ELSEVIER

Food Policy 29 (2004) 131–146

FOOD POLICY

www.elsevier.com/locate/foodpol

To spray or not to spray: pesticides, banana exports, and food safety

John S. Wilson [a], Tsunehiro Otsuki [b,*]

[a] *Transport Unit and Urban Development Department (TUDTR), The World Bank, 1818 H Street NW, Washington, DC 20433, USA*

[b] *Development Research Group (DECRG), The World Bank, 1818 H Street NW, Washington, DC 20433, USA*

Abstract

How governments regulate food safety and environmental protection, including pesticide residue levels, has important implications for trade. This paper explores food safety standards and whether regulations on pesticide residues in food have an effect on trade flows. We examine regulatory data from 11 Organization for Economic Cooperation and Development importing countries and trade data from 21 exporting countries, including Latin America, Asia, and Africa. Our results suggest that a 1% increase in regulatory stringency—tighter restrictions on the pesticide chlorpyrifos—leads to a decrease in banana imports by 1.63%. This represents a significant impact on trade with particular relevance to developing countries that rely on exports of agricultural commodities such as bananas. In addition, our findings suggest that lack of consensus on international standards and divergent national regulations on pesticides is costly.

JEL classification: F14; Q17

Introduction

How governments regulate food safety and environmental protection, including pesticide residue levels, has important implications for international trade. Within this context, the growing use of pesticides accounts for a significant portion of the increase in food productivity over the past several decades. Pesticides clearly have assisted in controlling pests and maintaining the availability of low cost and high

* Corresponding author. Tel./fax: +1-202-522-1159.
E-mail address: totsuki@worldbank.org (T. Otsuki).

0306-9192/$ - see front matter © 2004 Published by Elsevier Ltd.
doi:10.1016/j.foodpol.2004.02.003

quality food. For example, Owens (1986) reports that crop and livestock production in the US would drop by 25–30%, and prices of agricultural products would increase by 50–75%, if pesticides were completely withdrawn from use. Pesticides also allow for improved storage and distribution of crops, fruits, and grains. There are also health risks, however, associated with pesticides. These risks include on-farm ingestion by workers, discharge of toxic chemicals into the air and water, and consumption of foods that contain pesticide residues by consumers.

Setting a balance between risk and methods to increase agricultural productivity is particularly important for developing countries. Many developing countries depend on food exports for exchange earning, particularly in cash crops. Developing countries constituted 20% of the total world demand for pesticides in 1995. The World Bank estimates that demand will grow to 40% over the period 1995–2000 (Poapongsakorn et al., 1999). Moreover, the most hazardous pesticides are still used in developing countries while many of these are now banned or heavily regulated in developed countries. For example, Thailand imports large quantities of World Health Organization (WHO) I and II (most hazardous) pesticides (Poapongsakorn et al., 1999).[1] Hazardous pesticides are mostly prevalent in sub-Saharan Africa, where regulations are relatively weak (Paarlberg, 1993).

The way in which pesticides are regulated and standards are set for maximum residue levels are also of importance in the context of developing country exports. Otsuki et al. (2001a, b) suggest that a change in food safety standards by one importing country can affect a broad range of exporting countries. Forgone exports due to additional compliance costs with more restrictive standards can be significant.

The increasingly contentious debate over the balance between risk, precaution, and multilateral trade obligations increases the utility of empirical analysis involving the effect of standards on trade. This paper attempts to broaden the understanding of how standards on pesticide residues affect food exports. We conducted an empirical analysis of the relationship between pesticide residue standards in 11 Organization for Economic Cooperation and Development (OECD) countries and banana exports from 21 developing countries. Bananas are the world's fourth most important export commodity among food crops (World Bank, 1999)[2] and the developing countries' share of the world banana trade is high at 68%.[3] A gravity model is used to examine the hypothesis that pesticide residue standards can be trade limiting. We focus on chlorpyrifos pesticide in our analysis, as it is one of the most commonly used pesticides in worldwide banana production.

The organization of this paper is as follows. Section 2 reviews toxic pesticides that are or have been commonly used in the world along with their health implications. The section then reviews standard setting regarding pesticide residues in food

[1] The WHO has classified pesticides into four categories (I, II, III, and IV) with the lower numbers indicating higher level of toxicity.

[2] World Development Indicator (World Bank, 1999)

[3] It is calculated based on the UN Comtrade Records. The data are total value of bananas and plantains. But bananas have a dominant share at 99%.

in line with the guideline provided by the Codex Alimentarius Commission (Codex) and standard setting in major importing countries of bananas. Section 3 provides an overview of global banana trade, and reviews the European Union (EU) and international policies regarding banana trade. Section 4 develops an empirical framework to analyze the relationship between pesticide residue standards and bilateral trade flows. Section 5 reports the results of the gravity model. Section 6 predicts trade flows under alternative levels of harmonized standards and finally Section 7 provides policy implications of the analysis.

Health hazards of pesticides and maximum residue standards

Pesticides are diverse and omnipresent. Approximately 1400 pesticides are in use worldwide. Commonly used pesticides include herbicides (destroys unwanted weeds and plants), insecticides (kills insects and other arthropods), rodenticide (controls mice and other rodents), and fungicides (kills fungi). All pesticides are toxic by their nature, and hence, they cause health hazards to human and animal through exposure or dietary intake.

Prior Informed Consent (PIC) held in September 1998 identified 22 harmful pesticides and five industrial chemicals that have been banned or severely restricted in a number of countries and required that these pesticides cannot be exported unless agreed by the importing country. Pesticides such as DDT, chlordane, lindane and aldrin have been completely banned or severely restricted in North America and Europe because of their acute toxicity.

Human health hazards vary with the type of the pesticides and also with the extent of exposure. Immediate human health hazards from pesticides include mild headaches, flu, skin rashes, blurred vision and other neurological disorders, and rarely, paralysis, blindness, and even death. Long run health impacts include cancer, infertility, miscarriage, male sterility, birth defects, and effects on the nervous system (Moses, 1995). Farm workers are at much greater risk of toxicity due to exposure to pesticides (see Garry et al. (1996), Pingali et al. (1994), Crissman et al. (1994), US Environmental Protection Agency (EPA) (1992) for cases and scientific evidence). People residing close to farmland can also experience pesticide related problems due to dumping of pesticide wastes, wind drafts from aerial spraying, or from the use of empty pesticide containers for drinking water storage (see Repetto and Baliga (1996), US Environmental Protection Agency (EPA) (1992) for cases and scientific evidence).

Risk of dietary exposure to pesticide residues also has been of public concern while solid scientific evidence has not been completely established. In an EPA report of 1987, pesticides in food were considered to be most hazardous to human health. The EPA identified 55 pesticides that could leave carcinogenic residues in food (National Academy of Sciences, 1989). The probability of aggregated cancer risk[4]

[4] Excess cancer risk estimates the probability that a person will die from cancer due to exposure of pesticides based on the current number of survivors to such exposures.

is estimated to increase by 0.6% assuming consumption of food with residues at the level of maximum limits (National Research Council, 1987).

Our case study focuses on the import regulation on residues of chlorpyrifos pesticides. Information on residue standards is available for a relatively greater number of importing countries. Chlorpyrifos is a type of organophosphates pesticides under the Class II pesticide category (a moderately high level of toxicity) of the WHO which are widely used in the world. Chlorpyrifos is mainly used on agricultural farms and in non-agricultural settings such as homes and office buildings, primarily to kill ants, mites, cockroaches, etc. (US EPA, 2000, 2003). Among agricultural uses of chlorpyrifos, its application to banana production to repel rust thrips is common (Pinese and Elder, 1994). For example, Chiquita Brands International Inc, one of the world's largest banana companies, uses a method to impregnate chlorpyrifos on the bags that cover ripening bananas, in order to protect them from rust thrips (Gallagher et al., 1998).

The acceptable daily intake (ADI) of the pesticide residue which is established "on the basis of a complete review of the available information, including data on the biochemical, metabolic, pharmacological, and toxicological properties of the pesticide is derived from studies of experimental animals and observations in humans" (GEMS/Food, 1997). The total dietary intake of a particular pesticide residue in a food product is calculated by summing the consumption of all the food containing the residue, weighted by the maximum residue level (MRL) of a particular pesticide in each food. The MRL is an index that represents the maximum concentration of a pesticide residue (expressed as mg/kg) legally permitted in food commodities and animal feeds. MRLs on food imports are set by each country and are imposed as regulatory standards at the border.

While regional trade arrangements were formed, some efforts to harmonize MRLs have been made in the 1990s. The EU has been implementing a program to harmonize MRLs of pesticides in food sold since 1993 (Chan and King, 2000). Between 1993 and July 2000, the EU established MRLs for specific crop and pesticide combinations for 102 active pesticide ingredients[5] All the EU MRL positions established in July 2000 were approved and implemented as national legislation by all the EU member countries in July 2001 (Chan and King, 2000).[6]

Efforts have been made to develop guidelines for global food trade by international standard setting bodies. The Codex Committee on Pesticide Residues (CCPR), a subsidiary body of the Codex, develops MRL based on food consumption data in order to ensure that it stays within the limits of ADI. The Global Environment Monitoring System–Food Contamination Monitoring and Assessment Program (GEMS/Food), in collaboration with CCPR (FAO/WHO) prepared the guidelines for predicting dietary intake of pesticide residue in 1989 and

[5] Data were not available for some crop/active ingredient combinations, and the MRL was set at the analytical limit of determination (LOD), i.e., analytical zero for that combination.

[6] Another set of MRLs for 585 pesticides were closed off in December 2000 with the legislation intended to be implemented in December 2001.

revised them in 1995. These guidelines assist in the formulation of international dietary exposure assessments for most pesticides, and provide the foundation for the Codex MRLs such that a dietary intake of a pesticide will not exceed its ADI.

Banana trade and policy environment

Bananas are the fourth highest exported food product in the world with US$ 4.6 billion total export in 1999. The developing countries' share of the world banana trade is 68% (UN Comtrade Records, 1998). The developing countries' share of bananas as a percentage of total developing countries' fruits and vegetables exports is 14%. As shown in Table 1, the US, Japan and the EU countries are major importers of bananas. Central and Latin American countries and also several EU countries are dominant in banana exports.

As the collectively largest banana importer, the EU's trade policies have affected exports from exporting countries worldwide. The EU banana market underwent a drastic change in the early to mid-1990s as represented by the single European market (SEM). Under the SEM, the various national schemes throughout the EU were harmonized and replaced by a common market regulation for bananas. Under the new regime, the ACP (African Caribbean and Pacific Countries), suppliers were allowed up to 857.7 thousand tonnes of duty free exports. However, the non-ACP suppliers including the dollar exporters[7] had to face tariffs of 100 ECUs per tonne for a 2 million tonne quota. The ACP suppliers had country-specific quota and countries like Cameroon and Cote d'Ivoire met their quota levels. These countries were categorized as non-traditional ACP banana suppliers and they faced the same tariff-quota regime as the non-ACP countries (Thagesen and Mathews, 1997; Verissimo, 2001).

A GATT ruling in response to the opposition by five non-ACP Latin American countries led to a modification of the SEM regime, and the four Latin American countries except Guatemala reached an agreement with the EU in December 22, 1994 known as the Banana Framework Agreement (BFA) (Thagesen and Mathews, 1997).[8] The BFA regime set out differentiated tariff-rate quota between dollar countries, non-traditional ACP countries and the third countries. Table 2 summarizes the tariff-rate quota across the country groups based on Thagesen and Mathews (1997) and Verissimo (2001). The total quota was increased from 2 million to 2.2 million tonnes, and the specific tariff was reduced from 100 to 75 ECUs per tonne for the third countries and non-traditional ACP countries. The BFA countries, Costa Rica, Colombia, Nicaragua and Venezuela were allocated a 49.4% share of 2.2 million tonnes. A further 90,000 tonne quota was allocated to the non-traditional ACP suppliers that include Cote d'Ivoire, Cameroon, Belize and Dominican Republic. The remaining 50.6% minus 90,000 tonnes went to the

[7] Dollar exporting countries include Colombia, Costa Rica, Guatemala, Honduras, Panamá, Ecuador and Brazil.

[8] The opposing countries included Colombia, Costa Rica, Guatemala, Nicaragua and Venezuela.

Table 1
Major world importers and exporters of bananas and plantains[a]

Top 10 importers	Value (US$ million)	Percentage of the world total	Top 10 exporters	Value (US$ million)	Percentage of the world total
USA	1389	20	Ecuador	954	20
Germany	689	17	Belgium–Luxembourg	800	17
Belgium–Luxembourg	556	12	Costa Rica	564	12
Japan	548	12	Colombia	560	12
UK	534	5	Philippines	241	5
Italy	346	4	Panama	184	4
France	201	3	Italy	165	3
Sweden	152	3	USA	161	3
Russian Federation	151	3	France	151	3
Canada	149	3	Guatemala	147	3

[a] *Source*: Food and Agricultural Organization (1998).

third countries, i.e., the non-BFA countries and was mainly shared by Ecuador, Panama, Honduras and Guatemala.

With a ruling from the WTO Dispute Settlement Panel in late 1999, the third country quota was further increased to 2.55 million tonnes, with a specific tariff of 75 €/tonne (McCorriston, 2000). These quotas were further assigned to each of the non-ACP exporting countries. Among those, Columbia, Costa Rica, Ecuador, and Panama accounted for 95% of the total quota share assigned to the third countries. Each of them had an allocation of 23.03%, 25.61%, 26.17% and 15.76%, respectively.

Table 2
The banana trade regime (Banana Framework Agreement)[a]

Traditional ACP banana suppliers (quota = 857,700 tonnes)	Countries not categorized as traditional ACP banana suppliers (quota = 2.2 million tonnes)		
	BFA countries (quota = 1.1 million tonnes)	Non-traditional ACP banana suppliers (quota = 90,000 tonnes)	Non-BFA countries (quota = 1.0 million tonnes)
African, Caribbean and Pacific Countries except Cote d'Ivoire, Cameroon, and Dominican Republic[b]	Costa Rica*, Colombia*, Nicaragua, Venezuela	Cote d'Ivoire*, Cameroon*, Belize, Dominican Republic	The rest of the countries

Source: Thagesen and Mathews (1997) and Verissimo (2001).
[a] Countries with * are in the sample for our analysis.
[b] Jamaica and St. Lucia are traditional ACP countries in the sample for our analysis.

In order to check whether these EU quotas were binding, actual banana exports from the ACP and non-ACP countries were examined by the WTO in April 1999. The WTO reports that the total exports from the ACP countries were below the total quota of 857.7 thousand tonnes, but that the quotas on the non-ACP countries were actually binding in 1998 (WTO, WT/DS27/ARB, 1999).

The econometric model and data

The 11 importing countries studied here include, six EU countries (Belgium, Luxembourg, France, Germany, the Netherlands and the UK), Canada, Japan, New Zealand, Switzerland, and the US. The six EU countries are aggregated and treated as one country. The 21 exporting countries studied include 10 Central and Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico and Panama), two Caribbean countries (Jamaica and St. Lucia), four African countries (Cameroon, Cote d'Ivoire, Morocco and South Africa), and five Asian countries (China, India, Indonesia, Philippines and Taiwan). These exporting countries are the major exporters of bananas in each region.

Maskus et al. (2001) and Otsuki et al. (2001a, b) summarize alternative approaches to measure the impact of non-tariff barriers, particularly the impact of standards on trade. Computable general equilibrium (CGE), partial equilibrium, and econometric approaches are most commonly used to quantify the effect of non-tariff barriers on trade. The first two approaches rely on assumed parameter values on demand and supply elasticities, and hence, estimated results often lack statistical foundations. Otsuki, Wilson and Sewadeh indicate the advantages of using an econometric approach when direct measures of stringency of standards are available. First, researchers do not need to impose the direction of effect of standards—whether positive or negative. Therefore, an econometric approach can be used for hypothesis testing, as well as for estimating elasticity of trade flows with respect to standards. Second, variation of bilateral trade flows can be accounted for by standards that vary across countries, along with some other variable such as geographic distance and some other basic economic indicators such as gross national product (GNP). The effect of differing levels of stringency of standards on trade can be demonstrated, therefore, across countries.

Econometric models for bilateral trade flows are referred to as a gravity model. In their gravity model, Otsuki et al. (2001a, b) employ a direct measure of the impact of food safety standards expressed in maximum allowable contamination in their econometric analysis. Our data on maximum residue limit (MRL) on chlorpyrifos pesticide residue standards can be considered as a similar direct measure of standards to the above mentioned study.

In this study, a gravity model is developed to analyze the effects of pesticide residue standards on bilateral trade flows. A logarithm of bilateral trade flows in real value is regressed on logarithms of GNP of the exporters and the importers, geographical distance between each pair of importers and exporters, pesticide residue standards for chlorpyrifos in the importing country, and dummies for regional trade agreements (RTAs), colonial ties, and years.

The specification of the gravity model is as follows:

$$\begin{aligned}\ln\left(V_{ij}^t\right) = {} & b_0 + b_1\ln\left(\mathrm{GNP}_i^t\right) + b_2\ln\left(\mathrm{GNP}_j^t\right) + b_3\ln\left(\mathrm{POP}_i^t\right) + b_4\ln\left(\mathrm{POP}_j^t\right) \\ & + b_5\ln\left(\mathrm{DIST}_{ij}\right) + b_6\ln\left(\mathrm{MRL}_i^t\right) + b_7\ln(100 + \mathrm{TARIFF}) + b_8 D_{\mathrm{BFA}} \\ & + b_9 D_{\mathrm{TACP}} + b_{10} D_{\mathrm{NTACP}} + b_{11} D_{\mathrm{REST}} + b_{12} D_{\mathrm{RTA}} + b_{13} D_{\mathrm{COL}ij} \\ & + b_{14} D_{1997} + b_{15} D_{1998} + \varepsilon_{ij}^t\end{aligned}$$

where i and j stand for the importer and exporter, respectively, and t denotes time. Parameter bs are coefficients, and ε_{ij} is the error term that is assumed to be normally distributed with mean zero. The data used here are for the time period 1997–1999. V_{ij} denotes the value of trade from country j to country i. It is obtained from the trade database of the United Nations Statistical Office. Banana and plantains (SITC Revision 1 code of 0513) are the products included here for the analysis. GNP_i and GNP_j are the real GNPs (expressed in 1995 US dollars) of the importing and exporting countries, respectively, as typically included in a gravity model. Linnemann (1966) extended the gravity model to include populations. POP_i and POP_j denote populations of the importing and exporting countries, respectively. They are obtained from the World Development Indicators of the World Bank for the period of 1997–1999. The total GNP and population of the six EU countries combined are used for the EU. DIST_{ij} is the geographical distance between countries i and j. TARIFF is an applied tariff rate (in an ad valorem term) between countries i and j. This variable is also included to control for the variation of the dependent variable that is not captured by the EU tariff-quota policy dummies. The tariff data are available from the TRAINS database of the United Nations Conference on Trade and Development (UNCTAD).

MRL_i is the maximum residue limit of the pesticide chlorpyrifos, imposed on imports by the importing country i. The maximum residue limit (MRL) is expressed in parts per million (ppm), and was obtained from the Ministry of Agriculture and Forestry, New Zealand. A higher (lower) value of the standard implies more lax (stringent) regulation of the pesticide residue limit. Assuming that the regulation on pesticide residue limits are strictly imposed by importing countries, chlorpyrifos residue contents in the imported bananas are less than the MRLs of the individual importing countries.[9] The coefficient for the pesticide residue standard implies that the change in the value of trade for an incremental change in the residue standard. The coefficient is expected to be positive if this standard limits trade.

The tariff-quota system in place in Europe on banana imports may have had a distinct impact on trade flows. It is not precisely known in many cases whether the

[9] The 0.05 ppm standard is used for the EU because all but the Netherlands had this standard. The validity of this assumption is tested in the post-regression analysis by omitting the Netherlands from the EU.

quotas in place were binding or not. It is therefore difficult to specify in the model how the EU tariff-quota policies might affect trade flow. Dummy variables for EU tariff-quota arrangements are used to control the effect of the tariff-quota system while the inclusion of these dummy variables necessarily imposes the assumption that the value of banana imports from all exporting countries within a given EU tariff-quota regime to the EU increases or decreases in the same proportion by the regime.

As Table 2 indicates, there are four mutually exclusive groups of countries that export bananas to the EU: (1) traditional ACP, (2) BFA, (3) non-traditional ACP, and (4) the rest. For example, the dummy for BFA supplier equals one if EU countries import from a BFA supplier, and zero otherwise. Likewise, the dummy variables for the other groups.[10] Assuming that there is no other systematic tariff-quota arrangement between the rest of the OECD countries and our exporting countries, the EU tariff-quota arrangement dummies can be compared with the no-arrangement case. Thus, we can test (1) whether the EU tariff-quota arrangement actually encouraged or discouraged banana trade, and (2) how the effect of the EU's differential treatment of exporting countries differs from each other.

A colonial tie dummy is included to control the omitted variable effect of colonial ties on trade flows as was done in Otsuki et al. (2001a, b). The NAFTA and APEC dummies (D_{APEC} and D_{NAFTA}, respectively) are included to capture the trade promoting effects due to RTAs. Year dummies, D_{1997} and D_{1998}, are included in the model to control for systematic differences across time.

A fixed-effects model is estimated and reported in Table 3, assuming that country-specific effects vary systematically among the exporting countries. The first two columns show the result of the base model (Model I). The alternative model (Model II), instead, omits the EU tariff-quota arrangement dummies in order to examine whether the base model is robust against specification.

Regression results

In Models I and II, an importing and exporting country's GNP is positive and significant while an importing country's population is negative and significant. The opposing signs are likely the result of multicollinearity between these variables.[11] Geographic distance is negative and significant as expected.

The chlorpyrifos standard is positive and significant in the both models. The positive sign indicates that banana imports are greater for a country that has less

[10] A dummy variable for the first group is not included in the analysis since there is no traditional ACP country in our sample.

[11] The GNP variables, when the population variables are omitted, are positive with greater coefficients than those in Model I. The same is true when the population variables are included while omitting the GNP variables. The coefficient estimates for the other variables are not greatly affected by these variations. This is likely the result of multicollinearity between the GNP and population variables. We decided to keep both the population and GNP variables in all models since such models are less subject to the omitted variable effect.

Table 3
Regression results[a]

Dependent variable: log (value of trade flow)	Model I		Model II	
	Coeff.	S.E.	Coeff.	S.E.
Constant	−1.80	601.36	13.72	43.92
Log (importing country's GNP)	5.16***	1.09	4.84***	1.18
Log (exporting country's GNP)	2.35	2.59	2.79	2.82
Log (importing country's population)	−4.73***	1.20	−4.37***	1.29
Log (exporting country's population)	2.01	35.73	−0.09	2.86
Log (geographic distance)	−2.19***	0.45	−1.80***	0.48
Log (chlorpyrifos standard)	1.63***	0.30	1.72***	0.33
Log (tariff)	−18.59*	9.88	−16.27	10.55
Dummy for the rest	−2.92	63.55		
Dummy for BFA countries	−4.29	63.55		
Dummy for ACP	7.14	63.48		
Dummy for non-traditional ACP	4.50	63.58		
Dummy for colonial ties	−2.05**	1.02	1.70*	0.91
Dummy for RTA	2.89***	0.90	2.66***	0.96
Dummy for year 1997	0.14	1.36	−0.11	0.52
Dummy for year 1998	0.30	0.77	0.11	0.47
Adjusted R^2	0.707		0.652	
Number of observation used	241		241	

[a] *Note*: A fixed-effects model is used with exporting countries as cross-section.
* 10% significance.
** 5% significance.
*** 1% significance.

stringent standards on pesticide residues. The results support the hypothesis that this pesticide standard can have a trade diversion effect.[12] The evidence indicates that decisions on banana export destinations are made considering these pesticide residue standards when the other major determinants of trade such as GNP, population, trade policies and the other country-specific effects are controlled.

The magnitude of the coefficient (1.63) in Model I, which can be described as the elasticity of chlorpyrifos standard for bilateral trade flow, shows a high responsive-

[12] A reviewer commented that the result should depend on the ability of exporting countries to adjust to meet more stringent standards. However, the cross-country data can partially account for the ability of an exporting country to comply with standards. The regression results indicate that the reality falls between the following two extreme cases: (1) firms do not have ability to comply with any higher standards in the short run, and (2) firms can meet any level of standards in the short run without cost. The negative relationship between the stringency of standards and exports reflects the fact that firms incur some cost (whether actual expenditure or time cost for adjustment) to comply with more stringent standards. The result also reflects the fact that a country is able to export to countries with various standards, indicating that a more stringent standard will not immediately arrest exports. Firms in one country are heterogeneous in terms of pesticide residue levels in their exports, and, for a given importing country, a higher standard will reduce both the number of firms that exports and the amount of export from each firm.

ness of banana exports.[13] This elasticity is greater than the case of the Aflatoxin B1 standard for cereals and nuts (from 0.34 to 1.12) that are found in Wilson and Otsuki's (2003) cross-country study on aflatoxin standards.

The coefficient estimate for the tariff variable is negative and significant in Model I but insignificant in Model II. If the significance is evaluated at 15% level, it is significant with a negative sign. The sign is consistent with the prior expectation, but the low confidence poses caution to interpret the coefficient.

None of the EU tariff-quota dummies is significant. It is, therefore, unclear whether the EU tariff-quota policies promoted or restricted trade. The comparison between Models I and II indicates that the coefficient estimates for the key explanatory variables are slightly affected by the omission of these dummies. The coefficient for the standards variable is 5.5% higher when the EU tariff-quota dummies are not included. This possibly implies that standard variable can erroneously capture the trade diverting effect of the EU tariff-quota, but the difference is not large.

Simulation

Table 4 presents the changes in the values of the banana exports from the 21 exporting countries under four alternative regulatory scenarios from those under the pre-harmonization status. These alternative scenarios include: (1) when all importers follow the standard of 0.05 ppm (the standard for the EU countries except for the Netherlands); (2) when a standard of 0.1 ppm followed by all the importers (the standard for the US, Canada and Switzerland); (3) when a harmonized standard of 0.5 ppm is followed (the standard for Japan and the Netherlands); and (4) when the standard is 2 ppm (New Zealand). Codex also recommends importing countries to adopt the MRL at 2.0 ppm as the international standard that is set in accordance with the ADI. We assume that the predicted increase or decrease in the value of export will not exceed 100% of the pre-harmonization level for each importing exporting country pair in order to avoid unrealistic cases, i.e., negative exports or more than double export.

The simulation results are inevitably dependent on the property of the regression model used for the simulation analysis. The results should, therefore, be viewed with caution. The monotonic relationship between standards and trade imposes a structure that a standard should be binding at any MRL. Where standards are not stringent, however, these standards may not be binding exports. Tightening (or relaxing) standards within a range above a certain threshold MRL consequently

[13] The validity of the assumption that all the six EU countries follow a single standard is examined by omitting the Netherlands when aggregating the variables for the EU. The magnitude and statistical significance of this coefficient estimate are found to be unchanged under the alternative data construction, and those of the other explanatory variables are found not to differ between the two cases. This implies that the single standard assumption is acceptable. The dynamics of export countries' response to more stringent standards should appropriately be incorporated if compliance ability individual firms in those countries is identified. Such an analysis is only possible with firm-level data.

Table 4
Change in trade flows under different harmonization scenarios compared with pre-harmonization status by exporting countries (without the EU quota in place)

	Percentage change (US$ 1000)							
Harmonized level	0.05 (ppm)		0.1 (ppm)		0.5 (ppm)		2.0 (ppm)	
Pre-harmonization level of	France, Germany, UK, Belgium, Luxembourg		USA, Canada, Switzerland		Japan, the Netherlands		New Zealand Codex	
Exporters								
Cameroon	−140	−0.1	+109,084	+99.8	+109,256	+100.0	+109,256	+100.0
Cote d'Ivoire	−493	−0.4	+117,942	+99.5	+118,547	+100.0	+118,547	+100.0
Morocco	−3	−6.1	+45	+91.8	+49	+100.0	+49	+100.0
South Africa	−10	−3.9	+245	+95.0	+256	+99.2	+258	+100.0
China	−5,655	−99.7	−5,632	−99.3	+25	+0.4	+5673	+100.0
India	−155	−71.8	+26	+12.0	+216	+100.0	+216	+100.0
Indonesia	−363	−98.9	−356	−97.0	+7	+1.9	+367	+100.0
Philippines	−335,862	−99.9	−334,465	−99.5	−1645	−0.5	+332,987	+99.0
Taiwan, China	−46,800	−100.0	−46,780	−99.9	+21	+0.0	+46,814	+100.0
Costa Rica	−398,218	−51.8	+277,916	+36.1	+766,138	+99.6	+768,981	+100.0
Guatemala	−159,247	−72.4	+24,384	+11.1	+219,883	+100.0	+219,883	+100.0
Honduras	−100,137	−61.6	+39,701	+24.4	+162,632	+100.0	+162,632	+100.0
Jamaica	−7	0.0	+54,805	+100.0	+54,813	+100.0	+54,813	+100.0
Mexico	−59,613	−78.6	+1,199	+1.6	+73,848	+97.4	+75,727	+99.9
Panama	−46,314	−19.7	+177,278	+75.6	+233,385	+99.5	+233,995	+99.7
St. Lucia	−10	0.0	+54,200	+100.0	+54,213	+100.0	+54,213	+100.0
Argentina	−3	−1.5	+197	+98.0	+201	+100.0	+201	+100.0
Brazil	−897	−31.7	+1732	+61.1	+2833	+100.0	+2833	+100.0
Chile	−81	−53.6	+52	+34.4	+151	+100.0	+151	+100.0
Colombia	−228,869	−38.6	+312,205	+52.6	+593,173	+100.0	+593,173	+100.0
Ecuador	−497,015	−56.1	+177,907	+20.1	+730,463	+82.5	+856,589	+96.7
Total	−1,879,892	−51.2	+961,685	+26.2	+3,118,465	+85.0	+3,637,358	+99.1

may result in a smaller decrease (increase) in trade flow than the estimated decrease (increase). This threshold MRL is unknown a priori and it is particularly difficult to identify when the threshold MRL differs across the exporting countries.

Under the first scenario, all countries will lose due to the standard of 0.05 ppm. China, Taiwan and South-East Asia are predicted to lose more in percentage, as their major trading partner is Japan, which had a relatively less stringent standard under the pre-harmonization status. The loss of Philippines, whose main trading partner is also Japan, is the greatest in terms of level because it is the largest banana exporter in Asia. On the contrary, the loss experienced by the African countries will be less as they have mainly exported to the EU, which had the most stringent standard. The percentage losses of Latin American countries will be between those extremes since their banana exports have been diversified between the EU and the US. Among these countries, Costa Rica, Guatemala, Columbia and Ecuador account for the significant part of these losses in terms of level as expected. India's percentage loss is greater than those of Latin America because its major export partner is the US.

When the standard is relaxed to 0.1 ppm, 17 of the exporting countries are predicted to increase exports while China, Indonesia and Philippines and Taiwan trading more with Japan will still lose. This is because Japan's pre-harmonization standard is still less stringent than this standard. Among the countries that increase export, African countries will increase most due to the EU's stringent pre-harmonization standard.

At the standard of 2.0 ppm, which is also recommended by the Codex, all the exporting countries will increase their exports by 96.7–100%. The total values of banana exports under the most stringent standard is US$ 1.9 billion or 51.2% less than that under the pre-harmonization status. The least stringent (Codex) standard will lead to a US$ 3.6 billion increase in banana exports. The total value of banana exports under the most stringent standards differs by US$ 5.5 billion or 75% lower than that under the least stringent (Codex) standard scenario. This implies that the both pre-harmonization and the EU standards will lead to a trade flow significantly smaller than that under the internationally recommended standard.

The improved dietary safety of imported food associated with the change in its imports due to a tighter standard also needs to be considered in the broader context of policymaking. Estimates of improved dietary safety with more stringent standards depends both on quantity of imports and actual levels of pesticide residue per unit. Decreased in imports and lower levels of pesticide residue per unit (particularly if the per unit pesticide residues is close to the tightened MRL) may result in heightened dietary safety. Internationally agreed levels of pesticide residue should clearly be based on scientific evaluation of dietary risks of the residues.

The simulated changes in trade flows of bananas here also suggest that a tighter standard may tend to discourage the use of pesticides in exporting countries. This is particularly the case when there is no alternative technique to reduce pesticide residues prior to shipment. The positive aspect of this is reduced health risks for farm workers and the environment. The result is more complicated when the effect of pesticide residue standards on productivity is present. In sum, where the above mentioned trade-offs of the pesticide residue regulation exist, setting harmonized standards will necessarily call for the estimation of the relative magnitudes of these trade-offs.

Conclusion

Understanding the trade-offs between public health, food productivity and economic development is essential for crafting efficient regulatory and trade policies. The purpose of this paper is to shed light on the impact of setting pesticide residue standard at various levels of stringency on trade. We employ a gravity model here to examine the relationship between chlorpyrifos pesticide standards and banana exports from 21 major exporting countries in the developing regions to major importing countries in the OECD group.

The results indicate a negative effect of chlorpyrifos standard imposed by the OECD countries on banana exports from the studied exporting countries. A 1% increase in regulatory stringency—tighter restrictions on the pesticide chlorpyrifos—leads to a decrease of banana imports by 1.63%. Our simulation analysis based on the gravity model parameter estimates indicates a significant difference in trade flow under alternative regulatory scenarios. It is estimated that US$ 5.5 billion in lost exports occur per year if an international standard were set at the EU levels of regulatory stringency in contrast to a world standard set by Codex at the internationally recommended level.

On the other hand, scientific findings on pesticide hazards do indicate that greater risks are borne by farm workers and those exposed to pesticide residues in the air, soil and drinking water. Health hazards are predominant in developing countries simply because of relatively more unsafe techniques involved with pesticide use, poor health condition among the population, and use of more toxic pesticides. In developing nations, it is estimated that there are as many as 3.5–5 million people reported to suffer from acute pesticide poisonings per year, with millions more exposed to lower but still dangerous levels (World Resources Institute, 1998). A reduced health risk associated with a more stringent pesticide residue standard may offset the direct losses and losses in potential productivity from reduced pesticide applications. In setting international pesticide residue standards better understanding the trade-offs among various objectives-reducing risk, improvement of health, and growth in trade should be considered. Our results provide empirical evidence on the trade impact of pesticide residue standards.

Acknowledgements

The authors also would like to thank Baishali Majumdar and Michelle Chester of the World Bank for assistance in producing the manuscript, and the editor and two anonymous referees for their helpful comments. Comments by Gerd Fleischer, Cornelis de Haan, Cornelis Van Der Meer, and Patrick Verissimo on the work are also appreciated. The view and interpretation expressed in this paper are those of the authors and do not necessarily represent the view and policies of the World Bank.

References

Chan, M.K., King, B., 2000. Review of the implications of changes in EU pesticides legislation on the production and export of fruits and vegetables from developing country suppliers. Rural livelihoods Department of the Department for International Development (DFID), National Resources Institute.

Crissman, C.C., Cole, D.C., Carpio, F., 1994. Pesticide use and farm worker health in Ecuadorian potato production. American Journal of Agricultural Economics 76, 593–597.

Gallagher, M., McWhirter, C., Wells, D., 1998. Chiquita secrets revealed. Cincinnati Enquirer, May 3. Available from <http://www.globalexchange.org/bananas/chiquitaSecretsRevealed.html>.

Garry, V.F., Schreinemachers, D., Harkins, M.E., Griffith, J., 1996. Pesticide appliers, biocides and birth defects in rural Minnesota. Environmental Health Perspectives 104, 394–399.

Global Environment Monitoring System–Food Contamination Monitoring and Assessment Programme (GEMS/Food), 1997. Guidelines for predicting dietary intakes of pesticide residues. Prepared in Collaboration with Codex Committee on Pesticide Residues.

Linnemann, H., 1966. An Econometric Study of International Trade Flows. North-Holland, Amsterdam.

Maskus, K.E., Wilson, J.S., Otsuki, T., 2001. An empirical framework for analyzing technical regulations and trade. In: Maskus, K.E., Wilson, J.S. (Eds.), Quantifying Trade Effect of Technical Barriers: Can it be Done? University of Michigan Press, Ann Arbor, MI.

McCorriston, S., 2000. Market structure issues and the evaluation of the reform of the EU banana regime. World Economy 23 (7), 923–937.

Moses, M., 1995. Designer Poisons: How to Protect Your Health and Home from Toxic Pesticides. Pesticide Education Center, San Francisco.

National Academy of Sciences, 1989. Pesticide Residues in Foods: Is Food Safety Just a Matter of Organic versus Traditional Farming? University of Kentucky. Available from <http://www.uky.edu/Agriculture/Entomology/entfacts/misc/ef009.htm>.

National Research Council, 1987. Regulating Pesticides in Food: The Delaney Paradox. National Academy of Sciences, Washington, DC.

Otsuki, T., Wilson, J.S., Sewadeh, M., 2001a. What price precaution? European harmonization of aflatoxin regulations and African groundnuts exports. European Review of Agricultural Economics 28 (3), 263–283.

Otsuki, T., Wilson, J.S., Sewadeh, M., 2001b. Saving two in a billion: quantifying the trade effect of European Food Safety Standards on African Exports. Food Policy 26, 495–514.

Owens, E.W., 1986. Social control of pesticides—some health effects. International Journal of Social Economics 13 (1–2), 93–97.

Paarlberg, R.L., 1993. Managing pesticide use in developing countries. In: Haas, P.M., Keohane, R.O., Levy, M.A. (Eds.), Institutions for the Earth: Promoting International Environmental Protection. Global Environmental Accords Series. MIT Press, Cambridge, London, pp. 309–350.

Pingali, P.L., Marquez, C.B., Palis, F.G., 1994. Pesticides and Philippine rice farmer health: a medical and economic analysis. American Journal of Agricultural Economics 76, 587–592.

Pinese, B., Elder, R., 1994. Banana: rust thrips in bananas. Adapted from Pinese, B. and Piper, R., Bananas: insect and mite management. Department of Primary Industries, Brisbane. Available from <http://www.dpi.qld.gov.au/horticulture/5528.html>.

Poapongsakorn, N., Lakchai, M., Waibel, H., Jungbluth, F., 1999. Approaches to Pesticide Policy Reform-Building Consensus for Future Action. A Publication of the Pesticide Policy Project, Hannover, April, 1999, Publication Series No. 7.

Repetto, R., Baliga, S., 1996. Pesticides and the Immune System: Overview. World Resources Institute, Washington, DC.

Thagesen, R., Matthews, A., 1997. The EU's common banana regime: initial evaluation. Journal of Common Market Studies 35 (4), 615–627.

US Environmental Protection Agency, 1992. Office of Pesticide Programs, Regulatory Impact of the Worker Protection Standard for Agricultural Pesticides, US EPA Contract No. 68-D1-0134, v-2.
US Environmental Protection Agency, 2003. Chlorpyrifos Revised Risk Assessment and Risk Mitigation Measures. Available from <http://www.epa.gov/oppsrrd1/op/chlorpyrifos/consumerqs.htm>.
US Environmental Protection Agency, 2000. Chlorpyrifos Revised Risk Assessment and Risk Mitigation Measures, September 5. Available from <http://www.epa.gov/pesticides/op/chlorpyrifos/consumerqs.htm#2>.
US Environmental Protection Agency, 1987. Unfinished Business: A Comparative Assessment of Environmental Problems. Washington, DC.
Verissimo, P., 2001. Implications of the EU banana trade regime for selected import markets: economic analysis and political dimension. Dissertation Com.
Wilson, J.S., Otsuki, T., 2003. Food safety and trade: winners and losers in a non-harmonized world. Journal of Economic Integration 18 (2), 266–287.
World Resources Institute, 1998. World Resources 1998–99: Environmental Change and Human Health. Washington, DC.
World Trade Organization, 1999. European Communities—Regime for the Importation, Sale and Distribution of Bananas—Recourse to Arbitration by the European Communities Under Article 22.6 of the DSU. WT/DS27/ARB. Geneva.