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Pesticide regulatory homogeneity and firms' import decisions: Evidence from EU-Swiss agri-food trade

Dela-Dem Doe Fiankor[1,2] | **Anirudh Shingal**[3,4]

[1]Department of Agricultural Economics and Rural Development, University of Goettingen, Göttingen, Germany

[2]Economic Modelling and Policy Analysis Group, Agroscope, Ettenhausen, Switzerland

[3]S. P. Jain Institute of Management and Research, Mumbai, India

[4]European University Institute, Florence, Italy

Correspondence
Dela-Dem Doe Fiankor, Department of Agricultural Economics and Rural Development, University of Goettingen. Platz der Göttinger Sieben 5, D-37073. Göttingen, Germany.
Email: dela-dem.fiankor@uni-goettingen.de

Abstract

Country-specific variations in food standards often reflect national regulatory traditions, but they also disrupt trade by increasing associated costs and limiting market access. Aligning such standards between countries should reduce or eliminate the additional market access costs and enhance trade. Yet, whereas evidence abounds on the trade effects of country-specific public mandatory food standards, relatively little is known about the trade effects of regulatory homogeneity across countries. Exploiting the EU–Swiss trade relationship and data on maximum residue limits (MRLs) for pesticides, we assess the channels that explain the effects of regulatory homogeneity of standards on agri-food imports. Estimating a reduced-form gravity model, we find that similarity in Swiss-EU MRLs on a product-pesticide pair increases Swiss product-level imports from the EU by 10%. This consists of a 7.7% increase in the average import value per product per firm, a 1.4% increase in the number of product varieties imported and a 0.6% increase in the number of importing firms. Regulatory homogeneity also increases import volumes by 9.4% and decreases import prices by 1.6%. Accounting for firm heterogeneity, we find more pronounced trade effects for smaller firms. These findings are confirmed in firm-product level estimations, where we also find that the import-enhancing effects increase with increasing regulatory heterogeneity. Our results imply that even with mutual recognition, there remains a preference for imports that align with domestic standards. In terms of policy implications, our findings show that regulatory homogeneity enhances food security by increasing product variety and lowering prices.

KEYWORDS
Brexit, firms, imports, pesticides regulations, standards harmonisation, Switzerland

JEL CLASSIFICATION
F14, Q17, Q18

1 | INTRODUCTION

Regulatory heterogeneity, defined as differences in regulatory standards between exporting and importing countries, poses trade costs for trading firms. It increases the fixed product adaptation costs that exporting firms must pay for market access, discouraging entry and reducing the range of exported products and export destinations. It also increases the costs of importers developing trade relationships with foreign suppliers and maintaining an international sourcing network. By contrast, regulatory homogeneity harmonises product characteristics across countries and reduces country-specific investment costs. Firms no longer need to alter their production processes when selling to other countries leading to increased trade. Yet, even if harmonisation is perceived as a welfare-enhancing means of reducing behind-the-border trade barriers, we have limited empirical evidence of how it affects trade flows (Schmidt & Steingress, 2022). Using the case of country-specific pesticide regulations, this paper assesses the different economic channels that explain the trade effects of harmonised standards in the agricultural sector.

We measure standards using maximum residue levels (MRLs). MRLs are the highest level of pesticide residue that is legally tolerated in or on food or feed when producers apply pesticides correctly. Whereas quantifying standards and technical regulations remain an empirical challenge, MRLs are one of the few prominent standard-like non-tariff measures to exhibit clearly defined, continuous and bilaterally quantifiable requirements. This feature of MRLs allows us to identify product-pesticide combinations in which there is either a divergence or convergence in standards across countries. We then examine the effects of regulatory homogeneity on imports using a reduced-form gravity framework.

Changes in aggregate imports can be driven by proportionate changes in the import values of all firms, or by some firms exiting the import market leaving surviving firms with increased market shares, or by firms varying the range of products they import. Either of these cases will have different implications for policy. For instance, if imports are diversified and firms source more product varieties, then consumers, who often love variety, are better off. In contrast, if more firms exit the market, the surviving firms can exploit the reduced competitive environment to exercise market power to the detriment of consumers. Thus, to offer a detailed understanding of the channels underlying the trade effect, we perform a product-level decomposition of total imports into extensive (i.e. number of imported product varieties and the number of active importing firms) and intensive (i.e. average imports per product per firm, average import volumes and average import prices) margins. We then assess how each margin of import adjustment contributes to the trade effects induced by regulatory homogeneity.

Our empirical analysis is based on Swiss firm-level data on agri-food imports from the EU over the period 2016–2018. The Swiss case allows us to assess the effect of pesticide regulatory homogeneity on an economic outcome in a politically relevant context. Switzerland is a net agri-food importing country with strict regulations amid heightened consumer interest in the application of synthetic pesticides (Huber & Finger, 2019).[1] The EU context is also important as the list of pesticides regulated by the European Union is much more exhaustive and the limits set more stringent than that of the Codex Alimentarius Commission and other developing regions (Fiankor, Curzi, & Olper, 2021). The EU is Switzerland's most important trading partner, while Switzerland consistently ranks as the EU's fourth largest trading partner outside the Common Market (behind the United States, China and the United Kingdom).[2] Being neighbours, geographic and cultural proximity matter for Swiss-EU trade; however, close alignment, mutual recognition and equivalence of product standards between the two partners—an outcome of years of intense negotiations—is also a strong determinant in a near-zero-tariff environment. Nevertheless, there are still cases in which Swiss standards differ from those of the EU, for example, electrical plugs; some product-specific rules for cheese (e.g. the fat content); and labelling requirements (Copenhagen Economics, 2016). Furthermore, in both the EU and Switzerland, the use of standard-like non-tariff measures to regulate trade is increasing (Figure A1). Relations between the two countries, therefore, offer us a relevant setting to analyse the effects of regulatory homogeneity.

To guide the empirical exercise, we take theoretical insights from trade models that extend Melitz (2003) to incorporate imports (Antras et al., 2017; Bas & Strauss-Kahn, 2014; Kasahara & Lapham, 2013; Movchan et al., 2020). In this class of models, due to the fixed and variable costs of importing, only inherently highly productive firms will import with low productivity firms sourcing domestically. Country- and product-specific MRLs are government-imposed minimum quality standards that enhance trade costs and impact market access (Xiong & Beghin, 2014). The marginal costs of production and imports increase with increasing regulatory heterogeneity (Fernandes et al., 2019; Traoré & Tamini, 2022). However, similarity in standards lower or eliminate these costs, leading to more trade (Schmidt & Steingress, 2022; Shingal & Ehrich, 2024).

Our results are in line with these theoretical predictions. We show that, on average, the similarity between Swiss-EU MRL regulations on a product-pesticide pair increases Swiss product-level imports of agri-food products from the EU by 10%. This is driven in order of magnitude by a 7.7% increase in the average import value per product per firm, a 1.4% increase in the number of product varieties imported and a 0.6% increase in the number of importing firms. We further decompose the increase in average imports per product per firm into a price and quantity component and show that regulatory homogeneity increases import volumes by 9.4% and decreases import prices by 1.6%. Accounting for firm heterogeneity, we find more pronounced trade effects of regulatory homogeneity for smaller firms but no statistically significant effects for large firms in terms of import values and quantities. To support our product-level findings, we also conduct the empirical analysis at the firm-product level. Here too our findings show that regulatory homogeneity increases firm-level import values and quantities, with the effects being more pronounced for smaller firms.

This paper is related to three strands of the literature. First, the paper contributes to the literature on the impact of regulatory heterogeneity on trade patterns, focusing on both country-product studies- (Chen & Mattoo, 2008; De Frahan & Vancauteren, 2006; Disdier et al., 2015; Fiankor, Curzi, & Olper, 2021; Fiankor, Haase, & Brümmer, 2021; Hejazi et al., 2022; Parenti & Vannoorenberghe, 2024; Peterson et al., 2013; Reyes, 2011; Ridley et al., 2024; Shingal et al., 2021; Shingal & Ehrich, 2024) and firm-level analyses (Curzi et al., 2020; Fernandes et al., 2019; Fontagné et al., 2015). Whereas these papers focus on exports and regulatory heterogeneity, our contribution

[1]In June 2021, Swiss citizens voted on two initiatives that sought to ban the use of synthetic weed killers, insecticides, and fungicides in agriculture. The first popular initiative, named 'For a Switzerland without synthetic pesticides', called for a domestic ban within 10 years, and the outlawing of imported foodstuffs produced using such pesticides. Under a second initiative called 'For clean drinking water and healthy food: no subsidies for the use of pesticides and prophylactic antibiotics', only farms not using pesticides would be eligible for government subsidies.

[2]According to UNComtrade data, 61% of Swiss merchandise imports were sourced from the EU27 on average over 2017–2019 while Switzerland supplied 5.5% of extra-EU imports of goods in the same period.

focuses on imports and regulatory homogeneity. This distinction is non-trivial. The abundance of empirical evidence concerning the export behaviour of firms (Curzi et al., 2020; Fernandes et al., 2019; Fontagné et al., 2015) contrasts with the sparsity of studies focusing on their importing activities (Fiankor et al., 2023, 2024; Movchan et al., 2020). We provide a first set of estimates on the trade effects of harmonising standards on firm-level imports.

Second, whereas the magnitudes of the trade effects of country-specific variations in standards are well established in the agricultural trade literature (see Santeramo & Lamonaca, 2019, for a review of this literature including a meta-analysis of the estimates), we know little about the potential benefits of regulatory homogeneity. Our work contributes to filling this gap. In this regard, our work is closest to Schmidt and Steingress (2022) and Shingal and Ehrich (2024). Schmidt and Steingress (2022) create a novel database on cross-country standards and show that harmonised standards have contributed up to 13% of the growth in global trade. Also related is the nascent literature stream that assesses the effects of voluntary sustainability standards on trade (Bemelmans et al., 2023; Chen et al., 2024; Ehrich & Mangelsdorf, 2018; Fiankor et al., 2019, 2020). As there are no country-specific variations in the application of voluntary sustainability standards, such as GlobalGAP, FairTrade or Organic standards, they act as a harmonised standard. Where we fundamentally differ from this group of papers is their focus on voluntary standards as against our interest in mandatory public standards. In the end, whereas firms have the choice to get certified to voluntary standards to enhance sales, public standards are mandatory market access requirements that firms cannot sidestep. As such, the potential trade gains from harmonising a public standard may be more pronounced than a private voluntary regulation, even if the latter is becoming de facto mandatory. Finally, in more recent work, Shingal and Ehrich (2024), examine the impact of the EU's 2008 harmonisation of pesticide MRLs on intra-EU and third-country exports to the Single Market, and on the prices and quality of exported products. Shingal and Ehrich (2024) exploit regulatory homogeneity via the near-natural experiment setting of the EU's MRLs harmonisation policy using HS6-digit level trade data in a cross-country panel. In contrast, we work at the micro level and study the import behaviour of firms exploiting the mutual recognition of MRL standards by the EU and Switzerland.

Our work also relates directly to papers that study the effects of pesticide regulations on trade flows (Curzi et al., 2018; Fernandes et al., 2019; Fiankor et al., 2024; Fiankor, Curzi, & Olper, 2021; Hejazi et al., 2022; Shingal et al., 2021; Winchester et al., 2012). These papers work at the product level and find that cross-country differences in MRLs hinder export, the exception being Shingal et al. (2021) who estimate a positive effect. This literature exploits variation only at the product level and does not consider that the estimated trade effects may vary depending on where relative standards lie on a continuum. We extend this literature stream in two ways. One, our paper contributes an analysis at the detailed product-pesticide level. Two, it also shows that the impact of regulatory homogeneity on imports is positive and increasing along the conditional distribution of MRL differences.

The remainder of the paper proceeds as follows. We review and summarise the relevant theoretical literature that guides our analysis and help explain our findings in Section 2. We present the MRL and trade datasets in Section 3. Our empirical analysis is discussed in Section 4. We present and discuss the empirical findings in Section 5, and offer concluding remarks in Section 6.

2 | THEORETICAL DISCUSSION

Our analysis tests empirical predictions from a series of theoretical works, beginning with Melitz (2003) who studies international trade from a firm-level perspective. The heterogeneous firms' literature (Bernard et al., 2003; Chaney, 2008; Melitz, 2003) stresses that the heterogeneous impact of trade costs on firm-level trade is a direct consequence of the firms' initial heterogeneity in productivity. Firms produce a uniquely horizontally differentiated variety for the domestic market if their productivity is below some threshold, and they export to a foreign market if their productivity exceeds a higher threshold. While the early empirical literature using firm-level customs transaction data focused on exports, subsequent work showed that importers display similar characteristics (Melitz & Redding, 2014). This section highlights the necessary theoretical predictions from these literature streams that guide our empirical approach and findings.

We consider a government-imposed, minimum quality regulation that serves as both a variable and trade cost measure that moderates market access. The stricter the pesticide regulations, the more difficult it is to access the market. The regulation constitutes both a fixed and a variable cost for firms. The nature of these costs depends on the features of both the producing and importing country. On the supply-side, firms aiming to supply the destination country with a stricter regulation incur costs, including R&D and compliance, to meet the minimum pesticide quality standard. On the demand side, firms in the importing country incur information costs to identify firms in different source countries that are producing according to standards in the destination country. In equilibrium, only firms producing or exporting products with quality equal to or stricter than the government-imposed standard in the destination serve the market. The marginal costs of production also increase with the stringency of regulations. Thus, the introduction of a new limit on a particular pesticide or the tightening of an existing limit will impose extra costs for imports, especially from countries where existing public regulations are weak.

In a model with heterogeneous firms, the productivity cut-off for trading differs with the accessibility of the destination (Chaney, 2008). This induces a selection of firms into trading which is driven by trade costs and only the most productive firms remain profitable (Bernard et al., 2006). In this class of models, changes in trade costs alter the micro-economic composition of aggregate bilateral trade flows through an extensive margin, that is, a change in the number of firms engaging in trade (Chaney, 2008; Melitz, 2003), or within-firm product selection (Bernard et al., 2011), which affects the average value of exports per firm (i.e. the intensive margin). The regulatory standard imposes extra costs that affect trade at both the intensive and extensive margins. The fixed cost component of the standard is expected to mainly affect the extensive margin as only productive firms that meet the fixed costs imposed by the standard would serve the market maintaining the standard. The variable cost component (e.g. recurrent costs of quality control and product testing) would affect both the extensive and intensive trade margins. When variable costs are high, successful firms reduce their trade volumes (i.e. the intensive margin) and low-productive firms exit the destination market (i.e. the extensive margin), and vice versa.

The underlying prediction is that differences in standards will reduce trade flows, with the effects being more pronounced for low-productivity firms. As such, if these trade costs induced by standards are lowered or reduced due to regulatory homogeneity, we should expect an increase in trade which should then also be more pronounced for low-productivity firms.

3 | DATA

To answer our research question, we exploit two main datasets: (i) data on cross-country differences in pesticide regulations and (ii) Swiss firm-level customs transaction data. In this section, we describe the two datasets and offer relevant descriptive statistics. But, first we provide some background information on the Swiss-EU agricultural trade relationship, which is the setting we exploit to test the predictions from our theoretical framework.

3.1 | The Swiss-EU agricultural trade relationship

Agriculture is a sensitive sector for both Switzerland and the EU, and political economy factors are therefore a strong determinant of both tariff and non-tariff measures in Swiss–EU agri-food trade. Swiss–EU economic and trade relations are governed by the 1972 FTA and the Bilateral Agreements of 1999. These agreements provide Switzerland direct access to key sectors of the EU's internal market, including the free movement of people; mutual recognition of product standards and liberalised markets for public procurement, air transport and road and rail transport of passengers and goods. The EU–Switzerland Agricultural Agreement ('Agreement between the European Community and the Swiss Confederation on Trade in Agricultural Products') is one of the seven sectoral agreements under Bilaterals I, which entered into force in 2002. Under this agreement, tariffs were reduced on cheese, fruits and vegetables, horticulture, meat and wine, and NTMs emanating from regulatory differences were eliminated by mutually recognising as equivalent regulations in plant health, animal feed, seeds, organic farming, wine and spirits and fruit and vegetables (Copenhagen Economics, 2016). With the adoption of the Agreement on Processed Agricultural Products under Bilaterals II, the EU–Swiss trade in processed agri-food products was also gradually liberalised. The agreement that entered into force in 2005 also addressed compensation for the difference in prices of raw materials. The EU allowed duty-free access to a range of Swiss agri-food products (including chocolate, biscuits and sweets) and did not pay export subsidies. In return, Switzerland reduced tariffs on EU exports and its subsidies on exports to the EU commensurate with the difference in raw materials prices.

That said, the EU-Swiss trade agreements do not cover all agri-products. The original EU-Switzerland FTA provided preferential access with zero tariffs for only around 5% of the 600 traded agri-food products. Once the Bilaterals were fully phased in, coverage increased to 25% of the number of agri-products exported from the EU to Switzerland and 38% of the number of Swiss agri-food exports to the EU (Copenhagen Economics, 2016). Thus, these agreements have given more preferential access to agri-food products exported from Switzerland to the EU than vice versa. At the same time, the EU's trade-weighted average tariff on Swiss agri-food exports declined from 15% in 1999 to 2% in 2015.

3.2 | Maximum residue limits

To protect consumers from adverse health risks, governments set MRLs, which are measured in parts-per-million (ppm) on pesticides and veterinary drugs. Agrochemical use is at the core of agricultural production. These plant protection products reduce yield or quality losses caused by harmful organisms. Notwithstanding, increased exposure levels constitute health and environmental risks. To protect their consumers from health risks and reduce the impact of chemicals on the environment, biodiversity and ecosystem services, many countries have set maximum residue limits (MRLs) on pesticides and veterinary drugs (Fiankor, Curzi, & Olper, 2021). The Codex Alimentarius Commission—which is the body responsible for all matters regarding the implementation of the Joint FAO/WHO Food Standards Programme—sets MRLs as an international benchmark, but countries are allowed to deviate from this benchmark in the presence of scientific evidence. Countries take advantage of this provision to set their own national MRLs. To prevent the abuse of this provision, national standards must be based on a scientific risk assessment, not discriminatory towards countries with similar conditions and must be minimally trade-distorting. These principles are not always achieved, as standards can be abused for protectionist trade policy objectives. This happens when countries are tempted to use standards not only to protect their consumers but also their domestic

TABLE 1 Comparison of maximum residue limits (in parts-per-million) on selected products in 2018.

Active element	Product	Switzerland	EU
Carbaryl	Mandarins	0.01	0.01
Captan	Apple	3	10
Fenbutatin-Oxide	Apple	2	2
Acetamiprid	Apple	0.8	0.8
Azoxystrobin	Tomatoes	3	3
Folpet	Avocado	0.02	0.03

producers from international competition (Fiankor, Haase, & Brümmer, 2021). Regarding pesticide regulatory standards, MRLs are continuous measures of relative stringency that can be unambiguously ranked on a vertical scale. The differences in the limits set across countries can be minor, but in most cases, they also vary substantially.

We access the MRL dataset from the Global Crop Protection database (Homologa).[3] Each MRL addresses a specific substance (i.e. pesticides, fertilisers or certain chemicals) in a specific commodity in a specific country. The EU harmonised its MRLs in 2008, which means that there is no divergence in MRLs across EU member states over the study period. Hence, we treat the EU countries as one unit. We present a sample of the MRL data structure in Table 1. The resulting Swiss-EU MRL dataset comprises 356,371 observations over 2016–2018: 235 HS8-digit products and 500 pesticides (active elements). For 82% of our data, pesticide-product MRL combinations are equal across the EU and Switzerland. Thus, regulatory differences characterised 18% of all observations. Based on the similarity or otherwise in MRLs, we generate a variable SAME = 1 if pesticide-product combinations are the same between the EU and Switzerland and 0 otherwise.

3.3 | Firm-level import data

Our second data source is a dataset from Swiss customs that contains shipments in value (CHF) and volume (kg) by firm-product-origin from 2016 to 2018. We restrict our sample to products for which an MRL is applied and to imports from EU countries (see Table A2 of the appendix for a list of products). We match the names of the products in the Homologa dataset to HS8-digit product codes from Swiss customs.

In Table 2, we present the summary statistics of the importing firms. Over the period of study, we observe 2347 unique importing firms, importing 98 HS8-digit products from the EU. The number of importing firms increased over the study period. The number of unique HS8-digit products imported and the number of products imported per firm remained fairly stable over time. The same is true for import values and volume. The average prices paid for imports increased over time. Our data include a categorical variable that captures the number of people employed within a firm. Based on this information, we define two sets of sized-based firm structures: (i) small firms with ≤249 employees and (iii) large firms with ≥250 employees. Only about 7% of the firms we observe are large. However, these large firms account for a disproportionately large share of imports.

[3]Homologa maintains the Global Plant Protection Products and Maximum Residue Limits Database using information from pertinent national ministries and legal publications. It collects monthly changes in allowable pesticides for approximately 61 importing countries. More information on the database can be accessed at https://homologa.com/.

TABLE 2 Characteristics of importing firms.

	Firms	Products	Products per firm	Import value per firm (CHF)	Import volume per firm (kg)	Unit values per firm (CHF/kg)
Years						
2016	1326	92	60	71,480	81,677	17
2017	1339	92	60	67,101	82,845	14
2018	1392	93	59	68,801	82,215	19
Firm size						
Large	141	83	9	343,303	343,751	22
Small	1904	98	79	45,322	60,706	16

Note: The number of observations across years does not equal the number of observations across firm sizes because, for some firms, the dataset does not record information on firm size defined as the number of employees.

4 | ESTIMATION STRATEGY

In this section, we detail our estimation strategy. We exploit the similarity in product-pesticide pairs between the EU and Switzerland as a predictor of imports along different margins of import adjustment. Our analysis are carried out within a reduced form gravity framework.

4.1 | Decomposing Swiss imports from the EU into different margins

The effects of pesticide regulatory heterogeneity on observed import values may only be a part of the story. How it affects market structure may be just as important. Hence, we decompose the bilateral trade flow into the product of the extensive and intensive margin. The decomposition will shed light on the underlying channels through which the regulatory homogeneity of standards affects imports. To assess the effects of regulatory homogeneity on different margins of trade adjustment, we express total Swiss imports from the EU of HS6-digit product k on which pesticide or active element p is applied in year t summed across firms f and HS8-digit products $\left(X_{pkt}\right)$ into extensive and intensive margins in Equation 1:

$$V_{pkt} = N_{pkt} \times F_{pkt} \times \overline{V}_{fpkt} \tag{1}$$

where V_{pkt} is the total value of Swiss imports from the EU in pesticide-product pair pk at time t , N_{pkt} is the number of unique HS8-digit products imported within an HS6-digit sector, F_{pkt} is the number of active importing firms, and $\overline{V}_{fpkt}$ is the average import value per product per firm. N_{pkt} and F_{pkt} are the extensive margin and $\overline{V}_{fpkt}$ is the intensive margin. We go a step further to decompose the intensive margin into price and quantity components. Specifically, $\overline{V}_{fpkt}$ is the product of the average price $\left(UV_{fpkt}\right)$ and quantity of k imported in t (Q_{fpkt}). In Equation 1, the different import margins (i.e. N_{pkt} , F_{pkt} and $\overline{V}_{fpkt}$) are a linear combination of total product-level imports (V_{pkt}). Thus, the elasticity of each margin with respect to MRL_{opt} adds up to and reflects the elasticity of aggregate product-level imports with respect to SAME_{pkt}. A graph of the different imports margins and total imports shows a positive correlation (Figure A2).

This decomposition allows us to assess the contribution of each margin to the overall trade effect. This is important because, the extent to which regulatory homogeneity affects the intensive and extensive margins may hinge on the elasticity of substitution in the industry (Chaney, 2008). Within homogeneous goods where substitution elasticities are usually high, lower trade costs mainly increase the intensive margin, whereas the extensive margin effect is weak. Within differentiated product wherein the elasticity of substitution is low, trade cost reductions mainly increase the extensive margin (Scoppola et al., 2018). Our empirical analyses tests which of these two mechanisms dominate in the Swiss-EU case. That said, given that we are analysing the agri-food sector, which largely comprises homogeneous goods, we expect the trade effect to be dominated by the intensive margin.

4.2 | Empirical model specification

We estimate the following baseline equation:

$$\ln X_{pkt} = \beta_1 \text{SAME}_{pkt} + \beta_2 \ln\left(1 + \text{Tariff}_{kt}\right) + \mu_{pk} + \gamma_t + \epsilon_{pkt} \quad (2)$$

where X_{pkt} is one of the five import margins defined in Equation 1.[4] Since trade policies are the same within the EU, there are no country variations in our policy variables—that is, MRLs and Tariffs. As such, we aggregate imports from individual EU member countries and treat the EU as a single entity following a rather standard approach in the literature that considers regulatory frameworks between the EU and its trading partners (see Curzi et al., 2018; Murina & Nicita, 2017).[5] SAME_{pkt} is a dummy variable that takes the value 1 for pesticide-product combinations where the Swiss MRL equals the EU MRL, and 0 otherwise. Tariff_{kt} are product-specific applied Swiss tariffs on imports from the EU. μ_{pk} and γ_t are pesticide-product and year fixed effects. We cluster the error term ϵ_{pkt} at the pesticide-product level. We estimate Equation 2 using ordinary least squares (OLS).[6]

Following the theoretical discussion outlined in Section 2, we expect regulatory homogeneity to have a positive effect on trade flows at all margins of import adjustment except for import prices where we expect it to have a negative effect.

4.3 | Identification strategy

Our identification strategy exploits heterogeneity in the liberalisation of EU-Swiss agricultural trade. The β_1 coefficient thus captures how similarity in MRLs across product-pesticide pairs affect different margins of import adjustment. The inclusion of product-pesticide $\left(\mu_{pk}\right)$ and year $\left(\gamma_t\right)$ fixed effects to capture additional potential confounding effects reduce endogeneity stemming from omitted variable biases. Whereas μ_{pk} controls for all characteristics specific to the product and active ingredient, γ_t controls for all macro-economic shocks. MRLs in both the EU and Switzerland are set by national health authorities which are all external to the firm. The fact that importing firms have limited

[4]The export side of the story is not particularly relevant because while the EU supplies a significant amount of Swiss imports, the amount of products going in the reverse direction are insignificant. For instance, according to UNComtrade data, 61% of Swiss merchandise imports were sourced from the EU27 on average over 2017–2019 while Switzerland supplied only 5.5% of extra-EU imports of goods in the same period. Most of these Swiss exports to the EU are also mainly processed food and beverages, on which MRLs are not usually applied.

[5]In our particular case, there is also a data management reason for doing this. Since, our unit of analyses is at the firm-product-pesticide-year level, it means each product level trade observation is matched to the 500 different active ingredients. Extending this to the origin level thus increase the number of observations 27 times without adding any other form of variation, as the variables of interest do not vary at the country level and all other sources of variation are taken into account by the fixed effects. Nevertheless, in sensitivity analyses, we relax this assumption to check the robustness of our findings.

[6]We also assess the effect of pesticide regulatory homogeneity on observed firm-product level imports using the Poisson pseudo maximum likelihood (PPML; Silva and Tenreyro (2006)) estimator. The results are presented in Table 5. Note that while the PPML is the go-to estimator in most applications of the gravity model, they will not allow us to decompose our effects on total imports into the different import margins. For the elasticity of each import margin with respect to SAME_{pkt} to add up to and reflect the elasticity of aggregate imports with respect to SAME_{pkt} requires that we estimate a model in its log–log form.

TABLE 3 Descriptive statistics for import margins by similarity status of crop-pesticide pairs.

Outcome variables	$\text{SAME}_{kpt}=0$ ($N=28{,}014$)	$\text{SAME}_{kpt}=1$ ($N=127{,}486$)	T-test
Import values (million CHF)	12.474	11.300	<0.001***
Number of firms	139.557	134.799	<0.001***
Number of products	3.374	4.106	<0.001***
Import values per product per firm ('000 CHF)	32.789	71.250	<0.001***
Import volume (million kg)	8.622	10.517	<0.001***
Unit values (CHF/kg)	0.245	0.229	0.003**

Note: ***, ** and * denote significance at 1%, 5%, and 10% respectively.

to no control over the regulations in both the origin and destination country mitigates the potential simultaneity between firm-level imports and pesticide regulations (see also Fiankor et al., 2024). Even if large and powerful domestic firms can lobby to relax or tighten domestic standards, they still have to source products from foreign countries where their domestic pesticide regulations do not necessarily apply, while ensuring that these imports meet the pesticide standards set at home. The Swiss-EU case also allows us to eliminate many other confounding factors. The EU and Switzerland are geographical neighbours; culturally very similar (with German, French and Italian being the official languages spoken in Switzerland, albeit in regional dialects); the Euro is almost legal tender across Switzerland and both partners have a series of deep trade deals. These factors are the major determinants of bilateral trade costs in a standard gravity model of trade. In our setting, there are little variations along the country-pair dimension that could be driving our findings except for trade policy. Given these similarities, and our regressions controlling for tariffs and different combinations of fixed effects, we can associate changes in trade flows to an additional effect arising from regulatory homogeneity at the product-pesticide level.

4.4 | Summary statistics

In Table 3, we test the differences in the outcome variables across the similarity status of pesticide-crop pairs. In all cases, we observe notable statistically significant mean differences across the two groups. The number of product varieties imported, average imports per product per firm, and imported quantities are higher when the pesticide standards are similar. Import prices are also lower when there is regulatory homogeneity. Import values are lower with similar standards which can be explained by the lower prices paid for imports. What is, however, surprising is that the number of active importing firms are higher when $\text{SAME}_{kpt}=0$. These initial findings nevertheless point towards a positive effect of regulatory homogeneity on imports. We will confirm this initial descriptive analysis empirically in the next section. Finally, summary descriptive statistics for the set of variables used in the regression models are presented in Table A1.

5 | RESULTS AND DISCUSSION

We first present the results of the effects of similarity in pesticide regulations on different margins of import in Section 5.1. We then test whether the effect of regulatory homogeneity

TABLE 4 The effect of pesticide regulatory homogeneity on product-level import margins.

	Total	Extensive margin		Intensive margin		
	Imports	Products	Firms	Average imports	Quantity	Prices
	X_{pkt}	N_{pkt}	F_{pkt}	$\overline{X}_{fpkt}$	Q_{fpkt}	UV_{fpkt}
Dependent variable (log)	(1)	(2)	(3)	(4)	(5)	(6)
SAME_{kpt}	0.097***	0.014***	0.006	0.077***	0.094***	−0.016**
	(0.015)	(0.003)	(0.005)	(0.013)	(0.017)	(0.008)
$\text{Log}(1+\text{Tariff}_{kt})$	−0.373***	0.182***	0.090***	−0.645***	−0.161***	−0.484***
	(0.009)	(0.004)	(0.007)	(0.007)	(0.007)	(0.008)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Product-pesticide FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	155,000	155,000	155,000	155,000	155,000	155,000
Adjusted R^2	0.962	0.980	0.976	0.933	0.970	0.986

Note: ***, ** and * denote significance at 1%, 5%, and 10% respectively. Intercepts included but not reported. Standard errors are clustered at the product-chemical-year level. X_{pkt} is total Swiss imports—summed across all firms, and HS8-digit products—of product k on which active element p is applied in year t. F_{pkt} is the number of firms importing in year t, N_{pkt} is the number of products imported in year t and $\overline{X}_{fpt}$ is the import value per product per firm in year t. The coefficients in columns (2) to (4) sum up to those in column (1). The coefficients in columns (5) and (6) also sum up to those in column (4).

on imports is heterogeneous across firms of different sizes in Section 5.2. Then we extend our findings to the firm-product level in Section 5.3.

5.1 | Regulatory homogeneity and product-level import margins

Our baseline results are presented in Table 4. The different columns reflect different outcome variables that capture different margins of import adjustment. In all cases, the findings are consistent with the theoretical priors. When pesticide regulations are similar between the EU and Switzerland, we observe a positive effect on all margins of trade adjustment, except for import prices. Specifically, similarity in pesticide regulations has a positive impact on the total value of Swiss imports of agri-food products from the EU, the number of unique HS8-digit products imported, and the average import value per product per firm. However, the effect on the number of importing firms is statistically insignificant. In terms of magnitude, pesticide regulatory similarity increases imports by 9.7%, product varieties by 1.4% and average firm-level imports by 8%. On import prices, the effects of pesticide similarity are negative and statistically significant, which is consistent with Swiss firms not having to bear the compliance costs associated with regulatory heterogeneity.

Our finding that the trade increase is driven largely by the intensive margin is also consistent with the sector we consider. Given that we study agri-food imports that are largely homogeneous goods and thus characterised by a high elasticity of substitution, reductions in trade costs emanating from regulatory homogeneity increase mainly the intensive margin, whereas the effect on the extensive margin is rather weak, as only few firms enter the market as new traders (Chaney, 2008; Scoppola et al., 2018). Our results suggest that the overall increase in imports due to regulatory homogeneity is largely driven by an increase in average imports per product per firm and an increase in the number of different HS8-digit product varieties they import. Regulatory homogeneity, however, does not induce market entry for new firms. Instead, incumbents expand the set of product varieties and the quantities they import. In terms of policy, our findings show that regulatory homogeneity promotes food security as consumers get access to more product varieties at lower prices.

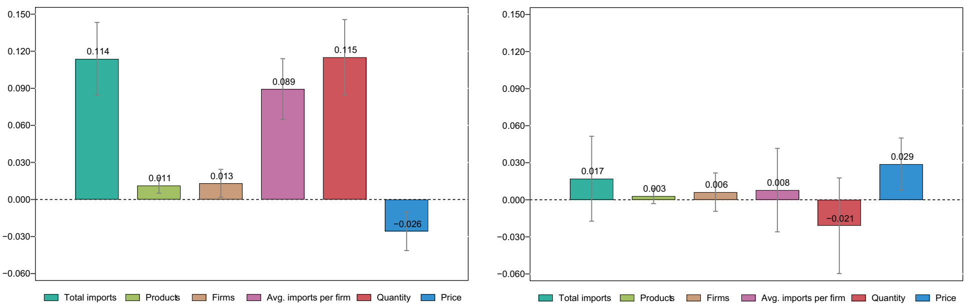
Overall, our findings are consistent with the existing literature showing that pesticide regulatory heterogeneity hinders exports and increases export prices (Fernandes et al., 2019; Fiankor, Curzi, & Olper, 2021; Hejazi et al., 2022; Shingal et al., 2021). Our work is, however, novel in showing the import-side effects (see also Fiankor et al., 2024), but more importantly the trade enhancing effects of harmonising cross-country differences in pesticide regulations. On the latter, Shingal and Ehrich (2024) offer insights into the impact of the EU's MRL harmonisation in 2008 on intra-EU and third-country exports to the Single Market. They estimate a positive impact of harmonisation on trade and product quality accompanied by a reduction in quality-adjusted prices. Shingal and Ehrich (2024) analyse country-level data and show that the EU's MRL harmonisation translates into a 55% increase in non-EU exports to the EU (via the relative importer stringency channel). At first glance, our overall firm-level and product-level trade and price effects appear relatively small in magnitude. However, both papers examine regulatory homogeneity via different channels and at different levels of data aggregation.

On tariffs, we find that a 10% increase in per-unit tariffs reduce Swiss imports from the EU by 37%, on average. Swiss tariffs on imports from the EU decrease imports at the intensive margin and increase trade at the extensive margin. Here again, the effects are dominated by the intensive margin of trade adjustment. The negative effect of tariffs on import prices deserve some attention. As tariffs are taxes on imports, exporters can either pass on the extra costs to consumers in the form of higher prices (i.e. the cost pass-through mechanism) or absorb some or all of the extra costs themselves in order to remain competitive in the importing market (i.e. the pricing-to-market mechanism). Our negative tariff effect on prices seem to point to the pricing-to-market channel. Given, however, that we consider imports, the unit values we calculate are not free-on-board prices but include cost, insurance and freight costs. As such the negative price effect we estimate here should be interpreted with some caution.

5.2 | Regulatory homogeneity and product-level import margins: Firm heterogeneity

Finally, in exploiting the heterogeneity of the firm-level data, we examine the trade effects of regulatory homogeneity across small and large firms. This is important because similar (heterogeneous) standards reduce (increase) trade costs and can reallocate market shares across firms depending on their productivity. Economic theory suggests that the impact of various trade facilitation provisions may be bigger for small firms compared to large firms. Particularly exposed to the consequences of NTM-related trade costs are small firms that trade infrequently and/or in small batches. These small firms often lack specialised teams and international operations departments, and cannot take advantage of productivity-related returns to scale (Fontagné et al., 2020). To this end, we proxy productivity using firm size and estimate Equation 2 on sub-samples of large and small firms. The results are presented in Figure 1.

There is considerable heterogeneity in the estimated effects across firm size. Small firms benefit from the similarity in pesticide regulations at both margins, including an increase in the number of importing firms. If regulatory standards get aligned between trading partners, the productivity threshold required for trading gets lowered. The resulting lower competitive environment in the domestic market reinforces the link between productivity and size, allowing



(a) Small firms **(b)** Large firms

FIGURE 1 The effect of pesticide regulatory homogeneity on import margins by firm size. We define two sets of sized-based firm structures based on number of employees engaged within a firm. Small firms are firms with ≤249 employees, and Large firms are firms with ≥250 employees. The table of results used to generate these figures are presented in Tables A3 and A4 of the Appendix. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 5 The effect of pesticide regulatory heterogeneity on import values and quantities.

	Import values		**Import quantity**	
Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
SAME_{kpt}	0.004	0.783***	0.013*	0.329***
	(0.006)	(0.048)	(0.007)	(0.052)
$\text{SAME}_{kpt} \times \text{logSize}_{ft}$		−0.035***		−0.014***
		(0.002)		(0.002)
$\text{Log}\,(1+\text{Tariff}_{kt})$	−0.104**	−0.108**	−0.131***	−0.132***
	(0.042)	(0.042)	(0.032)	(0.032)
Firm-year FE	Yes	Yes	Yes	Yes
Product-pesticide FE	Yes	Yes	Yes	Yes
Observations	8,150,500	8,150,500	8,150,500	8,150,500

Note: The dependent variable in column (1) is import values of firm f of HS8-digit product k—on which pesticide p is applied—in year t. The dependent variable in column (2) is import quantities of firm f of HS8-digit product k—on which pesticide p is applied—in year t. All models are estimated using the Poisson pseudo maximum likelihood estimator. p values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10%.

less productive and mostly small firms to either start trading at the extensive margin or increasing their trading activity at the intensive margin. By contrast, the estimated impact on large trading firms is not statistically different from zero. The finding here is consistent with a literature stream showing that small and medium enterprises are disproportionately adversely affected by non-tariff barriers (Curzi et al., 2020; Fernandes et al., 2019). This observation is also consistent with the idea that liberalising trade costs in general (Chen & Novy, 2022) and non-tariff measures in particular (Fiankor, Haase, & Brümmer, 2021) favour smaller trading partners more than well-established ones.

5.3 | Firm-product level estimations using the PPML estimator

In this sub-section, we use the full data sample of 2347 importing firms, 98 HS8-digit products and 500 active elements over 3 years to assess the effect of pesticide regulatory homogeneity on Swiss firm-product level imports using the Poisson pseudo-maximum likelihood estimator.

TABLE 6 The effect of pesticide regulatory heterogeneity on import values across quantiles of the MRL difference.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SAME_{kpt}	0.488***	0.507***	0.718***	−0.126	1.059***	0.972***	1.496***
	(0.122)	(0.129)	(0.073)	(0.165)	(0.125)	(0.126)	(0.136)
$\text{SAME}_{kpt} \times \text{logSize}_{ft}$	−0.022***	−0.023***	−0.033***	0.008	−0.045***	−0.041***	−0.067***
	(0.005)	(0.006)	(0.003)	(0.008)	(0.005)	(0.006)	(0.006)
$\text{Log}\,(1+\text{Tariff}_{kt})$	−0.155***	−0.156***	−0.138***	−0.163***	−0.156***	−0.156***	−0.157***
	(0.041)	(0.041)	(0.042)	(0.041)	(0.041)	(0.041)	(0.041)
Firm-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product-pesticide FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,974,818	6,984,500	7,301,143	6,906,485	6,930,067	6,949,386	6,928,714
Average difference in MRL	0.009	0.028	0.040	0.050	0.091	0.458	9.199

Note: The dependent variable is import values of firm f of HS8-digit product k—on which pesticide p is applied—in year t. All models are estimated using the Poisson pseudo maximum likelihood estimator. p values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10%.

The estimator's log-linear objective function allows us to specify the gravity equation in its multiplicative form without log-transforming the dependent variable and is consistent under heteroskedasticity (Silva & Tenreyro, 2006). However, we estimate the model on the sample of only positive trade observations.[7] This also means that with the PPML estimator, we assess only the intensive margin of trade. However, this step has the advantage that it allows us to validate our product-level findings in Sections 5.1 and 5.2 at the firm-product level. Our estimation equation is the following:

$$V_{fpkt} = \exp\left[\beta_1 \text{SAME}_{pkt} + \beta_2 \ln\left(1 + \text{Tariff}_{kt}\right) + \mu_{pk} + \gamma_{ft}\right] + \epsilon_{fpkt} \tag{3}$$

where the dependent variable V_{fpkt} is either the import value in CHF or quantity in kg of HS8-digit product k on which active element p is applied of Swiss firm f from the EU in year t. μ_{pk} and γ_{ft} are product-pesticide and firm-year fixed effects. We cluster the error term ϵ_{fpkt} at the firm-pesticide-product level. To assess the effect of productivity and confirm the heterogeneous effects across firm sizes, we follow another approach in the literature and use the total import values or quantities per firm irrespective of product as a measure of size (see Curzi et al., 2020; Fontagné et al., 2015). Thus, we introduce an interaction of the log of firm size and the variable SAME_{pkt} in Equation 3 to assess the moderating role of productivity proxied by firm size. The results presented in Table 5 confirm our main finding that regulatory homogeneity increases trade, with the effects decreasing in firm size.

Given that there exists mutual recognition of MRL standards between the EU and Switzerland, there may be concerns as to whether our regressions indeed capture a true regulatory homogeneity effect. To this end, we re-estimate the regressions at different percentiles of the distribution of MRL differences. The mean absolute value of the MRL differences ranges from a low of 0.009 to a high of 9.199; these values are reported in the lower panel of Table 6. Our argument here is a simple one; if indeed the similarity in standards is what is driving the positive trade effects we find, then we should expect smaller trade effects where the difference

[7]This is the case because squaring the trade data set to include zero trade observations generates over 340 million observations (i.e. 2347 firms × 98 products × 500 active elements × 3 years).

in the MRLs across the two partners is small and larger effects when the MRL differences are large. Put differently, the positive effect of regulatory heterogeneity on trade should be relatively small if the MRL differences across the country-pairs is near 0 but it should become large as this difference approaches 9, which is the sample maximum. The results in Table 6 confirm this proposition. We find the import-enhancing effect of pesticide regulatory homogeneity to increase with increasing differences in regulatory standards. Moreover, across percentiles, the impact of regulatory homogeneity is found to be more pronounced for smaller firms, which again corroborates the overall estimates reported in Table 5.

6 | CONCLUSION

MRLs mandate the maximum level of pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly. Yet, the legal limits per product can in many cases vary across countries. Even if the regulations are aimed at domestic consumption, their implementation influences the distribution of domestic and foreign firms active in the market. Using data on pesticide MRLs and Swiss firm-level agri-food imports, we assess the effects of regulatory homogeneity on Swiss-EU trade. We show that when pesticide regulations are similar there is a positive effect on the total value of Swiss agri-food imports from the EU, the number of product varieties imported and the average product value per product per firm. Import prices are also lower. These effects are pronounced for smaller firms, which is consistent with such firms disproportionately bearing the adverse effects of non-tariff barriers.

Our results have important implications for policy making. If standards are specific to each country, the associated increase in production costs prevent firms and ultimately consumers, from reaping the benefits of standardisation, which is especially important in a globalised world where products cross multiple borders (Schmidt & Steingress, 2022). This is very much the case for agricultural products where regulations on pesticide use and application rates vary substantially across countries. Importing firms may need to change product origins or sourcing procedures in response to changing country-specific pesticide regulations. As our results show, similarity in standards—even between country-pairs that already trade a lot with each other—enhance trade and increase the participation of small firms. Yet, even if regulatory convergence or harmonisation of food standards globally may be the ultimate goal, pragmatically it remains a difficult goal to achieve (Wieck & Grant, 2021) at least in the immediate term. Questions, including, whose standard becomes the 'standard', would there be a 'race to the top or bottom' in terms of standards remain and need to be sorted out. That notwithstanding, our results point to the potential trade benefits of such attempts at regulatory homogeneity.

In particular, the positive extensive margin effects for small firms highlight the fixed cost component of regulatory standards and their compliance, a cost which is often prohibitive for small (Curzi et al., 2020) and less productive (Movchan et al., 2020) firms. The exclusion of small and less productive firms from trade has, inter alia, implications for workers directly employed in these firms and for workers in other upstream and downstream sectors dependent on this trade. From a policy perspective, this emphasises the need for governments to complement trade policy with domestic policy programmes aimed especially at assisting small and less productive firms in meeting international product standards and with possible labour market interventions to help displaced workers find alternative sources of employment.

Our findings are also policy relevant especially for the United Kingdom, a net agri-food importer, in a post-Brexit world, where the nature of the EU–UK relationship is still evolving.[8] Since the EU–UK Trade and Cooperation Agreement remains basically a free trade agreement, it will not offer the same trade advantages as the single market the United Kingdom decided to leave, so UK–EU trade must inevitably face some customs procedures, including rules of origin but also quality standards and technical regulations that require testing and certification (Buigut & Kapar, 2023). Pesticide MRLs were harmonised across EU member states in 2008. This meant that there were no differences between United Kingdom and EU MRLs before Brexit. Any divergence in United Kingdom and EU27 agri-standards post-Brexit is likely to mirror the EU's situation with Switzerland. Our results on the adverse trade effects of Swiss-EU regulatory heterogeneity are thus likely to apply, mutatis mutandis, to a post-Brexit UK. They reveal the potential trade gains for the United Kingdom from aligning its standards with those of the EU after Brexit. If post-Brexit UK and EU agri-food standards do not diverge, our findings would still be relevant for those product standards, including those in non-agricultural sectors, where UK standards differ from the EU's. This inference is consistent with a series of analysis that have addressed the trade reduction effects induced by Brexit (Cheptea et al., 2021).

Going forward, just as there has developed a large literature assessing the trade effects of non-tariff measures on agricultural and food trade (Santeramo & Lamonaca, 2019), our results open up the discussion to assess the trade effects of regulatory homogeneity via mutual recognition, harmonisation and/or convergence of regulatory standards. Furthermore, it would also be worthwhile to assess how such homogeneity affects product quality upgrading of imports (Vaquero Piñeiro & Curzi, 2024). Finally, it may be worth commenting upon the external validity of our findings. Our case study focusses on Swiss-EU trade—a setting in which standards are already fairly close. Thus, the extent to which our results can be extended to other country pairs with different regulatory environments, trade dynamics and culture is not evident. While harmonisation is clearly the way to go, the question remains whose standards become the *standard*? Paradoxically, the Codex Alimentarius already provides us with plenty of common ground issuing science-based recommendations that are reflective of cultural and community preferences across the globe. Yet, the continuing disregard of Codex standards, in favour of country-specific regulations, goes to show that countries care little about anybody's standards but their own. Our analysis, nonetheless, contributes in pointing out the potential trade gains that come with regulatory homogeneity.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from The Global Pesticide Database. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from https://homologa.com/ with the permission of The Global Pesticide Database.

[8]There are several options available to the UK post-Brexit (Dhingra et al., 2017). It could (i) join the European Economic Association (EEA) and remain part of the Single Market, similar to Norway; (ii) become a member of the European Free Trade Association (EFTA) by negotiating bilateral deals providing partial access to the Single Market, similar to Switzerland; (iii) enter into a Customs Union with the EU and get duty-free quota-free access for its industrial exports to the Common Market, similar to Turkey; (iv) sign a (comprehensive) free trade agreement (FTA) with the EU, similar to Canada or (v) trade with the EU under WTO rules, similar to the United States.

ORCID

Dela-Dem Doe Fiankor https://orcid.org/0000-0003-0510-0476

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APPENDIX A

TABLE A1 Summary statistics.

Variable	Mean	SD	Min	Max	*N*
Number of firms	135.656	190.33	1	1730	155,500
Number of products	3.974	4.87	1	28	155,500
Import value (mln. CHF)	11.51	18.69	0	86.85	155,500
Import volume (mln. kg)	10.18	29.35	0	287.22	155,500
Average import ('000 CHF)	64.32	438.99	0	7122.47	155,500
Unit values (CHF/kg)	0.232	0.83	0	7.71	155,500
MFN Tariff (CHF/kg)	18.653	29.56	0	189.37	155,500
SAME	0.820	0.384	0	1	155,500

TABLE A2 List of HS8-digit products.

07011010, 07020020, 07031013, 07031021, 07031029, 07031049, 07031051, 07031060, 07031071, 07031079, 07032000, 07039010, 07041010, 07041021, 07041029, 07041090, 07041099, 07049011, 07049020, 07049030, 07049060, 07049069, 07049080, 07051129, 07051198, 07052910, 07052969, 07061010, 07069011, 07069060, 07069069, 07070050, 07094010, 07097011, 07097019, 07099918, 07099929, 07099940, 07099959, 07099979, 07132011, 07133599, 07135012, 07141090, 08011900, 08012100, 08013200, 08025100, 08025200, 08044000, 08045000, 08052000, 08052100, 08054000, 08055000, 08059000, 08071900, 08072000, 08084011, 08092910, 08093020, 08101010, 08102030, 08103012, 08103021, 08103029, 08104000, 08105000, 08107000, 08134019, 09022000, 09024000, 09030000, 09052000, 09072000, 09082100, 09083200, 09092100, 09093200, 09096110, 09102000, 10059039, 10061010, 10082100, 10086010, 12019010, 12019023, 12019099, 12023000, 12075023, 12079111, 12079117, 12129110, 12129189, 12129299, 12129310, 12129410, 18010000

TABLE A3 The effect of pesticide regulatory homogeneity on product-level import margins for small firms.

	Total	Extensive margin		Intensive margin		
	Imports	Products	Firms	Average imports	Quantity	Prices
	X_{pkt}	N_{pkt}	F_{pkt}	$\overline{X}_{fpkt}$	Q_{fpkt}	UV_{fpkt}
Dependent variable (log)	(1)	(2)	(3)	(4)	(5)	(6)
$SAME_{kpt}$	0.114***	0.011***	0.013**	0.089***	0.115***	−0.026***
	(0.015)	(0.003)	(0.006)	(0.013)	(0.016)	(0.008)
Log $(1+Tariff_{kt})$	−0.361***	0.173***	0.070***	−0.604***	−0.128***	−0.476***
	(0.010)	(0.004)	(0.006)	(0.007)	(0.007)	(0.007)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Product-pesticide FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	154,000	154,000	154,000	154,000	154,000	154,000
Adjusted R^2	0.959	0.982	0.971	0.934	0.974	0.987

Note: ***, ** and * denote significance at 1%, 5% and 10%, respectively. Intercepts included but not reported. Standard errors are clustered at the product-chemical-year level. X_{pkt} is total Swiss imports—summed across all firms, and HS8-digit products—of product k on which active element p is applied in year t. F_{pkt} is the number of firms importing in year t, N_{pkt} is the number of products imported in year t and $\overline{X}_{fpt}$ is the import value per product per firm in year t. The coefficients in columns (2) to (4) sum up to those in column (1). The coefficients in columns (5) and (6) also sum up to those in column (4).

TABLE A4 The effect of pesticide regulatory homogeneity on product-level import margins for large firms.

	Total	Extensive margin		Intensive margin		
	Imports	Products	Firms	Average imports	Quantity	Prices
	X_{pkt}	N_{pkt}	F_{pkt}	$\overline{X}_{fpkt}$	Q_{fpkt}	UV_{fpkt}
Dependent variable (log)	(1)	(2)	(3)	(4)	(5)	(6)
SAME_{kpt}	0.017	0.003	0.006	0.008	−0.021	0.029***
	(0.018)	(0.003)	(0.008)	(0.017)	(0.020)	(0.011)
$\text{Log}\,(1+\text{Tariff}_{kt})$	−2.565***	−0.016***	−0.241***	−2.308***	−3.092***	0.784***
	(0.074)	(0.006)	(0.006)	(0.076)	(0.091)	(0.016)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Product-pesticide FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	137,000	137,000	137,000	137,000	137,000	137,000
Adjusted R^2	0.885	0.982	0.902	0.777	0.905	0.961

Note: ***, ** and * denote significance at 1%, 5% and 10%, respectively. Intercepts included but not reported. Standard errors are clustered at the product-chemical-year level. X_{pkt} is total Swiss imports—summed across all firms, and HS8-digit products—of product k on which active element p is applied in year t. F_{pkt} is the number of firms importing in year t, N_{pkt} is the number of products imported in year t and $\overline{X}_{fpt}$ is the import value per product per firm in year t. The coefficients in columns (2) to (4) sum up to those in column (1). The coefficients in columns (5) and (6) also sum up to those in column (4).

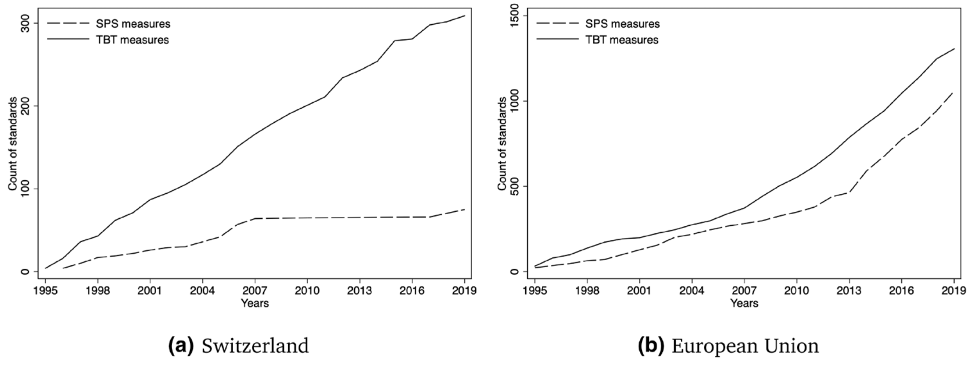

FIGURE A1 Proliferation of standard-like non-tariff measures.
Source: Ghodsi et al. (2017) based on UNCTAD TRAINS dataset.

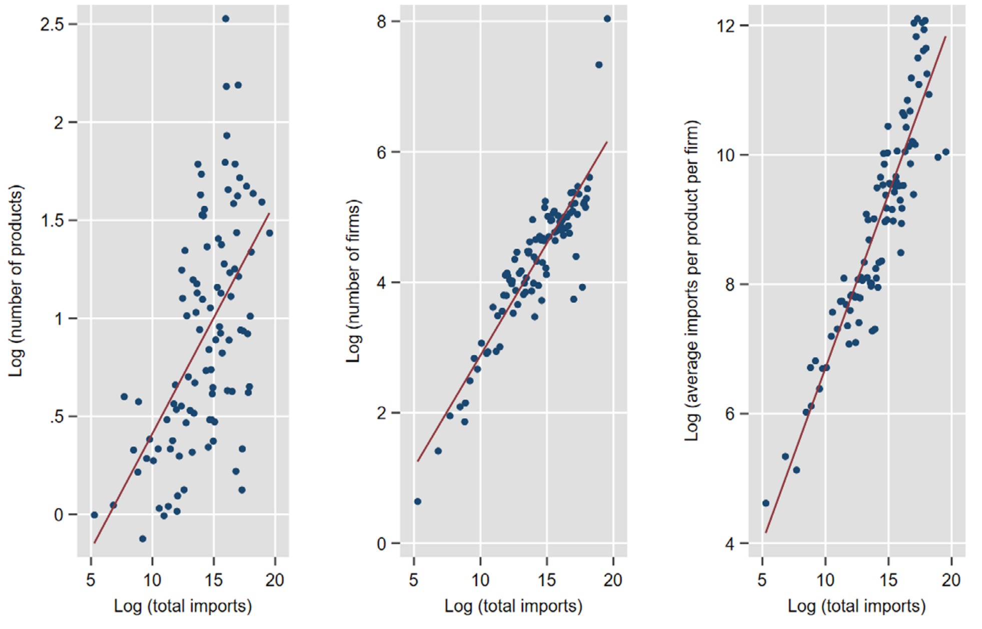

FIGURE A2 Total imports versus the intensive and extensive margins of imports. [Colour figure can be viewed at wileyonlinelibrary.com]