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EXPLAINING INTERNATIONAL DIFFERENCES IN GENETICALLY MODIFIED FOOD LABELING REGULATIONS

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Abstract. More than forty countries have adopted labeling policies for genetically modified (GM) food and the regulations vary considerably across countries. We measure the importance of domestic and international factors implicit in the choice of GM food labeling regulations. Our results show that European and Asian countries tend to follow the labeling policies of the European Union and Japan, respectively. Countries producing GM crops are more likely to have less stringent labeling policies. Countries with no labeling policies are less developed, with relatively large rural economies and are more likely to have ratified the Cartagena Protocol on Biosafety.

1. INTRODUCTION

The main international actors in food trade have adopted dramatically different positions on the labeling of genetically modified (GM) food. In total, more than forty countries have adopted labeling regulations and the characteristics of the regulations vary greatly (Carter and Gruère 2003a, Sheldon 2002, Phillips and McNeill 2000). At one end of the spectrum, the United States is the largest producer of GM crops, and has adopted voluntary labeling guidelines for non-GM food. At the other end of the spectrum, the European Union (EU) has stringent mandatory labeling regulations, and requires the labeling of GM food and GM ingredients with a 0.9% tolerance level for the adventitious presence of approved GM crops. Australia and New Zealand have mandatory labeling policies at the 1% level of GM ingredients; Japan requires GM food labeling at the 5% level for the top three ingredients and has a voluntary labeling system for food guaranteed to be free of GM ingredients; and South Korea has a 3% mandatory requirement for the top five ingredients. Canada is the world's third largest producer of GM crops and has adopted voluntary labeling guidelines for non-GM food. Less developed countries are caught in between the EU and the U.S. position on labeling. Argentina produces GM crops and does not have any labeling requirements. Alternatively, Brazil approved the production of GM soybeans and requires labeling at the 1% level. China produces GM cotton and leads the world in funding for public research on agricultural biotechnology (Huang, Rozelle, Pray and Wang 2002), and requires labeling of GM food ingredients at the 1% level.

In the EU and in Japan, the initial labeling requirements were introduced in response to consumer concerns. They were intended to provide consumer choice and consumer information. However, the mandatory labeling policies in the EU and Japan have resulted in the virtual disappearance of any labeled GM product on the food shelves. These policies encourage processors and retailers to avoid using GM ingredients in their food (Carter and Gruère 2003b). Thus, mandatory labeling acts as an import barrier against GM crops in these countries, and has failed to provide consumer choice. Eastern European countries and Russia adopted labeling regulations comparable to those in the EU, because they are dependent on trade with the EU. And some South Eastern Asian countries (such as Vietnam or Indonesia) have adopted regulations similar to those in Japan.

Some developing countries have taken a position on GM food labeling according to their major export markets, sometimes adopting mandatory labeling policies that do not seem to respond to genuine consumer concerns or may be unenforceable. In addition, according to Cohen and Paarlberg (2002), the rich importers' labeling regulations have been one of the main factors explaining the restricted availability and use of agricultural biotechnology in developing countries. Yet, recent empirical studies have provided evidence of the benefits of GM crops for many small farmers in developing countries (Qaim and Zilberman 2003, Pray, Huang, Hu and Rozelle 2002, Ismael, Bennett and Morse 2002, Qaim, Cap and De Janvry 2003).

Previous literature has acknowledged the difficulty associated with explaining the heterogeneous pattern of labeling regulations across countries. Caswell (2000) argued that this "patchwork of regulation" is the result of domestic rational choices. Mitchell (2002) provided a first empirical comparative study of international labeling regulations. Using international cross-sectional data, she used logit regressions to explain the presence of GM food labeling requirements and to test a set of hypotheses. She draws several conclusions. First countries with higher income are associated with mandatory labeling, but the test for an inverse U-shaped relationship between income and mandatory labeling failed. Second, countries with biotechnology crop trials are more likely to mandate labeling, but other export dependence does not make a country more likely to have labeling requirements. Importers of food from the United States are less likely to have labeling requirements.

Some of Mitchell’s results are not robust and she concluded that more work needs to be done to explain international regulations. More recently, Fulton and Giannakas (2004) analytically compared different GM labeling and regulation scenarios, and found that labeling regulations and adoption decisions raise conflicts of interest among consumers, farmers, and seed companies. They determined that four main factors affect the welfare of these different groups: consumer perception, the cost efficiency of biotech products, the amplitude of marketing margins and the degree of market power among seed companies. Fulton and Giannakas concluded that there is no easy explanation as to why different labeling regulations have been introduced in different countries.

Anderson and Jackson (2003) use a general equilibrium model to simulate the effects of the EU moratorium on new GM crops. They found that EU producers benefit from the restrictive policies in the EU, whereas U.S. producers would benefit if there were no regulatory barriers in the EU and elsewhere. They conclude that producer differences may explain the dramatically different regulatory approaches between the EU and the United States. Graff and Zilberman (2004) expand this argument, by observing that farmers and agriculture chemical producers in the EU benefit from having strong regulations covering GM crops and GM food. Biotech policies in Europe are conventionally attributed to the concerns of European consumers, but they are also helping European chemical firms and European farmers.

In this paper, we try to explain international choices of GM food labeling policies using an empirical approach. We aim to measure what may have motivated different countries to choose their specific set of regulations. Using a more recent and a more detailed data set, we will verify the results of Mitchell (2002), and test additional hypotheses. We evaluate how domestic conflicts of interest (consumer versus producers, environmental activists versus farmers, science versus precaution) and external conflicts of interest (trade relationships, trade dependency) can help explain the current international patchwork of labeling regulations.

We present the data in section 2. In section 3, we use a multivariate descriptive analysis to compare international labeling regulations. We then show the results of our regression analysis in section 4, and provide conclusions in section 5.

2. DATA

We have gathered data on GM food labeling regulations for one hundred and eight selected countries presented in table 1. Our data comes from various sources, including the U.S. Department of Agriculture Foreign Agricultural Service Attaché Reports and a number of published lists of international labeling regulations (Richey 2003, International Forum on Globalization and the Center for Food Safety 2003, Center for Food Safety 2004, National Food Processors Association 2004, Kochenderfer 2004, Rao 2004). We include countries with labeling policies, and countries without labeling regulations but who are producing GM crops, considering the introduction of a labeling policy or play a key role in world food trade. We treat the EU as a block of 15 countries (before May 2004), but we also add Germany and Spain as the only two EU countries producing GM crops. For each country listed in Table 1, we have gathered data on GM food regulations, crop production, international trade, and political and socio-economic variables. We present a table of summary statistics for the main variables in the Appendix.

We divide the countries into three categories depending on their labeling policies, and define the indicator variable TYP as follows: $TYP = 0$ for countries with no labeling regulations or guidelines, $TYP = 1$ for countries with voluntary labeling, and $TYP = 2$ for countries with mandatory labeling.[1] The regulatory variables include the threshold level for adventitious presence of GM ingredients (TOL, in %), whether the regulation includes feed ($FEED$), meat ($MEAT$), additives (ADD) and flavoring (FLV), whether it is applied to restaurants ($REST$), and products derived from GM ingredients but without any detectable trace of the transgenic DNA (DER), and a dummy variable equal to 1 if the country has enforced its regulation as of April 2004 (ENF).[2] We also construct a discrete variable representing the number of ingredients subject

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[1] Japan and New Zealand have a mixed labeling system, with mandatory GM labeling but voluntary guidelines for non-GM products. For simplicity we decide to include them in the category of countries with mandatory labeling ($TYP = 2$).

[2] Some countries (such as Russia) have published labeling regulations, but have not enforced them effectively (Richey 2003).

TABLE 1. **List of countries included in the study according to the presence of GM labeling regulations as of April 2004 (Sources: FAS Attaché Reports; Richey 2003).**

Region	**Countries with GM labeling**	**Countries considering GM labeling**	**Countries with no labeling**
Africa	South Africa, Mauritius	Cameroun, Ethiopia, Ivory Coast, Namibia, Sudan, Zambia	Algeria, Angola, Benin, Botswana, Burkina-Faso, Central Africa, Chad, Congo, Congo D.R., Egypt, Gambia, Ghana, Guinea, Kenya, Libya, Madagascar, Malawi, Mali, Morocco, Mozambique, Niger, Nigeria, Senegal, Syria, Tanzania, Togo, Tunisia, Uganda, Zimbabwe
Asia	China, Japan, Hong-Kong, Indonesia, Philippines, South Korea, Taiwan, Thailand, Vietnam	India, Malaysia, Singapore	Bangladesh, Bhutan, Cambodia, Kazakhstan, Myanmar, Nepal, North Korea, Pakistan, Papua-New Guinea, Sri Lanka, Uzbekistan
Europe	European Union, Croatia, Czech Republic, Germany, Hungary, Poland, Norway, Russia, Serbia, Spain, Switzerland	Georgia	Albania, Belarus, Bulgaria, Iceland, Macedonia, Romania, Turkey, Ukraine
Middle East	Saudi Arabia	Israel, United Arabian Emirates	Iran, Jordan, Oman, Yemen
North America	Canada, United States	Mexico	
South America	Argentina, Brazil, Chile	Bolivia, Ecuador	Colombia, Costa Rica, Cuba, El Salvador, Guatemala, Honduras, Panama, Paraguay, Peru, Uruguay, Venezuela
Oceania	Australia, New Zealand		

to the adventitious presence threshold (ING). This variable takes on the value 15 if all ingredients must be labeled (as in the EU), 0 if no ingredients are subject to requirement, or the number of major ingredients subject to the regulation.

On the production side, we have data from the Food and Agriculture Organization (FAO) database and International Service for the Acquisition of Agri-biotech Applications (ISAAA) publications on GM and total acreage of the four major GM crops (corn, soybeans, cotton and canola) for 1999, 2000, 2001, and 2002. We use these data to compute the average share of transgenic crops among these four crops in each country (noted as $SGM^C, SGM^S, SGM^T, SGM^{LA}$). We also have data on the number of varieties approved as of 2003 (from the AGBIOS database 2003,[3] noted $Nvar$).

To represent the trade variables, we collected import and exports quantities for the four GM crops for 1999, 2000, and 2001 and bilateral trade values for corn between these countries and Japan and the European

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[3] The AGBIOS Essential Biodafety Database is available for free on the WorldWideWeb at: http://www.essentialbiosafety.info/.

Union (15 countries), from the FAO database. We also added data on the quantity of exports of soybeans, canola and cotton (at the four digit ITC level) from each of country to the EU in 1999, 2000 and 2001, from the EUROSTAT database. We use these data to derive the average trade balances (from year 1999, 2000 and 2001) for each of the four crops (Tr^I, $I \in \{C, S, T, LA\}$ for corn, soybean, cotton and canola), and we compute the share of corn exports of each country to Japan (X^C_{jap}) and the average share of exports of the four crops to the EU ($X^C_{eu}, X^S_{eu}, X^T_{eu}, X^{LA}_{eu}$) for the years 1999, 2000 and 2001. We also use the USDA database to determine the share of exports of corn, soybean and cotton from the United States to each importer ($M^C_{us}, M^S_{us}, M^T_{us}$). In addition, we have data on the share of agricultural imports in total merchandise imports ($Agshimp$) and on the share of exports in total merchandise exports ($Agshexp$) for each country, published by the WTO in 1999. We use average trade balances of agricultural chemicals - pesticides ($Pest$), insecticides ($Insc$), and herbicides ($Herb$) in 1999, 2000 and 2001- from the FAO database, as proxy variables representing the importance of the chemical industry in each country. Finally, we add the consumption of fertilizers ($Fert$, in kg/ha of arable land) to represent the degree of agriculture intensification.

The political factors are difficult to assess quantitatively. We use qualitative data on the level of participation in the Cartagena Protocol on Biosafety (not signed, signed, ratified, variable noted CPB), membership in the WTO (noted WTO) and in the Organization for Economics Cooperation and Development (noted $OECD$), and the presence of active environmental campaign of Greenpeace and Friends of the Earth against transgenic crops, obtained from their websites ($Green \in \{0, 1, 2\}$). We also add the Human Development Index (HDI) developed by the United Nations Development Program (UNDP), which is a composite variable measuring three human development indicators: longevity, knowledge and standards of living.

We set up two proxy variables for the consumer acceptance of GM food, using various international surveys published in the literature. We derive them by computing a weighted average share of the population willingness to buy GM food. Given the lack of surveys in many countries, we use two alternative ways to fill the gap: for the first variable (WTB_1), we take the average value for each country without data; for the second variable (WTB_2) we assume that some countries share the same level of consumer acceptance as their neighboring countries that have the same level of income.[4]

We add macro-economic measurements of income, such as per capita GDP in 2003 ($pGDP$), annual percentage GDP growth from 2000 to 2002 (from the Economist Intelligent Unit and the IMF development indicators, noted $Grwth$), and the share of agriculture in total GDP (AG). We also use dummy variables to represent the different regions of the world (AFR for Africa, ASI for Asia, NAM for North America, SAM for South America, EUR for continental Europe, MDE for Middle East, and Oceania is omitted in estimations).

3. MULTIDIMENSIONAL DESCRIPTIVE ANALYSIS

We first use descriptive statistics to obtain an initial understanding of the main characteristics of each labeling policy. We follow a geometric approach, known as principal component analysis (PCA), to identify the multiple linear correlations between labeling characteristics and countries' other socio-economic and political characteristics, without imposing any strong assumptions.

The purpose of PCA is to determine a system of axes (called principal components) on which to project a set of individual points in order to obtain the least distorted representation of each of the points and their relative positions across the data set. We have 108 individual countries and 51 variables, and PCA allows us to observe the multiple correlation across individual countries and across variables on the same projection plane.

First PCA determines a gravity center for the new representation of the countries, whose coordinates are the standardized distance to the average of each variable. To minimize the total inertia (dispersion) of the individual points, the axes are determined by the eigenvectors associated with the largest eigenvalues of the variance-covariance matrix. The contribution of each axis is obtained by computing the ratio of the cumulative sum of the eigenvalues corresponding to each axis to the trace of the covariance matrix. We then

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[4] For instance, under this assumption, India has the same willingness-to-buy GM food as China.

represent the points in the new set of axes by translating each point into the new space. The axes do not provide perfectly identified dimensions, but by associating the countries and the variables with the axes, it is possible to find an interpretation for each of the axes.

3.1. **Results: Labeling regulations.**

We first focus on variables related to the labeling regulations in order to identify the correlation among labeling systems. We only include the 44 countries with labeling policies or those considering labeling in the near future.

We obtain two graphical representations, one for the individual countries and the other for the variables using the new basis. Both representations use the same system of axes, Axis 1 and 2. We show the variables in the correlation circle in Figure 1. The numbers used for projections are the linear correlations of the variables with each of the two axes, and thus each coordinate is within [-1,1], inside what is called the ‘correlation circle’. Variables that are better represented are closer to the circle, variables less well represented are closer to the center. Variables located at opposite one another are negatively correlated, whereas variables represented at orthogonal positions are not correlated. Variables that lie close to one another are correlated with each other. Finally the variables closer to the axes are the ones best representing the axes.

By observing the correlation circle (Figure 1), we see that Axis 1 (the horizontal axis) is correlated with the number of ingredients (ING), whereas Axis 2 (the vertical axis) is correlated with the tolerance level (TOL). Axis 1 is also correlated with the dummy variables representing the different products covered by the regulations. We can interpret the first principal component associated with this axis as a proxy variable for the ”coverage” of the labeling policies. The second component, associated with the tolerance level may be interpreted as the degree of strictness of the labeling policy.

Second, we show the representation of the set of countries on the basis of the two same axes in Figure 2. The 2-axis representation explain about 98% of the total inertia (variability) of the system. In this figure, two projections far from each other mean that the countries they represent are not well correlated, and two

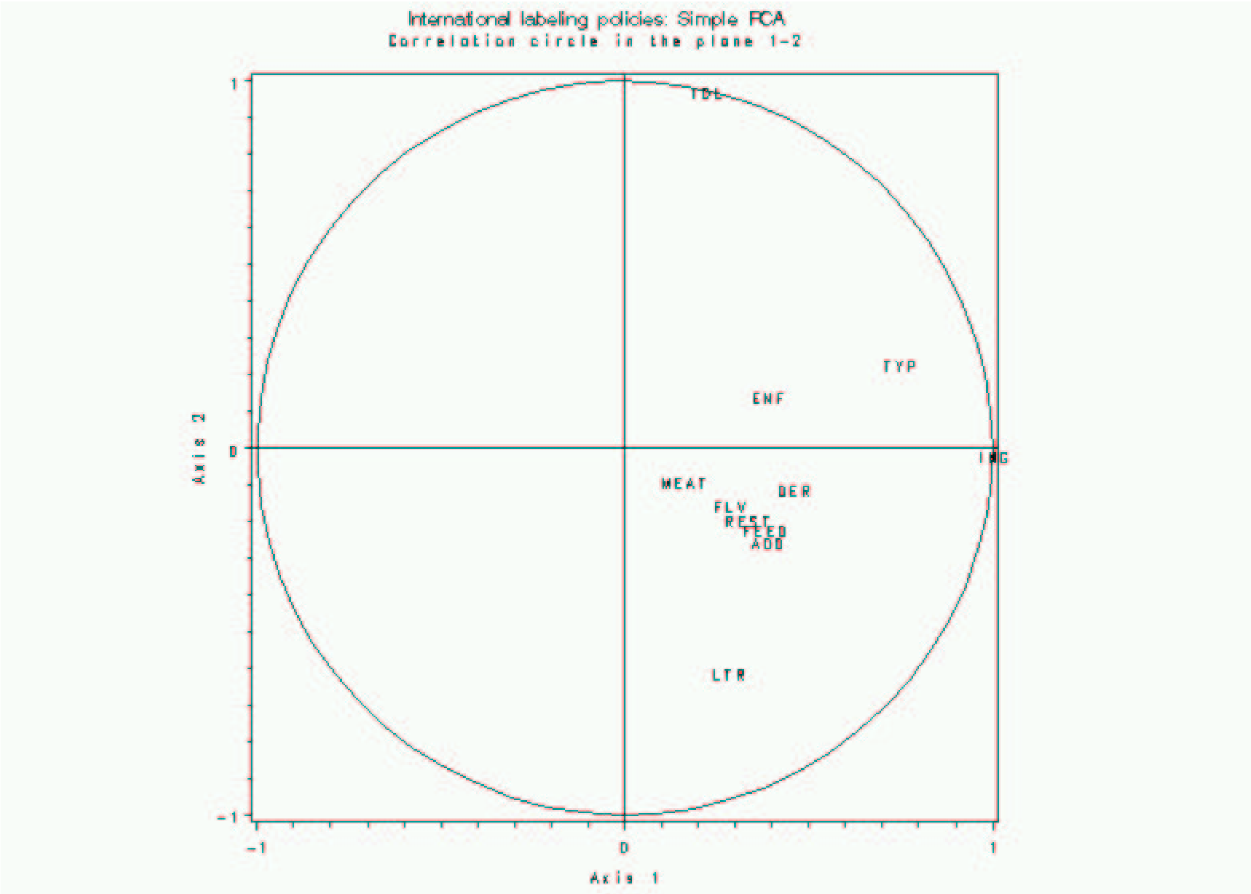

FIGURE 1. Comparing international labeling policies: representation of the variables

close projections may or may not be correlated. The countries closer to the axis are well represented, and better represented if they are further from the gravity center.

We find that there are four clusters of countries located in each of the four quadrants of Figure 2. The first group in the North West quadrant includes the United States, Canada, Argentina, Hong Kong, Thailand, Japan, Korea, and Chile. These countries have a tolerance level between 2% and 5% and do not require all ingredients to be labeled.[5] These countries produce or import GM crops, they have adopted a pragmatic approach to labeling.

At the other extreme, in the South-East quadrant of Figure 2, countries in Europe (the EU, Poland, Hungary, Czech Republic, Croatia, Switzerland and Norway), Australia, New Zealand, Russia, Saudi Arabia,

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[5] In particular, Canada and the United States' system of voluntary labeling does not require any ingredients to be labeled.

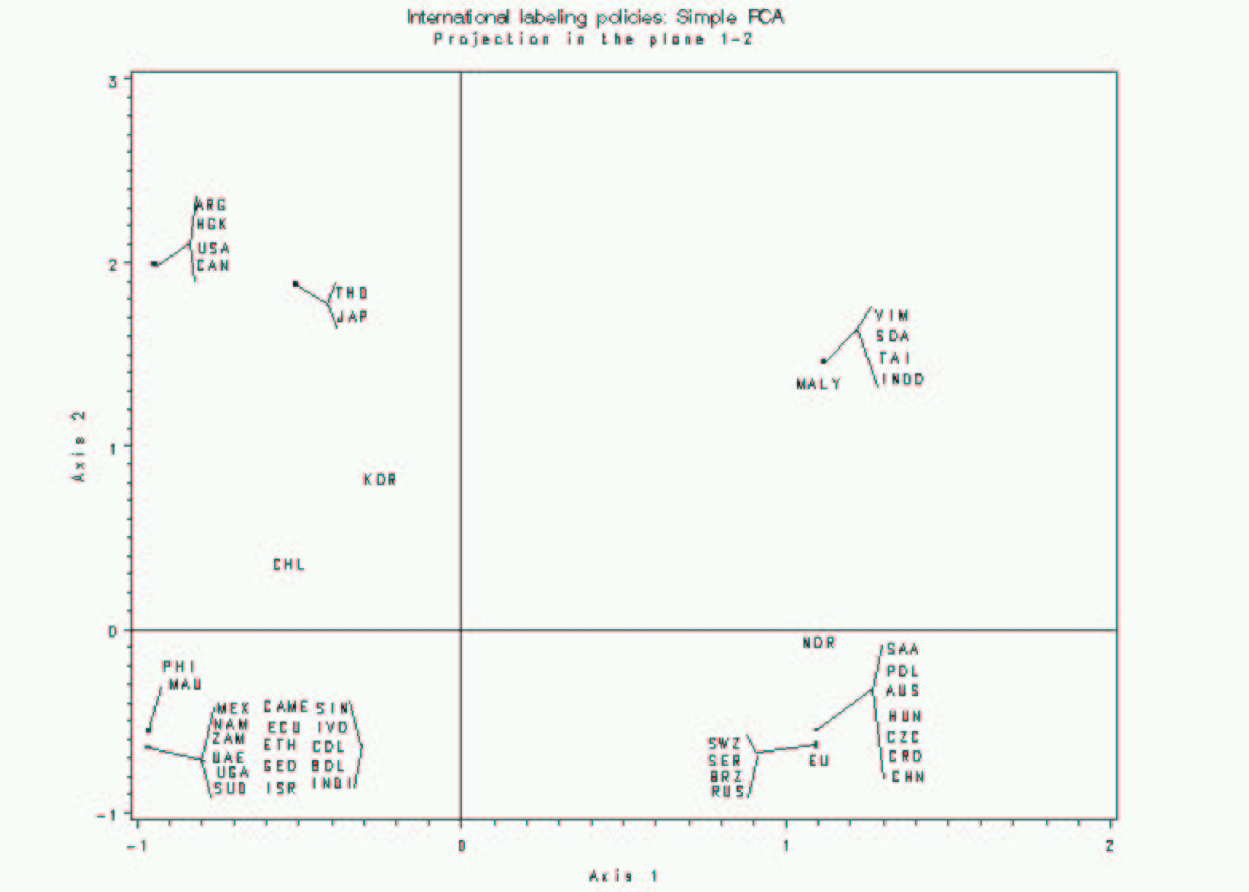

FIGURE 2. Comparing international labeling policies: representation of the individual countries

China and Brazil have labeling policies including all ingredients, covering a large number of products, and with a tolerance level of 1% or 0.9%. Countries in Europe tend to follow the EU labeling regulations. Eastern European countries are expecting to become members of the EU in the near future, and they are trying to harmonize their regulations with those ones in the EU. Australia and New Zealand were among the first countries to choose to require the labeling of GM food at the 1% level. Saudi Arabia introduced mandatory labeling of GM food officially for religious reasons. Finally three large countries are included in this group: Brazil, China and Russia. Brazil is a large agricultural exporter to the EU, China exports food to the EU and Japan, and Russia is also a trade partner of the EU. All the countries in this group have adopted costly and stringent regulations.

In the North-East quadrant of the Figure, we find five countries: Taiwan, Vietnam, Indonesia, Malaysia, and South Africa. Most of these countries have not enforced their regulations. Based on current information, their choice of regulation is between the Japanese and EU approach. They have announced a 5% threshold level, but have not specified a restriction on the number of ingredients covered in each product. By default, we assumed that their regulations will cover all ingredients. But *a priori*, the Asiatic countries in this group will use a system comparable to the one in Japan or South Korea, who only require the main ingredients in each product to be labeled. Finally, the fourth group of countries in the South-West quadrant do not have any precise requirements but intend to introduce mandatory labeling in the near future.

If we take into account the uncertainties related to the last two groups of countries, we can distinguish three clusters of countries by comparing their labeling approaches: first, countries with pragmatic and lower cost labeling regulations (with voluntary or mandatory labeling); second, countries with stringent and more comprehensive labeling requirements more costly to set up and enforce; and third countries caught in the middle that have indicated their intention to implement mandatory labeling and that will follow the EU or the Japanese approach.

3.2. **Index of labeling and other factors.**

We conduct further multivariate PCA, presented in Figures 3 and 4. We set up an index representing the degree of strictness of each labeling policy. The index is based on a few assumptions: first, the more products covered, the stricter the labeling; second, labeling policies are more stringent if they are mandatory, if they are enforced, and if the percentage of GM food in a product implicitly or explicitly labeled as non-GM is closer to zero. This index is continuous, and is computed with the following formula:

$$LBL = (TYP + \frac{LTR}{2}) * \frac{1+ENF}{2} * \frac{1 + FEED + MEAT + DER + REST + ADD + FLV}{1-(TOL * 100 * \frac{ING}{15})} \quad (1)$$

We also include the following aggregated variables based on some of the initial variables:

-$SGM = SGM^C + SGM^T + SGM^S + SGM^{LA}$ indicates the presence of GM varieties among the four

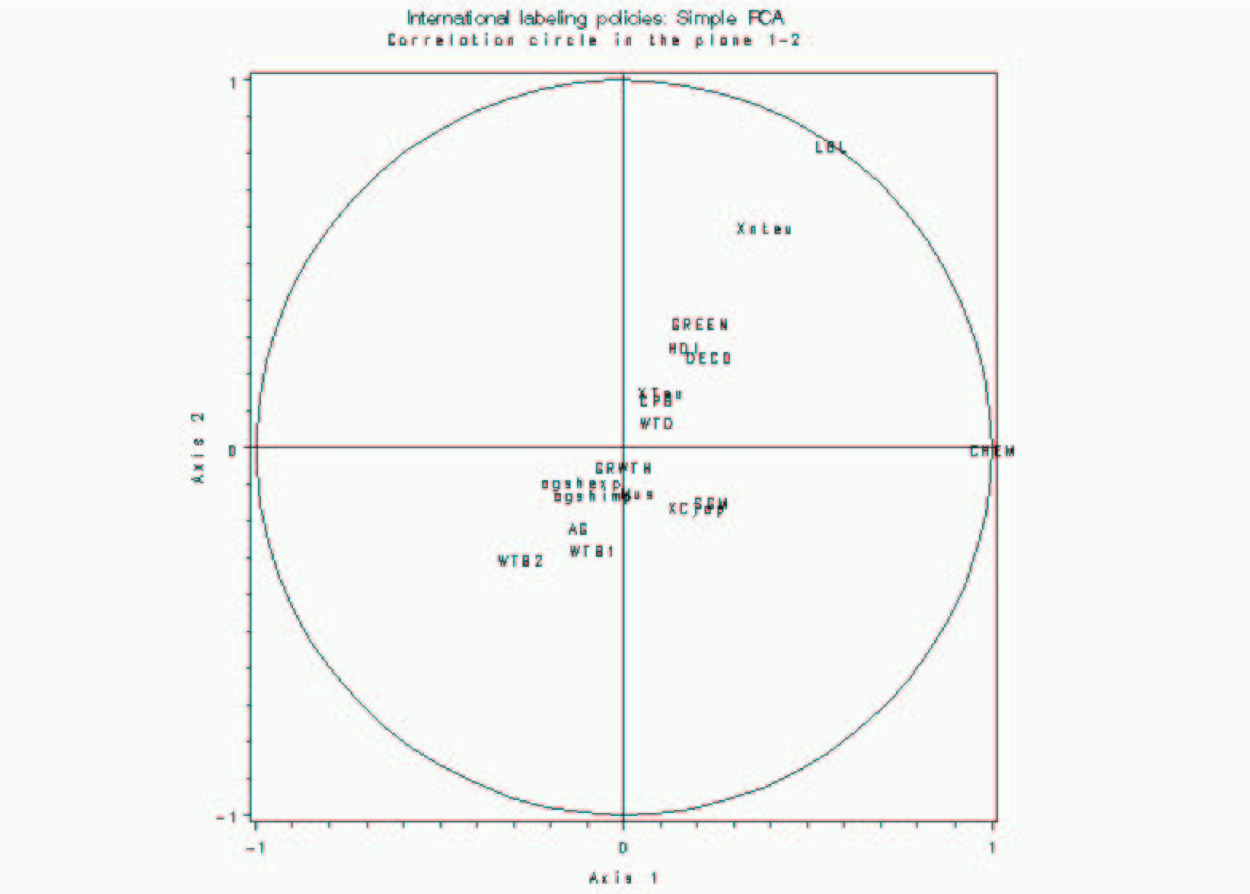

FIGURE 3

crops;

-$X_{eu}^{NT} = X_{eu}^{C} + X_{eu}^{S} + X_{eu}^{LA}$ represents the sum of export shares of the four **food or feed** crops to the EU;

-$M_{us} = M_{us}^{C} + M_{us}^{T} + M_{us}^{S}$ represents the sum of import share of corn, cotton and soybean from the United States in each country's total import;

-$Chem = Pest + Insc + Herb$ is the total net trade balance of agricultural chemicals.

In the correlation circle (Figure 3), the first component (Axis 1) is almost perfectly correlated with the exports of chemicals. The second principal component (Axis 2) is not well correlated with most variables. There is a third invisible line, a diagonal from the lower left to the upper right panel in figure 3, which is correlated with the labeling index (LBL). The labeling index is partially correlated with Axis 1, so it is

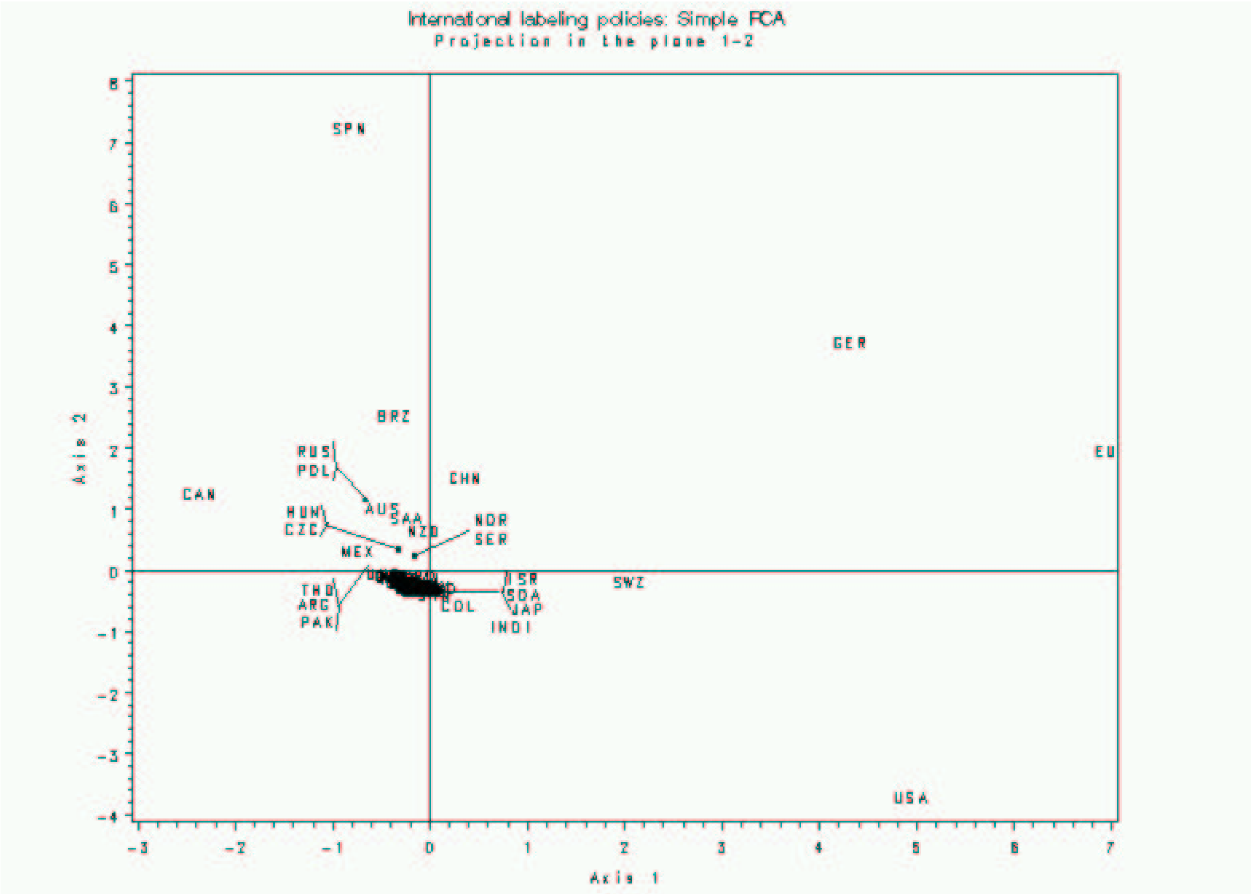

FIGURE 4

partially correlated with the chemical exports. On the "third" line, the variables representing the exports to the EU (X_{eu}^{NT}) and the presence of a Green campaign ($Green$), the human development index (HDI) and the dummy for OECD countries appears to be correlated with the labeling index, whereas the agricultural share of GDP (AG) and the average willingness to buy GM (WTB_1, WTB_2) appear to be negatively correlated with this index.

In the country representation (Figure 4), we find the ranking of chemical exports in the horizontal direction, with the EU, the United States, Germany, Switzerland, India and China on the right side of Axis 2 as exporters. Along the diagonal, countries are ranked according to their labeling index, from the EU (most stringent) to the United States (least stringent labeling regime) and a large cluster of countries with no labeling policies. Countries higher on the diagonal are likely food exporters to the EU, with consumers opposed to GM food as well as having active green NGO campaigns, and countries where agriculture represents a relatively low share of total GDP. Most of the countries in our data set are close to the center (not well represented) or in the left lower corner, meaning that they import chemicals, with consumers less opposed to GM and with rural economies.

Base on our PCA analysis, we can draw three main conclusions:

i) We distinguish three groups of countries according to their labeling policies: first, the countries with a "pragmatic" approach to labeling, that either import or export GM crops and explicitly consider the cost of the regulations. Second, some countries are linked with the EU and have adopted relatively stringent regulations. Third, we find a group of countries that are caught in the middle, and that have decided to opt for mandatory labeling regimes, following the approach of the EU or Japan.

ii) European countries and Asian countries that are implementing a labeling policy tend to follow the labeling regulations of the EU and Japan, respectively. We found that all labeling countries in Europe are in the second group of countries, with labeling requirements similar to the EU's. Asian countries with labeling policies, except China, have adopted mandatory labeling with tolerance levels exceeding 2%, following the approach of Japan.

iii) Our analysis suggests several possible linear correlations. First the projection of the labeling index (LBL) variable representing the degree of stringency and cost appeared positively correlated to the variables representing the share of export of the four crops to the EU and the presence of a green campaign. The labeling index also appeared negatively correlated to the average consumer willingness-to-buy GM food and the agricultural share of GDP.

4. REGRESSION ANALYSIS

We employ regression analysis to further determine which of the above mentioned factors affects GM food labeling regulations and to test a set of hypotheses. The characterization of labeling regulations is inherently multidimensional. We use two econometric approaches to try to explain labeling regulations. First, we employ a discrete choice approach, by estimating single equation logit models to explain the probability of choosing a labeling regulation (as done by Mitchell) and by using a multinomial logit estimation on the type of labeling regime (no labeling, voluntary labeling, and mandatory labeling). Second we run single equation linear regressions on three indexes of labeling policies.

Based on the previous literature and the PCA results, we will test the following hypotheses.

i) Is there a (linear or U-shaped) relationship between the level of income and the presence of a particular type of GM food labeling policy?

ii) Are labeling regulations related to the level of consumer acceptance of GM food or the presence of a green national campaign?

iii) Are labeling regulations related to the domestic production of GM crops?

iv) Are labeling regulations related to the importance of the chemical industry?[6]

v) Are food importers more likely to have stringent labeling regulations? Are food exporters less likely to have labeling requirements?

vi) More specifically are countries exporting soybeans, corn, cotton or canola to the EU or Japan more likely to have similar labeling regulations as these two countries? Are countries importing these crops from the United States less likely to adopt stringent labeling regulations?

vii) Does the participation level in the Cartagena Protocol, WTO membership, or the regional location affect the regulatory choice of a particular country?

4.1. **Discrete choice approach: type of labeling policy.**

a) Adoption of labeling requirements

We first run simple logit regressions on the adoption of mandatory labeling across countries. We combine a reduced set of variables to preserve degrees of freedom, and we avoid using any two variables that have a strong linear correlation in the same regression, in order to reduce the risk of multicollinearity (which translates into inefficient estimates). The results are shown in Table 2.

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[6] According to Graff and Zilberman (2004), one of the potential factors in the EU's opposition to transgenic crops is that the EU has large chemical companies.

TABLE 2. **Coefficient estimates: simple logit regressions on the dummy for mandatory labeling for the 108 countries (Regressions 1& 2) and logit regression on the dummy for prospective mandatory labeling countries for the 78 non labeling countries (Regression 3).**(the standard errors are shown in parenthesis, and * means 10%, ** 5% and *** 1% level of statistical significance)

	Dependent variable ML		Dependent variable $DLTR$
Independent Variables	**Regression 1** (for all countries)	**Regression 2** w/o EU, US, and Japan	**Regression 3** non labeling countries
SGM	-6.17**(2.42)	-8.90** (4.50)	23.43 (14.8)
Tr	-3.98E-8(4E-7)	7.37E-7(1.3E-6)	-7.31E-6***(1.54E-6)
X_{eu}^{NT}	3.54**(1.40)	3.34**(1.55)	-13.52**(6.31)
X_{eu}^{T}	-2.09 (2.05)	-2.40(2.35)	-3.48 (2.31)
X_{jap}^{C}	24.5**(11.5)	28.56**(13.8)	
M_{us}	-0.32 (1.21)	-0.23 (1.18)	-0.38 (0.82)
$Green$	3.42 (2.42)	3.52 (2.3)	1.17 (1.28)
$OECD$	-0.40 (1.18)	-0.47 (1.18)	-13.95***(5.1)
WTO	-3.36 (2.23)	-3.45 (2.14)	-0.039 (0.98)
HDI	13.96**(6.85)	12.05(7.57)	3.94 (5.35)
CPB	-0.87 (0.63)	-0.65 (0.70)	-1.08*(0.60)
$pGDP$	-3E-4 (2.4E-4)	-2.7E-4 (2.2E-4)	-0.0004 (4.99)
$pGDP^2$	6.37E-9 (5.6E-9)	6.3E-9 (5.4E-9)	4.46E-8**(2.1E-8)
AG	-6.86(6.05)	-6.62(6.1)	1.21 (4.81)
$Grwth$	71.39***(24.8)	71.6***(27.2)	-11.66 (18.6)
$Agshexp$	-4.0 (3.03)	-4.90 (3.03)	5.39**(2.22)
$Agshimp$	-0.65 (5.93)	-1.04 (7.2)	-18.64**(8.19)
$Chem$	-8.5E-7 (3.4E-5)	-1.2E-5 (1.3E-5)	4.48E-5**(1.9E-5)
$Fert$	-2.8E-4 (2.2E-4)	-1.3E-4 (1.3E-4)	-3.55E-4**(1.6E-4)
WTB_1	8.76 (8.68)	24.0 (21.8)	
$Constant$	-14.56**(6.83)	-19.85**(10.1)	-0.16 (4.7)
Pseudo R^2	0.69	0.66	0.47

First, we use all countries and run a regression on the dependent variable ML, which is equal to 1 if the country has adopted mandatory labeling as of April 2004, and 0 otherwise (Regression 1). We find no evidence of an inverse-U relationship between the probability of adopting mandatory labeling and income. The coefficients on the share of exports of soybeans, corn and canola to the EU (X_{eu}^{NT}), exports of corn to Japan (X_{jap}^{C}), human development index (HDI) and economic growth ($Grwth$) are positive and significant. Exporters of the four crops (except cotton) mainly to the EU or corn mainly to Japan, countries with higher levels of development and with positive economic growth are more likely to mandate labeling. At the same time, the coefficient on the total share of GM crop (SGM) is negative and statistically significant. Countries producing GM crops are less likely to have adopted mandatory labeling of GM food.

The second regression is run without the three potential outliers, Japan, the EU and the United States on the same set of explanatory variables (Regression 2 in Table 2) to verify our results. Without these three countries, we confirm the positive relationship between exports of the three food and feed crops to the EU, exports of corn to Japan, or economic growth and the probability of adopting a mandatory labeling requirement. Only the human development index (HDI) is no longer explaining the probability of adopting mandatory labeling.

All the other variables were not statistically significant. As in Mitchell (2002), we find that imports of crops from the United States (M_{us}) do not affect the probability of having a labeling requirement. But unlike Mitchell, we find that there is a correlation between exporting crops to the EU and the probability of adopting a labeling requirement.

In the third column of Table 2 we present regression results for the dependent variable $DLTR$ equal to 1 for countries considering the use of mandatory labeling and 0 otherwise. We only use countries with no labeling policies today, to estimate likely factors influencing future decisions to require the labeling of GM food. The variables X_{jap}^{C} and WTB_1 are omitted in the estimation to avoid hidden collinearity and perfect determination of the dependent variables.

We find different results (Regression 3). The coefficients on income square ($pGDP^2$), the share of agriculture in total merchandise exports ($Agshexp$), and the chemical trade balance ($Chem$) are positive and significant, which implies that these variables increase the probability of plans to adopt mandatory labeling. On the other hand, the coefficients on Tr, X_{eu}^{NT}, $OECD$, CPB, $Agshimp$ and $Fert$ are negative and statistically significant. Thus, countries expected to require labeling in the near future tend to be net importers of the four crops, not exporting the three GM food and feed crops to the EU, but for whom agriculture represents a large share of total merchandise exports and a relatively small share of total imports. In other words, they may be exporters of non-GM crops to the EU or elsewhere. Furthermore, these countries use less fertilizer, they export chemicals, and they are not OECD countries, or not committed to the CPB.

Finally, these countries are likely to have high or low incomes compared to the ones with no intention to label.

So if current adopters of mandatory labeling requirements are agricultural exporters with links to the EU or Japan, are developed countries, and are experiencing positive economic growth, in contrast, prospective labeling countries tend to be net importers of the four GM crops, exporting non-GM commodities, and not OECD countries.

b) Mandatory versus voluntary labeling

As a second approach, we take the labeling decision as a choice between three alternative regimes: no labeling, voluntary labeling, and mandatory labeling. As in the previous section, we will present the regression results on past and recent labeling decisions (dependent variable TYP) with all countries, and then run the same regressions without the three potential outliers (the EU, the United States and Japan). To proceed with the estimation, we avoid the overuse of dummies and combine meaningful independent variables. In each case, we present two alternative multinomial logit regressions based on two different set of independent variables. The results are shown in Table 3.

Regression 4 includes variables on agricultural production and trade, economics and political factors, with a reasonable Pseudo R-square of 0.6. Regression 5 combines other variables representing mainly political and economic factors.

First, the variables SGM, Tr, and $Chem$ increase the probability of opting for a voluntary labeling policy. At the same time, the variables $Agshimp$, $Grwth$ and X_{eu}^{T} are negatively correlated with this probability. We also observe a U shaped relationship between the adoption of voluntary labeling and per capita income. On the one hand, countries producing GM crops, exporting chemicals, that are net exporters of the four main GM crops are more likely to choose a voluntary labeling policy. On the other hand, countries whose agricultural imports are relatively important, who export cotton mainly to the EU, or who have a significant economic growth are less likely to opt for voluntary labeling.

TABLE 3. **Estimated coefficients: multinomial logit regressions on the type of labeling (**TYP**).** * 10%, ** 5%, *** 1% level of statistical significance.

Variables	All countries				w/o EU, US and Japan			
	Regression 4		Regression 5		Regression 6		Regression 7	
	Voluntary	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory
SGM	17.62***	0.91			19.56***	2.78		
Tr	6.7E-6***	1.6E-7			7.3E-6***	6.2E-7		
X_{eu}^{NT}	0.95	1.07**			0.628	0.45		
X_{eu}^{T}	-451.1***	-1.44			-452.9***	-1.62		
X_{jap}^{C}	-19.22	14.6**			-15.36	15.85***		
$Green$	8.0***	2.74***			8.21***	3.04***		
$Agshexp$	-32.26***	-6.11***			-34.02***	-6.85***		
$Chem$	3.3E-5**	-4.5 E-7			2.3E-5*	-9.98E-6*		
CPB			-9.38**	-1.07**			-9.35**	-1.06**
AG			-109.7**	-10.93**			-109.4**	-10.92**
$Grwth$			-166.8*	5.83			-166.4	5.83
$Agshimp$			-249.07***	-11.70			-248.3**	-11.7
M_{us}			-0.45	0.41			-0.45	-0.41
HDI			236.9**	16.23***			236.2**	16.22***
WTB_1			33.58	-108.9***			120.8	-103.7**
$pGDP$			-0.0038**	-4.2E-4**			-0.004**	-4.2E-4**
$pGDP^2$			7.7E-8**	8.8E-9			7.7E-8**	8.8E-9
SGM^T			34.58	65.84***			-48.24*	63.32**
$Constant$	-6.41***	-2.26***	-151.7*	38.28**	-6.37***	-2.20***	-188.2***	36.07*
Pseudo R^2	**0.61**		**0.55**		**0.56**		**0.48**	

Secondly, the probability of implementing a mandatory labeling policy increases with the variables X_{eu}^{NT}, X_{jap}^{C}, and SGM^T. Moreover, the coefficient on WTB_1 is negative and significant. Countries exporting the GM food and feed crops to the EU and Japan, who produce GM cotton or who have a lower consumer acceptance are more likely to have adopted mandatory labeling policies as opposed to voluntary labeling.

Finally for these two regressions, the variables $Green$ and HDI are positively correlated with the adoption of both labeling types, whereas the variables AG, CPB and $Agshexp$ decrease the probability of introducing both types of labeling. Less developed countries, with no green campaign, but who are committed to the Cartagena Protocol on Biosafety, with rural economies, and with large agricultural share of exports in total merchandise exports, are less likely to have adopted any labeling policy. Countries without labeling may have decided to ratify the Protocol on Biosafety as a substitute for a clear domestic policy on GM food and crops.

In comparison, when we omit the three outlying countries (Regressions 6 & 7), we just find a few differences among significant factors. In the case of voluntary labeling, we find that the factor $Grwth$ is no longer significant whereas SGM^T becomes negative and significant. For mandatory labeling, the factor X_{eu}^{NT} is no longer significant, whereas the variable $Chem$ becomes negative and significant. These four variables are partially driven by the outliers in the comparison of the three types of labeling.

4.2. **Characteristics of the labeling regulations.**

a) First principal component (coverage index)

We use the ordinary least squares (OLS) estimator to explain a coverage index ($PC1$) of labeling defined as the first principal component of the PCA on labeling policies presented in section 3.1. This variable is correlated with the different types of products covered in the regulations and with the variable on the number of ingredients required to be labeled.

We include all countries, and we set up a dummy variable equal to 1 for countries with no labeling. To find the proper value for the dependent variable in the countries without labeling, we use the vector of changes of the original labeling variables to the principal component. We use White's heteroskedastic consistent standard errors to take into account the different variances. The regression results of the reduced regressions (without including insignificant variables) are shown in the second column (Regression 9) in Table 4.

We find that the coefficients on $Green$, $Grwth$, $pGDP$ and X_{eu}^{LA} are positive and significant while the coefficients on $pGDP^2$, AG and $Fert$ are negative and significant. Thus, countries with an anti-GM green campaign, positive economic growth, or exporting canola to the EU are more likely to have adopted stringent regulations. Countries with relatively large rural economies and a large use of fertilizer tend to implement less stringent regulations (or no labeling regulations). In addition we find an inverse U relationship between per capita income and our dependent variable: countries with low and high income per capita tend to have less complete regulations than countries with medium income per capita. Finally, the dummy variables on China ($China$) and North America (NAM) are positive and significant.

TABLE 4. **OLS regressions on the first principal component, the tolerance level and the labeling composite index** (the standard errors are indicated in parenthesis, * 10% level, ** 5% and *** 1% level of statistical significance)

Variables	**Regression 8 on $PC1$**	**Regression 9 on TOL**	**Regression 10 on LBL**
SGM	-1.07***(0.24)		-185.47**(89.7)
SGM^{NT}		2.35***(0.48)	
X_{eu}^{LA}	1.54***(0.4)		
X_{eu}^{NT}			282.39***(96.5)
Tr^{T}		-1.41E-6**(5.7E-7)	
Tr^{LA}			1.08E-4**(4.93E-5)
$Green$	0.40**(0.18)	0.55**(0.21)	
$pGDP$	1.16E-4***(4E-5)		0.0169**(7.97E-3)
$pGDP^2$	-2.2E-9**(1.1E-9)		-6.11E-7**(3E-7)
$Grwth$	6.36***(2.15)	12.43***(4.63)	
AG	-2.97***(0.93)		
$Chem$			1.13E-3***(3.47E-4)
$Fert$	-3.8E-5**(1.7E-5)		
WTB_{av}			-1229.95**(619.9)
ASI		0.87**(0.403)	
NAM	0.85*(0.46)		
SAM		-0.812***(0.25)	
EUN		-1.187***(0.45)	
$China$	2.36***(0.31)	-2.03***(0.61)	1253.22***(172)
$NOLB$	1.27E-6***(4.9E-8)	3.75E-7***(1E-7)	6.76E-5***(8.3E-6)
$Constant$	-0.87***(0.078)	0.54*(0.30)	584.28*(298.2)
$adj.R^2$	0.65	0.48	0.73

b) Tolerance level

We use the tolerance level as a second characteristic of labeling policies.[7] The results are reported in the third column of Table 4 (Regression 10). We find that the coefficients on SGM^{NT}, $Green$, $Grwth$, and ASI, are positive and significant, while the coefficients on Tr^{T}, and SAM are negative and significant. Thus countries producing GM soybeans, corn, or canola, with a green campaign, a positive economic growth, or located in Asia are more likely to choose a higher tolerance level. At the same time, countries that are net exporters of cotton, or that are located in South America are more likely to have a low tolerance level. Countries with no labeling policies have a tolerance level of 0 by default, and the dummy variable $NoLB$ is negative and significant as expected. In addition the dummies on China and the European Union (EUN) are negative and statistically significant, as expected.

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[7] The tolerance level is strongly correlated with the second principal component of our first PCA.

c) Stringency and cost of labeling

As a third approach, we use the labeling index LBL defined by equation (1) in section 3.2. It is computed as a ratio of factors (including TOL) representing the coverage and the cost of the labeling regulations. We find that the coefficients on Tr^{LA}, $pGDP$, X_{eu}^{NT} and $Chem$ are positive and significant, whereas the coefficients on SGM, $pGDP^2$, and WTB_{av} (variable defined as the average between WTB_1 and WTB_2) are negative and significant. Thus countries with the highest index of strictness are exporters to the EU, exporters of canola, and chemical exporters. Countries producing GM and with a larger consumer acceptance of GM food have adopted less stringent and less costly regulations overall. Finally we confirm the inverse U relationship between the degree of stringency and the income level.

4.3. **Synthesis of the results.**

We summarize our results by answering the questions posed at the beginning of this section.

i) **Countries with low or high income per capita are less likely to have a stringent labeling policy, and more likely to have a voluntary labeling policy or no labeling policy.** We find an inverse U relationship between GDP per capita and the coverage index, as well as the composite labeling index. We find a U shaped relationship between per capita income and the adoption of voluntary labeling. These relationships should be interpreted carefully, because the implicit intermediate income countries include a large range of per capita incomes from China at the low end to countries of the EU at the high end. Furthermore, we cannot verify this relationship in our analysis of the factors of adoption of mandatory labeling policies. Besides, we find that countries that are planning the introduction of labeling policies tend to have relatively higher incomes among the group of countries with no current labeling policy.

ii) **Countries that have no green campaigns tend to have no labeling policies. Countries with a lower level of consumer acceptance of GM are more likely to opt for a stringent mandatory labeling policy.** The variable measuring the presence of a double green campaign (Greenpeace and Friends of the Earth) is positive and significant for both voluntary and mandatory labeling in the multinomial logit estimations, meaning that it reduces the chance of having no labeling policy. Furthermore, the coefficient on the dummy $Green$ is positively correlated with the coverage and composite labeling index but also with the tolerance level. The only caveat to these results is the possibility of simultaneity, because the $Green$ variable was measured in 2003 after many labeling decisions were already in place.

Apart from that, we found that countries with lower consumer acceptance are more likely to have a stringent labeling policy rather than no labeling policy, and to have opted for mandatory labeling rather than voluntary labeling. However, our measurement of consumer acceptance is approximate.

iii) **Countries that have been producing or that are producing GM crops are more likely to have implemented voluntary labeling or less stringent labeling policies.** We found that the variables associated with the production of GM crops increases the likelihood of opting for voluntary labeling rather than mandatory labeling, and that they increase the likelihood of having lower coverage and labeling indexes. The exception is the case of GM cotton, as it appears that countries with GM cotton tend to have mandatory labeling requirements for GM food.

iv) **Exports of agricultural chemicals (pesticides, insecticides, and herbicides) are correlated with stringent and voluntary labeling policies. Countries with intensive agriculture, as measured by fertilizer usage, tend to have less complete labeling regulations.** We found that the chemical trade balance is positively correlated with the labeling index and the probability of opting for voluntary labeling. In addition, the variable on fertilizer consumption is negatively correlated with the coverage index. But these two factors were determined partially by the outlying countries (EU, US and Japan). In addition we found that countries who have indicated their intention to implement mandatory labeling are exporters of chemicals and low fertilizer users.

v) **Countries exporting mainly agricultural commodities are more likely to have avoided labeling GM food. Countries importing mainly agricultural commodities are less likely to opt for voluntary labeling. Countries exporting the main four GM crops are more likely to opt for voluntary labeling.** The coefficient on $Agshexp$ was negative for both types of labeling in the multinomial logit regressions. In contrast, countries considering the labeling of GM food are more likely to be exporting a significant share of agricultural commodities. The coefficient on Tr was positive for voluntary labeling. Among the exporters of cotton that have adopted labeling we found that they were more likely to have chosen a low tolerance level.

vi) **Countries exporting soybeans, corn and canola mainly to the European Union are more likely to choose a stringent mandatory labeling regime. Countries exporting corn mainly to Japan are more likely to adopt a mandatory labeling regime.** We found the variable X_{eu}^{NT} correlated with the index of labeling and with a positive coefficient on the adoption of mandatory labeling. The variable X_{jap}^{C} is also a significant explanatory factor for the adoption of mandatory labeling. In contrast, we did not find that the shares of imports of the four crops from the United States were correlated with the type of labeling regulation.

vii) **Membership to the WTO is not related to labeling decisions. Participation in the Cartagena Protocol on Biosafety (CPB) is higher among countries with no labeling requirements. At the regional level, Asiatic countries are more likely to implement labeling regulations with higher tolerance levels.** In addition, we found that among the countries with no labeling today, the ones committed to the CPB were less likely to opt for the adoption of a labeling policy in the near future. Thus the CPB acts as a default regulation for countries without any position on labeling.

viii) **Finally, less developed countries with low human development index, and relatively large rural economies are less likely to adopt any labeling policy, and countries experiencing larger economic growth are more likely to implement mandatory labeling with relatively more products covered and a high tolerance level.** The variable AG is negatively correlated with the coverage index, and it is also negatively correlated with the adoption of voluntary or mandatory labeling. The variable $Grwth$ as positively correlated with the coverage index, the tolerance level, and the probability of opting for a mandatory labeling regime

5. CONCLUSION

Many countries have decided to implement labeling regimes for genetically modified food and the regulations differ widely across the world. In this paper we conducted a cross-national comparison of GM food labeling regulations, and tried to explain why countries choose to label, and why some opt for a specific labeling regime.

We found that we can group labeling countries into three categories. The first group includes the adopters of GM technology (such as the United States and Canada), and exporters or importers of the major GM crops (e.g., Japan), who adopted pragmatic labeling regulations. The second group is connected with the European Union (EU) and implemented costly and more complete GM labeling systems. The third group is caught between the first two, and adopted labeling systems comparable to the EU or to Japan, or they are considering labeling policies that resemble one of these two.

We considered three sources of explanations for GM labeling policies: domestic political factors (consumer and producer preferences), international trade factors (trade dependency and trade relationships) and macro economic factors (income, importance of agriculture). Based on a cross-national data set of 108 countries, we first found that countries labeling GM food are usually more developed, and less dependent on agriculture. Furthermore, countries that did not adopt any labeling policy tend to be ratifying parties of the Cartagena Protocol on Biosafety and do not present anti-GM campaigns from green NGOs. Then among labeling options, we found that some political and trade variables were relevant explanatory variables. On the one hand, countries producing GM crops tend to adopt more pragmatic and less costly labeling policies, and large exporters of cotton, corn, soybeans and canola tend to adopt voluntary labeling. On the other hand, countries with low consumer acceptance, exporting soybeans, corn, or canola mainly to the EU or corn mainly to Japan are more likely to mandate the labeling of GM food. Among these, countries in Asia or exporting corn mainly to Japan are more likely to have a relative higher threshold level for the adventitious presence of GM ingredients and to regulate only a restricted number of ingredients in each product.

In contrast, countries located in Europe or exporting mainly corn, soybean and canola to the EU are more likely to have very stringent and costly policies, with low threshold levels and all ingredients covered.

Interestingly, in the transatlantic comparison of opposite policy approaches, consumers and producers seem to find advantage in their own countries' choice of labeling policy. This confirms the thesis of Caswell (2000) that each country will choose its own labeling regime to respond to its economic and political interests. Our results also support the conclusions of Anderson and Jackson (2003) and Graff and Zilberman (2004), that production factors are determinants of transatlantic differences in biotechnology regulations. These results partially contradict the prediction of Fulton and Giannakas (2004), who concluded that consumers, producers and seed companies never agree as to which labeling option to choose.

Apart from OECD countries, who seem to have made choices according to their own national interest, we can comment on labeling choices in less developed countries. Regional influence and trade relationship are important factors in the determination of labeling policies in poor countries. We found that Asian countries tend to adopt similar regulations as Japan, and European countries tend to follow EU regulations. The trade factors are more important than the consumer or green factors. In particular, transition countries like Brazil, China and Russia have adopted mandatory labeling of GM food without surveying their consumers. The main remaining factors in our study are production choices and exports to the EU and to Japan. These three factors combined may partially explain the regulations in transition countries.

While this study provides some interesting results, many questions remain and further work should strive to obtain an improved data set. First, more countries would increase the efficiency of our estimations. We would like to include data on bilateral trade of all crops with the EU, Japan, and the United States. As regulations get published, and enter into force, this will reduce the potential measurement error on the regulation variables. In addition, it would be worthwhile to find a more adequate variable to represent consumer acceptance.

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TABLE 5. **Summary Statistics**

Variables	**Notation**	**Mean**	**Standard Dev.**
Type of label	TYP	0.833	0.971
Dummy future mandatory labeling	$DLTR$	0.157	0.366
Tolerance level in %	TOL	0.856	1.682
Number of ingredients	ING	3.463	6.233
Dummy Feed included	$FEED$	0.046	0.211
Dummy Meat included	$MEAT$	0.009	0.096
Dummy labeling enforced in 2004	ENF	0.130	0.337
Dummy Food derived from GM	DER	0.065	0.247
Dummy Restaurants	$REST$	0.037	0.190
Dummy Additives	ADD	0.046	0.211
Dummy Flavors	FLV	0.028	0.165
Total GM crops area (Mha)	$TotGM$	1668	11790
Share of GM corn	SGM^C	0.008	0.044
Share of GM soy	SGM^S	0.035	0.161
Share of GM cotton	SGM^T	0.020	0.119
Share of GM canola	SGM^{LA}	0.015	0.108
Trade balance of corn (mmt)	Tr^C	-18933	5236443
Trade balance of soy (mmt)	Tr^S	-96353	3479214
Trade balance of cotton (mmt)	Tr^T	-5745	210745
Trade balance of canola (mmt)	Tr^{LA}	-7226	512991
Share of corn exports sent to Japan	X^C_{jap}	0.016	0.063
Share of corn exports sent to the EU	X^C_{eu}	0.094	0.240
Share of soy exports sent to the EU	X^S_{eu}	0.106	0.248
Share of cotton exports sent to the EU	X^T_{eu}	0.147	0.232
Share of canola exports sent tot the EU	X^{LA}_{eu}	0.089	0.237
Imports of Corn from the US	M^C_{us}	0.278	0.358
Imports of soy from the US	M^S_{us}	0.206	0.309
Imports of cotton from the US	M^T_{us}	0.145	0.258
Share of agriculture in total exports	$Agshexp$	0.244	0.233
Share of agriculture in total imports	$Agshimp$	0.158	0.097
Average trade balance in pesticides	$Pest$	10547	243322
Average trade balance in insecticides	$Insc$	6224	67662
Average trade balance in herbicides	$Herb$	2425	86820
Average consumption of fertilizers	$Fert$	1731	4591
Dummy member to the WTO	WTO	0.75	0.435
Commitment to the Cartagena Protocol	CPB	1.037	0.772
Double dummy green campaign	$Green$	0.579	0.688
Dummy member of the OECD	$OECD$	0.241	0.429
Human Development Index	HDI	0.672	0.179
Consumer willingness-to-buy GMF (1)	WTB_1	0.423	0.041
Consumer willingness-to-buy GMF (2)	WTB_2	0.560	0.102
Per capita GDP	$PGDG$	5239.5	8372.4
Average economic growth	$Grwth$	0.030	0.0265
Share of agricultural GDP	AG	0.184	0.156
Dummy Africa	AFR	0.343	0.477
Dummy Asia (excl. Middle East)	ASI	0.222	0.418
Dummy Europe	EUR	0.167	0.374
Dummy Middle-East	MDE	0.065	0.247
Dummy North America	NAM	0.028	0.165
Dummy South America	SAM	0.148	0.357