MEASURING THE EXTENT OF GMO ASYNCHRONOUS APPROVAL USING REGULATORY DISSIMILARITY INDICES: THE CASE OF MAIZE AND SOYBEAN

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Abstract

The purpose of this paper is to assess the extent of asynchronicity in the authorisations of new genetically modified organism (GMO) events between importing and exporting countries. Based on the literature, we systemise the GMO regulatory framework and use dissimilarity and stringency indices to assess the regulatory differences. The results show an increase in the asynchronous approval across the majority of country pairs. However, focusing only on commercialised events and considering only regulatory differences in which the importers are more stringent than the exporters, the asynchronous approval is considerably lower, and the result indicates that the major trade leaders have synchronised their approval status for GMOs over time.

Keywords: genetically modified organism, asynchronous approval, dissimilarity index, regulatory heterogeneity.

1 Introduction

Nowadays the main worldwide cultivated transgenic crops are cotton, maize and soybean and the share of the global area planted with GMO soybean and cotton is 81% and with maize is around 35%. An increasing number of new GMO events[1] have been authorized to be commercialized worldwide and the leaders in the adoption of agricultural biotechnology are also the major exporting countries of these crops which implies a significant share of transgenic crop in international trade (James, 2012). About 70% of global soybean exports origin from the Unites States and Brazil while the imports are mostly concentrated in China and European Union (68%). The United States is the major exporter of maize with a global share of 41% and the main importing destinations are Japan and Mexico accounting for 28% of global imports (USDA, 2012).

Although widely traded, the commercialisation of GMO crops is regulated by domestic regulations, such as regulatory approval for importing or cultivation, labelling policy and traceability, all of which vary considerably among countries (Gruère, 2006; Davison, 2010; Wohlers, 2010; Viju et al., 2011; Vigani and Olper, 2013). This large regulatory heterogeneity, especially as related to varied timings of approvals for commercial use as feed and/or food or for cultivation, has created a situation known as asynchronous approval (AA), which means that the approval of a new GMO event does not occur simultaneously across countries. A similar situation known as "asymmetric foreign approval" occurs when the biotech crop developer does not seek regulatory approval for his products in other importing countries because the crop is suitable to be marketed only in a domestic market (Stein and Rodríguez-Cerezo, 2010). Under these two circumstances a new biotech crop might be cultivated and marketed for food and feed in one or more countries but remain unauthorised in the other countries (Kalaitzandonakes, 2011).

The number of unexpected contaminations is likely to increase as a result of a more widespread cultivation of GMOs in exporting countries but not yet approved commercialization in the importing ones. The potential trade disruptions might become more severe, more frequent, and affect more products (Backus, et al., 2008).

[1] According to the GMO Compass Glossary (GMO-COMPASS, 2013), a GMO event refers to "the unique DNA recombination event that took place in one plant cell, which was then used to generate entire transgenic plants. Every cell that successfully incorporates the gene of interest represents a unique "event". The derived transgenic line is identified by an abbreviation (e.g. Bt11, MON 863)".

Empirical evidence on the economic impact of the AA has been addressed recently in the literature through either *ex ante* studies or *ex post* ones (Kalaitzandonakes, 2011). In the first set of studies different scenarios of import bans, due to the presence of nationally unapproved events, are created and the potential economic impacts such as changes in domestic demand, supply and prices are assessed through partial or general computable equilibrium model (Pérez-Domínguez and Jongeneel, 2011, Kalaitzandonakes et al., 2013, Philippidis, 2010, Henseler et al. 2013). In the second group the economic impacts of specific incidents of unauthorized events such as the discoveries of Starlink maize (Carter and Smith, 2007), the Liberty Link rice (Li et al., 2010) and Triffid flax (Ryan and Smith, 2012) are assessed mainly through partial equilibrium models and times series.

Even though, some authors have been addressing this issue, there is a lack of literature on the assessment of the extent of the AA itself and its potential for trade disruption. According to Kalaitzandonakes et al. (2013) the potential trade disruptions depend on the extent of the asynchronicity in the authorizations of new GMO events between a particular importing country and various exporting ones. In line with this, we answer two research questions: what is the extent of the AA across countries and how did AA change over time?

Considering that the AA approval might be a result of different regulations across countries and taking advantage of a relatively new but growing literature regarding regulatory heterogeneity indicators across countries (Kox and Lejour, 2006; Winchester et al., 2012; Drogué and DeMaria, 2012; Burnquist et al., 2011; Vigani et al., 2012, Li and Beghin, 2012), we apply the heterogeneity index of trade (HIT) developed by Rau et al. (2010) to assess the extent of (dis-)similarity or asynchronous approval across countries. To assess also the regulatory stringency differences between importing and exporting country, we apply the directional heterogeneity index (DHIT) developed by Burnquist et al. (2011) which indicates the potential for trade frictions between two asynchronous countries. Furthermore, we focus on the main importing and exporting countries of maize and soybean which are Argentina, Brazil, China, EU, Japan, Mexico and the United States and consider the regulatory developments within the time period 2000-2013 in order to assess the variation of indices over time since the asynchronous approval is a very dynamic process.

The paper is organized as follows. Section 2 presents the conceptual framework based on the literature review. Section 3 presents the data and the strategy to calculate the indices. Section 4 provides the indices results and, finally section 5 is a discussion of main conclusion.

2 Conceptual Framework

The approval of a new GMO event is the essential criterion for its introduction into the domestic market (Vigani and Olper, 2013), and consequently, the approval is a direct measure that affects market access (Gruère, 2006). This is especially true for countries that have already implemented a comprehensive GMO regulatory framework, as have many developed countries (e.g., the United States, EU, Japan) and some developing countries (e.g., Argentina, Brazil, China). However, many countries are either without regulations or are in the process of implementing GMO regulations (e.g., Bangladesh and Thailand) and the majority of these countries have been trading genetically modified commodities or products derived thereof with no specific regulatory requirements (Gruère, 2011).

As regulatory reviews and approvals for the cultivation and marketing of GMO events are country-specific, there is significant heterogeneity across countries. More stringent regulations will generally require more costly approval and compliance procedures and might also have a more important trade effect (Gruère, 2006; Kalaitzandonakes, 2011; Vigani and Olper, 2013). The crop developers encounter a huge discrepancy in terms of requirements with which they must comply with (e.g., administrative procedures, dossiers, field trials, political decision-making) to obtain the food, feed and environmental authorisations for the import and/or cultivation of a new GMO event. These disparities in the regulatory approval process, including the discrepancies in the amount of time required to complete it, which can be quite long for some countries, arise in the literature as the main drivers of AA approval across countries (Kalaitzandonakes, 2011; Stein and Rodriguez-Cerezo, 2010; Demek and Perry, 2013).

Apart from countries with well-defined regulations, there is a large heterogeneity with respect to the development stages of a regulatory framework across countries (Gruère, 2006) [2]. The countries that have already implemented GMO regulations have authorised the commercialisation of GMO events in their territories, whereas countries without approval and marketing regulations have become more dissimilar in terms of approved events over time, resulting in dissimilar implications for international trade.

AA might become a particularly difficult problem for broadly traded commodities, such as cotton, maize and soybean, when the segregation of authorised and unauthorised GMO events is not feasible or is too costly. In this situation, the commodity trade system would inevitably lead to a Low Level Presence (LLP[3]) and the bilateral trade between two countries might be disrupted (Kalaitzandonakes, 2011). However, the likely impact of a LLP on trade depends widely on the national LLP policies set by the importing country to address the incidence of unauthorised biotech events. Countries have different strategies regarding how to address LLP issues. These strategies vary from zero-tolerance and "technical zero" policies to a no LLP policy. Gruère (2011) has showed that, ceteris paribus, there is more chance that a shipment will be rejected at a low tolerance level than at a high one.

Figure 1 shows the importance of the GMO regulatory framework as the main source of AA and the main determinant of trade disruption. We separated Figure 1 into two parts to highlight the different implications for international trade when considering the environment of a dissimilar regulatory approval process and the complete lack of GMO regulation.

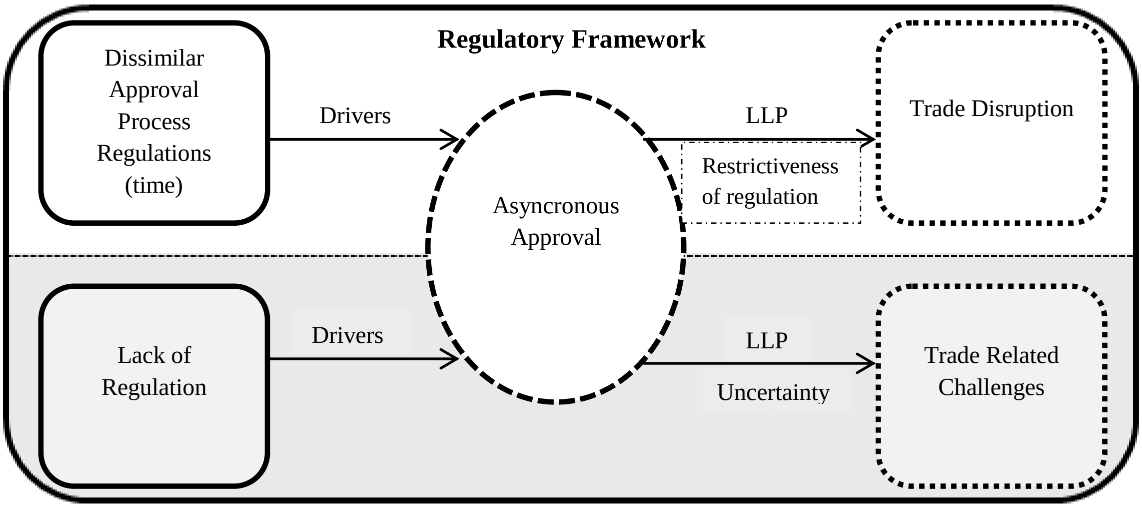

Figure 1. GMO Regulatory Dissimilarity and Potential for Trade Disruption.

Source: Own compilation.

[2] The term "countries with well-defined regulations" include those countries that have already adopted their regulatory framework with a set of safety approval and labeling policies with specific characteristics.

[3] The Codex Guideline for the conduct of Food Safety Assessment of foods derived from Recombinant-DNA Plants defines LLP as low levels of recombinant DNA plant materials that have passed a food safety assessment according to the Codex Guidelines in one or more countries that may on occasion be present in food in importing countries in which the food safety of the relevant recombinant-DNA plants has not been determined (CODEX; 2003). In the academic literature the term has been adopted to describe "the accidental presence of small amounts of biotech events that have undergone full safety assessment and have received regulatory approval for all possible uses in one or more countries but are still unauthorized in others due to regulatory asynchronicity or expiration of their approvals" (Kalaitzandonakes, 2011).

In the white part, above the dashed line in Figure 1, we present the situation of those countries with well-defined regulations, expertise on biosafety issues and GMO detection facilities. Under this circumstance, the large heterogeneity in the approval process across countries drives AA, yet the restrictiveness of the LLP policy in the importing country drives the potential impact on trade. Furthermore, it is worth noting that the asynchronicity increases whenever a country decides to approve a new GMO event. However asynchronous approval and consequently trade disruption only arises when a specific GMO event is approved for commercial use in the exporting country but not in the importing one.

In the grey part of Figure 1, the lack of regulations drives AA across countries, and providing there is no or only limited GMO regulatory requirements, the implication for bilateral trade is uncertain. According to Gruère (2011), many developing countries are in the process of developing their GMO regulations although most have continued to accept the presence of unauthorised GMO events in import shipments. Nonetheless, considering the uncertain environment, some trade-related challenges may arise at any time as these countries may decide to enforce a comprehensive biosafety regulation with import authorisation procedures for GMO events or decide to conduct rigorous tests and monitoring of GMO crops at the port of entry.

3 Methodological Approach

3.1 Indices of Regulatory Dissimilarity

The heterogeneity index of trade (HIT) was developed by Rau et al. (2010) and it is defined and calculated on a bilateral basis by comparing standards and regulations set by an importing and an exporting country. As such, the HIT index provides information about the dissimilarity of requirements across countries, and it is suitable to measure the extent of AA between two countries.

Based on the Gower index of (dis-)similarity, the HIT index for trade between importing country *j* and exporting country *i* at point *t* for a given product *k* (maize and soybean) is defined as follows:

$$HIT_{kijt} = \frac{1}{M}\left(\sum_{m=1}^{M} DS_{kijmt}^{HIT}\right) \tag{1}$$

Where DS_{kijmt}^{HIT} is the dissimilarity measure for the GMO event *m* and *M* is the total number of GMO events for each product. For ordinal data the calculation is defined as in equation 2:

$$DS_{kijmt}^{HIT} = \frac{\left|r_{kimt} - r_{kjmt}\right|}{\max(r_{kmt}) - \min(r_{kmt})} \tag{2}$$

where r is the rank of the approval status for a GMO event *m* and ranges from 1 to 4 in which the value 1 represents the most restrictive approval status (event is not approved) and the value 4 is the less restrictive approval status (event is approved for all uses). The ordinal information r is ranked as follows:

r = 1 if the GMO event is not approved for any use;
r = 2 if the GMO event is approved only for feed;
r = 3 if the GMO event is approved only for food;
r = 4 if the GMO event is approved for food and feed.

It is worth noting that import approval is the type of approval relevant in our paper since we are interested in differences that may impact on trade. If we consider EU, for instance, few cultivation approvals have been delivered, so far. However, significant number of GMO events has been approved for importing into the EU.

The HIT index ranges between [0,1] and increases with differences in regulations. For HIT = 0, there is no difference in the approval status at point *t* between the importing and exporting country, but as the index approaches the unit value (HIT = 1), this regulatory difference increases. By averaging the sum of dissimilarity scores of each GMO event by the total number of GMO events, the index becomes invariant to the regulation intensity which is an important property since the number of GMO events varies depending on the product.

Burnquist et al. (2011) extended the HIT index to a directional heterogeneity index (DHIT), which is pertinent for evaluating differences in regulatory heterogeneity when the relative strictness of requirements between importer and exporter is relevant for the objective of the analysis. To evaluate the impact of regulatory dissimilarity upon trade, it is important to focus only on those aspects of regulatory heterogeneity where the importing country is stricter than the exporting country as this may involve compliance costs for exporting firms. The DHIT is one way to express the magnitude of the regulatory dissimilarity.[4] Therefore, the link between asynchronous approval between important exporting country and potential trade friction might be considered through the DHIT index. Similar to the formulation indicated in equation (1), the DHIT index is calculated as follows:

$$DHIT_{kijt} = \frac{1}{M}\left(\sum_{m=1}^{M} DS_{kijmt}^{DHIT}\right) \quad when\, DS_{kijmt}^{DHIT} \geq 0 \tag{3}$$

However, this calculation involves a pre-selection of the dissimilarity measure to express only the relatively more stringent measures directed to exporters. For that purpose, the dissimilarity measure for the DHIT is calculated as:

$$DS_{kijmt}^{DHIT} = \frac{r_{kimt} - r_{kjmt}}{\max(r_{kmt}) - \min(r_{kmt})} \tag{4}$$

The calculated values of the DS are selected to compose the DHIT index following specific procedures. A positive value for the dissimilarity measure $DS_{ijmt}^{DHIT} > 0$ indicates that the requirements presented by the importing country *j* are stricter for an event *m* than those of the exporting country *i*. In this case, this is an indication that the exporting country might have to make adjustments to comply with the requirements. These are consequently the values that are included in the DHIT calculation. All negative dissimilarity measures, $DS_{ijmt}^{DHIT} < 0$, are not included in the DHIT calculation because these values suggest that the regulations introduced by the importing country *j* for characteristic *m* are the same or less restrictive than the one of the exporting country *i*. Not-established regulations represent the most dissimilar case in our indices calculation. The asynchronous approval is higher when the countries have different approval processes or when they do not regulate (or approve).

If there is a specific GMO event that is approved for both commercial uses (food and feed) in the exporting country, but it has not yet been approved in the importing country, the exporters might have problems exporting to this specific country. Accordingly, this dissimilarity is taken into account in the index calculation by equation (4). On the other hand, if the importing country has already approved the event for both commercial uses (food and

[4] With the "Protectionism Index", Li and Beghin (2012) showed another way of accounting for stricter import regulations.

feed) and the exporting country has not, we are faced with a dissimilarity that is captured by the HIT, but not by the DHIT.

The DHIT index also ranges between [0,1] where values close to zero suggest lower stringency with respect to importer requirements. Values close to one indicate that requirements enforced by the importers are relatively more stringent than those of the exporting countries.

Compared to its initial versions, we have extended both indices with a time dimension to consider dynamic developments over time. In addition, we have adopted the simplest approach regarding the weighting of different events in that all GMO events have the same weight (and importance) in the index calculation.

An important issue considered in our index calculation is the proximity of the respective GMO event to the market (Stein and Rodríguez-Cerezo, 2010). Following these authors, we have considered two groups of GMO events: 1) all GMO events that comprise the events authorised in at least one country, and which are either commercialised or not yet commercialised, but whose commercialisation depends only on the decision of the developer and 2) a commercial event, which is a sub-group of 1 and which comprises only the GMO events currently marketed in at least one country[5].

In the HIT index calculation, both groups of events are considered as the aim is to verify where countries stand in terms of their regulatory approaches towards authorised GMO events. However, in the DHIT calculation, only those events that are currently marketed in at least one country worldwide are included, because the aim is to measure AA that might cause trade friction due to commercialised GMO events.

3.2 Data Collection

The main data sources are the ISAAA/GM Approval Database (ISAAA, 2013) and the CERA GM Crop Database (CERA, 2013), which provide approval process information regarding GMO events that are identified by their names and codes. A summary of regulatory approval is provided for each event with information on the countries that have already authorised the event, the first year of approval and the type of approval (food, feed or cultivation). Information about events currently marketed in at least one country worldwide is provided by the Biotechnology Industry Organization through the Biotradestatus website database (BIO, 2013). Moreover, additional information regarding the national GMO regulation aspects ruling GMO cultivation and commercialisation is provided by the Foreign Agricultural Service (FAS) of the United States Department of Agriculture (USDA) through the Global Agriculture Information Network (GAIN) reports on biotechnology (USDA/FAS, 2013). Based on this data, we built a dynamic data set which takes into account information on 185 authorized GMO events for cotton, maize and soybean across 41 countries over the period 2000-2013.

4 Results and Discussion

4.1 Approved GMO Events and Regulatory Differences

Focusing on the number of approved events for maize and soybean worldwide, Figure 2 indicates a rather dynamic development in the approval of new GMO events, particularly for maize, whose number of approved events jumped from 12 to 115 between 2000 and 2013. In the case of soybean the number of approved events increased from four to 20 over the same period of time.

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[5] Based on the market status for each event in 2013 (event is commercialized or not) and based on the first year of approval worldwide we could categorize the event as commercialised for the period 2000 and 2007.

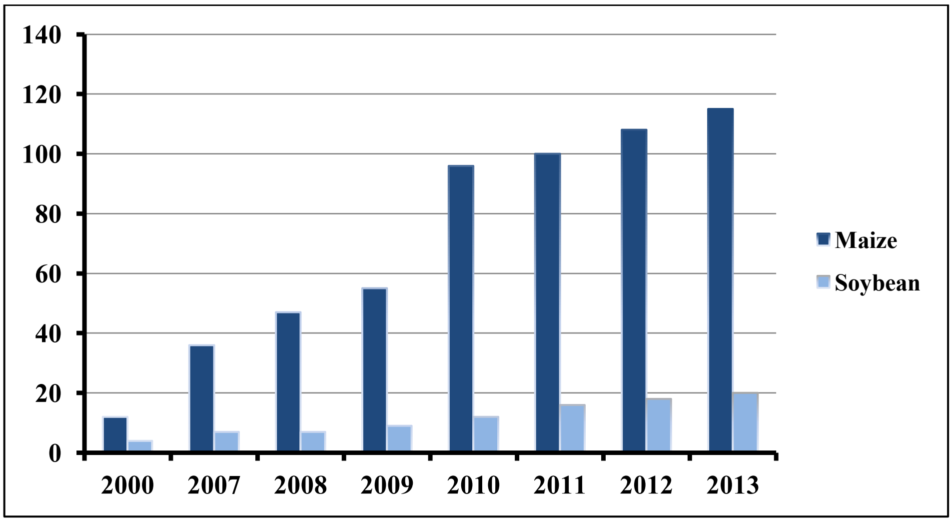

Figure 2. Change in the stock of approved GMO events worldwide.

Source: Own compilation.

As not all approved events are eventually commercialised, the significant increase in the stock of approved events worldwide does not necessarily mean a substantial increase in commercialised events (see Table 1). The case of soybean illustrates this possibility as only 20% of all approved GMO events are currently commercialised. In contrast, 40.8% of all approved events for maize are commercialised in at least one country.

Table 1. Number of commercialized events in at least one country worldwide by year

	2000	2007	2013
Maize	9	29	47
Soybean	2	3	4

Source: own compilation.

Regarding the seven main importing countries and exporting ones we are considering in this paper, Table 2 summarizes the total number of approved GMO events over the period 2000-2013. In 2000, the United States emerged as the leaders in the approval of new biotechnologies, and only a few countries had approved GMO events for maize or soybean. These figures changed considerably by 2007, as other countries moved towards the adoption of GMO regulations and consequently implemented an approval process for GMO events. For instance, Japan had not approved any GMO events by 2000. However, after setting the regulatory stage in 2001, the situation changed quickly, and in 2013, Japan is the recognised leader in the number of approved events for maize (103). The United States and Mexico maintained their positions as leaders in approved events for soybean.

Considering that in the year 2013 there were 15 approved GMO events for soybean and 115 for maize in the world, table 2 indicates that the leading players in international trade are also the major player in approval of GMO events with the exception of the EU. However, even among the most active countries, the number of approved events varies considerably indicating the existence of asynchronous approvals and related potential for trade frictions.

Table 2. Total number of approved GMO events by country and year

Country	Maize 2000	Maize 2007	Maize 2013	Soybean 2000	Soybean 2007	Soybean 2013
ARG	3	7	21	1	1	4
BRA	-	2	19	1	1	5
CHN	-	9	15	-	1	8
EU	5	10	30	-	1	7
JPN	-	33	103	-	5	11
MEX	-	23	57	1	3	14
USA	10	31	56	4	6	14

Note: ARG=Argentina, BRA=Brazil, CHN=China, EU=European Union, JPN=Japan, MEX=Mexico, USA=United States.
Source: own calculation.

Since the impact of asynchronous approval on trade depend widely on the restrictiveness of GMO regulations adopted by the importing countries, any analysis should also take into account the present regulatory framework. We highlight in Table 3 four key aspects of GMO regulation which might determine the impact on trade. The first one is the existence of a well-defined GMO regulation to address the approval process of new GMO event and its commercialization. The major players had already implemented their GMO regulation by 2005 which means that dissimilarity in GMO approval process drove the asynchronous approval across them. The other three ones are related to the restrictions regarding the importation of non-approved GMO events and as can be observed in Table 3 the main players only allow the entry of approved GMO event in their territories and they have monitoring and testing programs which encompasses the government agencies, public and private laboratories to certify it. Additionally, it can be noticed that the main importing countries set a zero-tolerance threshold for LLP of unapproved events. The exception is Mexico which manages the GMO LLP in the food and feed chain within the scope of the Codex Alimentarius. The restrictiveness in the LLP threshold means that the presence of a non-approved GMO event in the import shipments of the main importing countries can indeed lead to rejections and trade disruptions.

Table 3. Different national GMO regulation aspects

GMO regulation aspects	ARG	BRA	CHN	EU	JPN	MEX	USA
Approved GMO Law - year	2003	2005	2002	2003	2001	2005	1986
Presence of non-approved GMO event through importation	No	No	No	No	No	No	No
Monitoring and testing	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Threshold value (%)	-	-	0	0.1	0		-

Note: "*In 2011, the EU Commission clarified its zero threshold policy for unapproved GMOs by setting the threshold level for such GMOs destined for feed markets at 0.1% – the lowest level where GM test results are satisfactorily reproducible between official laboratories. This level has been termed ''practical zero.'' No such threshold has been defined for unapproved GMOs destined for food uses" (Kalaitzandonakes et al., 2013:6).*
Source: own compilation.

4.2 Regulatory dissimilarity for all GMO events across countries

Table 4 shows the HIT index results by product, pair of countries and selected years considering all GMO events. The HIT index has been calculated following equation (1) and it measures the dissimilarity in the approval status for a pair of countries for a GMO event. The result is a symmetric matrix, which means, for instance, that the difference between Argentina and Brazil is the same as that between Brazil and Argentina.

Several interesting patterns emerge from Table 4. First of all, the index has changed considerably over time showing the dynamics behind the approval process of GMO events. An increasing index over time indicates a diverging regulatory path between a pair of countries, a decreasing index shows mutual "regulatory accordance" or harmonization over time. In general, it is observed that the index has increased for the majority of pair of countries which means that the countries have become more dissimilar in terms of their approval status for GMO events over time. In 2000, only few countries had already introduced GMO regulations and cultivation and even commercial use of GMO crop were not allowed in the majority of them. Consequently, they were more similar in terms of approved events and the HIT index assumes a zero values for many pairs of countries. A different pattern can be observed for the United States as a steady decrease in its index value for the study period is evidenced. Since the early nineties the United States has been approving GMO events for cultivation and consumption and is the leading country in the development and adoption of GMO crop. As other major players introduced their GMO regulations and started approving GMO events the dissimilarities between the United States and other countries decreased. This was the case for Japan which approved the GMO regulation in 2001, for the EU in 2003 and Brazil and Mexico in 2005.

Table 4. HIT index by product, pair of countries and selected year – all GMO events

Product Maize - HIT																					
	ARG			BRA			CHN			EU			JPN			MEX			USA		
	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013
ARG				0.25	0.14	0.06	0.25	0.11	0.14	0.17	0.25	0.23	0.25	0.72	0.73	0.25	0.4	0.29	0.58	0.67	0.32
BRA							0.00	0.19	0.14	0.42	0.33	0.2	0.00	0.86	0.73	0.00	0.41	0.28	0.83	0.81	0.34
CHN										0.42	0.19	0.22	0.00	0.67	0.77	0.00	0.38	0.31	0.83	0.61	0.36
EU													0.42	0.64	0.65	0.42	0.33	0.32	0.75	0.58	0.33
JPN																0.00	0.53	0.65	0.83	0.22	0.55
MEX																			0.83	0.47	0.33
USA																					

Product Soybean - HIT																					
	ARG			BRA			CHN			EU			JPN			MEX			USA		
	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013
ARG				0.00	0.00	0.05	0.25	0.00	0.30	0.25	0.14	0.25	0.25	0.57	0.35	0.08	0.24	0.43	0.75	0.71	0.50
BRA							0.25	0.00	0.25	0.25	0.14	0.20	0.25	0.57	0.40	0.08	0.24	0.42	0.75	0.71	0.55
CHN										0.00	0.14	0.15	0.00	0.57	0.35	0.17	0.24	0.43	1.00	0.71	0.40
EU													0.00	0.71	0.40	0.17	0.29	0.38	1.00	0.86	0.45
JPN																0.17	0.43	0.45	1.00	0.43	0.35
MEX																			0.83	0.57	0.53
USA																					

Source: own calculation using our data set.

Focusing on the current AA situation in the year 2013, for maize, we find that the most asynchronous pair of countries is Japan-China (0.77). It is also noted that Japan is by far the most dissimilar country when compared with its counterparts. The situation is different for soybean in which the most asynchronous country when compared with its counterparts is the United States. On the other hand, Argentina-Brazil is the most similar pair both for maize and soybean. In general, it is noticed higher asynchronous approval for soybean than maize, except for Japan.

4.3 *Potential trade frictions through more strict regulations for commercial events in importing countries*

While the HIT index indicates the extent of the asynchronous approval across countries, the DHIT index provides information about the potential trade friction that might arise from the asynchronous approval. Therefore, in this calculation only commercial events are considered and only the dissimilarities indicating that the approval status of the importing country is more stringent than the exporting one are summed up.

Table 5 presents all results by pair of countries, product and selected years. The DHIT index is not symmetric as the HIT is because the direction of the dissimilarity matters so is relevant to consider a country as a benchmark. The exporting countries are shown in the columns and the importing ones are shown in the rows. The higher the DHIT value between a country pair, the more stringent GMO approval regulation exists in the importing country compared to the exporting one. This indicates that compliance costs for exporting firms with importing country regulations may occur leading to trade frictions or trade deflection.

Table 5. DHIT index by product, pair of countries and selected year – commercial events

Product Maize - DHIT

	ARG			BRA			CHN			EU			JPN			MEX			USA		
	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013
ARG	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.10	0.06	0.22	0.21	0.26	0.00	0.72	0.54	0.00	0.37	0.33	0.44	0.62	0.43
BRA	0.33	0.17	0.07	0.00	0.00	0.00	0.00	0.24	0.09	0.56	0.34	0.24	0.00	0.90	0.56	0.00	0.46	0.33	0.78	0.79	0.45
CHN	0.33	0.03	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.56	0.14	0.30	0.00	0.66	0.66	0.00	0.32	0.41	0.78	0.55	0.53
EU	0.00	0.10	0.14	0.00	0.07	0.11	0.00	0.10	0.06	0.00	0.00	0.00	0.00	0.62	0.45	0.00	0.28	0.24	0.44	0.52	0.32
JPN	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.01	0.78	0.03	0.06
MEX	0.33	0.10	0.14	0.00	0.02	0.12	0.00	0.13	0.11	0.56	0.11	0.17	0.00	0.48	0.37	0.00	0.00	0.00	0.78	0.38	0.34
USA	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.22	0.00	0.02	0.00	0.14	0.19	0.00	0.02	0.11	0.00	0.00	0.00

Product Soybean - DHIT

	ARG			BRA			CHN			EU			JPN			MEX			USA		
	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013	2000	2007	2013
ARG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.25	0.00	0.67	0.25	0.00	0.22	0.17	0.50	0.67	0.25
BRA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.25	0.00	0.67	0.25	0.00	0.22	0.17	0.50	0.67	0.25
CHN	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.33	0.22	0.00	1.00	0.67	0.00
EU	0.50	0.33	0.00	0.50	0.33	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.33	0.44	0.00	1.00	1.00	0.00
JPN	0.50	0.00	0.25	0.50	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.33	0.00	0.17	1.00	0.00	0.00
MEX	0.17	0.11	0.25	0.17	0.11	0.25	0.00	0.11	0.33	0.00	0.00	0.33	0.00	0.56	0.25	0.00	0.00	0.00	0.67	0.56	0.25
USA	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00

Note: Colum = exporter and row=importer
Source: own calculation using our data set.

Although the HIT value has risen for the major players, thus indicating an increasing AA over time, the same pattern is not observable for the DHIT. Considering only commercial events, the results indicate that the main exporting countries (Argentina, Brazil and The United States) have synchronized their approved events with the main importing ones over time. The case of soybean is emblematic of this synchronicity given that, in 2013, the exporting countries are found to be perfectly synchronised with China and the EU, indicating that these importing countries are not more stringent in their approval status of GMO events.

Despite the movement towards a more synchronised approval status as a whole, some potential for trade disruption is emphasised by the highest DHIT value for maize in the United States-China (0.53) country pair followed by the United States-Mexico (0.34) pair and the United States-EU (0.32) pair. Considering the zero-tolerance level that China and the EU have established for unapproved events, the bilateral trade between the United States and these two countries might be disrupted any time. Furthermore, considering Argentina and Brazil as exporters the more stringent importing countries are China followed by Mexico and EU, however the DHIT value is not high relatively to the United States.

5 Conclusion

Using two dissimilarity indices and drawing on a comprehensive database, we measure both the extent of the asynchronicity in the authorisation of GMO events and the differences in stringency between importing and exporting countries with respect to maize and soybean for the period 2000 to 2013. With an increase of approved GMO events for maize from 12 to 115, we observe a rather dynamic development in the approval of GMO events between 2000 and 2013. However, the regulatory frameworks of countries to address these new technologies move at different paces that results in a situation that is characterised by AA processes and potential trade-related compliance and deflection issues.

Using the regulatory dissimilarity index HIT and focusing on all GMO events, an increase in the regulatory dissimilarity across country pairs is observed, thus indicating that the countries have become more dissimilar in terms of their approval status for GMO events over time. The approval status for GMO events differs considerably across the major players in the maize and soybean markets which suggest a relatively weak harmonization of GMO approval events among them and existence of AA.

However, when we consider the asymmetric stringency between importing and exporting countries and focus only on commercialised events, AA that might disrupt trade is considerably lower for the major leaders in trade, thus indicating that they have synchronised their approval status for the GMO over time. This result may reveal the strategy of these countries, especially exporting countries, to address AA and reduce trade frictions by selecting GMO events to be commercialised only when the loss of sensitive import markets is not a serious thread, as already shown by Berwald et al. (2006). In this context they may act strategically and wait for the approval process in the main importing markets before launching the event in the market.

Despite the observed synchronicity across countries when we examine the maize market we observe a potential for trade disruption mainly for the bilateral trade between the United States and its partners China, Mexico and European Union. As there is a diversified GMO events portfolio currently in the "waiting line" and there is no guarantee that the synchronicity between the leading countries will persist in the near future, it is likely that problems of asynchronous approval will become more urgent.

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