeed, while the potential gains from GMO adoption by several Asian and African countries appear particularly high (see Huang et al. 2004; Anderson, 2005; Smale et al., 2009; Gruére et al. 2009), developing countries are struggling because of the trade–off between the expected production and agronomic benefit from GM crops, and the potential loss of access to rich markets with strong consumer opposition to GMOs.

The purpose of this paper is to investigate the trade effect of GMO standards across a large sample of developing and developed countries. To deal with, the paper develops a composite index of the stringency of GMO regulations for a sample of about sixty countries, to study how similarity / dissimilarity in GMO regulations affects bilateral trade flows.

The paper adds to the existing literature in three main directions. First, we study the trade effect of GMO regulations using an 'objective' multidimensional index of GMO standard and its sub-components, to shed light on which regulatory dimensions matter the most for trade flow. Thus, we depart from the standard approach of using simple dummy variable to capture the trade effect of GMO regulation as, for example, in Disdier and Fontagnè (2008).[1] Second, we focus on 'harmonization' issues instead of the more traditional concern about standards as a barrier to trade. This is done by using in the empirical analysis a bilateral measure of GMO standards, with the aim of

[1] Obviously, this does not means that using a dummy for capturing the trade effect of GMOs is *a priori* less interesting, as what is the best strategy also depend by the research question and/or data availability. However, it is clear that if we want to understand which GMO regulatory dimension matter for trade flow, then one need to go behind a simple categorization based on dummy variable. Gruère et al. (2009) represent an example in that direction, however they limited the investigation to GMO labeling policies.

capturing the level of 'harmonization' in GMO regulations. Thus, our research does not directly address the trade reduction effect induced by the stringency in GMO regulations. Indeed, we try to answer a slightly different question: how much does similarity, or dissimilarity, in GMO regulations between exporting and importing countries affect bilateral trade in GMO related products? This question appears more relevant to understand the actual pattern of a (developing) country's strategy to GMO regulations.

The final contribution of the analysis is the tentative to account for the potential bias induced by the endogeneity of GMO standards to trade flow, an issue rarely covered by existing empirical studies.[2] Indeed, both political economy motives and genuine economic reasons – namely the idea that countries set-up GMO regulations by trading-off internal benefits with external (trade) costs – call for the endogenous nature of GMO regulations to bilateral trade flows.

The paper is related to several studies on the trade-related aspects of the introduction of GMO and the costs induced by its regulations.[3] Within this literature, particularly relevant for our analysis are studies by Cadot et al (2001), Parcell and Kalaitzandonakes (2004), Disdier and Fontagné (2008), Tothova and Oehmke (2004), Veyssiere (2007), and Gruére et al. (2009).

Cadot et al (2001) discuss the 'regulatory protectionism' aspect of EU GMO regulations, reporting preliminary evidence indicating that there were no repercussions to the US export of corn seeds. However, they did find a negative effect with regard to other forms of corn, suggesting that downstream traders' and food retailers' private decisions not to purchase GM products were more important than the cultivation bans. Using a different approach, Parcell and Kalaitzandonakes (2004) did not find any effect on future prices after major food companies announced a voluntary ban on GMO crops.

[2] To date, in the gravity literature concerning the trade effect of non-tariff barriers (NTBs) the problem of the endogeneity of NTBs to trade flow is rarely taken into account. Exception to this rule can be found in Olper and Raimondi (2008) and Djankov et al. (2008).

[3] Important studies about trade-related aspects of genetically modified organisms (GMOs) introduction and regulations, can be found in Lapan and Moschini (2004) and Smyth et al. (2006). The first paper shows that labeling regulations on trade in GMOs can redistribute income among trading nations, and may benefit the importing country. Differently Smyth et al. (2006) show that the trade patterns of GMO products displayed changes after the introduction of GMO regulations. Concerning GMO labeling issues, see also: Runge and Jackson (2000), Fulton and Giannakas (2004) and Veyssiere and Giannakas (2004), among others. Finally, see Josling et al. (2005), Sheldon (2002) and Gruére (2006) about EU, US and worldwide GMO regulatory systems.

More recently, Disdier and Fontagné (2008) used a gravity equation to estimate the reduction of exports from complainants to the EU *de facto* moratorium on GMOs for potentially affected products. In general terms, and contrary to the findings of Cadot et al (2001) and Parcell and Kalaitzandonakes (2004), they show that the EU moratorium, as well as other European GMO regulations, have negative trade effects on exporting country.

Particularly relevant to our analysis are studies of Tothova and Oehmke (2004), Veyssiere (2007) and Gruére et al. (2009). The first paper developed a Krugman-style trade model to study the endogenous choice of different countries to set GMO standards, and the consequent endogenous formation of 'clubs' of countries that acts as a sub-global preferential trading agreement. Their model suggests the formation of two trading blocs, one in favor, the other against GMOs. In between these two blocs there emerges a third group of developing countries potential losers, that face a tension coming from lower production costs (through the adoption of GM crops) and the maintenance of an export market of conventional varieties, such maintenance being achieved by restricting GMO production. A similar question is analyzed by Veyssiere (2007), who studied the dilemma facing large exporting countries of agricultural products; such countries have to determine whether or not to approve GM products with or without a labeling regime. An interesting result from their model is that GM product approval is optimal under a labeling regime, whereas non-approval is optimal in the absence of mandatory labeling requirements.

Finally, Gruére et al. (2009) adopt a political economy approach to evaluate the importance of socio-economic factors in the selection of GM labeling regulation. They show, theoretically and empirically, that interests related to production and trade has an important role on GM labeling regulation choices. In particular, in developing countries regional influences and trade factors may be more important than domestic consumer preferences or anti-GM campaigns. Clearly, all these evidence highlight the importance of treating GM regulations as potentially endogenous to trade flows.

The organization of the paper is as follows: Section (2) explains how we constructed the GMO regulatory index; Section (3) presents the data and specifications of the empirical model; Section (4) gives the results and discusses them; while Section (5) conclude.

2. An index of GMO regulations

2.1 Sample, data and computational strategy

We build our GMO index for 60 countries for which has been possible to collect information on laws and acts regulating GMO cultivation and commercialization. We collect available information on GMO regulations until June 2008, so that the large fraction of GMO standards considered was in place in the year 2007, or before. However, it is important to keep in mind that, especially for some developing countries, there could be significant delays in the regulation enforcement, due to both political and technical reasons. Thus, the relative GMO restrictiveness ranking for some developing countries could be slight bias up-ward (see below).

The considered countries include most EU countries and OECD members, important exporters of agricultural goods like Argentina, Brazil, China, India, Ukraine and Asian countries, important producers like Bangladesh, Hong Kong, Indonesia, Malaysia, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam. Moreover we also included Chile, Colombia, Guatemala, Israel, Jamaica, Peru, Russia, Saudi Arabia, Venezuela and some African countries: Kenya, South Africa, Zambia, and Zimbabwe Table A1, gives the full list of countries considered). The criteria for choosing the countries was based on both their economic relevance in the agricultural international markets, as well as sufficient availability information related to laws and acts regulating GMO cultivation and commercialization.

The main information source used to classify the GMO regulations is the Global Agriculture Information Network (GAIN) reports on biotechnology provided by the Foreign Agricultural Service (FAS) of the United States Department of Agriculture (USDA). For missing information we refer to official national acts, reports or essays.

Six categories of GMO production and commercialization regulations were considered:

1. Approval process;
2. Risk assessment;
3. Labeling policies;
4. Traceability system;
5. Coexistence management;
6. Membership in international agreements GMO related.

Each GMO regulatory dimension was scored with values ranging from 0 (first condition) to the total number of *conditions* identified for each category (description of categories and conditions are discussed below). Higher scores indicate an increasing restrictiveness of the regulation. For example, for those countries that declare themselves to be 'GM free', which means that no GM products can be cultivated domestically or introduced, the highest score is assumed.

The overall GMO index is then obtained by the summation of each normalized scores sub-component – each score component being normalized to vary between 0 and 1. The final GMO index, after further normalization, can take on any value between 0 and 1, with higher values indicating a more complex national regulation on GMO production and commercialization, which suggests increasing restrictions to cultivation and trade.

Stringent regulations generally require more expansive procedures for exporters, and comprehensive policies can have a greater trade effect. It is assumed that approval procedures represent fixed costs, traceability and labeling variable costs, influencing present and future GM and non-GM crop exports (see Gruére, 2006).

Some categories are strongly related to each other. For example, in many regulations an approval process cannot be conducted without a product risk assessment. However, this logic does not apply systematically to the GMO standards context. The analysis of 60 country policies suggests many unexpected and ambiguous stages of implementation. For example, there are countries which require a mandatory approval process but the risk analysis is under the responsibility of the importer (e.g. EU countries), and countries with a voluntary labeling regime but with no required traceability or segregation system (e.g. Canada).

An overview of the GMO index ranking and score is given in Table A.1. Several interesting patterns emerge. First, as expected, there is the well known polarization between the US and the EU countries. The former has a GMO regulatory index of 0.35, which contrasts with the EU average of 0.69. Secondly, with the exception of Zambia and Zimbabwe, which declared to be both GMO-free countries, developing countries tend to be positioned in the low part of the ranking. All the considered EU countries, as well as food importers like Japan (but not South Korea), displayed a high GMO index. However, it is interesting to note that also within the EU there exist some differences in the GMO score. For example, the highest score of 0.75 was found for countries like Austria and Italy that have imposed a ban on the cultivation of EU approved GMO maize. Differently, EU countries like Spain and Germany have significantly lower scores, equal to 0.60 and 0.65, respectively.

The next sections justify and discuss in details how each regulatory dimension of the GMO index has been classified (by a score) and considered.

2.1.1 Approval process

The first condition that allows any possible handling of a GMO product is its approved status in a country. In contrast with the majority of conventional commodities, GM foods need specific approval procedures, both for import and cultivation, related to safety issues that are managed in different ways among countries: from a very comprehensive pathway including assessment of effect on mammals to, in several countries, a complete ban.

In contrast with requirements like traceability and labeling, which act similarly to trade standards, import approval for a GM food is a measure directly affecting market access: if a GM event is not approved it is not possible to introduce it in the country.

The requirements for an approval process vary widely across countries. There are two main groups of countries which share similar approaches. One follows the EU regulations, based on the ‘precautionary principle’, which means that any product produced with, or derived from, transgenic crops is subject to GM regulations and the consumers’ ‘right to know’. The second group follows the US attitude of ‘substantial equivalence’, which exempts for essentially equivalent products any specific requirements (Gruére 2006). Between the two groups there are many different approaches to the approval process.

We defined *five* levels of restrictiveness (from 0 to 4) of approval processes based on the degree of domestic implementation of the regulation. A score of 0 is given when there are no constraints on GMO cultivation and marketing; a score of 1 if there exists a mandatory approval process established at the legislative level, but not yet implemented; a score of 2 when the mandatory approval process follows the principle of substantial equivalence; a score of 3 when a mandatory approval process follows the precautionary principle; finally a score of 4 in situations of GMO free status (prohibition of cultivation and marketing, see Table 1).

Most EU members, Japan and fast-growing income countries like China and India are scored in the third condition, which is the most comprehensive. The zero or first conditions include developing or emerging countries, which take what is called a 'wait and see' position with respect to the international polarization led by the EU and US.

2.1.2 Risk assessment

Assessments are based on the biological characteristics of the new organism, and test the safety of food, fodder and the environment. Authorization depends on a positive risk assessment, usually conducted by an independent body that establishes standards for testing and detection. The typology of the testing depends on the country's approach, whether based on substantial equivalent or precautionary principle. In many cases the exporter is the legal subject responsible for the assessment.

On the international scenario biosafety assessment is gaining importance, being the target for international harmonization efforts for setting a common methodology, though still at the discussion stage. Biosafety assessment requires deeper analysis through the adoption of field trials. Indeed, for those countries possessing native plants, testing of potential gene flow from GM crops to their wild (native) relatives is needed. The scheduling and realization of programs for field trials is expensive and some countries (e.g. developing countries) are not able to deal with these costs.

We identified a scoring classification of requirement levels (range 0-3) for a national risk assessment regulation. The conditions scoring 0 and 3 indicate a lack in the risk assessment framework, but the differences are substantial: a score of 0 (e.g. Ukraine) means a normative void that does not affect trade or cultivation as there are no standards; score 3, on the contrary, applies to countries declaring themselves 'GMO free', hence totally opposed to the importation (and cultivation) of GMOs and imposing the strongest degree of regulation restrictiveness. Between these two scores, we have 1 if the risk assessment is at a regulation proposal stage, and 2 if risk assessment is compulsory.

2.1.3 Labeling policies

In 1997, the EU introduced GMO labeling policies with the purpose of guaranteeing 'the consumer's right to know', but labels carry indications other than just the presence of GM ingredients, they also give information on health factors and product diversification (Veyssiere and Giannakas, 2004). Labeling has also met environmental issues, playing a role in consumption decisions of consumers concerned by environmental factors associated with GM products (Appleton, 2000). Indeed, a label can act as a warning, indicating potential hazards and thus affecting the demand for GM and non-GM products, particularly reducing the demand for the former (Gruère, 2006).

Over the past ten years, an increasing number of countries have become involved with labeling requirements, and all have different regulation characteristics (see Gruère and Rao, 2007). We have identified five categories of labeling characteristics, where thresholds play a fundamental role as a specific standard for trade issues. Compliance with a restrictive threshold implies an increase in production and commercialization costs.

The possibility of labeling is strictly related to segregation, identity preservation (IP) and traceability system, that can be considered alternative methods for differentiation. Even though IP is currently used to identify crop varieties in some countries (e.g. US and South Africa) permitting exports in countries with a mandatory labeling regime, it could represent a first step for traceabilty and coexistence. Hence, we focus on traceability system as a market mechanism to accommodate differences in labeling requirements. Though labeling and traceability represent two separate categories, several country's policies consider the two related.

A labeling regime is expected to influence trade flows, and, in particular, to affect the trade of the chief suppliers of GM crops (Gruère and Rao, 2007; Gruère et al. 2009). Costs caused by a labeling regime depend on: the threshold level, the capacity of the public authority to enforce labeling requirements, and the capacity of industry to comply with labeling rules. GM labels have effects on the whole agri-food chain. Actors have to collect and handle information concerning the presence of GM food components until reaching the final consumer, but the transfer of this information adds onerous management costs. Ultimately, labeling indirectly affects trade through the imposition of implementation costs for GM crop exporters.

Among countries we registered two main attitudes: voluntary and mandatory labeling regimes. Mandatory labeling requirements are divided into further two groups: label on the finished product (Australia and Japan), and on GM technology as a production process (EU and China). In the former case, the quantification of GM ingredients is required to be labeled, and, usually, the threshold is higher. In the latter case any product derived from GM crops has to be reported. In this case, thresholds decrease in entity and the process based system directly requires the exporters to have a form of identity preservation or a traceability system.

Labeling categories are scored from 0 to 5. We have a 0 score in the absence of labeling requirements; 1 with voluntary regime; 2 in the presence of a mandatory regime with a threshold equal or higher than 5%; 3 with mandatory regime but with a threshold equal or lower than 1%; and, finally, 4 in countries that declare themselves GM free.

2.1.4 Traceability requirements

Traceability is an instrument to create a network able to 'retrace history, use, or location of an entity by means of recorded identification', and that guarantees efficient withdrawal from the food and feed market if any unexpected effects occurs to mammalian health and the environment. In the case of GMO products, the traceability system is based on IP for the diversification between different productions, ensuring to the consumer the origin and the typology of the product. Moreover, producers, processors and retailers of food have to collect, retain and transmit information in each stage of the agri-food chain (Bailey, 2002).

Countries with a comprehensive traceability regulation must create procedures for the identification of industry chain participants who supply and demand products. Actors of the food chain must transmit information on the identity of the product and whether it contains GMOs, retain such information for a long period (post-market monitoring), i.e. 5 years, and guarantee its availability for applicants (Wilson et al., 2008).

At the producer level, farmers have to be certain of the absence of cross-pollination between neighboring crops, and must comply with certified storage and harvesting. Elevators, processors and retailers must keep information on product identity and transmit this information by lot numbers and test results.

All these requirements induce increasing costs, but also benefit the market niche gains. Cost increase is difficult to establish because traceability is an issue with long term implications, with variable costs depending on crops, e.g. soya and maize provide a great number of byproducts in different agri-food industries. Moreover, liability and compensation schemes are crucial. The main costs are referred to certification, record collection and information keeping, and are carried by GMO producers and suppliers countries, with a potentially higher final market price, for both GMO and GMO-free products.

For the traceability category we define the following scores: 0 if the regulation does not require a traceability or an IP system; 1 if the traceability requirement is at the proposal stage or if it is implemented an IP system; 2 if traceability is mandatory; and 3 if the country is GM free.

2.1.5 Coexistence guidelines

The purpose of managing coexistence is to guarantee to consumers and farmers the possibility of choosing what to consume or produce among GM, traditional and organic products. This is feasible only if there is the preservation of identity among crops, which must be segregated in space and time. Thus it is not possible to cultivate nearby fields of GM and organic crops, or to manage them in short rotations. Coexistence managing procedures require mechanisms preventing pollen flows (such as distances or pollen barriers between fields of GM, traditional and organic products), refuges areas and dedicated machineries, but also compensation and liability systems. It also requires strong cooperation between farmers in close proximity.

Production costs in a coexistence scenario arise due to isolation costs, monitoring, purity testing, dedicated equipment and/or its cleaning, which can vary at the establish purity levels, taking into account that zero threshold of transgene in GMO-free crops is not feasible in some agricultural systems. Some developing country policy makers assume that coexistence is not feasible or can be done only by facing prohibitive costs.

Because of the difficulties in establishing coexistence strategies, the level of implementation of coexistence policies varies widely across countries, and in several cases requirements are not stated clearly. For this reason we decided to score 0 those countries without any coexistence rule, 1 if coexistence policies are at embryonic stage, 2 if partial guidelines were prepared, 3 if exhaustive coexistence guidelines are adopted and 4 if the country is GM free.

2.1.6 Membership in international GMO related agreements

We considered two institutions, the Codex Alimentarius and the Cartagena Protocol on Biosafety, which, among several international agreements, have effects on the trading of biotech products.

The Codex Alimentarius has the purpose of define standards to protect consumer health, and promoting fair relationship in international trade practices. It has successfully reached an agreement on safety assessment procedures for GMOs, but no formal labeling standards were adopted, these remaining a disagreed issue.

The aim of the Cartagena Protocol on Biosafety (BSP), part of the United Nation Convention on Biodiversity, is to introduce a shared procedure for risk assessment, risk management and trans-boundary movements of Living Modified Organisms (LMOs). The BSP acts between importers and exporters, introducing an Advanced Informed Agreement (AIA) for the intentional introduction of LMOs into the environment. In particular, it requires a comprehensive risk assessment and risk management framework provided by the exporter before the first introduction of any LMO in the importer territory.

Rules from the BSP are on bundling, transport, packaging and identification during any LMO trans-boundary movement. This comprehensive mechanism for the safe movement of LMOs was offered by the Cartagena Protocol on Biosafety as a primary policy for all those countries without domestic regulations, including liability rules for the illegal flow of LMOs, and calls for a ban of GM crop imports as a precautionary measure. The compliance with the BSP requirements could impose higher production and marketing costs on agricultural goods, both GM and non-GM, because of the institution of domestic structures for annual testing.

If the country does not adhere to either of the two considered international agreements the score is 0, otherwise the score is 1 or 2 when the country subscribes to a one or both agreements, respectively.

It is important to note that, Until the Codex Alimentarius Commission reaches an agreement on labeling, and BSP became active with the necessary testing structures in all member countries, neither of the two international institutions will influence trade flows. However, we decide to consider also this index category on the ground that expected future enforcement could have an effect on actual trade.

3. GMO standards and international trade

3.1 Trade data

To study the effect of GMO standards on trade flow we have considered trade data related to three major potentially affected agricultural products: maize, soybean and rapeseed, both for human consumption and animal feed. We also include cotton products, mainly related to agri-food system. Trade data comes from the Commodity Trade database maintained by the United Nations Statistical Division (UN-COMTRADE). We work at the 6-digit level of the 2002 Harmonized System (HS) classification. Because it is not possible to distinguish between GMO and non-GMO products, we considered raw, transformed and by products, both for food and for feed recognized in the literature as potentially sensitive to transgenic crops (see USDA 2008).

As in previous empirical analyses (see Disdier and Fontagné 2008) we face a sort of identification problem, because a reduction in trade flows can only partially be attributed to the existence of GMO restrictions. We take care of this issue through a proper specification of the gravity equation, ruling out, as close as possible, the potential determinants of trade flow different from GMO standards, like other trade cost factors.

The four aggregates considered are called for simplicity: *Maize, Soybean*, *Oilseed Rape*, and *Cotton*. For cotton, we take into account headings related to the agri-food channel, particularly seeds, oils and cake that are exploited as animal fodder or as a part of such feed.[4] In the empirical analysis, we considered both an overall aggregate of the four potentially GMO affected trade, and each of the four groups individually.

The country sample is selected using the following rules. Within the importing country we select all the countries for which it was possible to build the GMO regulatory index. Instead, the selection criteria for exporters is based on trade and

[4] The HS 2002 (6-digits) headings used are as follow. *Maize (corn)*: 071040, 100510, 100590, 110220, 110313, 110320, 110423, 110812, 151521, 151529, 190410, 190420, 200580, 230210, 230310; *Soybean*: 120100, 120810, 150710, 150790, 210310, 210610, 230400; *Rape*: 120510, 120590, 151411, 151419, 151491, 151499, 230649; *Cotton*: 120720, 151221, 151229, 230610.

production data from FAO source, excluding those countries that, simultaneously, have no export or production of maize, soybean, rapeseed and cotton products, respectively.

Finally, the time period considered covers the average trade flows of three years: 2005, 2006 and 2007.[5] Up to 2008, international regulations were implemented in a wide number of countries. Despite the GMO adoption start in the second half of the nineties, only in more recent years we assisted to an acceleration of the diffusion of biotech regulations. Note that, this can be attributed not only to the growing amount of biotech products traded, but also to international trade controversy which has led to the defining of GMO import and export rules.

3.2 Econometric trade model

The objective of this section is to present our strategy to assess the potential trade effect of GMO regulations. The bilateral trade equation is derived from the now standard CES monopolistic competition trade model, with increasing returns to scale and iceberg trade costs, introduced by Krugman (1980). In the empirical version of the model the bilateral trade flow from *j* to *i* (M_{ij}) can be summarized by the following log-linear bilateral trade equation:

$$LogM_{ij} = \beta_0 + \lambda_j + \chi_i + \beta_1 LogD_{ij} + \beta_2 Log\tau_{ij} + \sum_n \alpha_n Z_{ij}^n + \varepsilon_{ij} \ , \qquad (1)$$

with λ_j and χ_i the exporter and importer fixed effects to control for the size terms as well as the unobserved number of varieties (firms) and the price term of the exporter, and for the expenditure and the unobserved price term of the importer, respectively. D_{ij} is the transport costs proxy by distance between *i* and *j*, τ_{ij} is the *ad valorem* bilateral tariff, Z_{ij} any other bilateral trade costs different from distance and tariffs and, finally, ε_{ij} is an error term. The parameters β_1, β_2, and α_n are the coefficients to be estimated.

We augment this basic trade equation through the introduction of the GMO regulatory index in the vector of other trade costs, Z_{ij}. Due to the cross-sectional nature of our dataset, we work with a GMO index on a bilateral basis. More specifically, we computed two different GMO bilateral indices.

[5] For practical reasons, we do not extend the sample period to 2008, to eliminate the possible confounding effect due to the financial crisis export slow down.

Our preferred index, called $GMOw_{ij}$, is based on the similarity index recently proposed by Anderson (2009) and based on the approach first introduced by Jaffe (1986). The index can be defined as follow:

$$GMOw_{ij} = \frac{\sum_{m=1}^{M} f_{im} f_{jm}}{\left(\sum_{m=1}^{M} f_{im}^{2}\right)^{1/2} \left(\sum_{m=1}^{M} f_{jm}^{2}\right)^{1/2}}$$

Where f_{im} is the ratio between the regulatory dimension score attributed to country *i* on the highest score assigned to the regulatory dimension *m*. This allow us to obtain a degree of bilateral regulatory 'closeness' between two countries, ranging between 0 (completely different) and 1 (identical regulation). In other words, this index defines vectors of national rationed score, named $f_i = (f_{i1},\ldots, f_{iM})$ with $M = 6$, which locates country *i* in the *M*-dimensional space. Similarity of the regulation can be computed through the proximity of the *f*-vectors, defined by the *cosine* of the angle between them. Jaffe (1989) indicate that proximity measures is 0 for countries whose vectors are orthogonal and is 1 for countries whose position vectors are identical.

This $GMOw_{ij}$ have several useful properties for measuring similarity. Indeed, it is conceptually similar to a correlation coefficient, and as such have the property to be completely symmetric. However, given our purpose of studying also which regulatory dimensions matter the most for trade flows, use was made of a second bilateral index called GMO_{ij}. This second index is simply obtained by taking the absolute deviation of our GMO index across country pairs, namely $GMO_{ij} = \left| GMO_i - GMO_j \right|$, as such it is also computable for each regulatory dimension taken individually. Thus the GMO_{ij} bilateral index increases in the level of dissimilarity or distance in GMO regulations across country pairs or, put differently, it represents an inverse index of 'harmonization' in GMO regulations. Finally, note that, given the definition of our bilateral indices they should display opposite sign coefficients in the regression results as *GMOwij* is a similarity index, while GMO_{ij} is a dissimilarity index. Indeed, the correlation coefficient between them is negative and equal to –0.60.

Data on distance, with dummies for other trade costs normally used in similar exercises (contiguity, language, and colony), are taken from CEPII (Centre d'Etude Prospectives et d'Informations Internationales). Finally, bilateral tariffs are obtained from the MAcMap database jointly developed by ITC (UNCTAD and WTO, Geneva) and CEPII (Paris). It includes *ad-valorem*, as well as specific components of each bilateral tariff line at the six digit level of the Harmonized System. Note that the inclusion of bilateral tariffs in the trade costs function is particularly important in our context to proper identify the effect of GMO regulations. Indeed, if our bilateral GMO index is positively correlated with bilateral tariffs, then omitting tariffs from the gravity equation results in an overestimation of the GMOs effect on trade flow.[6]

Finally, with concern to the estimation method, when equation (1) is applied at the disaggregated trade level, the first problem that emerges is the presence of a high number of zero bilateral trade flows. One of the most common methods of dealing with zero trade is the Heckman (1979) two stage selection correction: *i*) a Probit equation where all the trade flow determinants are regressed on the indicator variable, T_{ij}, equal to 1 when *j* exports to *i* and 0 when it does not; *ii*) an OLS second-stage with the same regressors as the Probit equation, plus the inverse Mills ratio from the first stage, correcting the biases generated by the sample selection problems.[7] Following the modification suggested by Helpman et al. (2008) and supported by Martin and Pham (2008), we omitted in the second OLS stage an independent variable associated with the fixed trade costs of establishing trade flow.[8]

4. Results

In this section the results of the econometric estimation of equation (1) are reported and discussed. First we focus the attention on results based on the assumption that the GMO index is an exogenous variable. Then with check for robustness of the results by considering the potential endogeneity issues. We follow this strategy for both comparability and practical reasons. Indeed, almost all previous papers have considered

[6] The correlation between tariffs and NTBs is an empirical question. To date, broad evidence of a positive correlation for agri-food products can be found in Kee et al (2008). In our sample, running a fixed effect regression of tariffs on the GMO index, the coefficients of tariffs is positive and strongly significant.

[7] As an alternative approach to deal with zero trade flows and heteroskedasticity problems, Santos Silva and Tenreyro (2006) recommended the Poisson Pseudo Maximum-Likelihood (PPML) estimator. However, Martin and Pham (2008) and Raimondi and Olper (2009) have shown that the PPML approach produces biased results when used in the presence of a large fraction of zero trade flow, a situation consistent with recent trade models with firms' heterogeneity (Melitz 2003; Helpman et al. 2008) and very frequently working at a disaggregated product level as in our application.

[8] The underlying idea is that fixed trade costs, here proxy by the language dummy, especially affect the probability to export. Thus it is included only in the (first stage) selection equation, but not in the level OLS equation (see Martin and Pham, 2008).

GMO regulations as an exogenous variable. Moreover, it is well know that instrumenting such variable it is a quite difficult task in a gravity environment (more on this below).

Table 2 reports the regression results of equation (1), pooling the data across the four groups of products and testing for the trade effect of the ‘aggregated’ GMO indices (Column 1 and 2) and their sub-components (Columns 3-9). Figures refer to the second stage of the Heckman procedure. The Mills ratio reported at the bottom of the table, is strongly significant in every regressions, giving a statistical justification to the use of the Heckman procedure to correct for selection bias. This is not surprising given the large fraction of zero trade flows of the dataset.

Starting from standard gravity covariates, the distance coefficient is always negative and significant, while the common border and colony dummies are positive and significant. As expected, bilateral tariffs have a negative and significant effect on bilateral trade flows. If we give a structural interpretation to the tariff coefficients, equal to $(1-\sigma)$ with $\sigma > 1$ the elasticity of substitution between home and foreign products, then we have an estimate of such elasticity. Its average value, around 3, is broadly in the same order of magnitude of recent estimate reported by Raimondi and Olper (2009).

Turning to the variable of interests, column (1) shows that the $GMOw_{ij}$ has a positive and strongly significant coefficient (p-value < 0.01). Because the index measures the across-countries closeness in GMO regulations, a positive coefficient means that bilateral trade flow is increasing in the similarity of GMO regulations. The magnitude of estimated coefficient implies that a one standard deviation increase in GMO regulatory distance, equal to 0.148 points, increases exports by about 30 percent, all else remaining equal. To give sense to this number, note that it approximately corresponds to a change in $GMOw_{ij}$ index from the value of France-Philippine (= 0.76) to that of France-Poland (= 0.92). Thus the effect it is not only statistically significant but appears also relevant from an economic point of view.

Column (2) reports results using our alternative GMO_{ij} index based on the absolute regulatory difference. The results are very similar, the only difference being the negative sign of the estimated coefficient as now we are measuring dissimilarity in GMO regulations. Columns from (3) to (9) investigate which GMO regulatory sub-components matter the most. In line with the results of column (2), all GMO components exert a negative effect on bilateral trade flow, and most of them are statistically significant at 5% level, with the exception of international agreements that is only barely significant, and the risk assessment component that is not significant. However, as the different regulatory components tend to be positive correlated with each other, to better disentangle their differentiated effect, in Column (9) we run a specification that consider them simultaneously. Not surprising, their estimated coefficient decrease some what in absolute magnitude. Interesting, the (theoretically) most important dimensions, namely labeling, the approval process, and traceability, remain strongly significant at 1% level. Because each component is normalized to vary from 0 to 1, the results suggest also that differences in Labeling policies are the GMO regulatory dimension most detrimental to trade, followed by the approval process and traceability requirements. This finding is in line with the notion that GMO labeling' provisions is a complex field of across countries conflict in terms of trade policies (Carrau, 2009). Thus as long as an agreements will not internationally shared, for example through the Codex Alimentarius, labeling is going to remain one of the major regulatory components that have effects, either directly (e.g. food marketing) or indirectly influencing consumers choice and information.

Table 3 investigates the sensitivity of different product groups to the $GMOw_{ij}$ regulatory index, by running regressions for each group separately. Column (1) replicates the pooled regression results from Table 2 (column (1)), for comparison purposes. The estimated coefficients on the $GMOw_{ij}$ is positive for all the product groups considered but statistically significant only for corn and soybean, suggesting that these agricultural commodities are the more affected by GMO regulations. Differently, we do not detect significant effect for either rape or cotton trade flows. While for cotton the results make sense as it is only partially involved in the agri-food chain, more surprising are the results for rape, as there is evidence that segregating non-GMO from GMO rapeseed is much more complicated than segregating non-GMO corn or soybean. However, note that when use is made of GMO_{ij} index instead of $GMOw_{ij}$, also the coefficient for rape turn out to be significant (results not shown).

4.1. Is GMO regulations endogenous to trade flows?

There are different potential sources of endogeneity bias in our model. However, here we are expecially concerned with endogeneity due to potential simultaneity bias between GMO regulations and bilateral trade flow. In fact, a large political economy literature on trade policy suggests that not only does trade policy affect imports, but also that trade policy itself is affected by the level of imports (see Trefler, 1993; Grossman and Helpman, 1994). In such a case, if import and protection are not modeled as being simultaneously determined, then the estimated impact of protection on imports will be biased downward.

The applicability of this reasoning to our specific context is not so clear, however, as standards regulation in general, and GM regulations in particular, *prima facie*, are not trade policy. However, in our specific context we have important reasons to suspect that GMO regulations could be affected by trade flow. Indeed, as discussed in the introduction, previous evidence and conceptual model stresses that in recent years many developing countries have set GMO standards taking care of the trade-off between agronomic advantage and market access loss in countries with GMO consumer concerns (see Tothova and Oehmke, 2004; Veyssiere, 2007; Gruére et al., 2009).

Generally speaking, it is difficult to address this simultaneity bias because of the lack of good instruments, as almost all the potential determinants of GMO regulations exert also an effect on bilateral trade flows, thus they tend to be weak instruments (see Baier and Bergstrand, 2007). Previous tentative to deal with this kind of endogeneity in gravity models have followed the idea of Lee and Swagel (1997), using industrial conditions as instruments for trade policy (see, e.g., Olper and Raimondi, 2008). However, working at the HS 6-digit level it is impossible to adopt this strategy due to data constraints. An alternative strategy followed in this paper is that propose by Djankov et al (2010), who deal with the potential endogeneity of trade times in gravity model by using the trade times of neighboring countries. The intuition is that while trade flows may affect domestic trade times, they are less likely to affect transit times abroad. Following a similar logic we instrument the GMO index by using the weighted average GMO index of the five closest neighbors, using the distance between capital as a weight.

The results of this exercise are reported in Table 4. Columns (1) and (2) report a benchmark OLS and a standard IV regression, respectively. We start from these regressions because, as it is well know (see Wooldridge 2002; Persson and Tabellini, 2003), instrumental variable is also an approach to dealing with selection bias problems. Interestingly, on passing from OLS to IV regression, the coefficient of the $GMOw_{ij}$

increases by a factor five (from 1.65 to 9.61), and moreover remain strongly significant. This result gives some credence to the idea that endogeneity matters for the final results. Columns 3 and 4 give a substantial confirmation to this hypothesis. Indeed, by running a IV second stage Heckman regression, the coefficient of the $GMOw_{ij}$ index increases by about four times and, as expected, it is now virtually the same as that obtained without using the Heckman selection correction.[9]

Keeping in mind the usual caveats about instruments, these results appear interesting, first because they support the idea that GMO regulations is endogenous to trade flows, and secondly because they suggest that selection bias concerns seem dominated by simultaneity issues. Indeed, based on our estimate, the downward bias due to simultaneity issues is several times more relevant than that due to selection bias. To see this, it is sufficient to compare the GMO index coefficients in Table 4. Indeed, sample selection induced a downward bias in the GMO index of about 17% = ((1.93-1.65)/1.65)*100. Differently simultaneity bias induces a downward estimation of the GMO coefficient of about 334% = ((8.38-1.93)/1.93)*100.

5. Summary and Conclusion

Motivated by the complex pattern and evolution of GMO regulations in the last decade, this paper deals with the quantification of GMO regulations on bilateral trade flows at global level. A composite index of the 'complexity' of such regulations for sixty countries, as well as an 'objective' score for six GMO regulatory sub-dimensions, has been developed. In a second step, using an econometric trade model, we have shown how bilateral similarity / dissimilarity in GMO regulations, affects trade flows for the composite index and its components. The empirical evidence highlights three main results.

First, countries with strong differences in GMO regulations trade significantly less, suggesting that what matters for trade flows are not only the stringency of the standards, but also the level of harmonization between countries. Second, the regulatory dimension that matters the most is that related to the labeling system, followed by the approval

[9] See Wooldrige (2002) and Bair and Bergstrand (2007) for a similar estimators. Basically it represent a three steps estimator. The first stage is the estimation of the predicted probabilities of trade, through a probit equation. The second stage is a linear regressions of $GMOw_{ij}$ on a constant, the Mills ratio from the first stage, all the covariates of the first stage plus the instruments. The first stage is estimation of the gravity equation substituting the predicted values from the second-stage regression for $GMOw_{ij}$.

process and traceability requirements. Not surprisingly, other GM regulatory dimensions like coexistence appears less important from the point of view of trade flows, as it is more related to agriculture production stage rather then to marketing and trade issues. Third, we highlight and test the endogeneity nature of GMO regulations to trade flows, showing that simultaneity bias is potentially important. Accounting for endogeneity, the GMO coefficients increase of about 4 times, and this effect largely dominates in magnitude the traditional selection bias issues in disaggregated gravity model due to zero trade flows.

The main policy implication of this study is that a process of harmonized international standardization, could have a positive trade effect, and that is especially true with regard the labeling policies. The GMO index developed in this study shows that there are ‘clubs’ of countries that shares similar GM regulations, a result in line with the Tothova and Ohemke’s (2004) theoretical prediction.

For some groups of countries, standards harmonization efforts has been done, for example between EU members, and the potential benefits to be gained push developing countries to set standards close to those of big markets, with the aim of not losing market access. However, a potential issue is whether this regulatory strategy on GMOs, followed by several less developed countries, is also the more suitable option for their development plans. This regulatory dilemma is clearly show by those developing countries that have not yet determined their ‘welfare maximizing’ standards, adopting a “wait and see” strategy where standards are still undefined. This reticence to take a position within a group respond to the fear of market access losses, and could undermine the potential development of their agricultural sectors.

References

Anderson, K. (2005). Interactions between trade policies and GM food regulations. Paper presented at the Conference 'Economics of Regulation of Agricultural Biotechnologies', Arlington VA, 10-12 March 2004.

Anderson, K. (2009). Terroir rising? Varietal and quality distinctiveness of Australia's wine regions. *Enometrica*, 1, 9-23.

Anderson, K. and Jackson, L.A. (2004). Standards, trade and protection: the case of GMOs. Selected Paper for the American Agricultural Economics Association Annual Meeting, Denver, Colorado, July 1-4, 2004

Appleton, A.E. (2000). The labeling of GMO products pursuant to international trade rules. N.Y.U. *Environmental Law Journal*, 8(3), 566-578.

Baier, S.L. and Bergstrand, J.H. (2007). Do free trade agreements actually increase member' international trade? *Journal of International Trade* 71, 72-95.

Bailey, R. (2002). The looming trade war over plant biotechnology. *Cato Trade Policy Analysis* n.18, August.

Cadot, O., Suwa-Eisenmann, A. and Traça, D. (2001). Trade-related issues in the regulation of genetically modified organism. Paper prepared for the workshop on European and American Perspectives on Regulating Genetically Engineered Food, Insead, 7/8 June 2001.

Carrau, J.G. (2009). Lack of Sherpas for a GMO Escape Route in the EU. *German Law Journal*, 10(8): 1169-1199.

Disdier, A.C. and Fontagne, L. (2008). Trade impact of European measure on GMOs condemned by the WTO panel. Paper prepared for presentation at the 12th EAAE Congress "People, Food and Environments: Global Trends and European Strategies", Gent (Belgium), 26-29 August 2008.

Djankov, S., Freund, C. and Pham, C. S. (2010). Trading on time, *Review of Economics and Statistics*. (Forthcoming).

Feld, L.P. and Voigt, S. (2003). Economic growth and judicial independence: cross-country evidence using a new set of indicators. *European Journal of Political Economy* 19, 497–527.

Fulton, M. and Giannakas, K. (2004). Inserting GM Products into the Food Chain: the Market and Welfare Effects of Different Labelling and Regulatory Regimes. *American Journal of Agricultural Economics*, 86(1), 42-60.

Grossman, G., and Helpman, E. (1994). Protection for Sale. *American Economic Review*, Vol. 84(4), 833-850.

Gruère, G.P. (2006). An Analysis of Trade Related International Regulations of Genetically Modified Food and their Effects on Developing Countries. IFPRI EPT Discussion Paper 147, February 2006.

Gruère, G.P. and Rao, S.R. (2007). A review of international labeling policies of genetically modified food to evaluate India's proposed rule. *AgBioForum*, 10(1), 51-64.

Gruère, G.P., Carter, C.A. and Farzin, Y.H (2009). Explaining International Differences in Genetically Modified Food Labeling Regulations. *Review of International Economics* 17(3), 393-408.

Gruère, G.P., Mevel, S. and Bouet, A. (2009). Balancing productivity and trade objectives in a competing environment: Should India commercialized GM rice with or without China? *Agricultural Economics* 40(4), 459-475.

Heckman J. (1979) Sample Selection Bias as a Specification Error, *Econometrica*, 47(1), 153-161.

Helpman E, Melitz M, Rubinstein Y. (2008) Estimating trade flows: Trading Partners and Trading Volumes. *Quarterly Journal of Economics*, 123(2), 441-487.

Huang, J., Hu, R., Van Mejil, H. and Van Tongeren, F. (2004). Biotechnology boosts to crop productivity in China: trade and welfare implications. *Journal of Development Economics*, 75, 27-54.

Isaac, G.E., Perdikis, N. and Kerr, W.A. (2004). Cracking export markets with genetically modified crops: What is the entry mode strategy?. *International Marketing Review*, 21, 4/5, 536-548.

Jaffe, A.B. (1986). Technological Opportunity and Spillovers of R&D: Evidence from Firm’s Patents, Profits and Market Value. *American Economic Review*, 76(5), 984-1001.

Jaffe, A.B. (1989). Real Effects of Academic Research. *American Economic Review*, 79(5), 957-970.

Josling, T., Roberts, D. and Orden, D . (2005). Food Regulation and Trade: Toward a Safe and Open Global System. *Journal of International Economic Low* 8(3), 793-802.

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. In: *American Economic Review* 70, 950-959.

Lapan, H.E. & Moschini, G. (2004). Innovation and Trade with Endogenous Market Failure: the Case of genetically Modified Products. *American Journal of Agricultural Economics*, 86(3), 634-648.

Lee, J-W., and Swagel, P. (1997) Trade barriers and trade flows across countries and industries, *Review of Economics and Statistics*, Vol. 79 (3), 372-382.

Martin W., Pham C. (2008) Estimating the gravity model when zero trade flows are frequent. Working Paper, The World Bank.

Melitz, M. (2003) The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity, *Econometrica* 71(6), 1695-1725.

Olper, A. and Raimondi, V. (2008). Explaining National Border Effects in the QUAD Food Trade, *Journal of Agricultural Economics*, Vol. 59 (3), 436-462.

Parcell J.L. and Kalaitzandonakes N.G. (2004). Do Agricultural Commodity Prices Respond to Bans against Bioengineered Crops? *Canadian Journal of Agricultural. Economics.* 52, 201-209.

Persson, T. and Tabellini, G. (2003). *The Economic Effect of Constitutions*. The MIT Press.

Raimondi, V. and Olper, A. (2009). The Sensitivity of trade flows to trade barriers, Paper presented at the 2009 AAEA&ACCI Joint Annual Meeting, Milwaukee, 26-28 July, 2009.

Runge, C.F. and Jackson, L.A. (2000). Labelling, trade and genetically modified organisms: A proposed solution. *Journal of World Trade*, 34(1), 111-122.

Sheldon, I.M. (2002). Regulation of biotechnology: will we ever “freely” trade GMOs? *European Review of Agricultural Economics*, 29(1), 155-176.

Silva J.M.C. Santos, Tenreyro S. (2006) The Log of gravity. *Review of Economics and Statistics*, Vol.88 (4), 641-658.

Smale, M., Zambrano, P., Gruère, G., Falck-Zepeda, J., Matuschke, I., Horna, D., Nagarajan, L., Yrremaredy, I., and H. Jones (2009). Impacts of Transgenic Crops in Developing Countries during the First Decade: Approaches, Findings, and Future

Directions. IFPRI Food Policy Review 10. Washington DC: International Food Policy Research Institute.
Smyth, S., Kerr, W. A., and Davey, K. A, (2006). Closing markets to biotechnology: Does it pose an economic risk if markets are globalised? *International Journal of Technology and Globalisation* 2 (3–4), 377–389.
Tothova, M. and Oehmke, J.F. (2004). Genetically modified food standards as trade barriers: harmonization, compromise and sub-global agreements. *Journal of Agricultural & Food Industrial Organization*, Vol.2.
Trefler, D. (1993) Trade liberalization and the theory of endogenous protection: An econometric study of U.S. import policy, *Journal of Political Economy*, Vol. 101(1), 138-160.
Veyssiere, L. (2007). Strategic response to GMOs by GM-free countries. *European Review of Agricultural Economics*, 34(3), 365-392.
Veyssiere, L. and Giannakas, K. (2004). Strategic labelling and Trade of GMOs. Paper prepared for the American Agricultural Economics Association Annual Meeting, Denver, August 1-4.
Wilson, W.W., De Vuyst, E.A., Taylor, R.D., Koo, W.W. and Dahl, B.L. (2008). Implications of biotech traits with segregation costs and market segments: the case of Roundup Ready ® Wheat. *European Review of Agricultural Economics*, 35(1), 51-73.
Wooldridge, J. (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT Press.

Table 1. Categories, conditions and relative score of the GMO regulatory index

1.	**Approval process**	**Score**
	Lack of rules or ambiguous situations that do not put constraints on the cultivation and marketing	0
	Mandatory approval process, established at legislative level but still far from implementation	1
	Mandatory approval process in accordance with the principle of substantial equivalence	2
	Mandatory approval process under the precautionary principle including products derived from GM crops	3
	Countries declared GM free, prohibiting cultivation and marketing	4
2.	**Risk assessment**	**Score**
	There is no implementation of risk analysis	0
	The necessity of a risk assessment is at proposal stage	1
	Mandatory risk assessment	2
	Countries declared GM free	3
3.	**Labeling policies**	**Score**
	It is not required a label or is just at proposal stage	0
	Voluntary GMO labelling	1
	Mandatory GMO label without threshold or with threshold >= 5%	2
	Mandatory GMO label with threshold <= 1%	3
	Countries declared GM free	4
4.	**Traceability requirements**	**Score**
	It is not required a GMO traceability process or an IP system	0
	GMO traceability process is at proposal stage, or is in place an IP system	1
	Mandatory GMO traceability	2
	Countries declared GM free	3
5.	**Coexistence guidelines**	**Score**
	No coexistence rules have been introduced	0
	GMO coexistence policies at embryonic stage	1
	Partial guidelines on GMO and non-GMO coexistence	2
	Exhaustive guidelines on GMO coexistence	3
	Countries declared GM free	4
6.	**Membership in international agreements**	**Score**
	No adherence to international agreements	0
	Adherence to a single international agreement	1
	Adherence to both international agreements	2

Note: see text.

Table 2. GMO regulations and trade: Regression results.

	GMOw $_{ij}$	---*GMO $_{ij}$*--							
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GMO Index	1.93***	-1.53***							
	(0.35)	*(0.19)*							
Labeling			-0.80***						-0.54***
			(0.13)						*(0.14)*
Approval				-0.76***					-0.36**
				(0.16)					*(0.17)*
Traceability					-0.52***				-0.29***
					(0.10)				*(0.11)*
Risk						-0.50			-0.02
						(0.49)			*(0.49)*
Coexistence							-0.31***		-0.14
							(0.08)		*(0.09)*
Agreements								-0.21*	-0.05
								(0.12)	*(0.12)*
Ln Distance $_{ij}$	-1.73***	-1.65***	-1.71***	-1.75***	-1.68***	-1.77***	-1.75***	-1.76***	-1.65***
	(0.06)	*(0.06)*	*(0.06)*	*(0.06)*	*(0.06)*	*(0.06)*	*(0.06)*	*(0.06)*	*(0.06)*
Contiguity	*1.27****	1.30***	1.30***	1.27***	1.29***	1.26***	1.26***	1.26***	1.31***
	(0.09)	*(0.09)*	*(0.09)*	*(0.09)*	*(0.09)*	*(0.09)*	*(0.09)*	*(0.09)*	*(0.09)*
Colony	*0.30****	0.36***	0.32***	0.30***	0.34***	0.25**	0.25**	0.27***	0.37***
	(0.10)	*(0.10)*	*(0.10)*	*(0.10)*	*(0.10)*	*(0.10)*	*(0.10)*	*(0.10)*	*(0.10)*
Ln (1 + tariff $_{ij}$)	*-1.95****	-1.88***	-1.97***	-2.01***	-1.88***	-2.02***	-1.99***	-2.02***	-1.88***
	(0.20)	*(0.20)*	*(0.20)*	*(0.20)*	*(0.20)*	*(0.20)*	*(0.20)*	*(0.20)*	*(0.20)*
Mills ratio	*2.20****	2.19***	2.19***	2.20***	2.17***	2.18***	2.19***	2.18***	2.18***
	(0.14)	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*
Constant	5.95***	10.40***	7.75***	7.99***	7.25***	7.87***	7.73***	7.84***	7.39***
	(0.67)	*(0.79)*	*(0.57)*	*(0.56)*	*(0.58)*	*(0.57)*	*(0.58)*	*(0.57)*	*(0.58)*
Observations	17112	17112	17112	17112	17112	17112	17112	17112	17112
FE Importer, exporter and HS2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: figures refer to the II stage of the Heckman regression. In parentheses robust standard error. ***, ** and * indicate significance level at the 1%, 5% and 10%, respectively. Each regression include country fixed effects for importer and exporter, and HS 2-digit products.

Table 3. GMO regulations and trade: Regressions at product group level

Variables	**Total**	**Corn**	**Soybean**	**Rape**	**Cotton**
$GMOw_{ij}$	1.93***	2.05***	3.27***	2.02	3.92
	(0.35)	*(0.46)*	*(0.74)*	*(1.23)*	*(3.07)*
Ln Distance $_{ij}$	-1.73***	-1.83***	-1.47***	-2.22***	-3.94***
	(0.06)	*(0.09)*	*(0.13)*	*(0.25)*	*(1.18)*
Contiguity	1.27***	1.09***	1.36***	1.58***	1.48
	(0.09)	*(0.11)*	*(0.19)*	*(0.23)*	*(0.93)*
Colony	0.30***	0.18	0.02	0.30	-0.23
	(0.10)	*(0.14)*	*(0.23)*	*(0.26)*	*(0.77)*
Ln (1 + tariff $_{ij}$)	-1.95***	-1.28***	-2.06***	-3.68**	2.86
	(0.20)	*(0.24)*	*(0.63)*	*(1.51)*	*(2.40)*
Mills ratio	2.20***	2.00***	1.70***	2.41***	5.30***
	(0.14)	*(0.19)*	*(0.29)*	*(0.46)*	*(1.87)*
Constant	5.95***	6.31***	2.18	6.73***	7.79*
	(0.67)	*(0.93)*	*(2.13)*	*(2.00)*	*(4.19)*
Observations	17112	8236	3983	2119	316
FE Importer, exporter and HS2	Yes	Yes	Yes	Yes	Yes

Notes: figures refer to the II stage of the Heckman regression. In parentheses robust standard error. ***, ** and * indicate significance level at the 1%, 5% and 10%, respectively. Each regression include country fixed effects for importer and exporter, and HS 2-digit products.

Table 4. GMO regulations and trade: IV regressions

Variables	OLS	IV	*Heckman procedure* II stage OLS	II stage IV
GMOwij	1.65***	9.61***	1.93***	8.38***
	(0.36)	*(3.13)*	*(0.35)*	*(2.98)*
Ln Distance $_{ij}$	-0.85***	-0.68***	-1.73***	-1.63***
	(0.03)	*(0.08)*	*(0.06)*	*(0.08)*
Contiguity	0.96***	1.05***	1.27***	1.33***
	(0.09)	*(0.10)*	*(0.09)*	*(0.09)*
Language	0.11	-0.10		
	(0.08)	*(0.11)*		
Colony	-0.15	0.11	0.30***	0.48***
	(0.10)	*(0.14)*	*(0.10)*	*(0.13)*
Ln (1 + tariff $_{ij}$)	-1.61***	-1.28***	-1.95***	-1.71***
	(0.20)	*(0.24)*	*(0.20)*	*(0.23)*
Mills ratio			2.20***	2.32***
			(0.14)	*(0.15)*
Constant	4.64***	-1.26	5.95***	-0.47
	(0.70)	*(2.59)*	*(0.67)*	*(3.03)*
Observations	17112	17112	17112	17112
FE Importer, exporter and HS2	Yes	Yes	Yes	Yes

Notes: In IV regressions the $GMOw_{ij}$ index is instrumented with the weighted average index of the five more close neighbors. In parentheses robust standard error. ***, ** and * indicate significance level at the 1%, 5% and 10%, respectively. Each regression include country fixed effects for importer and exporter, and HS 2-digit products.

Table A.1 GMO regulatory index score and ranking

	Rank	Country Code	Country	Index Value
1	1	ZMB	Zambia	1.00
2	1	ZWE	Zimbabwe	1.00
3	2	AUT	Austria	0.75
4	2	BEL	Belgium	0.75
5	2	CZE	Czech Republic	0.75
6	2	DNK	Denmark	0.75
7	2	FRA	France	0.75
8	2	HUN	Hungary	0.75
9	2	ITA	Italy	0.75
10	2	NLD	Netherlands	0.75
11	2	PRT	Portugal	0.75
12	3	EST	Estonia	0.70
13	3	FIN	Finland	0.70
14	3	JPN	Japan	0.70
15	4	EUN	European Union	0.69
16	5	DEU	Germany	0.65
17	5	GRC	Greece	0.65
18	5	IRL	Ireland	0.65
19	5	LUX	Luxembourg	0.65
20	5	NZL	New Zealand	0.65
21	5	ROM	Romania	0.65
22	5	SVK	Slovak Republic	0.65
23	5	SVN	Slovenia	0.65
24	5	SWE	Sweden	0.65
25	6	NOR	Norway	0.60
26	6	POL	Poland	0.60
27	6	ESP	Spain	0.60
28	6	GBR	United Kingdom	0.60
29	7	AUS	Australia	0.55
30	7	CHE	Switzerland	0.55
31	8	BRA	Brazil	0.50
32	8	CHN	China	0.50
33	9	COL	Colombia	0.45
34	9	KOR	Korea, Rep.	0.45
35	9	RUS	Russian Federation	0.45
36	9	SAU	Saudi Arabia	0.45
37	10	ARG	Argentina	0.40
38	10	THA	Thailand	0.40
39	11	CHL	Chile	0.35
40	11	IND	India	0.35
41	11	IDN	Indonesia	0.35
42	11	MYS	Malaysia	0.35
43	11	MEX	Mexico	0.35
44	11	USA	United States	0.35
45	12	CAN	Canada	0.30
46	12	GTM	Guatemala	0.30
47	12	PHL	Philippines	0.30
48	12	SGP	Singapore	0.30
49	12	ZAF	South Africa	0.30
50	12	TWN	Taiwan, China	0.30
51	12	VNM	Vietnam	0.30
52	13	ISR	Israel	0.20
53	13	JAM	Jamaica	0.20
54	13	KEN	Kenya	0.20
55	14	BGD	Bangladesh	0.15
56	14	PER	Peru	0.15
57	14	LKA	Sri Lanka	0.15
58	14	TUR	Turkey	0.15
59	14	UKR	Ukraine	0.15
60	14	VEN	Venezuela	0.15
61	15	HKG	Hong Kong, China	0.10

Notes: Mean = 0.50; Standard Deviation = 0.226