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Rain, food, and tariffs*

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Abstract

We examine whether and how rainfall shocks affect tariff setting in the agricultural sector. In a model of international oligopoly, we show that the impact of a negative rainfall shock on optimal import tariffs is generally ambiguous, depending on the weight placed by the domestic policy maker on tariff revenue, profits and the consumer surplus. The more weight placed on domestic profits, the more likely it is that the policy maker will respond to a rainfall shortage by reducing import tariffs. Using detailed panel data on applied tariffs and rainfall for 70 nations, we find that rainfall shortages generally induce policy makers to set lower tariffs on agricultural imports.

Keywords: Rainfall shocks; strategic trade policy; agriculture.

JEL: F1; L1; O1

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*The views expressed herein are those of the authors only and not those of the Inter-American Development Bank.

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"...drought [in "rice countries"] is, perhaps, scarce ever so universal as necessarily to occasion a famine, if the government would allow a free trade."–Adam Smith (1776, IV.5.45)

1 Introduction

Recent empirical research suggests that greater openness to trade mitigates the impacts of weather shocks on hunger and death. Using district-level panel data for colonial India in 1875-1919, and exploiting the construction of the railroad network to identify the effects of increased openness, Burgess and Donaldson (2011) document that the arrival of railroads dramatically constrained the ability of rainfall shortages to cause famine.[1] But while this evidence points to the existence of a causal link between openness and weather-related famine, import tariffs on agricultural goods remain high in many nations, and relatively little is known about the extent to which countries use trade policy *strategically* to mitigate the impacts of weather shocks on domestic welfare.[2]

In this paper, we examine whether and how rainfall shortages affect tariff setting in the agricultural sector. To identify key mechanisms at play, we first set up a model of international oligopoly in which domestic and foreign agricultural producers compete in the home market. International trade is potentially costly due to import tariffs optimally set by the domestic policy maker. A rainfall shortage increases the marginal costs of domestic producers, thus generating a shortfall in food output that foreign producers have an incentive to meet. Consequently, the shock affects the marginal effects of import tariffs on tariff revenue, domestic profits and the consumer surplus, and thereby the optimal policy response.

We find that the impact of a rainfall shock on optimal import tariffs is not clear-cut. A rainfall shortage leads to a higher volume of agricultural imports and therefore higher marginal tariff revenues. All else equal, this increases the optimal tariff. On the other hand, by making home production more costly, the shock reduces incentives for using tariffs as an instrument to shift rents from foreign to domestic producers. This leads, ceteris paribus, to a lower optimal tariff. Finally, a rainfall shortage also reduces domestic consumers' surplus due to a lower total supply of food. This reduces (increases) the negative effect of import tariffs on domestic consumers if food demand is not too (sufficiently) convex, leading, all else equal, to higher (lower) tariffs. The overall impact of the rainfall shock on optimal import tariffs is, therefore, generally ambiguous, depending

[1]This evidence is consistent with Donaldson (2010), who shows that railroads contributed to reduce the exposure of agricultural prices and real incomes to rainfall shocks.

[2]Gibson et al. (2001) emphasize that high protection for agricultural commodities in the form of tariffs continues to be the major factor restricting world trade.

on the weight placed by the domestic policy maker on each of these policy objectives, and on the shape of the food demand function. A larger weight placed on domestic profits will enlarge the scope for a rainfall shortage to cause tariff reductions. A stronger concern for domestic consumers may have a similar effect, but only if food demand is sufficiently convex, i.e., if the demand for food becomes sufficiently inelastic at lower consumption levels.

We proceed by estimating the effect of rainfall shocks on effectively applied tariffs. Using detailed panel data on applied tariffs and rainfall for 70 nations over the period 1988-2006, we find that rainfall shortages generally lead to lower applied tariffs on agricultural imports. This result is found to be robust across various econometric specifications, suggesting that governments around the world use trade policy strategically in response to rainfall shocks.

In addition to the work cited above, our paper is related to the theoretical and empirical literature on strategic trade policy, including Bickerdike (1907), Graaf (1949–1950), Dixit (1984), Eaton and Grossman (1986), Grossman and Helpman (1994, 1995), Brander (1985), Gawande et al. (2000), Broda et al. (2008) and Bagwell and Staiger (2012a, b). We are not aware of previous research, either theoretical or empirical, focusing on the effects of rainfall shocks on optimal tariffs in the agricultural sector. Our work is also broadly related to the emerging literature on how weather shocks shape economic, social and political outcomes (Deschênes and Greenstone, 2007; Maccini and Yang, 2009; Burgess et al., 2009; Brückner et al, 2011; Dell et al, 2011).

The remainder of the paper is organized as follows. Section 2 develops a theoretical model in which rainfall shocks impact on the optimal agricultural tariffs set by the domestic policy maker. Section 3 describes the empirical strategy, while section 4 presents the data employed in the empirical analysis. Section 5 presents the main results, before section 6 examines their robustness. Section 7 concludes.

2 A model of weather shocks and optimal agricultural tariffs

Consider an oligopolistic domestic market for a homogeneous agricultural good that is supplied by n domestic and m foreign producers.[3] Domestic demand for the agricultural good is given by the inverse demand function

$$p = 1 - Q, \tag{1}$$

[3] It is common to adopt oligopoly models to investigate international trade in agricultural markets. Early theoretical and empirical research in this literature includes Sarris and Freebairn (1983), Karp and McCalla (1983), Kolstad and Burris (1986), Paaarlberg and Abbott (1986) and Pick and Park (1991).

where

$$Q = \sum_{i=1}^{n} q_i + \sum_{j=1}^{m} \widehat{q}_j \tag{2}$$

is total supply of the good, with q_i and $\widehat{q}_j$ being quantities supplied by the domestic producer i and the foreign producer j, respectively.[4] There is a constant marginal cost of production equal to c ($\widehat{c}$) for domestic (foreign) producers. In addition, foreign producers must pay a per-unit tariff t for supplying the domestic market. This tariff is set by a domestic policy maker with the following objective function:

$$\Omega = T + \alpha \sum_{i=1}^{n} \pi_i + \beta S, \tag{3}$$

where

$$T = t \sum_{j=1}^{m} \widehat{q}_j \tag{4}$$

is total tariff revenue,

$$\pi_i = (p - c)\, q_i \tag{5}$$

is the profit of the domestic producer i, and

$$S = \frac{1}{2} Q^2 \tag{6}$$

is domestic consumers' surplus. The specification of Ω is sufficiently general to encompass a variety of different policy objectives, where we allow the policy maker to place different weights on domestic profits and consumers' surplus: $\alpha \in [0, 1]$ and $\beta \in [0, 1]$, respectively.

The profit of a foreign producer j is given by

$$\widehat{\pi}_j = (p - \widehat{c} - t)\, \widehat{q}_j. \tag{7}$$

We consider the following two-stage game:

Stage 1: The domestic policy maker sets the import tariff t.

Stage 2: The domestic and foreign producers choose quantities simultaneously and non-cooperatively.

We look for a subgame-perfect Nash equilibrium, solving the model by backwards induction.

[4] We adopt the simplifying assumption of linear demand in order to identify key mechanisms whereby a rainfall shortage shapes tariff setting incentives. Below we examine the implications of considering alternative specifications for food demand, and discuss their empirical relevance.

2.1 Equilibrium food supply

Each producer chooses its supply of the agricultural good to maximize its profits. The first-order conditions for a domestic and foreign producer, respectively, are given by

$$\frac{\partial \pi_i}{\partial q_i} = 1 - 2q_i - \left(\sum_{k=1}^{n} q_k - q_i \right) - \sum_{j=1}^{m} \widehat{q}_j - c = 0 \tag{8}$$

and

$$\frac{\partial \widehat{\pi}_j}{\partial \widehat{q}_j} = 1 - 2\widehat{q}_j - \left(\sum_{s=1}^{m} \widehat{q}_s - \widehat{q}_j \right) - \sum_{i=1}^{n} q_i - \widehat{c} - t = 0. \tag{9}$$

Applying symmetry, $q_i = q_k = q$ and $\widehat{q}_j = \widehat{q}_s = \widehat{q}$, the Nash equilibrium output of domestic and foreign producers, respectively, are given by

$$q = \frac{1 - (m+1)\,c + m\,(\widehat{c} + t)}{m+n+1} \tag{10}$$

and

$$\widehat{q} = \frac{1 - (n+1)\,(\widehat{c} + t) + nc}{m+n+1}. \tag{11}$$

Total output is therefore

$$Q = \frac{n\,(1-c) + m\,(1 - \widehat{c} - t)}{m+n+1}, \tag{12}$$

which gives a domestic market price

$$p = \frac{1 + nc + m\,(\widehat{c} + t)}{m+n+1}. \tag{13}$$

Profits of domestic and foreign producers are given by $\pi = q^2$ and $\widehat{\pi} = \widehat{q}^2$, respectively.

2.2 Optimal import tariff

At the first stage of the game, the domestic policy maker chooses the import tariff, t, to maximize its objective function, given by (3). The optimal tariff is implicitly given by

$$\frac{\partial \Omega}{\partial t} = \frac{\partial T}{\partial t} + \alpha n \frac{\partial \pi}{\partial t} + \beta \frac{\partial S}{\partial t} = 0, \tag{14}$$

and explicitly given by[5]

$$t^* = \frac{\left[\begin{array}{c} (1 - \widehat{c} + n\,(c - \widehat{c}))\,(m+n+1) + 2\alpha n\,(1 - c - m\,(c - \widehat{c})) \\ -\beta\,(m\,(1-\widehat{c}) + n\,(1-c)) \end{array} \right]}{2\,(n+1)\,(m+n+1) - (2\alpha n + \beta)\,m}. \tag{15}$$

[5] The second-order condition,

$$\frac{\partial^2 \Omega}{\partial t^2} = -m \left(\frac{2\,(n+1)\,(m+n+1) - (2\alpha n + \beta)\,m}{(m+n+1)^2} \right) < 0,$$

is satisfied for all $\alpha \in [0,1]$ and $\beta \in [0,1]$. This implies that the denominator in (15) is positive.

The optimal tariff balances three different policy concerns: (i) raising tariff revenues, (ii) shifting oligopoly rents from foreign to domestic producers, and (iii) increasing consumers' surplus. Notice that more rent shifting and an increase in consumers' surplus are conflicting policy targets. Thus, a larger weight on domestic profits leads to a higher optimal tariff,

$$\frac{\partial t^*}{\partial \alpha} = \left(\frac{2n\,(m+n+1)}{2\,(n+1)\,(m+n+1)-(2\alpha n+\beta)\,m}\right) q\,(t^*) > 0, \tag{16}$$

while a larger weight on consumers' surplus leads to a lower optimal tariff,

$$\frac{\partial t^*}{\partial \beta} = -\left(\frac{(m+n+1)}{2\,(n+1)\,(m+n+1)-(2\alpha n+\beta)\,m}\right) Q\,(t^*) < 0. \tag{17}$$

2.3 Rainfall shortage

A negative rainfall shock makes agricultural production more expensive. We model a domestic rainfall shortage as an increase in the marginal cost of domestic production, c. The effect on the optimal tariff can be summarized as follows:[6]

Proposition 1 *(i) A domestic rainfall shortage leads to a higher import tariff if α is sufficiently low.*

(ii) A domestic rainfall shortage leads to a lower import tariff if α is sufficiently high and n is sufficiently low relative to m.

(iii) The lower is β, the larger is the parameter space for which a domestic rainfall shortage leads to a lower import tariff.

Proof. (i) From (15) we have

$$\frac{\partial t^*}{\partial c} = n\left(\frac{m+n+1+\beta-2\alpha\,(m+1)}{2\,(n+1)\,(m+n+1)-(2\alpha n+\beta)\,m}\right), \tag{18}$$

which is positive for a sufficiently low value of α. (ii) From (18) we see that

$$\frac{\partial t^*}{\partial c} < 0 \text{ if } \alpha > \overline{\alpha} := \frac{m+n+\beta+1}{2\,(m+1)},$$

where $\overline{\alpha} < 1$ if $n < m+1-\beta$. (iii) Since $\overline{\alpha}$ is increasing in β, a lower β increases the parameter space defined by $\alpha > \overline{\alpha}$. ■

For a given level of the import tariff, a domestic rainfall shortage, by increasing the domestic cost of agricultural production, leads to lower market shares for domestic producers. Although some of the fall in domestic production is replaced by increased imports,

[6] We evaluate the effect of a domestic rainfall shortage by considering a marginal increase in the domestic cost of agricultural production. However, it can easily be shown that the effect on the optimal tariff is qualitatively identical if we instead consider a discrete increase in marginal production costs.

there will also be a reduction in the total supply of food to the domestic market. Thus, domestic producers as well as consumers are hurt by a negative rainfall shock. Since domestic producers (consumers) would suffer (benefit) from a lower import tariff, it might seem somewhat counterintuitive that a lower import tariff can be an optimal policy response to a rainfall shortage only if the policy maker places a sufficiently large weight on domestic profits, and that the scope for such a policy response is larger the less weight the policy maker places on consumers' surplus. The intuition for this result, though, can be found by considering how a domestic cost increase affects the policy maker's trade-off among its three different policy targets. These are given by the three terms in (14), and we will consider each of the three different policy targets in turn.

(i) The effect of using import tariffs to raise tax revenues is given by

$$\frac{\partial T}{\partial t} = m\left(\widehat{q} + t\frac{\partial \widehat{q}}{\partial t}\right) = m\left(\widehat{q} - t\left(\frac{n+1}{m+n+1}\right)\right). \tag{19}$$

An increase in domestic production costs leads to a higher import volume (since $\widehat{q}$ is increasing in c) and therefore higher marginal tariff revenues. All else equal, this increases the optimal tariff.

(ii) The effect of using import tariffs to shift oligopoly rents from foreign to domestic producers is given by

$$\frac{\partial \pi}{\partial t} = \frac{\partial p}{\partial t}q + (p-c)\frac{\partial q}{\partial t} = \left(\frac{2m}{m+n+1}\right)q. \tag{20}$$

An increase in domestic production costs reduces domestic output and price-cost margins (notice that $p - c = q$ in equilibrium), which in turn reduces the marginal rent-shifting effect of import tariffs. In other words, import tariffs become less effective as a rent-shifting instrument if domestic producers become more cost-disadvantaged. All else equal, this reduces the optimal tariff and, naturally, the effect is stronger the larger weight the policy maker places on domestic profits.

(iii) The effect of using import tariffs to increase domestic consumers' surplus is given by

$$\frac{\partial S}{\partial t} = Q\left(n\frac{\partial q}{\partial t} + m\frac{\partial \widehat{q}}{\partial t}\right) = -\left(\frac{m}{m+n+1}\right)Q. \tag{21}$$

An increase in domestic production costs reduces total supply of food in the domestic market. If consumers' surplus is convex in output, which is true for linear demand functions, this means that the reduction in consumers' surplus due to a marginal tariff increase is lower. All else equal, this increases the optimal tariff and, naturally, the effect is stronger the larger weight the policy maker places on consumers' surplus.

Thus, we can conclude that the policy maker will optimally respond to a domestic rainfall shortage by lowering import tariffs if the second of the three above described effects

– the reduced effectiveness of import tariffs as a rent-shifting instrument – is sufficiently strong to outweigh the other two effects. Otherwise, the import tariff will increase.

The above analysis is based on the simplifying assumption of linear demand. Although the main mechanisms of the model, as given by the three different effects described above, generalize well beyond the assumption of linear demand, it is worth considering the extent to which our results are robust to alternative demand assumptions. In particular, the result that a tariff increase has a larger negative impact on consumers at higher consumption levels relies on the assumption that consumers' surplus is convex in output. For a general inverse demand function $p(Q)$, this requires that

$$p'(Q) + Qp''(Q) < 0.$$

In other words, consumers' surplus is convex in output for concave, linear and 'not-too-convex' demand functions. However, since demand for food is likely to become quite inelastic for low consumption levels, consumers' surplus might be concave in output for the range of output levels that are relevant for rainfall shortages that cause a serious cut-back in domestic production.[7] If this is the case, a rainfall shortage will increase the negative effect of import tariffs on consumers' surplus, thereby increasing the scope for tariff reductions as an optimal response to a negative rainfall shock.

3 Empirical strategy

To estimate the impact of rainfall shocks on applied import tariffs we adopt the following econometric specification:

$$\ln \text{tariff}_{ict} = \alpha + \beta \ln \text{rain}_{ct} + \gamma \ln \text{rain}_{ct} * \text{agric}_i + \lambda_i + \tau_c + \tau_t + \mu_{ict}, \tag{22}$$

where tariff_{ict} is the import tariff effectively applied on product i by country c in year t; rain_{ct} is the amount of rainfall recorded in country c in year t; agric_i is a dummy variable that takes the value of one for agricultural products; λ_i is an industry fixed-effect, τ_c is a country fixed-effect and τ_t is a year fixed-effect. μ_{ict} is an idiosyncratic error term.

Our main interest lies on γ, which reveals whether and how countries use trade policy strategically to mitigate the adverse effects of rainfall shortages on the agricultural sector.

[7] In empirical studies, demand for food is generally found to be inelastic (Andreyeva et. al. 2010). O'Hare and Kammen (2008) argue that it seems reasonable to assume that demand for food becomes less and less elastic as agricultural output declines. As food consumption falls, consequences like malnutrition and starvation begin to appear, impacts much more compelling than the hedonic costs of consuming a less-preferred diet or wasting less food. Consistent with this hypothesis, Andreyeva et. al. (2010) survey a large body of evidence on the price elasticity of demand for food and conclude that demand is relatively more elastic for categories like "food away from home", "soft drinks" and "juice".

Conditional on industry and year fixed-effects, identification of the causal effect of interest relies on the plausible assumption that within-country variation in rainfall over time is orthogonal to other determinants of import tariffs.

4 Data

Our empirical analysis makes use of the following sets of data:

1. *Import tariffs* We use panel data on applied import tariffs by country and product (SITC 2-dig., Rev. 4) from the TRAINS database from the United Nations Conference on Trade and Development. These data are generally available from 1988 onwards, but the extent of time coverage differs considerably across countries. We use both simple and import-weighted tariffs. The latter are defined as the weighted average of tariffs applied on imports from the various source countries, where the weights are the share of each country in total product imports in a base period. Imports data (also by product-country) come from the United Nations Commodity Trade Statistics Database (COMTRADE).

2. *Rainfall* We draw on annual data on rainfall levels by country-year. These data come from the Terrestrial Air Temperature and Precipitation: 1900-2006 gridded monthly time series, compiled by Kenji Matsuura and Cort Willmott in conjunction with NASA.[8]

We combine these sets of data to construct an unbalanced panel at the product-country level, covering 70 nations over the period 1988-2006. Table A.1 in the appendix summarizes the data sources and variable definitions. To ensure adequate coverage for each country, we excluded information for nations that do not have at least three consecutive years of tariff and rainfall data. Table A.2 lists the countries and corresponding time periods covered in our sample, while Table A.3 details the product classification we employ. To identify agricultural products we use the UN statistics division of the SITC classification. For robustness, we also consider a broader definition that includes as well other food products.[9]

Figure 1 provides illustrative evidence on the rainfall variable we employ for a subset of countries. The dashed lines in these diagrams refer to major, widely-documented droughts observed in each nation. Many of these extreme weather events were associated with the *El Niño* or *La Niña* phenomena, including Argentina (1999), Bolivia (1998), Brazil (1998,

[8] These data are also used (and made available online) by Dell et al. (2011).

[9] As shown in Table A.3, this latter definition includes as well SITC product categories "08", "09", "11", "12" and "29".

2003), Colombia (1992, 1997), Chile (1998), Costa Rica (2001), Guatemala (1997, 2001) and Peru (2000).

[Figure 1 about here]

Our theory applies to countries that have discretion to set import tariffs on agricultural goods. A potential concern is that, in reality, tariff setting might be constraint by limits associated with GATT/WTO membership. As shown in Figure 2, however, countries typically set their tariffs on agricultural goods well below the bound tariffs imposed by such multilateral tariff agreements; see Gibson et. al (2001, pp. 20-21) for further data and discussion. This implies that policy makers have ample policy space to adjust tariffs strategically in response to rainfall shortages.

[Figure 2 about here]

Table 1 reports summary statistics on the final panel data set employed in the regression analysis. As can be seen, most observations refer to developing countries in Latin America and Caribbean, Asia-Pacific and Africa.

[Table 1 about here]

5 Main results

Table 2 reports our baseline results. Columns (1) and (2) report the estimates obtained using a simple average of import tariffs as the dependent variable, while columns (3) and (4) report results from using weighted tariffs. By definition, the former measures give equal weights to all bilateral applied tariffs within each importer-product pair. They are therefore less sensitive to potential bias arising from the fact that a higher tariff imposed on a given source country may lead to zero or little equilibrium imports from that nation. The latter measures have the advantage of placing a larger weight on tariffs imposed on countries for which import volumes of that product are larger to begin with. If such differential import shares reflect heterogeneity in fundamentals across source countries (e.g., due to stronger comparative advantage in agriculture), the policy maker may optimally favor larger adjustments to import tariffs imposed on major food exporters, so as to obtain larger impacts from the policy response. It is therefore important to use both measures.

[Table 2 about here]

The estimates reported in columns (1) and (3) of Table 2 shows no significant effects of rainfall shocks on overall import tariffs. This result is not surprising, considering that rainfall shortages would not be expected to affect tariff setting in the non-agricultural sector, and that food represents a relatively small proportion of the full spectrum of products. Columns (2) and (4) point, however, to significant impacts of rainfall shocks on import tariffs of agricultural products: the coefficient of interest is positive and statistically significant at the 1% level, suggesting that a rainfall shortage induces policy makers to set lower tariffs on agricultural imports.

6 Robustness

We conduct a number of checks to verify the robustness of our empirical findings. First, we examine the extent to which the results are sensitive to composition of our sample. To do this, we restrict the sample to include only countries that report at least four consecutive years of tariff and rainfall data. This reduces the number of countries in the estimation sample to 51, down from the 70 initially considered. Reassuringly, the estimates yielded by this restricted sample remain very similar, both qualitatively and quantitatively (Table 3).

[Table 3 about here]

We proceed by verifying the extent to which the results are sensitive to the definition of agricultural products we employ. In our baseline analysis, we rely on the UN statistics division of the SITC classification. For robustness, in Table 4 we consider a broader definition that includes as well other food products (Table A.3). The results reported in this table show that our findings remain very similar when this alternative definition is used.

[Table 4 about here]

Table 5 reports the estimates obtained when considering this broader definition of agricultural products and the restricted sample mentioned above. Once again, the results remain very similar.

[Table 5 about here]

Table 6 reports separate estimates by region. Since our sample comprises a very small number of jurisdictions in North America and Europe, we report results for countries in Africa, Latin America and Caribbean and Asia-Pacific. The estimates for the latter two regions are very similar to those obtained for the full sample. For Africa, however, we obtain insignificant coefficients on the interaction term of interest.

[Table 6 about here]

Table 7 shows that these conclusions remain generally unchanged when conducting this regional analysis on the restricted sample. Nevertheless, there are reasons to remain cautious in interpreting these insignificant results as evidence that African nations do not lower import tariffs strategically in response to rainfall shortages. First, sample size is considerably smaller for Africa than for the other two regions. Second, when using the main sample and weighted import tariffs as the dependent variable, the magnitude of the coefficient of interest is fairly similar across regions.

[Table 7 about here]

7 Concluding remarks

We have examined the effects of rainfall shocks on tariff setting in the agricultural sector. In a model of international oligopoly, we have shown that the impact of a negative rainfall shock on optimal tariffs is generally not clear-cut, depending crucially on the weight placed by the domestic policy maker on each of the various policy objectives, and on the shape of the food demand function. We have then estimated the impact of rainfall shocks on applied tariffs. Using detailed panel data on applied tariffs and rainfall for 70 nations, we have found that rainfall shortages generally lead to lower tariffs on agricultural imports.

Appendix

[Tables A.1-A.3 about here]

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Figure 1: Rainfall and droughts

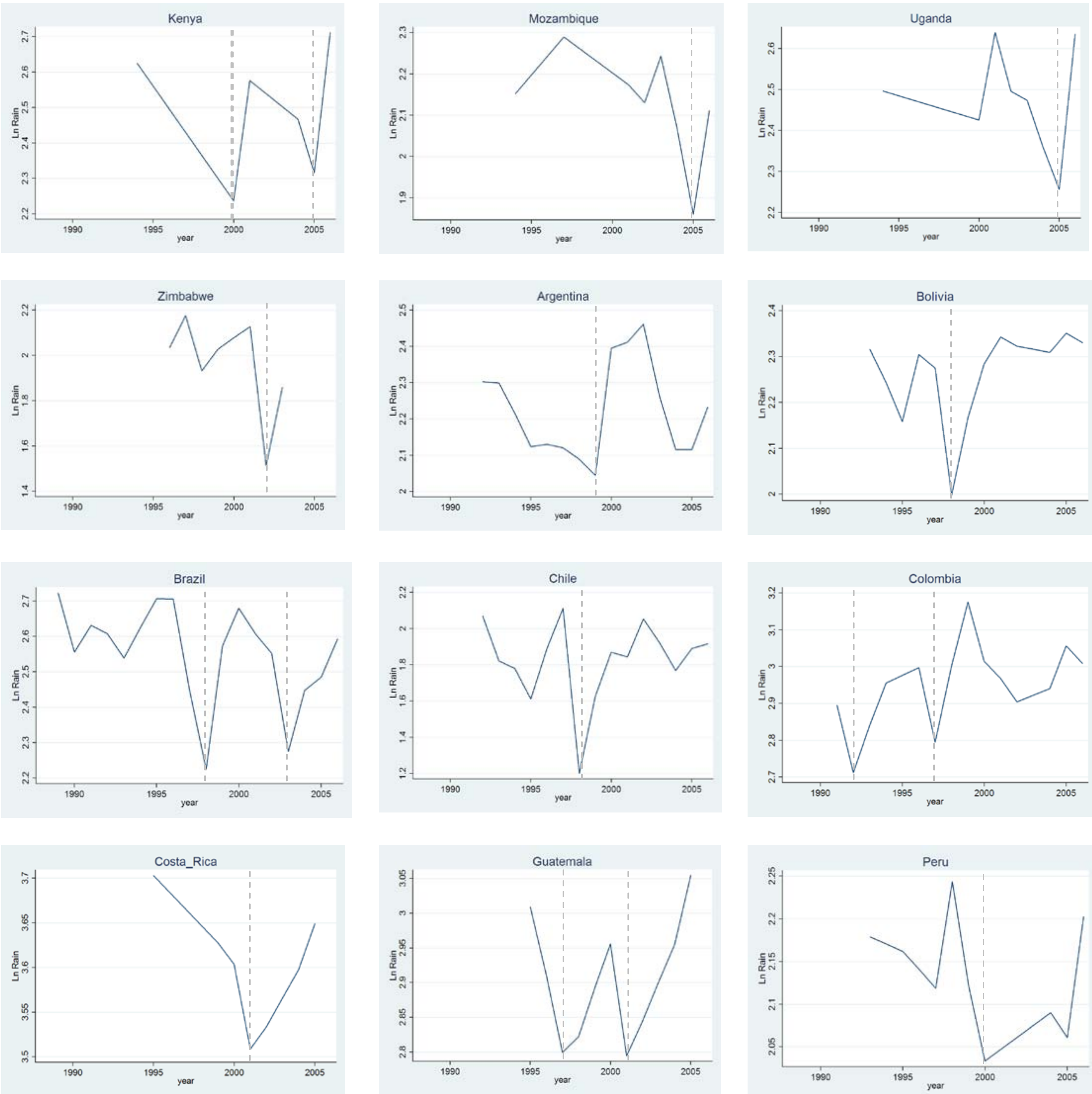
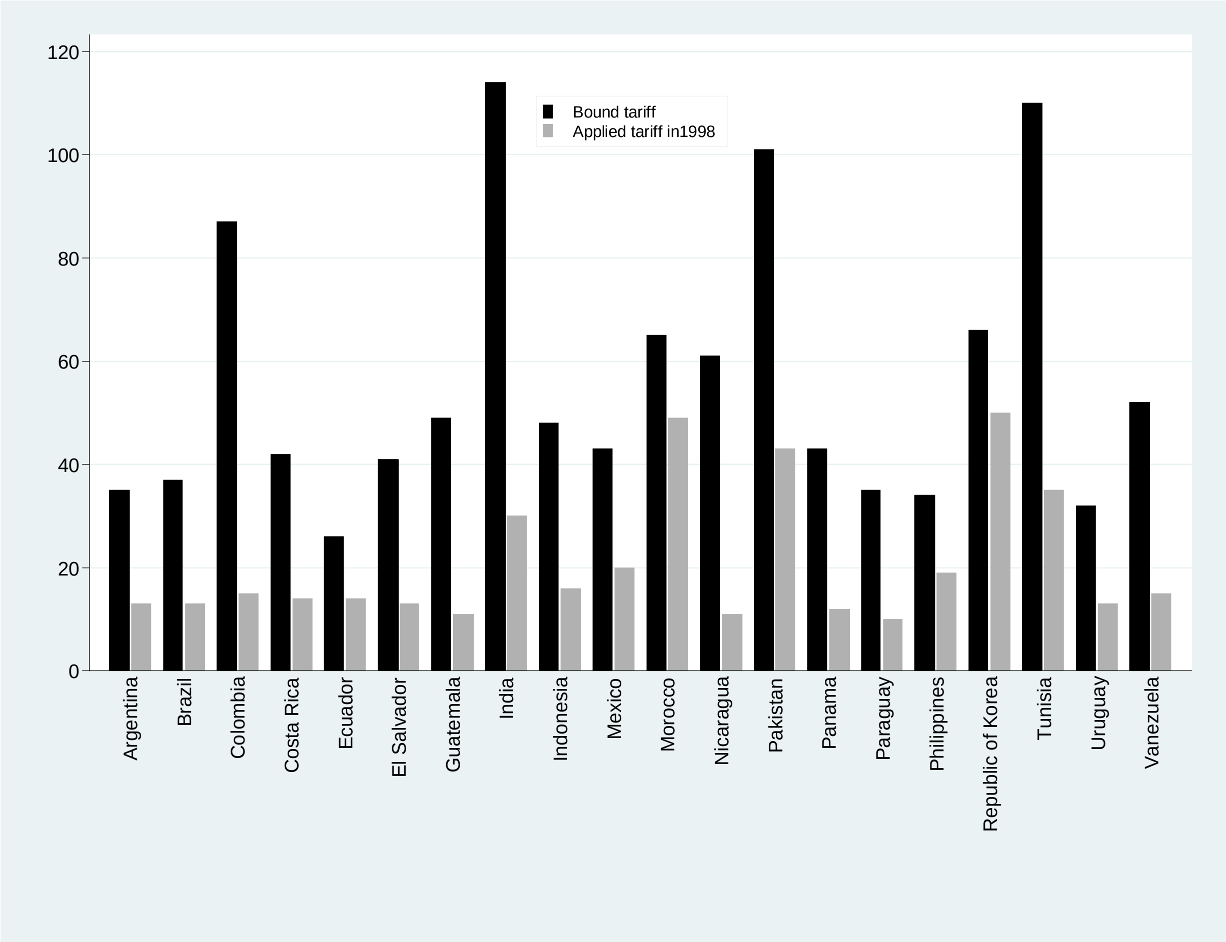


Figure 2: Average bound and applied import tariffs on agricultural goods



Note: Bound tariffs are MFN rates based on final URAA implementation. Applied tariffs represent annual average. Data on average applied import tariffs refer to 1998, with the exception of Costa Rica (1995), Republic of Korea (1996), Indonesia (1996), India (1997) and Morocco (1997). Source: Economic Research Service, USDA.

Table 1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.
ln simple tariffs	41,043	2.034	1.221
ln weighted tariffs	40,606	1.582	1.680
ln rain	41,043	2.469	0.757
agric	41,043	0.129	0.335
agric2	41,043	0.209	0.406
North America	41,043	0.046	0.211
Latin America and Caribbean	41,043	0.369	0.482
Europe	41,043	0.053	0.225
Africa	41,043	0.200	0.400
Asia-Pacific	41,043	0.329	0.469
Number of countries		70	
Number of products		65	

Table 2: Baseline estimates

Dep. variable	ln simple tariffs		ln weighted tariffs	
	(1)	(2)	(3)	(4)
ln rain_{jt}	0.064	0.035	0.125	0.082
	[0.076]	[0.076]	[0.094]	[0.093]
ln $\text{rain}_{jt} * \text{agric}_i$		0.230***		0.338***
		[0.047]		[0.064]
Observations	41,043	41,043	40,606	40,606
Number of countries	70	70	70	70
Number of products	65	65	65	65
R-squared	0.572	0.574	0.401	0.403

The estimation method is OLS. Each model includes product, country and year fixed effects. Robust standard errors clustered by country in brackets. *** $p \leq 0.01$,** $p \leq 0.05$, * $p \leq 0.1$

Table 3: Robustness, restricted sample

Dep. variable	ln simple tariffs		ln weighted tariffs	
	(1)	(2)	(3)	(4)
$\ln \text{rain}_{jt}$	0.039	0.006	0.106	0.061
	[0.092]	[0.091]	[0.113]	[0.111]
$\ln \text{rain}_{jt} * \text{agric}_i$		0.263***		0.354***
		[0.049]		[0.068]
Observations	32,436	32,436	32,117	32,117
Number of countries	51	51	51	51
Number of products	65	65	65	65
R-squared	0.579	0.582	0.415	0.418

The estimation method is OLS. Each model includes product, country and year fixed effects. Robust standard errors clustered by country in brackets. *** $p \leq 0.01$,** $p \leq 0.05$, * $p \leq 0.1$

Table 4: Robustness, alternative definition of agricultural goods

Dep. variable	ln simple tariffs		ln weighted tariffs	
	(1)	(2)	(3)	(4)
ln rain$_{jt}$	0.064	0.015	0.125	0.062
	[0.076]	[0.074]	[0.094]	[0.092]
ln rain$_{jt}$ $*$ agric$_i$		0.235***		0.304***
		[0.051]		[0.059]
Observations	41,043	41,043	40,606	40,606
Number of countries	70	70	70	70
Number of products	65	65	65	65
R-squared	0.572	0.574	0.401	0.403

The estimation method is OLS. Each model includes product, country and year fixed effects. Robust standard errors clustered by country in brackets. *** $p \leq 0.01$,** $p \leq 0.05$, * $p \leq 0.1$

Table 5: Robustness, alternative definition of agricultural goods and restricted sample

Dep. variable	ln simple tariffs		ln weighted tariffs	
	(1)	(2)	(3)	(4)
ln rain$_{jt}$	0.039	-0.015	0.106	0.040
	[0.092]	[0.089]	[0.113]	[0.110]
ln rain$_{jt} *$ agric$_i$		0.261***		0.317***
		[0.056]		[0.063]
Observations	32,436	32,436	32,117	32,117
Number of countries	51	51	51	51
Number of products	65	65	65	65
R-squared	0.579	0.583	0.415	0.418

The estimation method is OLS. Each model includes product, country and year fixed effects. Robust standard errors clustered by country in brackets. *** $p \leq 0.01$,** $p \leq 0.05$, * $p \leq 0.1$

Table 6: Estimates by region

Panel A	ln simple tariffs		
	LAC	Africa	Asia-Pacific
ln rain_{jt}	0.142	-0.058	-0.075
	[0.095]	[0.127]	[0.142]
ln $\text{rain}_{jt} * \text{agric}_i$	0.345***	-0.030	0.303**
	[0.076]	[0.81]	[0.115]
Observations	15,151	8,248	13,512
Number of countries	22	18	23
Number of products	65	65	65
R-squared	0.528	0.611	0.589
Panel B	ln weighted tariffs		
	LAC	Africa	Asia-Pacific
ln rain_{jt}	0.256*	-0.125	-0.113
	[0.134]	[0.217]	[0.183]
ln $\text{rain}_{jt} * \text{agric}_i$	0.398***	0.274	0.388**
	[0.128]	[0.316]	[0.155]
Observations	14,969	8,069	13,458
Number of countries	22	18	23
Number of products	65	65	65
R-squared	0.331	0.398	0.448

The estimation method is OLS. Each model includes product, country and year fixed effects. Robust standard errors clustered by country in brackets. *** $p \leq 0.01$,** $p \leq 0.05$, * $p \leq 0.1$

Table 7: Estimates by region, restricted sample

Panel A	ln simple tariffs		
	LAC	Africa	Asia-Pacific
ln rain_{jt}	0.086	-0.134	-0.112
	[0.094]	[0.159]	[0.166]
ln $\text{rain}_{jt} * \text{agric}_i$	0.324***	-0.026	0.368**
	[0.096]	[0.220]	[0.133]
Observations	12,859	5,295	10,628
Number of countries	18	11	17
Number of products	65	65	65
R-squared	0.511	0.602	0.608
Panel B	ln weighted tariffs		
	LAC	Africa	Asia-Pacific
ln rain_{jt}	0.201	-0.356	-0.123
	[0.155]	[0.288]	[0.217]
ln $\text{rain}_{jt} * \text{agric}_i$	0.390**	0.305	0.440**
	[0.142]	[0.361]	[0.183]
Observations	12,690	5,204	10,587
Number of countries	18	11	17
Number of products	65	65	65
R-squared	0.328	0.406	0.466

The estimation method is OLS. Each model includes product, country and year fixed effects. Robust standard errors clustered by country in brackets. *** $p \leq 0.01$,** $p \leq 0.05$, * $p \leq 0.1$

Table A.1 Variables and data sources

Variable	Definition	Source
Rainfall	Population weighted average annual rainfall in mm.	Kenji Matsuura and Cort Willmott (2007)
Simple Tariffs	Simple average of applied import tariffs, SITC classification	UNCTAD TRAINS
Weighted Tariffs	Weighted average of applied import tariffs based on initial share of each product-partner in total product imports, SITC classification	UNCTAD TRAINS and UN COMTRADE
Imports	Imports value by product, SITC classification	UN COMTRADE

Table A.2 Sample period by country

Country	Period	Country	Period
Algeria	1993, 1997-1998, 2001-2003, 2005-2006	Lesotho	2001, 2004-2006
Argentina	1992-1993, 1995-2006	Macedonia	2001, 2004-2006
Australia	1991, 1993, 1996-2006	Malawi	1994, 1996-1998, 2001, 2006
Bangladesh	1989, 1994,1999-2000, 2002-2006	Malasyia	1988, 1991-1993, 1996-1997, 2001-2003, 2005-2006
Belize	1996, 1999, 2001-2003,2006	Mali	1995, 2001-2006
Benin	2001-2006	Mexico	1991, 1995, 1997-2006
Bolivia	1993-2002, 2004-2006	Morocco	1993, 1997, 2000-2003, 2005-2006
Botswana	2001, 2004-2006	Mozambique	1994, 1997, 2001-2003, 2005-2006
Brazil	1989-2006	Myanmar	2001-2006
Brunei	1992, 2001-2006	Nepal	1993, 1998-2000, 2002-2006
Burkina Faso	1993, 2001-2006	New Zealand	1992-1993, 1996-2000, 2002-2006
Cambodia	2001-2003, 2005	Nicaragua	1995, 1998-2002, 2004-2005
Canada	1989, 1993, 1995-2006	Niger	2001-2006
Chile	1992-1995, 1997-2002, 2004-2006	Nigeria	1988-1990, 1992, 1995-2002, 2005-2006
China	1992-1994, 1996-2001, 2003-2006	Norway	1988, 1993, 1995-1996, 1998, 2000-2003, 2006
Colombia	1991-1992, 1994-1997, 1999-2002, 2004-2006	Pakistan	1995, 1998, 2001-2006
Costa Rica	1995, 1999-2005	Papua New Guinea	1997, 2002-2006
Croatia	2001, 2004-2006	Paraguay	1991, 1994-2006
Cuba	1993, 1997, 2002-2006	Peru	1993, 1995, 1997-2000, 2004-2006
Dominican Republic	1997, 2000-2006	Philippines	1988-1990, 1992-1995, 1998-2006
Ecuador	1993-1999, 2002, 2004-2006	Saudi Arabia	1994, 1999-2000, 2003-2006
El Salvador	1995, 1997-1998, 2000-2002, 2004-2006	Senegal	2001-2006
European Union	1988-2006	South Africa	1990-1991, 1993, 1996-1997, 1999, 2001, 2004-2006
Guatemala	1995, 1997-1998, 2000-2002, 2004-2005	Sri Lanka	1990, 1993-1994, 1997, 2000-2001, 2004-2006
Guyana	1996, 1999-2003, 2006	Switzerland	1990, 1993, 1995-2006
Honduras	1995, 1999-2002, 2004-2005	Taiwan	1989, 1992, 1996, 1999-2003, 2005-2006
Indonesia	1989-1990, 1993, 1995-1996, 1999-2006	Togo	2001-2006
Israel	1993, 2004-2006	Trinidad & Tobago	1991-1992, 1996, 1999, 2001-2003, 2006
Jamaica	1996, 2000-2003, 2006	Tunisia	1990, 1992, 1995, 1998, 2002-2006
Japan	1988-2006	Uganda	1994, 2000-2006
Jordan	2000-2003, 2005-2006	United States	1989-2006
Kenya	1994, 2000-2001, 2004-2006	Uruguay	1992, 1995-2002, 2004-2006
Korea, Republic of	1988-1990, 1992, 1995-1996, 1999, 2002, 2004, 2006	Venezuela	1992, 1995, 1997-2000, 2002, 2004-2006
Laos	2000-2001, 2004-2006	Vietnam	1994, 1999, 2001-2006
Lebanon	1999-2002, 2004-2006	Zimbabwe	1996-1999, 2001-2003

Table A.3 SITC Classification

SITC	Agric	Agric2	Description
00	1	1	Live animals other than animals of division 03
01	1	1	Meat and meat preparations
02	1	1	Dairy products and birds eggs
04	1	1	Cereals and cereal preparations
05	1	1	Vegetables and fruit
06	1	1	Sugars, sugar preparations and honey
07	1	1	Coffee, tea, cocoa, spices, and manufactures thereof
22	1	1	Oil-seeds and oleaginous fruits
08	0	1	Feeding stuff for animals
09	0	1	Miscellaneous edible products and preparations
11	0	1	Beverages
12	0	1	Tobacco and tobacco manufactures
29	0	1	Crude animal and vegetable materials, n.e.s.
03	0	0	Fish, crustaceans, molluscs and aquatic invertebrates, and preparations thereof
21	0	0	Hides, skins and furskins, raw
23	0	0	Crude rubber (including synthetic and reclaimed)
24	0	0	Cork and wood
25	0	0	Pulp and waste paper
26	0	0	Textile fibres (other than wool tops and other combed wool) and their wastes
27	0	0	Crude fertilizers, other than those of Division 56, and crude minerals
28	0	0	Metalliferous ores and metal scrap
32	0	0	Coal, coke and briquettes
33	0	0	Petroleum, petroleum products and related materials
34	0	0	Gas, natural and manufactured
35	0	0	Electric current
41	0	0	Animal oils and fats
42	0	0	Fixed vegetable fats and oils, crude, refined or fractionated
43	0	0	Animal or vegetable fats and oils, processed; waxes and mixtures
51	0	0	Organic chemicals
52	0	0	Inorganic chemicals
53	0	0	Dyeing, tanning and colouring materials
54	0	0	Medicinal and pharmaceutical products
55	0	0	Essential oils and resinoids and perfume materials; toilet, polishing and cleansing preparations
56	0	0	Fertilizers (other than those of group 272)
57	0	0	Plastics in primary forms
58	0	0	Plastics in non-primary forms
59	0	0	Chemical materials and products, n.e.s.
61	0	0	Leather, leather manufactures, n.e.s., and dressed furskins
62	0	0	Rubber manufactures, n.e.s.
63	0	0	Cork and wood manufactures (excluding furniture)
64	0	0	Paper, paperboard and articles of paper pulp, of paper or of paperboard
65	0	0	Textile yarn, fabrics, made-up articles, n.e.s., and related products
66	0	0	Non-metallic mineral manufactures, n.e.s.
67	0	0	Iron and steel
68	0	0	Non-ferrous metals
69	0	0	Manufactures of metals, n.e.s.
71	0	0	Power-generating machinery and equipment
72	0	0	Machinery specialized for particular industries
73	0	0	Metalworking machinery
74	0	0	General industrial machinery and equipment, n.e.s., and machine parts, n.e.s.
75	0	0	Office machines and automatic data-processing machines
76	0	0	Telecommunications and sound-recording and reproducing apparatus and equipment
77	0	0	Electrical machinery, apparatus and appliances, n.e.s., and electrical parts thereof
78	0	0	Road vehicles (including air-cushion vehicles)
79	0	0	Other transport equipment
81	0	0	Prefabricated buildings; sanitary, plumbing, heating and lighting fixtures and fittings, n.e.s.
82	0	0	Furniture and parts thereof; bedding, mattresses, mattress supports, cushions and similar stuff
83	0	0	Travel goods, handbags and similar containers
84	0	0	Articles of apparel and clothing accessories
85	0	0	Footwear
87	0	0	Professional, scientific and controlling instruments and apparatus, n.e.s.
88	0	0	Photographic apparatus, equipment and supplies and optical goods, n.e.s.; watches and clocks
89	0	0	Miscellaneous manufactured articles, n.e.s.
96	0	0	Coin (other than gold coin), not being legal tender
97	0	0	Gold, non-monetary (excluding gold ores and concentrates)

Note: Agricultural products are defined based on Standard International Trade Classification, Revision 4; United Nations Statistics Division

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