Pesticide Regulatory Heterogeneity, Foreign Sourcing, and Global Agricultural Value Chains

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Summary

- What is the effect of cross-country variations in pesticide regulations on the import decisions of agri-food firms?
- We combine **pesticide regulations data** with **firm-level import data** on Switzerland
- **Identification:** Pesticide regulations are exogenous to firm-level import decisions
- Regulatory heterogeneity decreases imports. Firms pay **higher import prices**
- GVC-active firms and large firms are more resilient.

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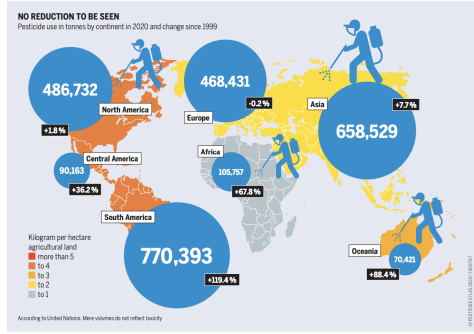
Pesticides and agriculture: a love-hate relationship

- Pesticide use in modern agriculture
- Consequences for the environment, biodiversity and human health
- Policy response — review and/or set new standards → maximum residue limits (MRL)



The global pesticide market is growing

[1] Image source: Pesticide Atlas, DW, WTO

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Consumers are taking action

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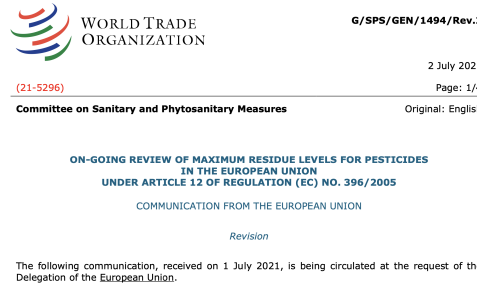

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ON-GOING REVIEW OF MAXIMUM RESIDUE LEVELS FOR PESTICIDES IN THE EUROPEAN UNION UNDER ARTICLE 12 OF REGULATION (EC) NO. 396/2005

COMMUNICATION FROM THE EUROPEAN UNION

Revision

The following communication, received on 1 July 2021, is being circulated at the request of the Delegation of the European Union.

Announcing ongoing review of EU MRLs

[1]Image source: Pesticide Atlas, DW, WTO

Often there is nothing “standard” about standards across countries

Table 1: Maximum Residue Limits on selected products in 2018 (Source: Homologa)

Active element	Product	CHE	EU	Japan	USA	Canada	China	Codex
Carbaryl	Mandarins	0.01	0.01	7	10	10		15
Fenbutatin-Oxide	Apple	2	2	5	15	3	5	5
Acetamiprid	Apple	0.8	0.8	2	1	1	0.8	0.8
Azoxystrobin	Tomatoes	3	3	3	0.2	0.2	3	3
Folpet	Avocado	0.02	0.03	30	25	25		

Notes: MRLs are measured in parts-per-million (ppm).

This paper: pesticide regulations and firm-level import decisions

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Setting: exploit unique Swiss firm-level imports and data on MRLs.

Previewing our findings

1. Regulatory heterogeneity decreases firm-level imports.
   - Total imports (↓↓↓) = Number of products (↓) + Average imports per product (↓↓)
   - Mechanism ⟶ Import prices (↑)
2. Firms that are engaged in GVC activity are more resilient
3. The effect is more pronounced for smaller firms

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A theoretical model of foreign sourcing

- Antras and Helpman (2004) provide a framework that models heterogeneous firms' decisions to outsource or insource
- Heterogeneous firms trade off higher fixed costs and lower variable costs of sourcing abroad against lower fixed costs and higher variable costs of sourcing at home.
- One of the main results of this model is that less productive firms source domestically while their more productive counterparts source inputs from abroad.

A theoretical model of foreign sourcing

- Consider Home firms, operating in a monopolistically competitive agrifood industry, differ in productivity, use $h(i)$ and $m(i)$ to produce a final good output level x according to the following Cobb-Douglas production function:

$$x_i = \theta \left[\frac{h(i)}{\eta}\right]^{\eta} \left[\frac{m(i)}{1-\eta}\right]^{1-\eta}, \tag{1}$$

- θ is the firm-specific productivity and η is a sector-specific parameter that captures the relative importance of $h(i)$ in the production process.

- $h(i)$: services that can only be performed at the firms headquarter or home location

- $m(i)$: intermediate inputs that Home firms can either import or source at home

A theoretical model of foreign sourcing

- Both the decision to offshore and to which country depends on differentials in cost structures faced by Home firms at home (H) and abroad (F).
- The final good firm can either produce the intermediate input $m(i)$ at Home with wage rate w^H, or source it from abroad at wage rate w^F.
- We assume a foreign wage advantage such that $w^H > w^F$.
- However, if a Home firm decides to source $m(i)$ from abroad, it also incurs trade costs $\tau > 1$. That notwithstanding, the marginal cost when sourcing from abroad are lower compared to production at home (i.e., $w^H > \tau w^F$).
- Fixed organizational costs f at home are lower than abroad

$$w^H f^H < w^H f^F \tag{2}$$

Integrating regulatory policy in the model

- Regulation on product quality and standards will affect the fixed and variable cost:

$$w^H f^H < \tau w^H f^F, \tag{3}$$

- But also variable costs and thereby overall revenue:

$$\pi^H = R(i) - w^H h(i) - \tau w^l m(i) - \tau w^H f^l. \tag{4}$$

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(1) Data on country and product specific pesticide regulations over time

- 522 products
- 511 active elements
- 65 countries

Table 2: Maximum Residue Limits on selected products in 2018 (Source: The Global Crop Protection database)

Active element	Product	CHE	EU	Japan	USA	Canada	China	Codex
Carbaryl	Mandarins	0.01	0.01	7	10	10		15
Fenbutatin-Oxide	Apple	2	2	5	15	3	5	5
Acetamiprid	Apple	0.8	0.8	2	1	1	0.8	0.8
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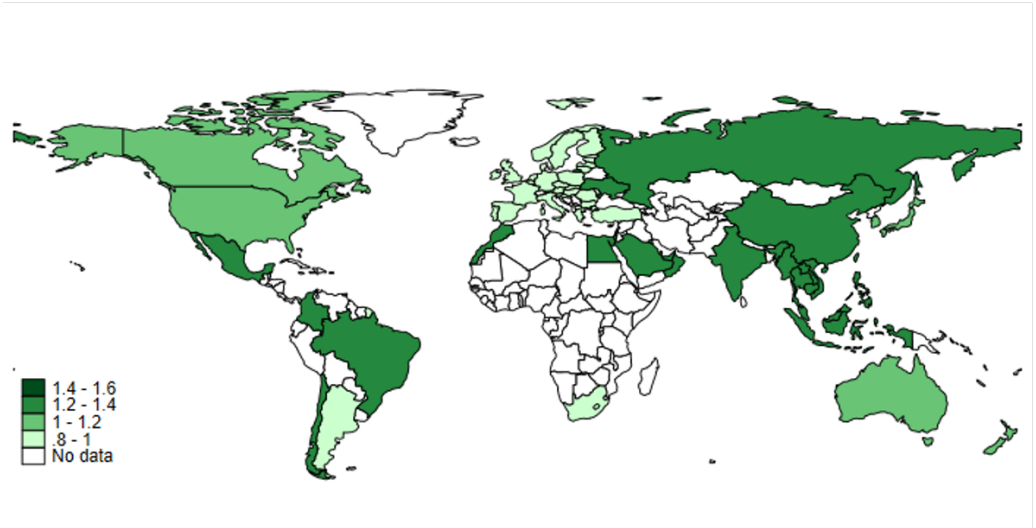
— Measuring regulatory heterogeneity across product and time

$$MRL_{odpt} = \frac{1}{N_{cp}} \left[\sum_{c \epsilon N_p} \exp\left(\frac{MRL_{opt} - MRL_{dpt}}{MRL_{opt}} \right) \right] \quad (5)$$

o = origin, d = Switzerland, p = product, t = time, c = active element

Bilateral variation in pesticide regulations (MRL_{odpt})



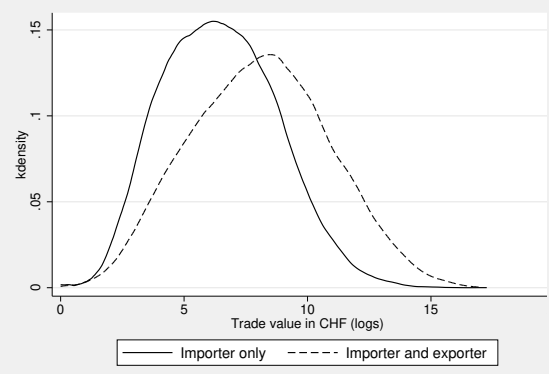
(2) Data on firm-level imports from Swiss-Impex

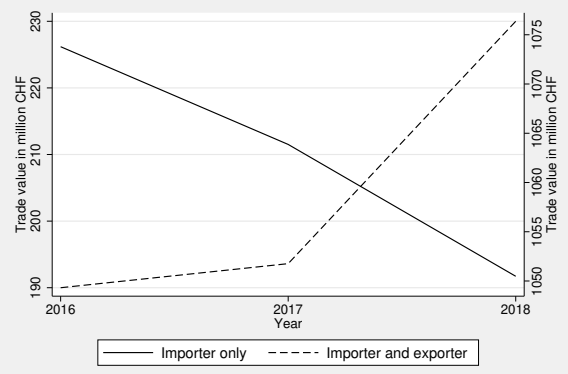
Our unit of analysis is the firm

- Imports by firm-product-origin from 2016 – 2018
- 10,271 firms
- 255 products (HS8 digit level)
- 65 origin countries

Proxies of productivity: Firm-level GVC participation

Imports by GVC participation





Notes: “Importer only” refers to firms that we observe in the dataset only as importers. “Importer and exporter” are firms that imported but also exported some agricultural and food products over the sample period.

Proxies of productivity: Number of employees

	Firms	Products	Origin per firm	Import value per firm (kg)	Origins per firm
Firm sizes					
Large (> 50 workers)	1,505	219	62	134,634	2.70
Medium (10 – 49 workers)	1,814	207	61	33,722	2.25
Small (< 10 workers)	5,804	250	64	15,729	1.61

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Specify and estimate empirical model

$$\log X_{fopt} = \beta_0 + \beta_1 MRL_{opt} + \beta_2 \log(1 + Tariff_{opt}) + \lambda_{fpo} + \lambda_{ot} + \varepsilon_{fopt} \quad (6)$$

- X_{fopt} = Import values in CHF
- MRL_{opt} = bilateral difference in MRL stringency between o and d
- $Tariff_{opt}$ = MFN tariffs imposed by Switzerland on imports from o
- λ_{fpo}, λ_{ot} = firm-product-origin and origin-time fixed effects
- Equation (7) is estimated using OLS (with ε_{fopt} clustered at the fpt level)

Identification: estimating β_1

$$\log X_{fopt} = \beta_0 + \beta_1 MRL_{opt} + \beta_2 \log(1 + Tariff_{opt}) + \lambda_{fpo} + \lambda_{ot} + \varepsilon_{fopt} \tag{7}$$

- Omitted variable bias — controlled using λ_{fpo} and λ_{ot}
- Simultaneity — Imports can affect standard setting.
- Country-level pesticide regulations are exogenous to firm-level decisions, i.e, $\mathrm{E}(\varepsilon_{fopt}|MRL_{opt}, \lambda_{fpo}, \lambda_{ot}) = 0$
- β_1 captures how cross-country and product variation in pesticide regulations affect within-firm import decisions.

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Pesticide regulatory differences decrease imports, less so for productive firms

	Baseline	GVC activity	Firm size
	(1)	(2)	(3)
MRL_{opt}	−0.672***	−0.758***	−0.890***
	(0.249)	(0.250)	(0.264)
GVC_{ft}		−0.133	
		(0.090)	
$MRL_{opt} \times GVC_{ft}$		0.181**	
		(0.083)	
$MRL_{opt} \times$ Medium-size firm			0.242***
			(0.078)
$MRL_{opt} \times$ Large-size firm			0.425***
			(0.085)
Log (1 + $Tariff_{opt}$)	−0.829***	−0.832***	−0.858***
	(0.206)	(0.206)	(0.212)
Firm-origin-product FE	Yes	Yes	Yes
Origin-Year FE	Yes	Yes	Yes
Observations	50,488	50,488	46,237
adj. R^2	0.868	0.868	0.871
Estimator	OLS	OLS	OLS

Putting the findings into perspective

- A one s.d. increase in MRL_{opt} reduces imports by 18%.

- Converting the magnitude into ad-valorem tariff equivalents

$$AVE_{MRL} = \left[\exp\left(\frac{\alpha \beta_1}{\sigma} \right) - 1 \right] \times 100 \tag{8}$$

where α measures a unit change in the policy variable.

- If we take the β_1 and $\sigma = \beta_2$ coefficients from column (1) of Table 5, we can compute the AVEs for different values of α.

- For a one standard-deviation increase in MRL_{opt}, we obtain a tariff rate of 24%.

Decompose firm-level imports into extensive and intensive margins

$$\underbrace{X_{fot}}_{\text{Total import values}} = \underbrace{N_{fopt}}_{\text{Extensive margin}} \times \underbrace{\bar{x}_{fopt}}_{\text{Intensive margin}} \tag{9}$$

where f = firms, o = origin, p = product, t = time

- The extensive margin is the unique number of products imported
- The intensive margin is the average import values per product per firm

This decomposition can be expressed in log form as:

$$\ln X_{fot} = \ln N_{fopt} + \ln \bar{x}_{fopt} \tag{10}$$

The negative effects are driven entirely by the intensive margin

Dependent variable (log)	x_{fot}	N_{fopt}	$\bar{x}_{fopt}$
	(1)	(2)	(3)
MRL_{opt}	−0.656***	0.012	−0.668***
	(0.247)	(0.046)	(0.252)
Log (1 + $Tariff_{opt}$)	−0.046	0.010	−0.056*
	(0.033)	(0.007)	(0.032)
Firm-origin-product FE	Yes	Yes	Yes
Origin-Year FE	Yes	Yes	Yes
Observations	47,033	47033	47,033
47,033			
adj. R^2	0.864	0.658	0.866
Estimator	OLS	OLS	OLS

Notes: The dependent variable is the product p imports of firm f from origin o in year t. p values are in parentheses. ***, ** and * denote significance at 1%, 5%, and 10%. Intercepts included but not reported. Standard errors are clustered at the firm-product-year level. All models are estimated using OLS. GVC_{ft} is a dummy variable that takes the value 1 if firm f imports and exports in year t. Large firms are importing firms with > 50 employees. Medium-sized firms are firms with 10 – 49 employees. The reference group is Small firms with < 10 employees. The number of observations is lower in columns (7) – (9) because some firms in the trade dataset do not have the number of employees specified.

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Mechanism: lower import quantities due to increased import prices

Dependent variable (Log)	Import quantity (1)	Import prices (2)
MRL_{opt}	−0.471*	0.122***
	(0.246)	(0.027)
Log (1 + $Tariff_{opt}$)	−1.043***	0.312***
	(0.212)	(0.068)
Firm-origin-product FE	Yes	Yes
Origin-Year FE	Yes	Yes
N	50305	50305
adj. R^2	0.893	0.854
Estimator	OLS	OLS

Notes: The dependent variable in column (1) is the import volume in kg. The dependent variable in column (2) is import price, measured as unit values, for product *p* imported from origin country *o* in year *t*, UV_{opt}.

The effects are more pronounced in higher-quality products

	Long quality ladder		Short quality ladder	
Dependent variable (log)	Import values	Import prices	Import values	Import prices
	(1)	(2)	(3)	(4)
MRL_{opt}	−1.986***	0.239***	−0.202	−0.005
	(0.675)	(0.033)	(0.303)	(0.025)
Log (1 + $Tariff_{opt}$)	−1.747***	−0.047	−2.016***	0.491
	(0.401)	(0.467)	(0.385)	(0.318)
Firm-origin-product FE	Yes	Yes	Yes	Yes
Origin-Year FE	Yes	Yes	Yes	Yes
Observations	24,429	18,474	23,988	17,868
adj. R^2	0.875	0.740	0.869	0.772

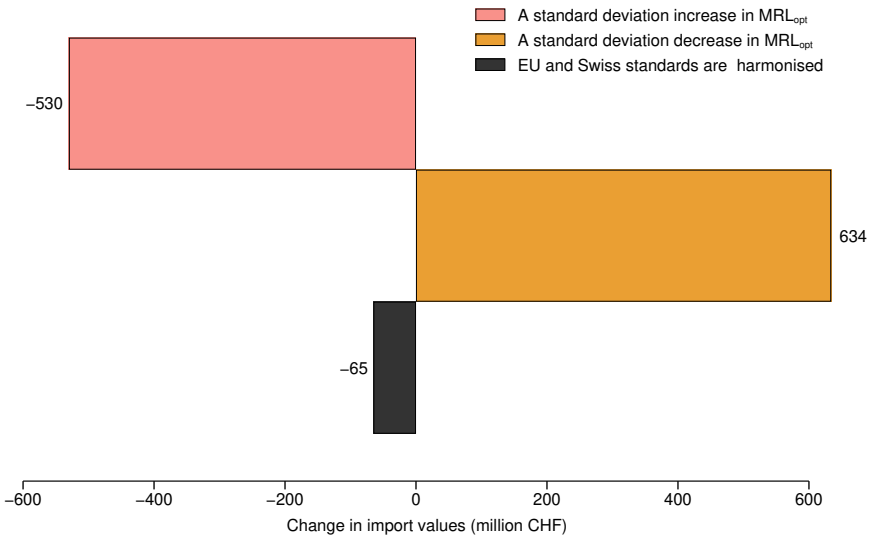
Notes: The dependent variable in column (1) is the aggregate value of firm *f* imports from origin *o* in year *t*. The extensive margin is the number of active firms importing product *p* from origin *o* in year *t*, and the intensive margin is the average import value per product per firm in year *t*. *p* values are in parentheses. ***, ** and * denote significance at 1%, 5%, and 10%. Intercepts included but not reported. Standard errors are clustered at the firm-product-year level. Intercepts included but not reported. The lower number of observations is because the elasticity of substitution used to estimate product quality is not available for all product-origin country pairs. We compute the quality ladder as the difference between the maximum and the minimum value of estimated quality in a given product category. Products with quality ladder values below or equal to the median fall in the short-quality ladder category.

Diversified firms are more resilient

Dependent variable (Log)	Import values	Import values
	(1)	(2)
MRL_{opt}	−0.788***	−0.774***
	(0.251)	(0.250)
MRL_{opt} × Multi-industry firms	0.120***	
	(0.034)	
MRL_{opt} × Multi-origin firms		0.104***
		(0.030)
Log (1 + $Tariff_{opt}$)	−0.832***	−0.827***
	(0.207)	(0.207)
Firm-origin-product FE	Yes	Yes
Origin-Year FE	Yes	Yes
Observations	50,488	50,488
adj. R^2	0.868	0.868

Notes: The dependent variable in column (1) is the aggregate value of firm *f* imports from origin *o* in year *t*. The extensive margin is the number of active firms importing product *p* from origin *o* in year *t*, and the intensive margin is the average import value per product per firm in year *t*. *p* values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10%. Intercepts included but not reported. Standard errors are clustered at the firm-product-year level. Intercepts included but not reported. Multi-industry firms are firms that import products in more than one four-digit industry over the study period. Multi-origin firms are firms that imported from more than one country over the study period.

Simulating imports due to hypothetical country-product equivalence



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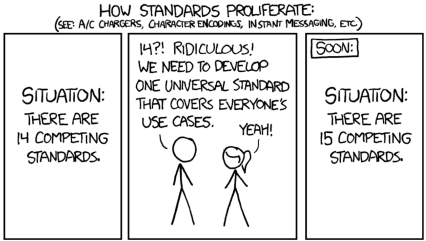
Implications for policy



What is the policy goal?

- Regulatory convergence $\rightarrow$ efficiency gains
- Whose standard becomes the "standard"?
- In Shingal and Fiankor (forthcoming) we show the benefit of regulatory convergence

Concluding remarks and main takeaways

- Differences in pesticide regulations decreases imports.
- Trade-off in welfare between prices and pesticide risks
- Smaller firms are less resilient ⇒ threatens inclusive supply chains
- Business diversification helps coping with policy (annd probably) other risks

[1] Image source: https://www.arc2020.eu

Thank you for your attention

References

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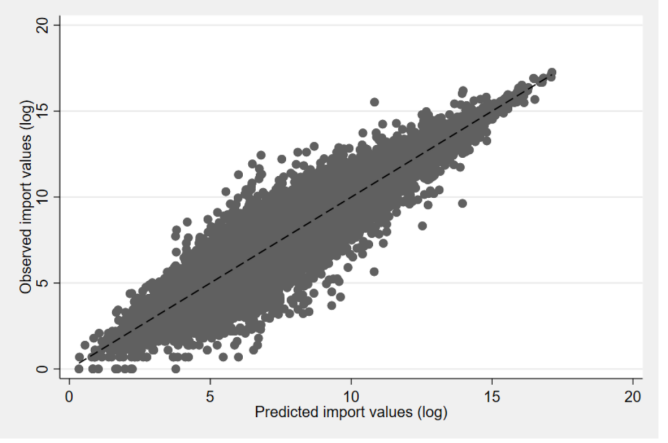
Fiankor, D.-D. D., Curzi, D. and Olper, A. (2021). Trade, price and quality upgrading effects of agri-food standards. *European Review of Agricultural Economics* 48: 835–877.

Hejazi, M., Grant, J. H. and Peterson, E. (2022). Trade impact of maximum residue limits in fresh fruits and vegetables. *Food Policy* 106: 102203.

Summary statistics

Variable	Mean	SD	Min	Max	*N*
Import value (000 CHF)	69965	520647	1	31340624	50488
Import volumes (tonnes)	53780	1033227	0	159124704	50488
Extensive margin	529	776	1	2503	50488
Intensive margin	1050	48206	0.001	7445081	50488
MRL_{opt}	1.044	0.267	0.795	2.371	50488
$Tariff_{opt}$ (CHF/kg)	40	86	0	1756	50488
GVC	0.443	0.497	0	1	50488

Observed and predicted import values



Alternative measure of firm size

Dependent variable (Log)	Total imports	Extensive margin	Intensive margin
	(1)	(2)	(3)
MRL_{opt}	-1.463^{***}	-0.098^{**}	-1.365^{***}
	(0.254)	(0.048)	(0.249)
MRL_{opt} × Medium-size firm	0.726^{***}	0.006	0.719^{***}
	(0.034)	(0.004)	(0.034)
MRL_{opt} × Large-size firm	1.179^{***}	0.006	1.173^{***}
	(0.065)	(0.008)	(0.065)
Log $(1 + Tariff_{opt})$	-0.872^{***}	-1.176^{***}	0.304
	(0.205)	(0.135)	(0.209)
Firm-origin-product FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	50488	50488	50488
adj. R^2	0.871	0.991	0.889

Notes: The dependent variable in column (1) is the aggregate value of firm f imports from origin o in year t. The extensive margin is the number of active firms importing product p from origin o in year t, and the intensive margin is the average import value per product per firm in year t. p values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. Standard errors are clustered at the firm-product-year level. Intercept included but not reported.

(3) Size matters: multi-product and multi-origin firms are more resilient

Table: Pesticide regulations and firm-level imports: multi-industry and multi-origin firms

Dependent variable (Log)	Total imports		Extensive margin		Intensive margin	
	(1)	(2)	(3)	(4)	(5)	(6)
MRL_{opt}	−0.785***	−0.772***	−0.096**	−0.104**	−0.689***	−0.667***
	(0.251)	(0.249)	(0.049)	(0.048)	(0.248)	(0.246)
MRL_{opt} × Multi-industry firms	0.120***		0.003		0.117***	
	(0.034)		(0.006)		(0.034)	
MRL_{opt} × Multi-origin firms		0.104***		0.011***		0.093***
		(0.030)		(0.004)		(0.029)
Log $(1 + \text{Tariff}_{opt})$	−0.832***	−0.827***	−1.176***	−1.175***	0.344	0.348*
	(0.207)	(0.207)	(0.135)	(0.135)	(0.211)	(0.211)
Firm-origin-product FE	Yes	Yes	Yes	Yes	Yes	Yes
Origin-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	504	50499	50488	50488	50488	50488
adj. R^2	0.868	0.868	0.991	0.991	0.887	0.887

Notes: The dependent variable in column (1) is the aggregate value of firm f imports from origin o in year t. The extensive margin is the number of active firms importing product p from origin o in year t, and the intensive margin is the average import value per product per firm in year t. p values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. Standard errors are clustered at the firm-product-year level. Intercepts included but not reported. Multi-industry firms are firms that import products in more than one four-digit industry over the study period. Multi-origin firms are firms that imported from more than one country over the study period.

Alternate estimator: PPML

$$X_{fopt} = \exp\left[\beta_0 + \beta_1 MRL_{opt} + \beta_2 \ln(1 + Tariff_{opt}) + \lambda_{fpo} + \lambda_{ot}\right] + \varepsilon_{fopt} \tag{11}$$

Table: Pesticide regulations and firm-level imports: PPML estimator

Dependent variable (Log)	Import value	Import volume
	(1)	(2)
MRL_{opt}	−0.973**	−2.244***
	(0.454)	(0.791)
Log (1 + $Tariff_{opt}$)	−0.946***	0.123
	(0.275)	(0.365)
Firm-origin-product FE	Yes	Yes
Origin-Year FE	Yes	Yes
Estimator	PPML	PPML
N	50488	50439

Notes: The dependent variable in column (1) is total Swiss import values in CHF of product p from origin country o in year t. The dependent variable in column (2) is total Swiss import volumes in kilograms of product p from origin country o in year t. p values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported.

Ad-valorem tariff equivalents of pesticide regulatory heterogeneity

$$AVE_{MRL} = \left[\exp\left(\frac{\alpha \beta_1}{\sigma} \right) - 1 \right] \times 100 \tag{12}$$

where α measures a unit change in the policy variable.

- If we take the β_1 and $\sigma = \beta_2$ coefficients from column (1) of Table 5, we can compute the AVEs for different values of α.

- For a one standard-deviation increase in MRL_{opt}, we obtain a tariff rate of 24%.

Measuring regulatory heterogeneity relative to Codex standards

$$MRL_{pt} = \frac{1}{N_{cp}} \left[\sum_{c \epsilon N_p} \exp \left(\frac{MRLCodex_{pt} - MRL_{dpt}}{MRLCodex_{pt}} \right) \right] \tag{13}$$

Table: Pesticide regulations and firm-level imports

Dependent variable (Log)	Total imports	Extensive margin	Intensive margin
	(1)	(2)	(3)
MRL_{pt}	−0.242***	−0.045	−0.197***
	(0.081)	(0.028)	(0.076)
Log (1 + $Tariff_{opt}$)	−0.295***	−0.229***	−0.066***
	(0.015)	(0.005)	(0.014)
Firm-origin FE	Yes	Yes	Yes
Origin-Year FE	Yes	Yes	Yes
N	20435	20435	20435
adj. R^2	0.554	0.387	0.570

Notes: The dependent variable in column (1) is total Swiss import values in CHF of product p from origin country o in year t. The dependent variable in column (2) is total Swiss import volumes in kilograms. of product p from origin country o in year t. p values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported.

Alternative set of fixed effects

Table: Pesticide regulations and firm-level imports

Dependent variable (Log)	Import value		Import volume	
	(1)	(2)	(3)	(4)
MRL_{opt}	−0.276***	−0.321***	−0.364***	−0.492***
	(0.044)	(0.112)	(0.048)	(0.130)
Log $(1 + Tariff_{opt})$	−1.608*	−3.471**	−1.560*	−2.609**
	(0.876)	(1.386)	(0.940)	(1.174)
Log GDP_{ot}	0.138***	0.121***	0.130***	0.251***
	(0.013)	(0.031)	(0.014)	(0.051)
Log $Distance_o$	−0.064***	−0.172***	−0.100***	−0.150***
	(0.019)	(0.051)	(0.021)	(0.057)
$Border_o$	0.565***	0.884***	0.516***	0.446**
	(0.068)	(0.138)	(0.073)	(0.176)
$Language_o$	−0.368***	−1.006***	−0.440***	−0.687***
	(0.062)	(0.120)	(0.067)	(0.152)
RTA_{ot}	0.176***	0.086	0.308***	0.273*
	(0.048)	(0.115)	(0.051)	(0.149)
Firm-product-year FE	Yes	Yes	Yes	Yes
N	37614	37614	37485	37599
Estimator	OLS	PPML	OLS	PPML

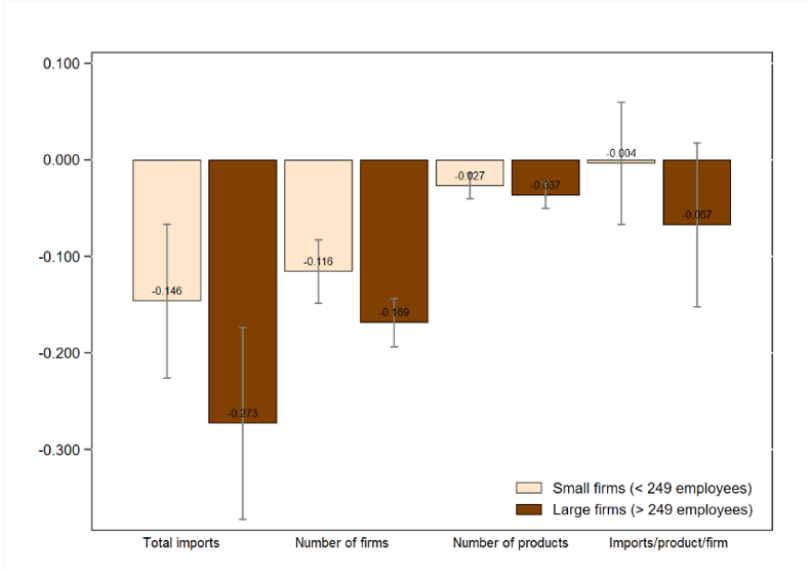
Notes: *p* values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10% respectively. Intercepts included but not reported. Standard errors are clustered at the firm-product-year level. Intercepts included but not reported.

Trade and price effects are more pronounced for higher quality products

	High quality products		Low quality products	
Dependent variable	Import values	Import prices	Import values	Import prices
	(1)	(2)	(3)	(4)
MRL_{opt}	−1.986***	0.239***	−0.202	−0.005
	(0.675)	(0.033)	(0.303)	(0.025)
Log (1 + $Tariff_{opt}$)	−1.747***	−0.047	−2.016***	0.491
	(0.401)	(0.467)	(0.385)	(0.318)
Firm-origin-product FE	Yes	Yes	Yes	Yes
Origin-Year FE	Yes	Yes	Yes	Yes
N	24429	18474	23988	17868
adj. R^2	0.875	0.740	0.869	0.772

Notes: *p* values are in parentheses. ***, ** and * denote significance at 1%, 5% and 10% respectively. Standard errors are clustered at the firm-product-year level. Intercepts included but not reported. The lower number of observations is because the elasticity of substitution used to estimate product quality are not available for all product-origin country pairs. We compute the quality ladder as the difference between the maximum and the minimum value of estimated quality in a given product category. Products with quality ladder values below or equal to the median fall in the short-quality ladder category.

… firm size (productivity) is not a guaranteed predictor of resilience



For a common global shock larger more productive firms are more affected (Fiankor et al., 2023; Food Policy)