Trade openness and the nutrient use of nations

Supplementary Information

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This document includes supplementary cross-sectional methods and results. Terms, abbreviations and symbols are the same as in the main text.

why does panel approach change geographic variables? ✻ ✻

S1 Instrumental Variables (IV) methods for ~~cross-section:~~

We apply the IV method in the cross section and an unbalanced panel data set for each of the years from 2002-2014. The IV procedure is provided in Equation 1 and 2. The first stage for the cross section is provided in Equation 1. In Equation 1, the endogenous variable, i.e. the real trade openness for country c, is regressed on the constructed trade openness variable for country c ($\hat{T}_c$) and control variables, $\mathbf{X}_c$ (i.e. log of area per person $log(A_c/P_c)$, log of capital stock per person $log(ck_c/P_c)$, log of population $log(P_c)$, precipitation pr_c, temperature tas_c, and latitude lat_c). The second stage for the cross section is provided in Equation 2. In Equation 2, log nutrient use for country c (U_c) is regressed on predicted values of real trade openness for country c, denoted as $\tilde{T}_c$, and all the controls. It is critical that both Equation 1 and 2 contain the same set of controls.

not in final

$$T_c = b_0 + b_1\hat{T}_c + \mathbf{b_2^T}\mathbf{X}_c + u_c \tag{1}$$

$$log(U_c) = c_0 + c_1\tilde{T}_c + \mathbf{c_2^T}\mathbf{X}_c + v_c \tag{2}$$

We first estimate the log transform of the bilateral trade share ($\tau_{ij} \equiv log\frac{t_{ij}}{GDP_i}$) using geographic factors. The bilateral trade share is defined to be the bilateral trade between country i and j (t_{ij}) as a fraction of GDP in country i. For predictors, we follow those introduced by *Frankel and Romer* (1999), which stems from the gravity model of international trade, but only uses geographic attributes as predictors (i.e. GDP is omitted as a predictor variable because of potential endogeneity concerns). To specify, the log transform of the bilateral trade share is estimated as:

✻ Frankel approach, not used in final Dong version

$$\begin{aligned}
\tau_{ij} \equiv log\frac{t_{ij}}{GDP_i} \\
= a_0 + a_1log(D_{ij}) + a_2log(P_i) + a_3log(A_i) + a_4log(P_j) + a_5log(A_j) \\
+ a_6(LL_i + LL_j) + a_7B_{ij} + a_8B_{ij}log(D_{ij}) + a_9B_{ij}log(P_i) + a_{10}B_{ij}log(A_i) \\
+ a_{11}B_{ij}log(P_j) + a_{12}B_{ij}log(A_j) + a_{13}B_{ij}(LL_i + LL_j) + e_{ij}
\end{aligned} \tag{3}$$

where t_{ij} is the bilateral trade in value (the sum of import value and export value) between country i and country j. D is distance, P is population, A is land area, LL is a landlocked dummy, which indicates whether the country is landlocked or not, and B is a border dummy, which indicates whether the two countries share a common border or not. The interaction terms between the border dummy and all of the other explanatory variables are included in this model. In this way, τ_{ij} refer to element i,j in a matrix of all estimated bilateral trade shares. Based on Equation 3, we get the estimated bilateral trade share ($\hat{\tau}_{ij}$) for all pairs of i and j ($i \neq j$), which forms matrix $\hat{\tau}$. Note that the matrix $\hat{\tau}$ is not symmetric (i.e. $\tau_{ij} \neq \tau_{ji}$).

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$\tau_{ij} \equiv log\frac{t_{ij}}{GDP_i}$, while $\tau_{ji} \equiv log\frac{t_{ji}}{GDP_j}$. The numerators are the same (i.e. $t_{ij} = t_{ji}$) because they are the total bilateral trade flow between country i and j. Yet the denominators are GDPs for country i and j respectively, which are different.

Second, as in *Frankel and Romer* (1999), the instrument for trade openness for country i is constructed by summing the estimated bilateral trade share between country i and all other countries:

$$\hat{T}_i = \sum_{j \neq i} exp(\hat{\tau}_{ij}) \tag{4}$$

where $\hat{T}_i$ is the constructed trade openness. Note that $\hat{T}_i$ is the instrument in our model. To estimate the standard errors we follow the approach of *Dang and Konar* (2016), as originally suggested by *Frankel and Romer* (1999).

As pointed out by *Frankel and Romer* (1999), the instrument should be:

$$
\begin{aligned}
\sum_{j \neq i} E(\frac{t_{ij}}{GDP_i}|\mathbf{X_{ij}}) &= \sum_{j \neq i} E(exp(\hat{\mathbf{a}}'\mathbf{X_{ij}} + e_{ij})|\mathbf{X_{ij}}) \\
&= \sum_{j \neq i} exp(\hat{\mathbf{a}}'\mathbf{X_{ij}})E(exp(e_{ij})|\mathbf{X_{ij}}) \\
&= \sum_{j \neq i} exp(\hat{\tau}_{ij})E(exp(e_{ij})|\mathbf{X_{ij}})
\end{aligned}
\tag{5}
$$

where $\hat{\mathbf{a}}'$ is the vector of the estimated coefficients in Equation 3. $\mathbf{X_{ij}}$ is the vector of all the independent variables between country i and country j included in Equation 3. We assume that e_{ij} is homoscedastic, such that $E(exp(e_{ij})|\mathbf{X_{ij}})$ is a constant. In this case, the instrument equals $\sum_{j \neq i} exp(\hat{\tau}_{ij})$ times a constant. We ignore this constant term since it does not impact the the IV method.

Note that we include an additional specification of Equation 1 and 2 to capture the reinforcing impact of comparative advantage and openness to trade. In this second version, we interact openness with a country's area per person (A/P), as well as with a country's capital stock per person (ck/P). In doing so, we follow *Antweiler et al.* (2001). We use constructed trade openness ($\hat{T}$) and the two interaction terms ($\hat{Z}1 \equiv \hat{T} \times log(A/P)$, $\hat{Z}2 \equiv \hat{T} \times log(ck/P)$) to instrument for the three endogenous variables, i.e. the real trade openness (T) and the two interaction terms ($Z1 \equiv T \times log(A/P)$, $Z2 \equiv T \times log(ck/P)$). The control variables $\mathbf{X}$ are the same as in Equation 1 and 2. Note that A/P and ck/P have to be independently included as control variables. The first stages are in Equation 6, 7, and 8, and the second stage is in Equation 9.

$$T_c = b_0 + b_1\hat{T}_c + b_2\hat{Z1}_c + b_3\hat{Z2}_c + \mathbf{b_4^T}\mathbf{X}_c + u_c \tag{6}$$

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$$Z1_c = c_0 + c_1 \hat{T}_c + c_2 \hat{Z1}_c + c_3 \hat{Z2}_c + \mathbf{c_4^T X}_c + u_c \tag{7}$$

$$Z2_c = d_0 + d_1 \hat{T}_c + d_2 \hat{Z1}_c + d_3 \hat{Z2}_c + \mathbf{d_4^T X}_c + u_c \tag{8}$$

$$log(U_c) = e_0 + e_1 \tilde{T}_c + e_2 \widetilde{Z1}_c + e_3 \widetilde{Z2}_c + \mathbf{c_2^T X}_c + v_c \tag{9}$$

S2 Estimated impact of trade openness on nutrient use using cross-sectional data

To examine the relationship between T and U we first turn to ordinary least squares (OLS) regression. OLS estimates the partial correlation between the two variables of interest; in this case, nutrient use and trade openness. The basic OLS cross sectional equation is given by:

$$log(U_c) = d_0 + d_1 T_c + \mathbf{d_2^T X_c} + v_c \tag{10}$$

where U is nutrient use, T is trade openness, and $\mathbf{X}$ is a set of control variables (which are the same as in the cross-section IV regression). Note that c is a country index, i is a year index and v is the error term, assumed to be independent, identical, and normally distributed. To be explicit, the control variables in our cross-sectional regression are land area (A), population (P), latitude (lat), precipitation(pr), and temperature (tas).

The coefficient of interest is d_1, which is a scalar and indicates the relationship between trade openness and nutrient use. d_2 is a vector and represents the coefficients corresponding to the set of control variables. OLS results for all years of the cross-section without interaction terms are presented in Section S3. The results tend to be similar across years and indicate that there is not a statistically significant relationship between trade openness and total nutrient use or nutrient use per area. In most instances, the OLS coefficient on openness is not statistically significant. As noted, the correlation between nutrients and openness is insufficient for understanding their causal relationship, as there are endogeneity concerns.

As indicated, we also run a variant of this regression that includes the interaction terms of openness with measures of a country's comparative advantage, i.e., its land abundance (A/P) and capital abundance (ck/P). As mentioned, while we have no priors on the impact of openness, we do expect that the capacity for a country to produce more or less agriculture could reinforce the impact of openness on especially the levels of nutrient use. Section S4 presents cross-sectional results for all years that include these interactions terms. When we introduce these interaction terms, both the OLS and IV coefficients remain statistically insignificant (with the exception of the IV coefficient on log(K), which becomes significant at the 10% level).

In sum, these results indicate that openness does not impact nutrient use. Our cross sectional estimates show no significant impact with or without the interactions for comparative advantage. In spite of our instrumental variables approach, cross sectional estimates have only cross sectional variation to work with, and remain vulnerable to unobserved heterogeneity that may affect the outcome. For this reason, panel estimates that utilize time variation can better control for unobserved heterogeneity. Panel estimates also tend to be less sensitive to outliers than the cross section. This is why the focus of the main manuscript is on the panel analysis. We present cross-sectional results in the SI document for the interested reader and for comparison with other IV cross-sectional studies.

S3 Cross-section regressions: Version 1

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.427	−0.329	0.777	−0.012	−0.765*	0.349
	(0.361)	(0.450)	(0.482)	(0.384)	(0.453)	(0.506)
B: IV (second stage)						
openness_real	0.21	0.91	2.39	-0.16	0.54	2.01
	(1.31)	(1.69)	(1.9)	(1.38)	(1.67)	(1.93)
C: IV (first stage)						
Weak instruments	10.24***	10.24***	10.24***	10.24***	10.24***	10.24***
n_obs	111	111	111	111	111	111

Table S1: OLS and IV coefficients for all nutrient outcome variables for the year 2002. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
			A: OLS			
openness_real	0.324	−0.171	0.499	−0.039	−0.535	0.128
	(0.387)	(0.467)	(0.481)	(0.401)	(0.459)	(0.483)
			B: IV (second stage)			
openness_real	-1.03	-0.15	0.36	-1.29	-0.42	0.11
	(1.34)	(1.41)	(1.47)	(1.42)	(1.43)	(1.5)
			C: IV (first stage)			
Weak instruments	15.18***	15.18***	15.18***	15.18***	15.18***	15.18***
n_obs	110	110	110	110	110	110

Table S2: OLS and IV coefficients for all nutrient outcome variables for the year 2003. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
			A: OLS			
openness_real	0.341	−0.438	0.679	0.140	−0.639	0.489
	(0.309)	(0.419)	(0.430)	(0.337)	(0.410)	(0.439)
			B: IV (second stage)			
openness_real	-0.03	-0.3	0.61	0.15	-0.11	0.81
	(0.72)	(0.97)	(1.01)	(0.76)	(0.93)	(1.02)
			C: IV (first stage)			
Weak instruments	30.16***	30.16***	30.16***	30.16***	30.16***	30.16***
n_obs	117	117	117	117	117	117

Table S3: OLS and IV coefficients for all nutrient outcome variables for the year 2004. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.355	−0.057	0.734*	0.190	−0.224	0.568
	(0.331)	(0.392)	(0.417)	(0.361)	(0.393)	(0.436)
B: IV (second stage)						
openness_real	-1.15	-0.42	-0.59	-1.08	-0.35	-0.52
	(1.35)	(1.29)	(1.45)	(1.46)	(1.31)	(1.51)
C: IV (first stage)						
Weak instruments	12.25***	12.25***	12.25***	12.25***	12.25***	12.25***
n_obs	118	118	118	118	118	118

Table S4: OLS and IV coefficients for all nutrient outcome variables for the year 2005. Note that these cross section results correspond to version 1.

Table S5: OLS and IV coefficients for all nutrient outcome variables for the year 2006. Note that these cross section results correspond to version 1 (without interaction terms).

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
				A: OLS		
openness_real	0.182	−0.280	0.593	0.088	−0.372	0.504
	(0.282)	(0.405)	(0.449)	(0.317)	(0.398)	(0.472)
				B: IV (second stage)		
openness_real	-0.18	-0.11	-0.12	-0.13	-0.06	-0.08
	(0.68)	(0.95)	(1.04)	(0.75)	(0.93)	(1.09)
				C: IV (first stage)		
F-stat	26.29***	26.29***	26.29***	26.29***	26.29***	26.29***
n_obs	115	115	115	115	115	115
Note:	*p<0.1; **p<0.05; ***p<0.01					

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.307	0.133	0.567	0.274	0.093	0.528
	(0.336)	(0.435)	(0.459)	(0.344)	(0.431)	(0.478)
B: IV (second stage)						
openness_real	-1.51	-1.11	-1.15	-1.52	-1.04	-1.07
	(1.19)	(1.37)	(1.45)	(1.2)	(1.35)	(1.47)
C: IV (first stage)						
Weak instruments	19.47***	19.47***	19.47***	19.47***	19.47***	19.47***
n_obs	114	114	114	114	114	114

Table S6: OLS and IV coefficients for all nutrient outcome variables for the year 2007. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.233	0.102	0.365	0.166	0.033	0.306
	(0.311)	(0.383)	(0.461)	(0.339)	(0.379)	(0.477)
B: IV (second stage)						
openness_real	-1.77	-0.75	-1.48	-1.79	-0.76	-1.49
	(1.24)	(1.08)	(1.5)	(1.29)	(1.07)	(1.55)
C: IV (first stage)						
Weak instruments	20.17***	20.17***	20.17***	20.17***	20.17***	20.17***
n_obs	113	113	113	113	113	113

Table S7: OLS and IV coefficients for all nutrient outcome variables for the year 2008. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.276	−0.286	0.334	0.237	−0.329	0.297
	(0.315)	(0.385)	(0.426)	(0.345)	(0.374)	(0.434)
B: IV (second stage)						
openness_real	-0.65	-1.07	-0.74	-0.6	-1.04	-0.68
	(0.96)	(1.14)	(1.3)	(1.03)	(1.09)	(1.28)
C: IV (first stage)						
Weak instruments	17.57***	17.57***	17.57***	17.57***	17.57***	17.57***
n_obs	116	116	116	116	116	116

Table S8: OLS and IV coefficients for all nutrient outcome variables for the year 2009. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.106	−0.249	0.372	0.038	−0.317	0.297
	(0.281)	(0.383)	(0.428)	(0.290)	(0.348)	(0.394)
B: IV (second stage)						
openness_real	-0.62	-0.32	-1.05	-0.73	-0.44	-1.04
	(0.9)	(1.14)	(1.54)	(0.92)	(1.03)	(1.43)
C: IV (first stage)						
Weak instruments	14.98***	14.98***	14.98***	14.98***	14.98***	14.98***
n_obs	113	113	113	113	113	113

Table S9: OLS and IV coefficients for all nutrient outcome variables for the year 2010. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.161	−0.136	0.332	0.052	−0.246	0.218
	(0.270)	(0.375)	(0.371)	(0.292)	(0.337)	(0.350)
B: IV (second stage)						
openness_real	-0.74	-1.18	-0.34	-0.82	-1.26	-0.43
	(0.92)	(1.22)	(1.2)	(0.98)	(1.11)	(1.11)
C: IV (first stage)						
Weak instruments	15.11***	15.11***	15.11***	15.11***	15.11***	15.11***
n_obs	118	118	118	118	118	118

Table S10: OLS and IV coefficients for all nutrient outcome variables for the year 2011. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.382	0.145	0.435	0.270	0.035	0.321
	(0.256)	(0.319)	(0.345)	(0.269)	(0.289)	(0.330)
B: IV (second stage)						
openness_real	-0.45	-0.25	-0.03	-0.62	-0.43	-0.2
	(0.8)	(0.9)	(1.02)	(0.84)	(0.83)	(0.96)
C: IV (first stage)						
Weak instruments	17.2***	17.2***	17.2***	17.2***	17.2***	17.2***
n_obs	122	122	122	122	122	122

Table S11: OLS and IV coefficients for all nutrient outcome variables for the year 2012. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.383	0.023	0.307	0.390	0.033	0.309
	(0.272)	(0.348)	(0.384)	(0.288)	(0.319)	(0.357)
B: IV (second stage)						
openness_real	-0.28	-0.89	0.03	-0.31	-0.9	-0.03
	(0.75)	(0.95)	(1.06)	(0.79)	(0.88)	(0.98)
C: IV (first stage)						
Weak instruments	21.45***	21.45***	21.45***	21.45***	21.45***	21.45***
n_obs	121	121	121	121	121	121

Table S12: OLS and IV coefficients for all nutrient outcome variables for the year 2013. Note that these cross section results correspond to version 1.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	0.091	−0.136	0.276	−0.027	−0.254	0.157
	(0.249)	(0.313)	(0.315)	(0.257)	(0.305)	(0.304)
B: IV (second stage)						
openness_real	-1.12	-0.88	-0.32	-1.43 *	-1.19	-0.63
	(0.76)	(0.79)	(0.79)	(0.81)	(0.8)	(0.77)
C: IV (first stage)						
Weak instruments	22.7***	22.7***	22.7***	22.7***	22.7***	22.7***
n_obs	113	113	113	113	113	113

Table S13: OLS and IV coefficients for all nutrient outcome variables for the year 2014. Note that these cross section results correspond to version 1.

S4   Cross-section regressions: Version 2

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	−2.587	−2.574	−0.197	−1.364	−1.334	1.240
	(1.854)	(2.331)	(2.501)	(1.997)	(2.358)	(2.630)
openness_real:log(lperP)	−0.466	−0.388	−0.038	−0.236	−0.155	0.231
	(0.327)	(0.411)	(0.441)	(0.352)	(0.416)	(0.464)
openness_real:log(ckperP)	−0.262	−0.141	−0.232	−0.082	0.038	−0.045
	(0.211)	(0.266)	(0.285)	(0.228)	(0.269)	(0.300)
B: IV (second stage)						
openness_real	3.98	5.58	14.31	2.03	3.67	12.47
openness_real_sd	(6.74)	(10.23)	(12.86)	(6.6)	(8.7)	(11.32)
openness_real:log(lperP)	0.7	1.09	2.35	0.25	0.64	1.92
openness_real:log(lperP)_sd	(1.14)	(1.72)	(2.16)	(1.11)	(1.46)	(1.89)
openness_real:log(ckperP)	-0.26	-0.82	-0.75	0.3	-0.26	-0.19
openness_real:log(ckperP)_sd	(0.77)	(1.2)	(1.48)	(0.73)	(1)	(1.27)
C: IV (first stage)						
Weak instruments (openness_real)	4.19***	4.19***	4.19***	4.19***	4.19***	4.19***
Weak instruments (openness_real:log(lperP))	7.25***	7.25***	7.25***	7.25***	7.25***	7.25***
Weak instruments (openness_real:log(ckperP))	1.02	1.02	1.02	1.02	1.02	1.02
n_obs	111	111	111	111	111	111

Table S14: OLS and IV coefficients for all nutrient outcome variables for the year 2002. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	−1.513	−1.842	2.341	0.711	0.360	4.629*
	(2.033)	(2.460)	(2.532)	(2.115)	(2.422)	(2.512)
openness_real:log(lperP)	−0.289	−0.240	0.334	0.123	0.168	0.757*
	(0.359)	(0.434)	(0.446)	(0.373)	(0.427)	(0.443)
openness_real:log(ckperP)	−0.145	−0.160	0.088	0.052	0.035	0.291
	(0.222)	(0.269)	(0.277)	(0.231)	(0.265)	(0.275)
B: IV (second stage)						
openness_real	2.39	8.33	18.99 *	0.46	6.32	17.25 *
openness_real_sd	(7.28)	(10.96)	(11.39)	(8.22)	(9.58)	(10.2)
openness_real:log(lperP)	0.47	1.4	2.88	0.08	1	2.52
openness_real:log(lperP)_sd	(1.17)	(1.78)	(1.83)	(1.33)	(1.56)	(1.64)
openness_real:log(ckperP)	0.14	-0.55	0.46	0.5	-0.19	0.8
openness_real:log(ckperP)_sd	(0.68)	(0.97)	(1.02)	(0.76)	(0.85)	(0.92)
C: IV (first stage)						
Weak instruments (openness_real)	3.15 **	3.15 **	3.15 **	3.15 **	3.15 **	3.15 **
Weak instruments (openness_real:log(lperP))	5.5***	5.5***	5.5***	5.5***	5.5***	5.5***
Weak instruments (openness_real:log(ckperP))	1.25	1.25	1.25	1.25	1.25	1.25
n_obs	110	110	110	110	110	110

Table S15: OLS and IV coefficients for all nutrient outcome variables for the year 2003. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
			A: OLS			
openness_real	−2.899*	−3.940*	0.594	−0.978	−2.010	2.513
	(1.621)	(2.210)	(2.299)	(1.797)	(2.185)	(2.342)
openness_real:log(lperP)	−0.612**	−0.704*	−0.085	−0.229	−0.319	0.303
	(0.286)	(0.390)	(0.406)	(0.317)	(0.386)	(0.414)
openness_real:log(ckperP)	−0.129	−0.085	0.087	−0.022	0.024	0.185
	(0.179)	(0.243)	(0.253)	(0.198)	(0.241)	(0.258)
			B: IV (second stage)			
openness_real	1.02	3.55	12.62	-0.08	2.43	11.42
openness_real_sd	(5.36)	(7.5)	(8.58)	(5.63)	(7.01)	(8.24)
openness_real:log(lperP)	0.26	0.71	1.86	0.04	0.48	1.62
openness_real:log(lperP)_sd	(0.9)	(1.26)	(1.44)	(0.95)	(1.18)	(1.38)
openness_real:log(ckperP)	-0.29	-0.16	0.42	-0.15	-0.01	0.55
openness_real:log(ckperP)_sd	(0.46)	(0.64)	(0.75)	(0.49)	(0.61)	(0.7)
			C: IV (first stage)			
Weak instruments (openness_real)	4.12***	4.12***	4.12***	4.12***	4.12***	4.12***
Weak instruments (openness_real:log(lperP))	6.33***	6.33***	6.33***	6.33***	6.33***	6.33***
Weak instruments (openness_real:log(ckperP))	2.09	2.09	2.09	2.09	2.09	2.09
n_obs	117	117	117	117	117	117

Table S16: OLS and IV coefficients for all nutrient outcome variables for the year 2004. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	−2.458	−2.644	−0.381	−0.601	−0.780	1.510
	(1.833)	(2.179)	(2.330)	(2.020)	(2.198)	(2.436)
openness_real:log(lperP)	−0.479	−0.423	−0.194	−0.125	−0.066	0.167
	(0.321)	(0.382)	(0.409)	(0.354)	(0.386)	(0.427)
openness_real:log(ckperP)	−0.186	−0.197	−0.067	−0.067	−0.079	0.052
	(0.213)	(0.253)	(0.271)	(0.235)	(0.255)	(0.283)
B: IV (second stage)						
openness_real	-0.69	2.17	8.54	-2.16	0.71	7.11
openness_real_sd	(5.7)	(6.21)	(7)	(7.05)	(6.06)	(7.37)
openness_real:log(lperP)	-0.12	0.56	1.11	-0.41	0.27	0.83
openness_real:log(lperP)_sd	(0.95)	(1.04)	(1.17)	(1.19)	(1.01)	(1.24)
openness_real:log(ckperP)	0.32	-0.34	0.76	0.64	-0.03	1.08
openness_real:log(ckperP)_sd	(0.85)	(0.79)	(0.94)	(1.04)	(0.8)	(1)
C: IV (first stage)						
Weak instruments (openness_real)	3.32 **	3.32 **	3.32 **	3.32 **	3.32 **	3.32 **
Weak instruments (openness_real:log(lperP))	5.34***	5.34***	5.34***	5.34***	5.34***	5.34***
Weak instruments (openness_real:log(ckperP))	0.94	0.94	0.94	0.94	0.94	0.94
n_obs	118	118	118	118	118	118

Table S17: OLS and IV coefficients for all nutrient outcome variables for the year 2005. Note that these cross section results correspond to version 2 with interaction terms.

Table S18: OLS and IV coefficients for all nutrient outcome variables for the year 2006. Note that these cross section results correspond to version 2 (with interaction terms).

	log(N) (1)	log(P) (2)	log(K) (3)	log(NperArea) (4)	log(PperArea) (5)	log(KperArea) (6)
A: OLS						
openness_real	−1.295	−3.170	−0.611	0.536	−1.375	1.298
	(1.582)	(2.275)	(2.542)	(1.792)	(2.253)	(2.672)
openness_real:log(lperP)	−0.329	−0.537	−0.212	0.017	−0.196	0.148
	(0.277)	(0.398)	(0.444)	(0.313)	(0.394)	(0.467)
openness_real:log(ckperP)	0.030	−0.118	−0.068	0.128	−0.024	0.031
	(0.182)	(0.262)	(0.293)	(0.206)	(0.260)	(0.308)
B: IV (second stage)						
openness_real	-0.2	3.08	14.47 *	-1.24	2.01	13.34
	(4.34)	(6.75)	(8.66)	(5.01)	(6.21)	(8.37)
openness_real:log(lperP)	0.09	0.78	2.21	-0.11	0.57	2
	(0.71)	(1.12)	(1.41)	(0.82)	(1.03)	(1.36)
openness_real:log(ckperP)	-0.24	-0.59	0.38	0.03	-0.32	0.64
	(0.39)	(0.59)	(0.73)	(0.45)	(0.55)	(0.71)
C: IV (first stage)						
F-stat (openness_real)	4.5***	4.5***	4.5***	4.5***	4.5***	4.5***
F-stat (openness_real:log(lperP))	6.82***	6.82***	6.82***	6.82***	6.82***	6.82***
F-stat (openness_real:log(ckperP))	2.81 **	2.81 **	2.81 **	2.81 **	2.81 **	2.81 **
n_obs	115	115	115	115	115	115

Note: *p<0.1; **p<0.05; ***p<0.01

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
			A: OLS			
openness_real	−3.483*	−3.853	−1.820	−1.124	−1.515	0.521
	(1.788)	(2.329)	(2.479)	(1.862)	(2.331)	(2.586)
openness_real:log(lperP)	−0.664**	−0.607	−0.300	−0.233	−0.180	0.128
	(0.309)	(0.402)	(0.428)	(0.321)	(0.402)	(0.446)
openness_real:log(ckperP)	−0.230	−0.396	−0.343	−0.105	−0.269	−0.218
	(0.213)	(0.277)	(0.295)	(0.221)	(0.277)	(0.307)
			B: IV (second stage)			
openness_real	-0.76	3.14	8.36	-3.25	0.88	6.1
openness_real_sd	(6.87)	(7.27)	(8.38)	(8.57)	(7.6)	(9.21)
openness_real:log(lperP)	-0.08	0.56	1.25	-0.54	0.15	0.84
openness_real:log(lperP)_sd	(1.18)	(1.27)	(1.47)	(1.48)	(1.33)	(1.62)
openness_real:log(ckperP)	0.57	0.15	0.97	0.92	0.44	1.25
openness_real:log(ckperP)_sd	(0.95)	(0.96)	(1.17)	(1.14)	(1)	(1.25)
			C: IV (first stage)			
Weak instruments (openness_real)	5.25***	5.25***	5.25***	5.25***	5.25***	5.25***
Weak instruments (openness_real:log(lperP))	7.81***	7.81***	7.81***	7.81***	7.81***	7.81***
Weak instruments (openness_real:log(ckperP))	1.21	1.21	1.21	1.21	1.21	1.21
n_obs	114	114	114	114	114	114

Table S19: OLS and IV coefficients for all nutrient outcome variables for the year 2007. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
			A: OLS			
openness_real	−2.759	−1.965	−0.173	−0.810	−0.042	1.879
	(1.739)	(2.156)	(2.618)	(1.919)	(2.144)	(2.699)
openness_real:log(lperP)	−0.526*	−0.258	−0.057	−0.172	0.090	0.316
	(0.300)	(0.372)	(0.451)	(0.331)	(0.370)	(0.465)
openness_real:log(ckperP)	−0.181	−0.316	−0.100	−0.059	−0.191	0.024
	(0.203)	(0.252)	(0.306)	(0.224)	(0.250)	(0.315)
			B: IV (second stage)			
openness_real	-3.02	7.11	5.95	-6.47	3.65	2.52
openness_real_sd	(8)	(7.71)	(9.87)	(11.05)	(6.76)	(12)
openness_real:log(lperP)	-0.5	1.37	0.75	-1.15	0.71	0.1
openness_real:log(lperP)_sd	(1.38)	(1.33)	(1.75)	(1.92)	(1.17)	(2.13)
openness_real:log(ckperP)	0.77	-0.42	1.49	1.26	0.07	1.96
openness_real:log(ckperP)_sd	(1.2)	(1.05)	(1.55)	(1.65)	(0.94)	(1.86)
			C: IV (first stage)			
Weak instruments (openness_real)	5.78***	5.78***	5.78***	5.78***	5.78***	5.78***
Weak instruments (openness_real:log(lperP))	8.85***	8.85***	8.85***	8.85***	8.85***	8.85***
Weak instruments (openness_real:log(ckperP))	0.96	0.96	0.96	0.96	0.96	0.96
n_obs	113	113	113	113	113	113

Table S20: OLS and IV coefficients for all nutrient outcome variables for the year 2008. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	−2.509	−5.144**	−2.450	0.431	−2.304	0.518
	(1.629)	(1.964)	(2.215)	(1.810)	(1.954)	(2.265)
openness_real:log(lperP)	−0.472*	−0.829**	−0.386	0.060	−0.315	0.149
	(0.278)	(0.336)	(0.378)	(0.309)	(0.334)	(0.387)
openness_real:log(ckperP)	−0.218	−0.370	−0.372	−0.034	−0.190	−0.184
	(0.209)	(0.252)	(0.284)	(0.232)	(0.251)	(0.290)
B: IV (second stage)						
openness_real	-0.68	0.21	1.73	-4.01	-3.24	-1.57
openness_real_sd	(6.37)	(10.2)	(10.04)	(8.27)	(8.75)	(9.8)
openness_real:log(lperP)	0.07	0.5	0.49	-0.58	-0.17	-0.16
openness_real:log(lperP)_sd	(1.09)	(1.76)	(1.76)	(1.42)	(1.49)	(1.71)
openness_real:log(ckperP)	-0.18	-0.54	0.14	0.15	-0.2	0.48
openness_real:log(ckperP)_sd	(0.59)	(0.77)	(0.86)	(0.74)	(0.76)	(0.93)
C: IV (first stage)						
Weak instruments (openness_real)	6.64***	6.64***	6.64***	6.64***	6.64***	6.64***
Weak instruments (openness_real:log(lperP))	9.83***	9.83***	9.83***	9.83***	9.83***	9.83***
Weak instruments (openness_real:log(ckperP))	1.85	1.85	1.85	1.85	1.85	1.85
n_obs	116	116	116	116	116	116

Table S21: OLS and IV coefficients for all nutrient outcome variables for the year 2009. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	−2.509*	−4.715**	−2.942	0.168	−2.056	−0.263
	(1.397)	(1.898)	(2.145)	(1.464)	(1.762)	(2.000)
openness_real:log(lperP)	−0.525**	−0.763**	−0.460	−0.072	−0.315	−0.008
	(0.240)	(0.326)	(0.368)	(0.251)	(0.303)	(0.343)
openness_real:log(ckperP)	−0.054	−0.341	−0.453	0.187	−0.100	−0.208
	(0.191)	(0.259)	(0.293)	(0.200)	(0.241)	(0.273)
B: IV (second stage)						
openness_real	3.42	3.11	6.2	0.8	0.5	3.7
openness_real_sd	(4.77)	(7.87)	(8.33)	(5.03)	(6.2)	(7.25)
openness_real:log(lperP)	0.7	0.86	1.05	0.2	0.37	0.59
openness_real:log(lperP)_sd	(0.8)	(1.32)	(1.45)	(0.84)	(1.04)	(1.26)
openness_real:log(ckperP)	-0.01	-0.51	0.48	0.39	-0.1	0.81
openness_real:log(ckperP)_sd	(0.6)	(0.85)	(1.01)	(0.61)	(0.72)	(1)
C: IV (first stage)						
Weak instruments (openness_real)	5.97***	5.97***	5.97***	5.97***	5.97***	5.97***
Weak instruments (openness_real:log(lperP))	8.53***	8.53***	8.53***	8.53***	8.53***	8.53***
Weak instruments (openness_real:log(ckperP))	2.06	2.06	2.06	2.06	2.06	2.06
n_obs	113	113	113	113	113	113

Table S22: OLS and IV coefficients for all nutrient outcome variables for the year 2010. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
			A: OLS			
openness_real	−1.657	−4.206**	−2.962*	0.895	−1.672	−0.421
	(1.291)	(1.760)	(1.759)	(1.402)	(1.613)	(1.686)
openness_real:log(lperP)	−0.261	−0.598**	−0.485	0.184	−0.157	−0.043
	(0.221)	(0.301)	(0.301)	(0.240)	(0.276)	(0.288)
openness_real:log(ckperP)	−0.239	−0.508**	−0.410*	−0.003	−0.272	−0.171
	(0.180)	(0.245)	(0.245)	(0.195)	(0.225)	(0.235)
			B: IV (second stage)			
openness_real	0.6	0.42	6.54	-2.59	-2.8	3.35
openness_real_sd	(3.85)	(6.27)	(7.53)	(4.95)	(5.59)	(5.83)
openness_real:log(lperP)	0.23	0.36	1.22	-0.27	-0.14	0.72
openness_real:log(lperP)_sd	(0.63)	(1.02)	(1.25)	(0.8)	(0.9)	(0.97)
openness_real:log(ckperP)	-0.23	-0.38	-0.14	0.08	-0.07	0.18
openness_real:log(ckperP)_sd	(0.53)	(0.74)	(0.82)	(0.67)	(0.74)	(0.7)
			C: IV (first stage)			
Weak instruments (openness_real)	6.3***	6.3***	6.3***	6.3***	6.3***	6.3***
Weak instruments (openness_real:log(lperP))	10.47***	10.47***	10.47***	10.47***	10.47***	10.47***
Weak instruments (openness_real:log(ckperP))	1.66	1.66	1.66	1.66	1.66	1.66
n_obs	118	118	118	118	118	118

Table S23: OLS and IV coefficients for all nutrient outcome variables for the year 2011. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
			A: OLS			
openness_real	−0.394	−1.307	−0.262	1.451	0.553	1.571
	(1.248)	(1.554)	(1.686)	(1.305)	(1.407)	(1.609)
openness_real:log(lperP)	−0.037	−0.140	−0.020	0.300	0.200	0.314
	(0.216)	(0.268)	(0.291)	(0.225)	(0.243)	(0.278)
openness_real:log(ckperP)	−0.244	−0.320	−0.243	−0.091	−0.170	−0.091
	(0.165)	(0.205)	(0.222)	(0.172)	(0.186)	(0.212)
			B: IV (second stage)			
openness_real	0.77	0.59	4.74	-2.19	-2.35	1.76
openness_real_sd	(3.38)	(4.24)	(4.44)	(4.11)	(4.34)	(4.25)
openness_real:log(lperP)	0.32	0.46	0.91	-0.15	0	0.44
openness_real:log(lperP)_sd	(0.54)	(0.67)	(0.73)	(0.66)	(0.68)	(0.7)
openness_real:log(ckperP)	-0.29	-0.59	-0.17	-0.02	-0.32	0.09
openness_real:log(ckperP)_sd	(0.39)	(0.49)	(0.54)	(0.48)	(0.5)	(0.5)
			C: IV (first stage)			
Weak instruments (openness_real)	5.46***	5.46***	5.46***	5.46***	5.46***	5.46***
Weak instruments (openness_real:log(lperP))	8.64***	8.64***	8.64***	8.64***	8.64***	8.64***
Weak instruments (openness_real:log(ckperP))	2.66 *	2.66 *	2.66 *	2.66 *	2.66 *	2.66 *
n_obs	122	122	122	122	122	122

Table S24: OLS and IV coefficients for all nutrient outcome variables for the year 2012. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	−0.310	−2.884*	−2.069	2.203*	−0.331	0.427
	(1.262)	(1.591)	(1.775)	(1.326)	(1.474)	(1.658)
openness_real:log(lperP)	−0.018	−0.361	−0.287	0.414*	0.079	0.140
	(0.218)	(0.275)	(0.306)	(0.229)	(0.254)	(0.286)
openness_real:log(ckperP)	−0.251	−0.490**	−0.416*	−0.068	−0.308	−0.227
	(0.173)	(0.217)	(0.243)	(0.181)	(0.201)	(0.227)
B: IV (second stage)						
openness_real	0.42	-1.32	3.39	-0.92	-2.62	2.08
openness_real_sd	(3.18)	(4.83)	(5.2)	(3.67)	(4.54)	(4.51)
openness_real:log(lperP)	0.27	0.24	0.8	0.04	0.01	0.57
openness_real:log(lperP)_sd	(0.51)	(0.78)	(0.86)	(0.59)	(0.72)	(0.75)
openness_real:log(ckperP)	-0.36	-0.62	-0.49	-0.1	-0.36	-0.21
openness_real:log(ckperP)_sd	(0.38)	(0.51)	(0.54)	(0.43)	(0.52)	(0.48)
C: IV (first stage)						
Weak instruments (openness_real)	6.62***	6.62***	6.62***	6.62***	6.62***	6.62***
Weak instruments (openness_real:log(lperP))	9.57***	9.57***	9.57***	9.57***	9.57***	9.57***
Weak instruments (openness_real:log(ckperP))	4.22***	4.22***	4.22***	4.22***	4.22***	4.22***
n_obs	121	121	121	121	121	121

Table S25: OLS and IV coefficients for all nutrient outcome variables for the year 2013. Note that these cross section results correspond to version 2 with interaction terms.

	log(N)	log(P)	log(K)	log(NperArea)	log(PperArea)	log(KperArea)
	(1)	(2)	(3)	(4)	(5)	(6)
A: OLS						
openness_real	−0.456	−0.786	0.127	0.840	0.525	1.421
	(1.265)	(1.582)	(1.588)	(1.307)	(1.545)	(1.534)
openness_real:log(lperP)	−0.066	−0.034	0.076	0.151	0.187	0.292
	(0.223)	(0.279)	(0.280)	(0.230)	(0.273)	(0.270)
openness_real:log(ckperP)	−0.097	−0.206	−0.221	0.055	−0.057	−0.069
	(0.153)	(0.192)	(0.193)	(0.159)	(0.187)	(0.186)
B: IV (second stage)						
openness_real	-0.06	-1.31	3.08	-2.12	-3.35	1.02
openness_real_sd	(3.5)	(4.48)	(3.95)	(3.88)	(4.7)	(3.94)
openness_real:log(lperP)	0.21	0.28	0.75	-0.16	-0.09	0.38
openness_real:log(lperP)_sd	(0.56)	(0.7)	(0.65)	(0.62)	(0.74)	(0.65)
openness_real:log(ckperP)	-0.03	-0.51	-0.19	0.15	-0.33	0
openness_real:log(ckperP)_sd	(0.29)	(0.38)	(0.32)	(0.32)	(0.4)	(0.32)
C: IV (first stage)						
Weak instruments (openness_real)	7.11***	7.11***	7.11***	7.11***	7.11***	7.11***
Weak instruments (openness_real:log(lperP))	9.68***	9.68***	9.68***	9.68***	9.68***	9.68***
Weak instruments (openness_real:log(ckperP))	9.24***	9.24***	9.24***	9.24***	9.24***	9.24***
n_obs	113	113	113	113	113	113

Table S26: OLS and IV coefficients for all nutrient outcome variables for the year 2014. Note that these cross section results correspond to version 2 with interaction terms.

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