DOI: 10.1093/aepp/ppw021

Applied Economic Perspectives and Policy (2017) volume 39, number 2, pp. 286–312.
doi:10.1093/aepp/ppw021
Advance Access publication on 3 November 2016.

Submitted Article

Are GMO Policies "Trade Related"? Empirical Analysis of Latin America

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Submitted 15 June 2016; editorial decision 2 September 2016.

Abstract *This paper empirically examines whether GMO policies are "trade related" for countries in Latin America (LA). First, we use the Balassa index to assess the "revealed comparative advantage" of LA countries. We find that LA countries have a revealed comparative advantage in GMO industries relative to the world, and that intra-regional trade in these industries is modest relative to external trade. Second, we estimate the Gravity model to examine the effects of importers' GMO policies on Argentina and Brazil's bilateral exports of soybeans and maize. We find that strong GMO policies in importers have a negative effect on Argentina's bilateral exports of soybeans (an industry and country with historically high GMO content). Further, we find that past GMO policies are a strong determinant of Argentina's future bilateral exports, and that the negative trade effects of strong GMO policies are increasing over time. In contrast, we find a weaker relationship between the GMO policies of importers and Brazil's bilateral exports (consistent with Brazil's more recent increases in GMO content). These findings for Argentina and Brazil provide a benchmark for other developing countries that are looking for guidance on servicing trading partners with diverse GMO policies.*

Key words: Empirical studies of trade, trade policy, Latin America, genetically modified organisms.

JEL codes: F13; F14, Q17.

This paper examines policies and trade related to goods with a high content of genetically modified organisms (GMOs). We focus on Latin America (and Argentina and Brazil in particular), and on their trade in soybeans and maize (the industries with the largest shares of GMO content globally). We refer to these industries as "GMO-intensive" or "GMO industries" for brevity. Our broad goal is to explore the extent to which GMO policies are "trade-related."

The motivation for this research is as follows. The history of global GMO adoption dates back to 1995, when the first GMO crops were commercialized in the United States. The development of these crops stemmed largely from private-sector innovation and was directed primarily toward crops intended for monoculture cultivation in technologically-developed settings. Argentina, with a highly developed agricultural sector and climate and soil conditions resembling those of the United States, was an early adopter, legalizing GMO crop cultivation in 1996. Due to extensive smuggling of seeds out of Argentina through Paraguay to Brazil and Uruguay, Argentina's neighbors soon found themselves with illicit GMO sectors of their own (Gaisford and Kerr, 2004). Indeed, GMO maize, soybeans, cotton, and canola thrived on the pampas of Paraguay and Uruguay and throughout southern Brazil, obliging Mercosur governments to legalize GMO crops and codify their regulation (Silva Gilli, 2010).

From these beginnings, Latin America (LA) as a region, and Mercosur countries in particular, have distinguished themselves globally by their rapid adoption of GMO technologies.[1] Eleven LA countries have legalized GMO crops as of 2013, representing half of all developing world adopters.[2] Indeed, 40% (or 71.2 million hectares) of global GMO crop hectares were located in LA as of 2013, and rates of expansion show no signs of slowing (see James 2013).

Nevertheless, policy makers charged with managing this transition find themselves confronted with several challenges. First, many LA agricultural producers have a history of exporting to either the United States or the European Union (EU). However, the EU's resistance to GMOs and strict tracking and labeling requirements means that countries choosing to adopt GMOs may jeopardize export markets for their products. Thus, trade relationships provide a context for adoption and regulation decisions. Second, countries face the technical challenges of maintaining their own national regulations as well as complying with international standards such as those established in the Codex Alimentarius (Joint FAO/WHO Codex Alimentarius Commission, 1992) (which defines international standards to protect consumer health and promote fair trade practices) and the Cartagena Protocol on Biosafety (Secretariat of the Convention on Biological Diversity, 2005) (which includes procedures for trans-boundary movements of living modified organisms). That is, countries need to develop their institutional infrastructure for managing national and international regulations relevant to GMO technologies.

In short, the countries of LA, and Mercosur in particular, are at the forefront of the developing world in grappling with the trade-related aspects of GMO policies. In this way, LA's experience provides a baseline for other developing countries contemplating how to manage the trade and policy challenges of this evolving technology area.

The body of economics literature on GMOs is modest but growing. The existing scholarly research falls into four overlapping categories covering production, consumption, international trade, and policy.[3] The body of

[1]Mercosur is a customs union consisting of Argentina, Brazil, Paraguay, Uruguay and Venezuela.

[2]Latin American countries that have legalized GM crops include Argentina, Brazil, Bolivia, Chile, Colombia, Costa Rica, Cuba, Honduras, Mexico, Paraguay, and Uruguay.

[3]Production studies tend to focus on the implications of GMO adoption for the welfare of producers (e.g., farmers). Farm-level effects of GMO adoption include changes in the profitability of crops associated with (reduced) pesticide use and (increased) yields, relative to the conventional counterparts. Additional

international trade literature on GMOs is in its infancy. Existing studies tend to focus on the implications of country differences in GMO adoption for the welfare of consumers, producers (i.e., farmers) and innovators (i.e., seed firms), and for the trade and welfare of nations in aggregate (e.g., Tothova and Oehmke 2004 and 2005; Anderson, Jackson, and Nielsen 2005; Hareau et al. 2005; Lence and Hayes 2005; Frisvold, Reeves, and Tronstad 2006; Plastina and Giannakas 2007; Veyssiere 2007; Anderson, Valenzuela, and Jackson 2008; Anderson 2010; Choi 2010; and Swinnen and Vandemoortele 2011). The primary modeling approaches include computable general equilibrium, game theory, and partial equilibrium models. Empirical trade studies of GMOs are few. This is due to the absence of data on GMO trade that is distinct from traditional crops, and the absence of data on GMO regulations. The latter data constraint has been recently addressed by Vigani, Raimondi, and Olper (2012) who create an index measure of the stringency of six types of GMO regulations for a sample of sixty countries. This measure allows for new empirical work and improves substantially on the approach of using dummy variables as policy measures.

Trade policy studies tend to be motivated by two real world observations.[4] One is that countries differ dramatically in their policies toward GMOs. Studies on this theme are motivated by the conflict between countries with relatively strict GMO policies (e.g., EU and Japan) vs. those with more relaxed policies (e.g., the United States, Canada, Argentina, and Brazil). The second observation is that countries make GMO adoption decisions under alternative policy scenarios including those of their trading partners. Studies on this issue are motivated by the dilemma faced by many developing countries about whether to adopt GMOs when the policies of their trading partners diverge. The dilemma is that such countries have an interest in maintaining their export markets for non-GMO products to countries with restrictive GMO policies, while at the same time taking advantage of GMO's benefits.

The literature on GMOs in LA is relatively more developed given the region's global dominance in GMO crop production and its complex policy environment. This research includes country case studies that examine policy regimes or individual policy areas such as biosafety or intellectual property rights (e.g., Qaim and de Janvry 2003 and 2005; Gaisford and Kerr 2004; Falck-Zepeda et al. 2009; and Silva Gilli 2010; Mitre and Reis 2014). However, to our knowledge there are no econometric studies for LA that quantify the effects of GMO policies on bilateral trade. Our paper seeks to fill this gap in the literature.

intangible impacts include the time savings to farmers, health and environmental consequences associated with changes in pesticide use, and biodiversity consequences. Consumption studies tend to focus on the implications of GMOs for consumer preferences. These studies consider the characteristics of consumer preferences that influence the acceptance or rejection of GMOs. Policy studies consider the economic and political determinants and effects of GMO-related policies. Policy studies overlap extensively with the consumption, production, and trade literatures. However, they also consider the "political economy" factors that influence policy adoption decisions, as well as the institutions for managing disputes. For a literature review, see Qaim (2009).

[4]*For a review of the recent literature, see Vigani and Olper (2015). For recent policy studies, see Basu and Qaim (2007), Beckmann, Soregaroli, and Wesseler (2006), Desquilbet and Bullock (2009), Disdier and Fontagne (2010), Gaisford, Hobbs, and Kerr (2007), Gruere (2006), Gruere, Carter, and Farzin (2009), Just, Alston, and Zilberman (2006), Perez (2007), Pray, Bengali, and Ramaswami (2005), and Young (2011).*

The contributions of our paper are most closely related to the research of Vigani, Raimondi, and Olper (2012), who examine the effects of GMO policy harmonization on bilateral trade globally. In contrast to their study, we focus on LA, and particularly on Argentina and Brazil as leaders in the region. We examine the effects of importing countries' GMO policies on the bilateral exports of Argentina and Brazil. Our focus on Argentina and Brazil has two important advantages. In contrast to Vigani, Raimondi, and Olper (ibid), we can reasonably assume that the exports we examine are GMO intensive, because more than 90% of soybean and maize production was GMO in Argentina and Brazil during the years that we consider. This is important because trade data do not distinguish between GMO and traditional crops. Second, our focus on Argentina and Brazil is advantageous because these countries are leaders in the developing world in GMO adoption. Currently, the fastest-growing GMO adopters are developing countries (i.e., China, Paraguay, Pakistan, South Africa, Uruguay, Philippines, and Mexico), and these countries are looking for guidance on servicing trading partners with diverse policies. Our study provides a benchmark for these developing countries.

The purpose of our paper is to examine the exports of LA countries into a global economy where countries differ in their GMO policies. We begin by constructing measures of "revealed comparative advantage" using the Balassa index. We use these measures to assess the comparative advantage of LA countries in GMO industries relative to the region and relative to the world. Second, we estimate the Gravity model of international trade. We use this model to examine the effects of importing country differences in GMO-related policies on the bilateral exports of Argentina and Brazil in soybeans and maize. Our overarching goal is to answer the question: To what extent are GMO policies "trade related"?

The remainder of the paper is organized as follows. The next section examines the revealed comparative advantage of LA countries using the Balassa index. The following section presents the theoretical model for examining policies and bilateral trade. The subsequent section considers econometric methods and data, followed by a section that presents the empirical findings. The last section provides conclusions.

Revealed Comparative Advantage

In this section we examine the patterns of comparative advantage of LA countries in the GMO industries. We use a measure of revealed comparative advantage known as the Balassa index.[5] This is an empirical measure of the extent to which a given country specializes in the export of a particular good, compared with a reference set of countries.

We calculate three alternative expressions of the Balassa index. Our baseline is

$$RCA_{ijw} = \ln\ (X_{ij}/X_{it}) \ - \ \ln\ (X_{wj}/X_{wt}) \tag{1}$$

where RCA_{ijw} is the revealed comparative advantage of exporting country i

[5] *The index of revealed comparative advantage originates from early work by Balassa (1965, 1989). More recent extensions or adaptations of the index can be found in Yu, Cai, and Leung (2008).*

in industry j relative to the reference region w, X_{ij} is the exports of country i in industry j, X_{it} is total exports of country i in all industries, X_{wj} is world exports in industry j, and X_{wt} is total world exports in all industries. This index reflects the share of industry j in country i's total exports relative to the share of industry j in total world exports. In this log form, the index values are symmetric around 0. Values greater than 0 indicate a revealed comparative advantage, and values less than 0 indicate a revealed comparative disadvantage. Further, the larger the absolute value of the index, the stronger the advantage or disadvantage. In the baseline expression (1) the reference set of countries is the world. Thus, RCA is defined for a given country relative to the world.

Our second expression of the Balassa index is the "regional" expression

$$RCA_{ijr} = \ln\ (X_{ij}/X_{it})\ -\ \ln\ (X_{rj}/X_{rt}) \tag{2}$$

where r indexes a given region that we define as LA. Thus, X_{rj} is LA exports in industry j, and X_{rt} is total LA exports in all industries. In expression (2), index values greater than 0 indicate that country i has a RCA relative to all countries in LA.[6]

Finally, we construct a variation of the Balassa index for internal trade within LA. To this end, we redefine export (X) in expression (2) as exports to destinations within LA. Thus, the numerator in equation (2) is the share of industry j in country i's exports to other LA countries relative to the share of industry j in LA's internal regional trade. In this third variation, RCA is defined for a given country's *exports* to LA, relative to all other countries in LA.

We use these variations of the Balassa index to answer three questions with respect to the GMO industries: (1) What are the patterns of comparative advantage of each Latin American country relative to the world? (2) What are the patterns of comparative advantage of each Latin American country relative to other countries in the region? (3) What are the patterns of comparative advantage of each Latin American country in intra-regional trade?

Table 1 reports the measures of RCA for 2011. Panel (a) shows countries' RCA relative to the world. As shown, Brazil, Argentina, and Paraguay have a strong RCA relative to the world in the broadest range of industries. This RCA is particularly strong for Argentina in soya oil fractions (4.33); for Brazil in soya beans (2.27); and for Paraguay in soya beans (4.14) and soya oil fractions (4.11). In contrast, the other LA countries have a revealed comparative disadvantage in a majority of the industries. The exceptions are that Uruguay has a RCA in soya beans (2.55), Bolivia in soya oil fractions (3.32), Mexico and Colombia in maize flour (1.21 and 2.34), and Costa Rica in maize flour (3.10) and soya oil fractions (0.16). These findings suggest that all of the countries have a RCA in at least one of the GMO industries relative to the world; and Argentina, Brazil, and Paraguay are export leaders.

Panel (b) reports countries' revealed RCA relative to the LA region. As one would expect, these values are more modest than those in panel (a) because the region as a whole has a RCA in the industries. Even so, the

[6]*We define Latin America to include Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras, Mexico, Panama, Paraguay, Peru, Uruguay, and Venezuela. Excluded countries have negligible volumes of soybeans and maize exports (in 2011).*

Table 1 Revealed Comparative Advantage, 2011

(a) Relative to world

Crops	Brazil	Argentina	Paraguay	Uruguay	Bolivia	Mexico	Colombia	Chile	Costa Rica
Maize unmilled	1.50	3.12	3.29	−1.01	−2.94	−2.82	−3.26	0.00	−7.48
Maize (corn) flour	1.64	1.04	−0.38	−3.89	−2.07	1.21	2.34	−8.84	3.10
Soya beans	2.27	2.29	4.14	2.55	−1.34	−9.62	−6.28	−3.09	−6.98
Soya oil, fractions	1.77	4.33	4.11	−2.70	3.32	−3.95	−1.05	−9.21	0.16
Cotton Seed	0.23	−0.17	−9.21	−9.21	−9.21	−2.88	−9.21	−9.21	−0.43
Cotton oil, fractions	−0.08	2.56	0.82	−9.21	−9.21	−5.56	−5.36	−9.21	−9.21
Rape or colza	−1.11	2.77	4.89	−9.21	−9.21	−9.21	−9.21	2.65	−9.21

(b) Relative to Latin American region

Crops	Brazil	Argentina	Paraguay	Uruguay	Bolivia	Mexico	Colombia	Chile	Costa Rica
Maize unmilled	0.26	1.88	2.05	−2.25	−4.18	−4.07	−4.50	−1.24	−8.72
Maize (corn) flour	0.43	−0.17	−1.59	−5.11	−3.28	−0.01	1.13	−10.05	1.89
Soya beans	0.90	0.92	2.78	1.19	−2.71	−10.98	−7.64	−4.46	−8.35
Soya oil, fractions	−0.41	2.15	1.93	−4.88	1.14	−6.13	−3.23	−9.21	−2.02
Cotton Seed	1.06	0.66	−9.21	−9.21	−9.21	−2.05	−9.21	−9.21	0.40
Cotton oil, fractions	−0.42	2.22	0.48	−9.21	−9.21	−5.90	−5.69	−9.21	−9.21
Rape or colza	−2.31	1.57	3.69	−9.21	−9.21	−9.21	−9.21	1.45	−9.21

(c) Intra-Regional trade in Latin America

Crops	Brazil	Argentina	Paraguay	Uruguay	Bolivia	Mexico	Colombia	Chile	Costa Rica
Maize unmilled	−0.95	1.05	1.76	−5.65	−4.17	−2.56	−4.50	−4.84	−9.21
Maize (corn) flour	−1.09	0.12	−9.21	−9.21	−1.05	−4.21	0.10	−9.21	−0.30
Soya beans	−3.74	−0.80	3.53	−1.18	−1.39	−9.21	−9.21	−9.21	−9.21
Soya oil, fractions	−1.62	0.99	1.06	−5.25	1.42	−5.74	−2.47	−9.21	−2.99
Cotton Seed	0.55	0.51	−9.21	−9.21	−9.21	−9.21	−9.21	−9.21	−5.92
Cotton oil, fractions	−9.85	1.40	−2.00	−9.21	−9.21	−5.38	−4.44	−9.21	−9.21
Rape or colza	−2.12	−1.12	2.79	−9.21	−9.21	−9.21	−9.21	−9.21	−9.21

Note: Panel (a) reports Balassa index shown in expression (1). Panel (b) reports Balassa index shown in expression (2). Panel (c) reports the intra-regional variation of the Balanssa index in expression (2).

patterns of RCA are similar to those in panel (a). With the exception of Mexico, we find that each country has a RCA in at least one GMO industry relative to other countries in LA. This result suggests a degree of specialization of countries within the LA region. However, when we compare the signs of the index in panels (a) and (b), we see distinct patterns. For example, Brazil has a RCA in soya oil fractions relative to the world (1.77), but not relative to other countries in LA (0.41).

Finally, panel (c) reports countries' RCA for *intra-regional trade* (the internal trade between LA countries). As shown, the index values in panel (c) tend to be small relative to those in panel (b), reflecting that intra-regional trade is more modest than external trade. We find that Argentina and Paraguay are the prominent exporters to other countries within the region. For example, Paraguay is the only country with a RCA in intra-regional trade of soya beans (3.53). Thus, although Paraguay has a strong RCA in this industry relative to the world (4.14) and relative to other LA countries (2.78), much of its soya bean exports are destined for other countries in LA. Of course, the propensity to export regionally makes sense considering Paraguay's landlocked location between Argentina, Brazil, and Bolivia.

In summary, we find that all countries in LA have a RCA in at least one GMO industry. Brazil, Argentina, and Paraguay have the strongest RCA; and Paraguay is unique in that a large volume of its exports are destined for other countries in LA. These results reflect the patterns of trade as they currently exist, and highlight the countries that are strong stakeholders in the GMO industries (e.g., Brazil and Argentina). However, these findings reflect the export behavior of countries without reference to their trading partners. In the remainder of the paper, we consider bilateral trade patterns and the role of importer's policies in shaping trade patterns.

Theoretical Model

Our theoretical framework is an adaptation of the Gravity model of international trade. This model provides a generalized framework consistent with a variety of general equilibrium trade models.[7] Research on the theory foundations of the Gravity model has generated a well-established set of predictions on the relationship between bilateral trade and country characteristics. (For recent studies, see Anderson and van Wincoop 2003 and 2004; Egger 2005; Santos Silva and Tenreyro, 2006; Chaney 2008; Helpman, Melitz, and Rubinstein 2008; Baier and Bergstrand, 2009a, 2009b; Kleinert and Toubal 2010; van Bergeijk and Brakman 2010; Bergstrand and Eggers 2011; Bergstrand, Egger, and Larch 2013). Policy variables are typically added to the model to examine deviations from baseline trade flows.

[7]*The Gravity model was originally introduced in international economics by Tinbergen (1962). Since that time, economists have worked to establish a theoretical grounding for the expression and extensions that account for a variety of real world behavior. For example, this research has examined border and price effects, and compatibility of the Gravity model with the Heckscher-Ohlin model of inter-industry trade and monopolistic competition models of intra-industry trade. Research has also examined the role of distance as a "trade friction" as well as policy-based trade barriers and economic geography aspects of distance and border effects.*

The empirical specification of the model has evolved as economists have worked to establish its theoretical foundations.[8] A common current expression that emerges from theory is

$$\begin{aligned}\ln\left(T_{ijk}\right) = \ & \beta_0 + \ \beta_1\ (\ln GDP_j\ GDP_k) + \ \beta_2\ (\ln DIST_{jk}) \\ & + \ \beta_3\ \left(ADJ_{jk}\right) + \ \beta_4\ \left(LANG_{jk}\right) + \ \beta_5\ \left(POL_{jk}\right) + \ \varepsilon_{jk}\end{aligned} \tag{3}$$

where T_{ijk} is bilateral trade in industry i from country j to country k, GDP_j and GDP_k are the gross domestic products of countries j and k, respectively, $DIST_{jk}$ is the bilateral distance between the economic centers of countries j and k, ADJ_{jk} is a dummy variable taking the value 1 if both countries share a common border and 0 otherwise, $LANG_{jk}$ is a dummy variable taking the value 1 if both countries share a common language and 0 otherwise, POL_{jk} is the bilateral difference between the policies of countries j and k, and ε_{jk} is a normally distributed error term.[9] Equation (3) says that bilateral trade in industry (i) depends on the GDP of the exporting and importing countries (j and k), the geographic distance between the countries, their contiguity, differences in languages, and differences in policies. Language serves as a measure of "cultural distance", while distance and contiguity are measures of geographic distance.

We adapt equation (3) in several ways for our application. First, we define industries (i) to include soybeans and maize. We focus on these industries as they have large shares of GMO content. For example, Argentina's soybean and maize production in 2013 was 100% and 97% GMO, respectively; and Brazil's soybean and maize production was 92% and 82% GMO, respectively (see James 2013). We estimate equation (3) separately for these two industries. Thus, T_{ijk} is the bilateral trade of soybeans (or maize) from exporting country j to importing country k. This definition is consistent with the underlying theory, which predicts industry-level bilateral trade as a function of country-level characteristics.

Second, we define the exporting countries (j) as Argentina and Brazil. We focus on these two countries as our reference countries because they have a strong comparative advantage in the GMO industries, and together exported 90% of the GMO-intensive exports from the region in 2011. We estimate equation (3) separately for these two countries. Thus, index j denotes Argentina (or Brazil), while index k denotes each of the other countries in the world. Since there is no variability across j, we can simplify equation (3) as

$$\begin{aligned}\ln\left(T_{ik}\right) = \ & \beta_0 + \ \beta_1\ (\ln GDP_k) + \ \beta_2\ (\ln DIST_k) \\ & + \ \beta_3\ (ADJ_k) + \ \beta_4\ (LANG_k) + \ \beta_5\ (POL_k) + \ \varepsilon_k\end{aligned} \tag{4}$$

where T_{ik} is the exports of Argentina (or Brazil) to countries k. Equation (4) indicates that the bilateral exports of Argentina (or Brazil) in industry (i)

[8]*Research on the theory foundations of the Gravity model considers the role of relative endowments (such as land and labor and capital). For example, endowments-based trade models such as the Heckscher-Ohlin model have been shown to be consistent with and/or nested within the Gravity model. In other words, the supply-side effects of endowments are embedded in the Gravity specification that we use. We have not added additional variables as we want our empirical specification to match the theory foundations as closely as possible.*

[9]*See for example, Baier and Bergstrand (2009a and 2009b).*

depend on the characteristics of the importers including their GDP, their geographic distance, contiguity, language, and policies.

Finally, we define the policy variable (POL_k) as GMO-related policies including the approval process, risk assessment, labeling, traceability requirements, coexistence guidelines, membership to international agreements, and intellectual property rights. We also consider a "policy regime" variable that captures the composite of regulations.[10]

The parameters *signs* in equation (4) have the following interpretations. As suggested by the underlying theory, we expect the parameter on *GDP* to be positive, reflecting that economic size attracts bilateral flows.[11] Second, we expect the parameter on distance to be negative if trade costs increase with geographic distance. The parameter on the distance can also provide a sense for the degree of a country's integration into the world economy. In this case, a positive parameter on distance would reflect a high degree of country integration (where the frictions associated with distance are negligible). Third, we expect the parameter on *adjacency* to be positive if our reference countries tend to export to countries that share a common border and negative otherwise.[12] This would reflect a country's high degree of economic integration with its neighbors. Fourth, we expect the parameter on language to be positive (negative) if our reference countries tend to export to countries with similar (dissimilar) languages. Finally, the signs of the policy parameters depend on whether the specific policy serves as a barrier or attractor to bilateral trade flows, which we will determine empirically.

The magnitudes of the parameters of equation (4) reflect elasticities or ratios of percentage changes. These parameters are comparable across reference countries and industries, and can be interpreted as the responsiveness of bilateral trade to the explanatory variables.[13]

Finally, for the purpose of sensitivity analysis, we consider three other variations of equation (4) that are common in the Gravity model literature:

$$\ln(T_{ik}) = \beta_0 + \beta_1 (\ln GDP_k) + \beta_2 (\ln POP_k) + \beta_3 (\ln DIST_k) + \beta_4 (ADJ_k) + \beta_5 (LANG_k) + \beta_6 (POL_k) + \varepsilon_{jk} \quad (5)$$

$$\ln(T_{ik}) = \delta_0 + \delta_1 (\ln GDP_k) + \delta_2 (\ln GDP_k/POP_k) + \delta_3 (\ln DIST_k) + \delta_4 (ADJ_k) + \delta_5 (LANG_k) + \delta_6 (POL_k) + \varepsilon_{jk} \quad (6)$$

[10] *It is plausible that countries with strict policies simply produce domestically rather than importing. As shown in appendix B, the countries with the strictest policies include Austria, Belgium, Czech Republic, France, Hungary, Italy, Netherlands, Portugal, Zambia, and Zimbabwe. As shown in appendix A, these same countries tend to have modest-to-no imports of soybean and maize from Argentina and Brazil. Studies of the theoretical foundations of the Gravity model demonstrate how supply and demand-side features underlie the trade equation that we estimate. In our specifications, these net effects of policies are captured in the parameter on the policy regime and individual policy variable. The negative parameter reflects the negative effect of a country's strict policies on her imports.*

[11] *In some theoretical expressions of the Gravity model where GDP represents income, the parameter on GDP can take a negative sign. In this exception, the income of the foreign destination has a negative effect on their demand for imports.*

[12] *Since we control for geographic distance, the contiguity variable captures conditions beyond those associated with transportation costs.*

[13] *For example, the magnitudes of the parameters on the policy variables help us to gauge the size of the impact of the policies on bilateral trade flows in terms of percentage changes.*

$$\ln(T_{ik}) = \gamma_0 + \gamma_1 (\ln POP_k) + \gamma_2 (\ln GDP_k/POP_k) + \gamma_3 (\ln DIST_k) + \gamma_4 (ADJ_k) + \gamma_5 (LANG_k) + \gamma_6 (POL_k) + \varepsilon_{jk}. \quad (7)$$

In equation (5), the concept of economic size (i.e., mass) is represented by population (POP_k) in addition to GDP_k. The population variable is typically interpreted as "market size" and the associated parameter is expected to be positive. The intuition is that a larger market size in the destination country results in larger bilateral trade flows to that destination.[14] Alternatively, in equations (6) and (7), economic size is represented by GDP_k and GDP_k/POP_k; and POP_k and GDP_k/POP_k, respectively. These equations are alternative expressions of the same relationship, and thus their parameters are transformations on one another.

We apply equations (4–7) to examine the following questions: (1) What are the baseline determinants of bilateral trade? (2) Do policies cause deviations from the baseline bilateral trade flows? (3) If so, are the policy effects positive or negative?

Method and Data

The econometric method involves estimating equations (4–7) for Argentina and Brazil, in the industries of soybeans and maize. We use cross-section data where Argentina or Brazil is the reference exporting country and their trading partners are the importing countries that comprise the rest of the world. We pool the data across three years (2008, 2011, and 2014) to create a panel. To control for inflation, all value data are in 2010 constant dollars. In contrast, the data on GMO policies are available for only a single year (2007). Thus, using the pooled data we examine the effects of policy adoption (in 2007) on trade behavior (on average, over 2008, 2011, and 2014). One important advantage of the lag between policy and trade is that past policies are expected to be exogenous with respect to future trade. Below we report results generated using the pooled data, as well as a sensitivity analysis using the individual cross-sections for each of the three years. A comparison of years allows us to further assess policy endogeneity, lagged policy effects, and time and country factors that affect trade.

We use three alternative estimation techniques including OLS, Tobit, and Poisson pseudo maximum likelihood. We explore these alternatives in order to address the presence of a non-trivial number of zero values for bilateral trade. In our context, the zero observations represent actual zero trade rather than missing values. Further, since we anchor our exporter to a single reference country, we consider only the exports of that country and not imports (which conceptually would be a negative trade flow). This choice is appropriate given the strong RCA of our reference countries (Argentina and Brazil) in the industries (soybeans and maize). The literature provides several methods for treating zero observations in such a context. One approach is to use OLS and assign small values to zero observations such that the log of these values is defined. A second approach is to estimate the log linear form of the model using Tobit methods,

[14] *In some theory frameworks, it is possible for the parameter on population to take a negative sign if an import substitution effect is stronger than the market size effect.*

which allows for censoring at zero. A third alternative is to estimate the model using the export values measured in levels and then implement a Poisson pseudo maximum likelihood (PPML) estimator, traditionally used in count regression models (see Santos Silva and Tenreyro 2006). As the PPML approach is now standard in the recent Gravity literature, we report findings generated using this technique. We reference the OLS and Tobit results in our sensitivity analysis.

The data include measures of trade, core variables, and policies. The trade data include data to construct the Balassa index and data for the regression analysis. The former are the U.S. dollar value of LA countries' exports to the world in aggregate, while the latter are the dollar value of bilateral exports from Argentina and Brazil to the 58 importers for which comparable data are available. These data are detailed by industry and year (2008, 2011, and 2014).[15] The industries include maize and soybeans.[16] All trade data are from the Comtrade database of the United Nations. As noted earlier, these data do not distinguish between GMO and traditional crops, as such data are not available. However, the industries and reference countries we consider are those with the largest shares of GMO content. For Argentina and Brazil, more than 90% of soybean and maize production was GMO during the years we consider. Thus, we can reasonably assume their exports are "GMO-intensive." Appendix A reports select country data on bilateral trade in 2011 and descriptive statistics.

The data on core variables include GDP and population from the World Development Indicators published by the World Bank (2015). GDP is measured in U.S. dollars for 2008, 2011, and 2014. The core variables also include distance, contiguity, and common language from the Centre d'Etudes Prospectives et d'Informations Internationales (2006). Distance is measured as kilometers between the economic centers of country pairs. Contiguity is a dummy variable taking a value of one if country pairs share a common border. Common language is a dummy variable taking a value of one if country pairs share a common language.

Data on policies include measures of intellectual property rights (IPRs) and GMO policies. The data on *IPR policies* is the index constructed by Park (2008). This index measures the strength of countries' patent policies based on the following: their extent of coverage in eight technology areas; length of protection; membership in five international treaties that address patents; provisions for loss of protection including working requirement, compulsory licensing, and revocation of patents; and enforcement mechanisms including preliminary pre-trial injunctions, contributory infringement, and burden of proof. Country scores range from 0 to 1 in each category based on the strength of laws. The composite index is the un-weighted sum of the scores in the five categories. The index ranges from 0 to 5 with higher values indicating stronger patent protections. These data are available on a 5-year basis. We use the index for 2010.

Finally, the data on GMO policies are the recently released measures developed by Vigani, Raimondi, and Olper (2012). This index is based on laws and acts regulating GMO production, commercialization, and trade as of

[15]*The countries include all those for which comparable data are available. When appropriate, we deflate the data into constant 2010 dollars to control for the effects of inflation across time.*

[16]*These aggregate industries are defined using the SITC Revision 3 classification system as follows: Maize: 044; and Soybeans: 2222.*

2007. The data covers six categories of regulation: approval process, risk assessment, labeling policies, traceability requirements, coexistence guidelines, and membership in international agreements. The composite index is the sum of scores in each category normalized to the range [0,1]. In our analysis we use the component scores to measure the distinct regulations and the composite index to measure the policy regime. Higher scores reflect more restrictive regulations. That is, countries with higher scores take a more preventative (anti-GMO) approach and those with lower scores take a more promotional (pro-GMO) approach. Appendix B reports the policy data and descriptive statistics. As shown, although the range is modest, there is considerable variability across countries.

The interpretation of this variability is as follows. The approval process reflects the country's approach to assessing product risk. Country policies range from the absence of approval procedures to mandatory processes based on the substantial equivalence principle, to mandatory processes based on the precautionary principle, to complete bans on GMOs. Second, risk assessment reflects the extent to which an evaluation process for GMO products is implemented. Country policies range from the absence of risk analysis, to proposed risk assessment without enforcement, to mandatory risk assessment, to complete bans on GMOs. Third, labeling concerns the information provided to buyers/consumers about the contents of a product. Country policies range from the absence of GMO labeling regulations, to voluntary labeling, to mandatory labeling with high thresholds, to mandatory labeling with low thresholds, to complete bans on GMOs. Fourth, traceability pertains to the ability to identify the origin, history or use of a product, such as the location of the field it came from, using a registered identification. Country policies range from the absence of processes for GMO traceability, to traceability requirements without enforcement, to mandatory traceability, to complete bans on GMOs. Fifth, coexistence concerns rules designed to preserve the identity of traditional crops vs. GMO crops. Country policies range from the absence of coexistence rules, to coexistence policies that are unenforced, to partial guidelines for coexistence, to exhaustive guidelines on coexistence, to complete bans of GMOs. Finally, country memberships to international agreements include the Cartagena Protocol and Codex Alimentarius. Countries that are signatories to these agreements are considered to have relatively stronger regulatory environments. Appendix C provides additional descriptions of country and regional patterns of policy strength.

Results

This section reports the regression results. Specifically, we report estimates of Gravity equations (4) through (7) and examine the parameter sign for their consistency with the underlying theory.

Baseline

To begin, we estimate the baseline specification (without policy variables) to assess the question: What are the baseline determinants of bilateral trade?

Table 2 reports PPML estimates of the Gravity model for the three-year panel (2008, 2011, and 2014). The columns correspond with equations (4–7)

Table 2. Baseline Poisson Pseudo-Maximum Likelihood Estimates of Gravity Model, 2008–2014

Variable	**Argentina (Soybeans)**				**Argentina (Maize)**				**Brazil (Soybeans)**				**Brazil (Maize)**			
	Eq (4)	**Eq (5)**	**Eq (6)**	**Eq (7)**	**Eq (4)**	**Eq (5)**	**Eq (6)**	**Eq (7)**	**Eq (4)**	**Eq (5)**	**Eq (6)**	**Eq (7)**	**Eq (4)**	**Eq (5)**	**Eq (6)**	**Eq (7)**
Constant	−76.10**	−75.99**	−55.95**	−113.48	9.64	9.59	10.80*	10.05	−36.46**	−36.46**	−26.63**	−23.21	−12.37*	−11.96	−12.98*	−13.05*
	(13.89)	(14.16)	(17.16)	(72.63)	(6.19)	(6.68)	(6.14)	(7.90)	(13.53)	(13.44)	(12.65)	(14.67)	(7.98)	(8.10)	(7.79)	(7.72)
GDP	1.34**	1.19**	1.52**		0.32**	0.24	0.41**		1.19**	1.20**	1.25**		0.34*	0.32	0.33**	
	(0.29)	(0.32)	(0.25)		(0.13)	(0.17)	(0.15)		(0.26)	(0.22)	(0.23)		(0.17)	(0.20)	(0.17)	
POP		0.45**		0.73**		0.13		0.26*		−0.02		0.61**		0.04		0.30*
		(0.14)		(0.17)		(0.17)		(0.14)		(0.16)		(0.14)		(0.14)		(0.17)
GDP/POP			−0.91**	−0.07			−0.24	0.11			−0.43	0.35			0.03	0.32
			(0.34)	(0.37)			(0.19)	(0.16)			(0.27)	(0.23)			(0.21)	(0.27)
Distance	5.93**	5.74**	4.29**	11.90	−0.65	−0.62	−0.72	−0.42	2.46**	2.46**	1.71	2.66*	1.64**	1.60*	1.69*	1.77**
	(1.17)	(1.16)	(1.58)	(7.78)	(0.75)	(0.78)	(0.71)	(0.82)	(1.10)	(1.10)	(1.10)	(1.61)	(0.94)	(0.93)	(0.88)	(0.88)
Adjacency	10.78**	10.27**	7.73**	23.16	−1.72	−1.61	−1.79	−1.19	−0.50	−0.47	−1.52	−2.82	2.34**	2.23**	2.41**	2.02*
	(2.69)	(2.73)	(3.53)	(16.48)	(1.31)	(1.40)	(1.19)	(1.45)	(1.69)	(1.59)	(1.69)	(1.90)	(1.09)	(1.14)	(1.06)	(1.14)
Language	3.25**	3.51**	3.40**	6.81	1.43**	1.32**	1.28*	1.32*	2.96**	2.94**	2.87**	1.67**	1.79**	1.80**	1.80**	1.77**
	(1.08)	(1.11)	(1.16)	(4.47)	(0.55)	(0.64)	(0.66)	(0.74)	(1.06)	(1.14)	(0.98)	(0.70)	(0.51)	(0.51)	(0.51)	(0.50)
R-squared	0.79	0.90	0.96	0.73	0.23	0.21	0.23	0.17	0.68	0.68	0.84	0.13	0.07	0.07	0.07	0.09
N	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174

Note:
Data are a panel of country cross-sections for 2008, 2011, and 2014. All value data are in constant 2010 dollars.
Endogenous variable is bilateral exports (Tik), detailed by industry (maize and soybeans) and by exporting country (Argentina and Brazil).
All regressions include time-fixed effects.
*Asterisks ** and * indicate significance at the 5% and 10% levels, respectively.*

for Argentina or Brazil in the industries of soybeans or maize. The results for equation (4) show that the GDP of importers has a positive effect on their bilateral inflows of soybeans and maize from Argentina and Brazil. Similarly, the results for equation (5) show that the population of importers also has a positive effect on bilateral inflows. These results are consistent with the underlying theory and intuition that economic/market size attracts bilateral inflows. Since equations (6) and (7) are alternative expressions of equation (5), the parameters are transformations of one another. We find that the estimates of equations (5–7) take the expected signs and relative magnitudes in relation to one another.

Next, we consider the estimates on adjacency, distance, and language. Table 2 shows that significant estimates on *adjacency* are positive. This result suggests that Argentina and Brazil tend to export to geographically nearby countries inside the contiguous region.[17] This is expected, as economic integration with neighboring countries is relatively strong. Table 2 also shows that significant estimates on *distance* are positive. This finding suggests that Argentina and Brazil are highly integrated into the external world economy in the industries of soybeans and maize. Consequently, after controlling for adjacency, geographic distance does not serve as a friction to bilateral flows. Finally, table 2 shows that significant estimates on language take the expected positive sign. This finding suggests that similarity in language tends to enhance bilateral trade flows, reflecting relatively strong cultural ties.

Thus, we conclude that our baseline results are consistent with expectations based on underlying theory.

Policy Analysis

Next, we estimate the extended specification (with the policy variables) to assess the question: Do policies cause deviations from the baseline bilateral trade flows? If so, are the policy effects positive or negative? Tables 3–6 report the PPML estimates of the Gravity model using the pooled data for 2008, 2011, and 2014. Tables 3 and 4 focus on Argentina's bilateral exports of soybeans and maize, respectively; while tables 5 and 6 focus on Brazil's bilateral exports of soybeans and maize, respectively. In each table, we consider the individual policies one at a time and then jointly.[18]

Table 3 reports estimates for Argentina's bilateral exports of soybeans. The results show that significant estimates on policies take negative signs. The policies that have an effect include risk assessment, traceability, coexistence guidelines, and intellectual property rights. In other words, the strength of importers' policies has an overwhelmingly negative effect on the bilateral exports of Argentina in soybeans. Table 3 also shows a negative and significant estimate on the GMO index, suggesting that Argentina tends to export less to importers with strong policy regimes. The last column of table 3 shows that when all policies are considered jointly, risk assessment, traceability, and intellectual property rights have the strongest negative effects.[19]

[17] Argentina is adjacent to Uruguay, Paraguay, Brazil, Bolivia, and Chile, while Brazil is adjacent to Argentina, Bolivia, Colombia, French Guiana, Guyana, Paraguay, Peru, Suriname, and Uruguay.

[18] The number of observations (N) varies across the policy regressions because the data on intellectual property rights and GMO policies come from different sources and consequently the country coverage differs slightly.

[19] This is consistent with expectations because the strength of intellectual property rights tends to be positively correlated with the strength of GMO policies.

Table 3 Poisson Pseudo-Maximum Likelihood Estimates of Gravity Model for Argentina's Bilateral Soybean Exports, 2008–2014

Variable	**Argentina's Bilateral Soybean Exports**								
Constant	−96.05**	−87.87**	−80.50**	−72.98**	−57.93**	−70.77**	−75.47**	−76.35**	−39.32**
	(15.99)	(18.49)	(14.20)	(12.51)	(11.03)	(10.17)	(15.66)	(12.63)	(17.11)
GDP	1.86**	1.62**	1.77**	1.11**	1.41**	1.32**	1.33**	2.07**	1.49**
	(0.32)	(0.39)	(0.45)	(0.35)	(0.22)	(0.21)	(0.30)	(0.51)	(0.31)
Distance	7.27**	6.71**	5.88**	5.95**	3.97**	5.49**	5.86**	5.21**	2.04
	(1.28)	(1.34)	(1.07)	(1.54)	(1.17)	(0.99)	(1.43)	(1.17)	(2.09)
Adjacency	14.05**	12.77**	11.11**	10.41**	6.20**	9.46**	10.62**	8.23**	1.72
	(3.26)	(3.36)	(2.56)	(3.26)	(2.99)	(2.47)	(3.36)	(2.92)	(5.46)
Language	5.13**	3.96**	3.87**	2.79**	3.23**	2.59**	3.19**	3.75**	2.03
	(1.38)	(1.24)	(1.23)	(1.05)	(1.27)	(1.06)	(1.24)	(1.14)	(2.02)
GMO Index	−8.91**								
	(3.06)								
Approval Process		−2.79							0.92
		(1.98)							(1.99)
Risk Assessment			−6.88**						−5.96**
			(2.94)						(2.37)
Labeling				2.67					1.93
				(3.17)					(1.32)
Traceability					−5.76**				−5.23**
					(1.29)				(1.30)
Coexistence Guidelines						−4.80**			−0.87
						(1.46)			(1.64)
International Agreements							0.21		2.00
							(1.60)		(2.47)
Intellectual Property Rights								−2.08**	−0.31*
								(0.80)	(0.58)
R-squared	0.97	0.81	0.82	0.91	0.98	0.98	0.79	0.95	0.99
N	174	174	174	174	174	174	174	168	168

Note:
Data are a panel of country cross-sections for 2008, 2011, and 2014. All value data are in constant 2010 dollars.
Endogenous variable is bilateral exports (Tik) of Argentina in Soybeans.
All regressions include time-fixed effects.
*Asterisks ** and * indicate significance at the 5% and 10% levels, respectively.*

Table 4 Poisson pseudo-maximum likelihood estimates of Gravity model for Argentina's bilateral maize exports, 2008-2014

Variable	**Argentina's Bilateral Maize Exports**								
Constant	8.00	9.61	8.10	6.79	8.87	10.84*	9.65	9.53	12.14*
	(6.73)	(7.14)	(5.33)	(7.24)	(7.06)	(5.86)	(6.25)	(7.64)	(6.49)
GDP	0.33**	0.32**	0.35**	0.34**	0.33**	0.28**	0.32**	0.49**	0.43**
	(0.11)	(0.11)	(0.14)	(0.12)	(0.12)	(0.13)	(0.13)	(0.17)	(0.15)
Distance	−0.45	−0.65	−0.48	−0.35	−0.57	−0.67	−0.65	−0.69	−0.85
	(0.77)	(0.88)	(0.63)	(0.81)	(0.79)	(0.66)	(0.74)	(0.85)	(0.64)
Adjacency	−1.33	−1.72	−1.25	−0.87	−1.52	−1.85	−1.72	−1.45	−1.52
	(1.35)	(1.41)	(1.11)	(1.64)	(1.37)	(1.14)	(1.35)	(1.58)	(1.56)
Language	1.39**	1.42**	1.48**	1.53**	1.35	1.07*	1.43**	1.12	0.89
	(0.64)	(0.54)	(0.54)	(0.62)	(0.71)	(0.59)	(0.55)	(0.81)	(0.89)
GMO Index	−1.25								
	(1.02)								
Approval Process		−0.01							0.78
		(1.01)							(2.36)
Risk Assessment			−1.40						0.16
			(1.34)						(2.60)
Labeling				−0.83					−0.70
				(0.91)					(1.87)
Traceability					−0.68				1.12
					(0.77)				(0.97)
Coexistence Guidelines						−1.73			−1.91
						(1.15)			(1.44)
International Agreements							−0.02		0.35
							(1.18)		(1.19)
Intellectual Property Rights								−0.78**	−0.85**
								(0.37)	(0.39)
R-squared	0.20	0.23	0.22	0.21	0.21	0.24	0.23	0.20	0.30
N	174	174	174	174	174	174	174	168	168

Note:
Data are a panel of country cross-sections for 2008, 2011, and 2014. All value data are in constant 2010 dollars.
Endogenous variable is bilateral exports (Tik) of Argentina in Maize.
All regressions include time-fixed effects.
*Asterisks ** and * indicate significance at the 5% and 10% levels, respectively.*

Table 5 Poisson pseudo-maximum likelihood estimates of Gravity model for Brazil's bilateral soybean exports, 2008-2014

Variable	**Brazil's Bilateral Soybean Exports**								
Constant	−36.23**	−33.69**	−36.41**	−36.75**	−33.22**	−37.59**	−32.79**	−34.46**	−19.85**
	(13.77)	(11.22)	(13.41)	(6.84)	(11.18)	(11.58)	(10.72)	(12.33)	(7.85)
GDP	1.19**	1.25**	1.20**	1.20**	1.19**	1.17**	1.30**	1.41**	1.20**
	(0.27)	(0.31)	(0.29)	(0.25)	(0.22)	(0.21)	(0.33)	(0.35)	(0.25)
Distance	2.42**	1.61	2.46**	2.06**	2.15**	2.66**	1.50	2.12**	0.49
	(1.11)	(1.10)	(1.11)	(0.88)	(1.01)	(1.02)	(1.17)	(1.06)	(1.04)
Adjacency	−0.48	−0.76	−0.54	0.81	−1.18	−0.47	−1.58	−1.35	−2.60
	(1.67)	(1.67)	(1.59)	(1.40)	(1.55)	(1.57)	(1.41)	(1.58)	(1.61)
Language	2.86**	2.38**	2.99**	2.20**	3.29**	3.94**	2.45**	3.40**	2.11**
	(1.42)	(0.92)	(1.17)	(0.69)	(1.18)	(1.46)	(0.88)	(1.27)	(0.92)
GMO Index	0.35								
	(2.29)								
Approval Process		5.53							2.36
		(4.18)							(1.79)
Risk Assessment			−0.34						−2.64
			(1.91)						(4.26)
Labeling				5.92**					3.36**
				(1.79)					(1.28)
Traceability					−1.20				−1.16
					(1.14)				(1.18)
Coexistence Guidelines						−1.52			−0.74
						(1.25)			(1.27)
International Agreements							3.17		2.67*
							(2.60)		(1.58)
Intellectual Property Rights								−0.81	−0.50
								(0.61)	(0.70)
R-squared	0.66	0.73	0.68	0.93	0.84	0.86	0.74	0.80	0.95
N	174	174	174	174	174	174	174	168	168

Note:
Data are a panel of country cross-sections for 2008, 2011, and 2014. All value data are in constant 2010 dollars.
Endogenous variable is bilateral exports (Tik) of Brazil in Soybeans.
All regressions include time-fixed effects.
*Asterisks ** and * indicate significance at the 5% and 10% levels, respectively.*

Table 6 Poisson pseudo-maximum likelihood estimates of Gravity model for Brazil's bilateral maize exports, 2008-2014

Variable	**Brazil's Bilateral Maize Exports**								
Constant	−14.06*	−12.36	−11.82	−13.57	−6.77**	−13.20*	−13.18	−10.12	−20.20**
	(7.46)	(7.91)	(8.32)	(8.37)	(5.94)	(7.42)	(8.18)	(8.90)	(9.72)
GDP	0.31*	0.34**	0.39**	0.31*	0.31**	0.33*	0.34*	0.41*	0.48**
	(0.17)	(0.15)	(0.17)	(0.19)	(0.16)	(0.17)	(0.18)	(0.22)	(0.22)
Distance	1.84**	1.64*	1.54	1.79*	2.14**	1.74*	1.58	1.39	2.31
	(0.92)	(0.89)	(0.94)	(1.00)	(0.82)	(0.94)	(0.99)	(1.02)	(1.21)
Adjacency	2.75**	2.33**	2.12*	2.70**	3.26**	2.53**	2.19**	1.81	3.26
	(1.06)	(1.02)	(1.17)	(1.15)	(0.92)	(1.14)	(1.08)	(1.31)	(1.55)
Language	1.61**	1.80**	1.89**	1.71**	1.67**	1.57**	1.62**	1.86**	1.92*
	(0.53)	(0.55)	(0.53)	(0.53)	(0.50)	(0.55)	(0.50)	(0.53)	(0.76)
GMO Index	0.99								
	(0.98)								
Approval Process		−0.02							−0.94
		(0.82)							(2.22)
Risk Assessment			−1.21						−0.91
			(1.43)						(2.72)
Labeling				0.64					1.31
				(0.74)					(2.22)
Traceability					1.04*				2.02
					(0.61)				(1.37)
Coexistence Guidelines						0.50			−0.49
						(0.77)			(1.22)
International Agreements							1.54		1.20
							(1.41)		(1.08)
Intellectual Property Rights								−0.36	−0.64
								(0.40)	(0.47)
R-squared	0.09	0.07	0.07	0.06	0.12	0.10	0.09	0.07	0.13
N	174	174	174	174	174	174	174	168	168

Note:
Data are a panel of country cross-sections for 2008, 2011, and 2014. All value data are in constant 2010 dollars.
Endogenous variable is bilateral exports (Tik) of Brazil in Maize.
All regressions include time-fixed effects.
*Asterisks ** and * indicate significance at the 5% and 10% levels, respectively.*

These findings on GMO policies are consistent with Vigani, Raimondi, and Olper (2012) who show that bilateral differences across countries in GMO regulations negatively affect trade. While these authors focus on bilateral trade between all countries, we focus on the bilateral exports of our two reference countries (i.e., Argentina and Brazil) to all importers. Our results show that either Argentinean soybean exporters factor regulatory differences into their decisions on where to export, or soybean importers factor GMO-content into their decisions over which countries to import from. Either way, the significant negative effects on trade (quantified here) suggest that policy makers need to consider more than domestic impacts when formulating GMO policies.

In contrast, tables (4–6) overwhelmingly show insignificant estimates on the policy variables in the regressions for Argentina and Brazil's maize exports, and Brazil's soybean exports. In other words, policies do not tend to cause deviations in bilateral flows away from the baseline in these cases. There are three exceptions. The first is that Argentina's bilateral exports of maize are negatively related to strong intellectual property rights in importers. Second, Brazil's bilateral exports of soybeans are positively related to strong labeling policies in importers. Third, Brazil's bilateral exports of maize are positively related to the strength of traceability policies in importers. The intuition for these exceptions will become clear when we consider changes in the effects of policies over time.

When we compare the findings (in tables 3–6), we see that Argentinean soybean trade is much more sensitive to importers' policies than are Argentinean maize or Brazilian soybeans and maize. One explanation is that there is a higher concentration of GMO content in soybeans. One hundred percent of Argentinean soybeans are GMO, and this has been the case for over ten years, according to James (2013). In contrast, Argentinean maize and Brazilian soybeans and maize have only recently seen rising GMO levels. For example, Argentinean maize was just 50% GMO in 2004, and only reached 80% in 2009. Only 8% of Brazil's soybean and maize output was GMO in 2005. In 2010, this value had climbed to 48%, and currently stands at around 87%.[20] Accordingly, the significant effects seen for Argentina's soybeans may be predictive of effects that will emerge in the future as importers adjust to the increasing GMO content in Argentinean maize and Brazilian soybeans and maize.

Extensions: Sensitivity Analysis

This section considers four extensions. First, are GMO policies endogenous with respect to bilateral trade flows? The intuition is that countries that are large importers in the GMO industries would tend to adopt pro-GMO policies. In our context, pro-GMO policies correspond with weak regulations. If policies are endogenous with respect to trade, we would expect the estimates on the policy variables to be biased such that they are larger in absolute value. That is, we may conclude that weak regulations in importing countries serve as a stronger attractor to bilateral trade flows than they actually do. The issue of policy endogeneity in international trade studies is typically addressed using instrumental variables and/or lagged measures of policy. In our specifications, however, policy endogeneity is less likely

[20] *For further details, see James (2013).*

because we anchor our exporters to single countries (i.e., Argentina and Brazil). That is, it is less likely that a single country's pattern of bilateral exports influences the variability of policy strength across all importers. Rather, we expect importers' policies to be sensitive to their trade with all major trading partners. However, since Argentina and Brazil have a strong comparative advantage in soybeans and maize, it is possible that importers' trade reliance on these countries influences their policies. Thus, we take a conservative approach and use lagged policy measures from 2007, which precede trade in 2008, 2011, and 2014. We do not expect future trade to have a strong influence on the adoption of past policies.

Second, we perform a lagged policy experiment that allows us to further assess endogeneity and also determine the character of any lag between GMO policies and their effects on trade. To this end, we re-estimate the expressions of the Gravity model shown in tables 3–6; however, we now use cross-sections for individual years rather than the pooled data. The new regressions correspond with one, four, and seven-year lags between 2007 policies and 2008, 2011, and 2014 trade, respectively. [21] It is not likely that trade in 2011 and 2014 influences past 2007 policies; however, it is plausible that 2008 trade influences 2007 policies, as policy makers may anticipate trade reliance in the near future. The intuition for this approach is that the longer the lag, the more exogenous the policy with respect to trade. If endogeneity is present, we would expect the parameter on the policy variables to be larger in absolute value, and for this bias to diminish as the lag increases. Before undertaking the lagged analysis, we employ the Hausman test to directly assess endogeneity. Appendix D reports the Hausman test statistics. We find weak-to-no evidence of endogeneity, with only two exceptions.[22]

Table 7 reports the results of the lagged approach. For simplicity, we report only the estimates on the policy variables. For example, the estimates in the first column correspond with eight different regressions, where each policy variable is considered one at a time. Further, in the 2008 columns, there is a one-year lag between 2007 policies and 2008 trade. In the 2011 columns, there is a four-year lag between 2007 policies and 2011 trade. In the 2014 columns, there is a seven-year lag between 2007 policies and 2014 trade.

Columns 1–6 report the findings for Argentina. As shown, the estimates on the policy variables tend to be negative and significant for Argentina's soybean and maize exports. Further, the significant estimates for soybeans tend to be smaller in absolute value in 2008 relative to the latter years (columns 1–3); the significant estimates for maize tend to be insignificant in 2008 and 2011 and significant in 2014 (columns 4–6). These findings suggest that the effects of importers' policies are larger and/or more statistically significant when the lag between policy adoption and trade is longer (e.g., four to seven years). These results run counter to the effects of endogeneity.

[21]*We convert all value data into 2010 constant dollars to control for the effects of inflation across time. This allows us to compare the results across time (i.e., 2008, 2011, and 2014).*

[22]*We apply the common approach that compares the parameters of random and fixed effects specifications. The null is that these parameters are equivalent. We find weak or no evidence of endogeneity (with only two exceptions). Specifically, we find that for Argentina's soybean trade, the null is rejected at the 10% level but not the 5% level, suggesting weak evidence of policy endogenity. For Argentina's maize trade, we again find weak evidence of endogeneity for all policies, except for coexistence guidelines and intellectual property rights. For these two exceptions, the null is rejected at the 5% level, suggesting endogeneity. Finally, for Brazil's soybean and maize trade, we find no evidence of endogeneity.*

Table 7 Poisson pseudo-maximum likelihood estimates of Gravity model, by year for 2008, 2011 and 2014

	Argentina						**Brazil**					
	Soybeans			**Maize**			**Soybeans**			**Maize**		
	2008	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**
GMO Index	−4.85**	−11.07**	−8.79**	1.09	−1.52	−3.49**	3.71**	−1.15	−0.26	3.30**	2.06*	0.79
	(2.18)	(3.65)	(2.81)	(1.57)	(1.60)	(0.79)	(1.86)	(2.90)	(2.60)	(1.65)	(1.19)	(1.32)
Approval Process	−3.51**	−2.54	−3.63	0.82	0.46	−2.00**	6.41**	4.08	4.91	2.51	0.57	−0.21
	(1.53)	(2.84)	(2.33)	(1.11)	(1.48)	(0.93)	(3.04)	(3.38)	(4.06)	(2.20)	(0.84)	(0.90)
Risk Assessment	−3.20*	−5.90	−10.69**	−1.99	−0.47	−2.24	2.32**	−1.27	−1.78	−1.11	0.07	−1.35
	(1.79)	(3.96)	(3.78)	(1.58)	(1.74)	(1.53)	(0.96)	(1.96)	(2.37)	(1.56)	(1.82)	(1.61)
Labeling	−2.76**	5.82	2.08	0.81	−1.28	−1.61*	3.25*	7.67**	5.19**	3.93**	0.76	0.62
	(1.28)	(3.86)	(2.52)	(1.09)	(1.42)	(0.86)	(1.75)	(2.60)	(1.55)	(1.55)	(0.70)	(1.72)
Traceability	−2.87**	−6.98**	−5.52**	1.60*	−1.98**	−1.72**	2.35*	−1.98	−1.53	2.48**	1.70**	0.73
	(1.13)	(1.64)	(1.36)	(0.93)	(0.94)	(0.74)	(1.32)	(1.28)	(1.10)	(1.18)	(0.77)	(0.76)
Coexistence Guidelines	−2.14	−7.52**	−4.15**	0.02	−2.31	−4.93**	0.98	−2.62**	−1.70	0.90	1.02	0.38
	(1.38)	(1.71)	(1.54)	(1.03)	(1.98)	(2.05)	(1.01)	(1.30)	(1.24)	(0.98)	(0.82)	(0.92)
International Agreements	0.29	−1.00	0.65	−0.31	0.73	−0.73	2.25	3.03	3.09	3.66	1.14	1.71
	(1.24)	(1.88)	(2.55)	(1.29)	(1.44)	(1.04)	(2.73)	(2.59)	(2.51)	(2.63)	(1.40)	(1.51)
Intellectual Property Rights	−0.96**	−2.64**	−2.30**	0.10	−1.11**	−0.89**	0.24	−1.04	−0.95	−0.12	−0.18	−0.44
	(0.22)	(1.23)	(0.72)	(0.88)	(0.42)	(0.39)	(0.71)	(0.72)	(0.62)	(0.76)	(0.59)	(0.43)

Note:
Data are cross-sections for the years 2008, 2011, and 2014. All value data are in constant 2010 dollars.
Endogenous variable is bilateral exports (Tik), detailed by industry (maize and soybeans), exporting country (Argentina and Brazil), and Year (2008, 2011, 2014).
All regressions include time-fixed effects.
*Asterisks ** and * indicate significance at the 5% and 10% levels, respectively.*

Instead, the findings suggest that past policy decisions serve as a stronger determinant of future bilateral trade.

Columns 7–12 report the related findings for Brazil. As shown, the estimates on the policy variables tend to be significant and positive for 2008 and insignificant for 2011 and 2014.[23] This pattern is evident for Brazil's exports of both soybeans and maize. These findings suggest that Brazil tends to export more soybeans and maize to countries with relatively strong GMO policies in 2008, but not thereafter. This finding could potentially suggest evidence of policy endogeneity for Brazil. However, a review of the underlying data suggests that trade patterns were changing between 2008 and 2014 as the GMO shares of soybean and maize increased dramatically in Brazil. Indeed, the data show that Brazil's exports to EU countries (where policies are stronger) decreased after 2008, while Brazil's exports to Asia (where policies are weaker) increased. This pattern in the data suggests that changes in GMO content prompted Brazil to search for import markets with pro-GMO policies.

Third, we ask whether the trade effects of GMO policies change over time? To answer this question, we estimate a variation of the Gravity model where we account for deviations in policy effects between the three equilibrium points in time. Specifically, we interact the policy variables with a time dummy to generate parameters representing the deviation in policy effects for the given year. We expect these parameters to be statistically different from one another if the trade effects of policies change over time. Appendix E reports the PPML (and Tobit) estimates of deviations in the trade effects of GMO policies over time. For Argentina, the findings show that the negative trade effects of strong policies among importers tend to increase over time. (This finding is particularly pronounced in the Tobit regressions.) For Brazil, the findings are more mixed; they show that the positive trade effects of strong policies among importers tend to decrease over time, and in some cases become negative, as GMO content rises. Thus, we anticipate that future strengthening of GMO policies in importers would adversely affect Argentina and Brazil's export opportunities.

Finally, we consider the robustness of our results along several dimensions. To this end, we estimate all of the reported regressions using Tobit and OLS techniques in addition to the reported PPML method. Appendices F and G report the Tobit and OLS estimates that are comparable to the PPML estimates in tables 3–7. While the quantitative results differ across methods (as expected), the qualitative results are indeed robust. Second, we assess the sensitivity of all of the reported results to time factors that could potentially affect trade. One potentially important time factor is weather and/or crop shortages. Such conditions could affect multiple countries in a given year and/or affect a given country over multiple years. We can control for the former using time-fixed effects, which we include in all reported regressions. We find that the parameter signs, relative magnitudes, and fit of the regressions are insensitive to the inclusion of time-fixed effects. This is not to say that weather and crop shortages on not important to trade, but

[23]*There are several additional findings. For example, Brazil tends to export more soybeans to countries with relatively strong labeling policies in all years and less to countries with relatively weak co-existence guidelines in 2011. Also, Brazil tends to export more maize to countries with relatively strong traceability regulations in 2008 and 2011, although the magnitude of this effect is diminishing. This cross-year variability is consistent with Brazil's dramatically changing GMO content and shifting trade patterns during the period examined.*

rather that our results are robust with respect to such conditions that occur in a given year.

Concluding Remarks

The purpose of our paper is to examine the exports of LA countries into a global economy where countries differ in GMO-related policies. We began by constructing measures of "revealed comparative advantage" using the Balassa index. We used these measures to assess the RCA of LA countries in GMO industries relative to the region and relative to the world. We found that all LA countries have a RCA in at least one GMO industry relative to the world; and Argentina, Brazil, and Paraguay are export leaders in the broadest range of these industries. We also found that almost all LA countries have a RCA in at least one GMO industry relative to the other countries in the region, suggesting specialization within LA. Further, we found that intra-regional trade is modest relative to external trade. For the intra-regional trade that does exist, Argentina and Paraguay are the prominent exporters within the region. These patterns of RCA support our decision to focus on Argentina and Brazil as influential GMO exporters.

Second, we estimated the Gravity model to examine the effects of importing countries' policies on the bilateral exports of Argentina and Brazil in soybeans and maize. We found that Argentina and Brazil tend to export more to countries that are large in economic and market size, geographically adjacent, distant (after controlling for adjacency), and similar in language. We also found that Argentina tends to export less to importers with strong policy regimes. The strength of importers' policies has an overwhelmingly negative effect on Argentina's bilateral exports of soybeans. The trade-affecting policies include risk assessment, traceability, coexistence guidelines, and intellectual property rights. In contrast, we found that policies do not tend to affect bilateral flows for Brazil and for maize (although there are several exceptions). This is not surprising given the historically higher concentration of GMO content in soybeans in Argentina. We conclude that the strong policy effects for Argentina's soybean exports may be predictive of effects that will emerge as importers adjust to the increasing GMO content in Argentinean maize and Brazilian soybeans and maize.

Third, we considered several extensions. First, we performed a lagged policy experiment to assess endogeneity as well as the lag structure between policies and their effects on trade. We found that importers' policies have a negative effect on Argentina's soybean and maize exports. Further, we found that the effects of importers' policies are larger and/or more statistically significant when the lag between policy adoption and trade increases. In contrast, we found that Brazil tended to export more soybeans and maize to countries with relatively strong policies in 2008, but not thereafter. This finding reflects Brazil's changing trade patterns away from the EU and toward Asia that occurred as the GMO shares of soybean and maize increased. This finding suggests that changes in GMO content prompted Brazil to search for import markets with pro-GMO policies. Second, we analyzed deviations in policy effects between 2008, 2011, and 2014. The findings were consistent with those discussed above. Third, we considered robustness with respect to method including OLS, Tobit, and PPML. We found that the quantitative results vary (as expected), but the qualitative results are indeed robust. Finally, we assessed robustness with respect to time factors that could potentially affect trade. One potentially important time factor is weather and/or crop shortages. While weather and crop shortages may indeed affect trade, we found that our results are robust with respect to time fixed effects that occur across multiple countries in a given year.

These findings have a number of practical policy implications for countries that export and import GMOs. First, we conclude that GMO exporters (such as Argentina and Brazil) could strengthen their labeling, traceability, and coexistence guidelines to ensure the transparency of product characteristics and the identity preservation that importing countries increasingly demand. Fortifying supply chains in this way could enable GMO exporters to soften the negative trade effects of importers' regulations. Also, efforts to harmonize their policies with those of their prominent importers could lower trade costs by reducing regulatory compliance costs. Further, exporters with increasing GMO content (i.e., China, Paraguay, Pakistan, South Africa, Uruguay, Philippines, and Mexico) could diversify their trading relationships and reorient trade toward countries with more permissive GMO policies. In practice, this would likely result in closer trade ties with importers in Asia (particularly China), the Middle East, and the Americas, and weaker ties with countries in Africa, the EU, and Oceania.

Second, our findings suggest that importing countries also have an interest in considering the trade impacts of their domestic GMO policies. Strict requirements raise the costs of regulatory compliance for importing firms and potentially force firms to import from higher-cost sources, thus raising consumer prices. Furthermore, our analysis shows evidence of a lag in the trade effects of GMO policies. Policy-driven impacts on trade may not appear immediately, but may grow over time as import/export firms adjust to new regulations. Accordingly, regulators could assess policies based on longer timeframes.

Finally, our results indicate that countries aiming to limit GMO imports (such as EU and some African countries) may be able to do so effectively without banning GMOs outright. Our results suggest that restrictive requirements (via multiple policy instruments) are associated with reductions in GMO imports, and may in the long-term serve to realign trade relationships away from GMO-heavy exporters. Nevertheless, the negative trade effect of regulations suggests that restrictive policies will continue to raise concerns/disputes over violations of the Sanitary and Phytosanitary and Technical Barriers to Trade agreements of the World Trade Organization.

In light of our results, we conclude that GMO policies are indeed "trade-related." Our analysis of LA (and Argentina and Brazil in particular) provides a benchmark for future research on other developing countries that are rapidly expanding their commitments to GMO crops.

Supplementary Material

Supplementary material is available at *Applied Economic Perspectives and Policy* online.

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