American Journal of Agricultural Economics Advance Access published June 10, 2010

Trade Costs and the Gains from Trade in Crop Agriculture

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We develop a simulation model of world crop markets that is based upon Ricardian comparative advantage. We apply the model to twenty-three countries and provide measures of the degree of globalization in this sector, the gains from trade, and the elasticity of trade volumes to trade costs. The distribution of the gains from trade across countries is uneven due to important differences in openness to imports, productivity, and other factors, some of which appear to be related to a country's level of development. Distance limits the extent by which changes in one country are transmitted to others.

Key words: geography, grains, trade costs, trade liberalization.

JEL codes: F18, Q17, Q54.

Although the theoretical case for the gains from trade is well established, we know little about the empirical magnitude of the gains from trade and the potential gains from trade as trade costs fall, particularly for the world crop sector. In this study we develop a global simulation model to answer these questions with respect to international trade in grains and oilseeds.

Examination of this sector is timely given the recent upheaval in commodity markets. During 2007–2008, export quantitative restrictions or export taxes were adopted in many exporting countries, including Argentina, China, Egypt, India, Indonesia, Russia, Ukraine, and Vietnam (Trostle 2008). This exacerbated the thinness of a world crop market that is already highly insulated. Global average bound tariffs (the maximum rate of tariff allowed by the World Trade Organization for imports from any member state) are roughly double those in other sectors of the economy (Effland et al. 2008). Prospects for further multilateral trade liberalization are uncertain (McClanahan 2008). Since countries are often quite hesitant to make concessions in exchange for trade liberalization in other countries, it may help to illuminate basic facts about this sector and get new perspectives on the size and distribution of the gains from trade, by country.

In this study we propose a new conceptual framework for international crop agriculture based on the class of Ricardian trade models developed by Eaton and Kortum (2002; hereafter EK) and adapted by Bernard et al. (2003) and Alvarez and Lucas (2005). Unlike the textbook Ricardian model, in which two countries each specialize in one of two goods, these authors model the goods sector as a continuum, with multiple countries specializing in sections of this continuum according to comparative advantage. While the aforementioned studies focus on labor usage in manufacturing, we adapt the model to land usage in crop agriculture. Specialization is determined by productivity, land endowments, and the bilateral costs of trade. In many respects, the model applies more naturally in this setting. Productivity is determined through a random draw from country-specific distributions, which translates nicely to crop yields. Each country has a chance of being a low-cost supplier depending on whether it has a bumper crop or crop failure in a given year. Because of the availability of comparable international yield data, we can introduce some innovative ways of estimating parameters of the model.

The resulting framework provides an alternative to computable general equilibrium (CGE) models (e.g., Hertel 1997). The characterization of the global trading equilibrium

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Amer. J. Agr. Econ. 1–16; doi: 10.1093/ajae/aaq046
Received November 2008; accepted April 2010

differs in important ways. For example, countries specialize in a subset of homogeneous crops as determined by their productivity distributions and the costs of trading with foreign markets. By contrast, most CGE models invoke specialization through differentiation by country, following Armington (1969). Relative to that approach, this model has greater flexibility in the extent to which trade patterns adjust in response to shocks to the system.

In this way the framework is more like a spatial equilibrium model, which allocates trade flows on the basis of lowest possible transportation cost (Abbott, Paarlberg, and Patterson 1988). Unlike spatial equilibrium models, however, our framework is based on a gravity model, which does a better job at replicating and predicting trade flows (e.g., Disdier, Fontagné, and Mimouni 2008; Grant and Lambert 2008). Our gravity model is different from theirs, in turn, in that it is derived from the trade model used for the simulation analysis. It incorporates structural parameters from the yield distributions that govern specialization. Furthermore, gravity studies tend to focus only on what gets traded. We allow the size of the sector to be endogenous and account for the amount of trade relative to overall consumption, i.e., the extent of "home bias" in consumption that is an important area of research within the international economics literature.[1]

While our approach has many strengths, we are unable to account for every potential channel by which changes in trade costs affect welfare. For example, we do not account for scale effects, varietal gains, or pass-through effects, all of which are associated with imperfect competition. We do not account for the dynamic gains from trade that may arise from new patterns of investment (Baldwin and Venables 1995). We believe that our static, competitive model captures much of the gains from trade, however, since trade costs appear to be particularly high for this sector, at least when compared with what EK find for the manufacturing sector. The credibility of our results is enhanced by the fact that we econometrically estimate the parameters of the model and allow the data an opportunity to accept or reject a number of hypotheses.

Our approach to measuring trade costs differs from studies that use index numbers to measure trade restrictiveness for individual countries (e.g., Anderson and Neary 1996; Niroomand and Nissan 1997; Lloyd and MacLaren 2002; Reimer and Kang 2010). By contrast, we are interested in the *bilateral* costs of trade and how a change of some sort in one country affects other countries. For example, if a large country experiences technological change, the greatest effect in relative terms may not be on itself, but on smaller nations with whom it trades. This point may not arise when trade restrictiveness indexes are calculated for individual countries, one at a time.

While our approach can be used to evaluate specific policy initiatives, in this study we consider broad definitions of trade costs in six counterfactual scenarios to illustrate basic points about the model and the world trading system. We calculate bilateral iceberg trade costs using a structural gravity model, which means that trade costs can include any factor that restricts trade relative to what would occur in a completely frictionless trading system (Anderson and van Wincoop 2004). Trade costs can therefore include tariff and non-tariff policy barriers, freight costs, the time cost of shipping, information costs, contract enforcement costs, currency costs, and legal and regulatory costs.[2]

In the first two simulations, we compare observed global trade volumes with those that would occur under zero trade cost and autarkic equilibria. We find far less trade than one might expect given the large degree of variation in crop prices, land rental rates, and crop yields across countries (the coefficient of variation in yields across countries averages 47% for our sample of crops). We show that the aggregate international crops market is quite thin, with observed trade volumes only one-fifteenth of that which would occur under costless trade. The volume of trade, in turn, is elastic to small changes in trade costs. A 1% reduction in aggregate trade costs increases world trade volumes 2.0–2.5%. We compare our results for alternative parameterizations of the model.

[1] The term "home bias" has become commonplace due to studies by McCallum (1995), among others. He finds that trade between two Canadian provinces is more than twenty times larger than trade between a Canadian province and a U.S. state, all else the same.

[2] Iceberg trade costs are calculated as an ad valorem tax equivalent, implying that pricier goods are costlier to trade. In practice, trade costs are a mixture of per unit (specific) and ad valorem rates. The role of per unit trade costs may matter most at highly disaggregated product levels (Irarrazabal, Moxnes, and Opromolla 2010).

In the third and fourth simulations, we distinguish trade costs that are in principle reducible, such as tariffs, from those that are difficult to reduce, such as transportation costs. We find that small reductions in reducible trade costs can lead to big welfare gains. This is mainly because consumer prices in most countries can potentially fall a great deal from present levels. We show how the results are affected by variations in how easy it is to bring new cropland into production.

The final two simulations examine how changes in supply in one country affect the welfare of other countries. Distance in particular can greatly reduce the extent by which an event in one country is transmitted to others. The distribution of the gains from trade also depends on characteristics such as a country's competitiveness in the crop sector and its trade costs with major trading partners. Many of the phenomena that we observe appear to have a relationship with national per capita income. The countries that are most productive at producing grains and oilseeds and that export a higher than average share of production are more likely to be at the high end of the global income distribution. The countries most open to imports are also more likely to be at the high end of the global income distribution.

Conceptual Framework

In the classical Ricardian model, goods are competitively produced with a single factor of production using constant-returns-to-scale technologies. Dornbusch, Fisher, and Samuelson (1977) extend the model to multiple goods, showing that the goods can be ranked on a continuum according to the relative amount of labor required to produce them. The two countries generally have a comparative advantage on opposite ends of this continuum. This approach does not work for more than two countries, however. In a pathbreaking study, EK extend the model to more than two countries while at the same time accounting for bilateral trade. Productivity is determined by a draw from a probability distribution, with each country having some chance of producing at a lower cost than any other country. This probabilistic representation assigns comparative advantage in the context of many goods and countries and determines the fraction of a country's goods that get imported and exported. Since there are bilateral trade costs, countries may produce goods for which they are otherwise not the world's lowest-cost producer.

In our application of this approach, we identify land instead of labor as the key factor of production. Therefore, the wage in the standard framework becomes the land rental rate.[3] This gives a meaningful interpretation of the random productivity shocks. In our version, they arise from the weather-induced randomness of agricultural production, as well as relatively permanent differences in weather, soil quality, or technology across countries. With land as the principal factor of production, productivity is defined as crop output per area of land (yield). Since yield data are readily available, we can directly estimate the parameters of this distribution. We discuss other differences below.

There are N countries indexed alternatively by i and n. Land used for crop production is denoted L_i. The yield of crop j in country i is $z_i(j)$ and the rental rate of cropland is w_i (in reality, this corresponds to the entire bundle of resources associated with land). With constant returns to scale, the cost of producing j in i is $w_i/z_i(j)$.

To model bilateral trade, the export country is denoted i and the import country is denoted n, with $i = n$ when a country buys from home. Trade costs follow the iceberg assumption, implying that delivery of one unit to country n requires d_{ni} units produced in i.[4] The crop sector is modeled as a continuum indexed on the unit interval $j \in [0, 1]$. The representative buyer in country n has symmetric preferences over the different crops, with utility given by:

$$(1) \qquad U_n = \left[\int_0^1 q_n(j)^{(\sigma-1)/\sigma} dj \right]^{\sigma/(\sigma-1)}$$

where $q_n(j)$ is the quantity purchased and $\sigma > 0$ is the elasticity of substitution among crops. Country n's representative buyer maximizes equation (1) subject to spending constraint X_n. In a perfectly competitive market, the price

[3] This idea has been productively employed by Donaldson (2009), although he does not use yield data to estimate parameters, as we do.

[4] A trade cost is anything that restricts imports or exports of a good. If strict quarantine measures restrict grain imports, for example, then this will be captured as a trade cost. However, if freight costs fall, yet imports cannot increase due to very strict quarantine measures, the fall in freight costs would not be counted as a fall in trade costs.

that n pays for crop j from country i is:

$$(2) \qquad p_{ni}(j) = \frac{d_{ni} w_i}{z_i(j)}.$$

Since users in country n seek to buy crop j from the cheapest source, they pay:

$$(3) \qquad p_n(j) = \min\{p_{n1}(j), p_{n2}(j), p_{n3}(j), \ldots, p_{nN}(j)\}$$

where N is the total number of countries.

We now let yields be the random variable $Z_i(j)$ in place of the constant $z_i(j)$. Since price depends on $Z_i(j)$ it is also a random variable, denoted $P_{ni}(j)$. Therefore, n chooses the minimum from a sequence of random variables involving $Z_i(j)$. In this particular context, the Fréchet Type II extreme value distribution is an appropriate distribution for $Z_i(j)$:

$$(4) \qquad F_i(z) = \Pr[Z_i \le z] = \exp\left(-T_i z^{-\theta}\right)$$

where $T_i > 0$, $\theta > 1$, and $z > 0$.[5] Higher T_i means higher average crop yields in i. Lower θ means that yield distributions are broader and a country's relative strengths and weaknesses in the productivity of different crops are more pronounced. As strengths and weaknesses become magnified, comparative advantage exerts a greater force, and high-productivity crops will be exported, while low productivity crops will be imported.

Due to the continuum assumption in conjunction with identical cost and demand structures, the index for crops (j) can be dropped, and we focus on the crop sector in the aggregate. As shown in EK, the probability that country i supplies country n at the lowest price is:

$$(5) \qquad \Pr\left[P_{ni}(j) \le \min\{P_{ns}(j); s \ne i\}\right] = \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}}.$$

equation (5) says that n's probability of buying from i is increased by higher average yields in i (T_i), lowered by trade costs between n and i (d_{ni}), and lowered by land rental rates in i (w_i). equation (5) can also be related to the share of n's spending on crops from i. Let X_{ni} be n's spending on crops from country i, with $i = n$ when a country buys from home. Summing over all sources of supply gives: $\sum_{i=1}^{N} (X_{ni}/X_n) = 1$. Due to the continuum assumption, the share of n's spending on crops from i is equal to equation (5), which implies that:

$$(6) \qquad \frac{X_{ni}}{X_n} = \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}}.$$

equation (6) relates trade shares back to the yield parameters (T_i and θ), bilateral trade costs (d_{ni}), and land rental rates (w_i). The price index for country n can be derived using the moment-generating function for the extreme value distribution (EK). The result is:

$$(7) \qquad P_n = \left[\Gamma\left(\frac{\theta + 1 - \sigma}{\theta}\right)\right]^{1/1-\sigma} \times \left[\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}\right]^{-1/\theta}$$

where Γ is the Gamma function used to express certain types of definite integrals.[6] Price index P_n relates the overall prices paid in country n back to the yield distributions, trade costs, and land rental rates.

The total domestic product derived from cropland equals the sum of country i's worldwide crop sales: $w_i L_i = \sum_{n=1}^{N} X_{ni}$. Alternatively, this is land value added in the crop sector. There is also a second, land-based non-crop agricultural sector, denoted Y_i^O. It is a numéraire good and remains fixed in all counterfactual simulations. Our model therefore captures all land value added, similar to how EK capture all labor value added in their model. Overall crop spending in country n is given by $X_n = \alpha(w_n L_n + Y_n^O)$, where α is crops' fixed share of total spending. Using this and equation (6), the cropland market clearing condition can be calculated to be:

$$(8) \qquad w_i L_i = \sum_{n=1}^{N} \left(\frac{T_i (w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}} \times \left[\alpha(w_n L_n + Y_n^O)\right] \right).$$

[5] See Billingsley (1986) for a discussion of this distribution.

[6] A useful reference is Johnson and Kotz (1970). The derivation of all equations in the model is available upon request from the authors.

The structure of equation (8) allows for two polar cases regarding land mobility across sectors. When land is immobile across sectors, equations (6), (7), and (8) are solved simultaneously for trade shares, crop prices, and land rental rates. Land rental rates, total agricultural income, and crop spending all adjust. When land is mobile across sectors, however, equation (8) is solved for equilibrium cropland values only after equations (6) and (7) have been solved for trade shares and prices. Land rental rates, total agricultural income, and crop spending are all fixed.

Equations (6), (7), and (8) are comprised in our two-sector model of the agricultural sector, but with all detail and focus on the crop sector. Data to implement the model come from the Global Trade Analysis Project (GTAP) and the United Nations Food and Agricultural Organization (FAO). The model is calibrated to the following categories in the GTAP database: paddy rice, wheat, cereal grains not elsewhere classified, and oil seeds. GTAP factor market data show that land not used in crop sectors tends to be used in other food and agricultural sectors (Dimaranan and McDougall 2007). According to our data, the share that the crop sector has of economy-wide GDP is 2.2% in the average country. The share of the crop sector in land value added is 23.4% for the average country, and ranges from a low of 12.3% (Greece) to a high of 44.1% (Argentina).

Unlike EK, who model intermediate inputs, we assume that all crop production is used in final consumption.[7] Of course, in reality some crops are grown for seed. However, the use of crops as input to own production is minor compared with inputs to manufactures. For example, according to GTAP data, the share that rice has in the cost of its own production is only 0.07, while the corresponding input shares for electronic equipment and chemical products are 0.28 and 0.31, respectively.

A major benefit of excluding intermediate inputs is that the model is much simplified and we can develop new ways of estimating certain parameters. For example, we can use the model itself to solve for base land rental rates (w_i). This frees us to directly estimate parameters such as T_i and θ instead of inferring them through indirect means. Before we turn to these issues, however, we consider estimation of trade costs.

[7] This is equivalent to assuming that β equals 1 in EK's model.

Estimation of Trade Costs

According to the GTAP data, average spending on domestic crops as a share of total spending on crops is 88.6%.[8] This is clear evidence of so-called home bias in consumption in the trade literature. Partly since we account for this, our gravity approach to trade costs ends up being somewhat different than other gravity studies. Using equation (6), a trade equation, we follow EK and normalize (X_{ni}/X_n) by the home sales of a buyer (X_{nn}/X_n) to get:

$$(9) \qquad \frac{X_{ni}}{X_{nn}} = \frac{T_i(w_i d_{ni})^{-\theta}}{T_n w_n^{-\theta}} = \frac{T_i}{T_n}\left(\frac{w_i}{w_n}\right)^{-\theta} d_{ni}^{-\theta}.$$

Now take the log:

$$(10) \qquad \ln\left(\frac{X_{ni}}{X_{nn}}\right) = \ln\frac{T_i}{T_n} - \theta\ln\frac{w_i}{w_n} - \theta\ln d_{ni}.$$

To make this more useful, we introduce an expression, $S_i \equiv \ln T_i - \theta \ln w_i$, that is productivity adjusted for costs. It could be considered a measure of competitiveness. We substitute S_i into equation (10) to get:

$$(11) \qquad \ln\left(\frac{X_{ni}}{X_{nn}}\right) = -\theta\ln d_{ni} + S_i - S_n.$$

When we go to estimate equation (11), the S_i are captured by way of dummies. Since we cannot observe d_{ni}, we estimate this using variables typically employed in gravity equations. Distance is accounted for by using six dummy variables representing different intervals of great-circle distance between capitals. The associated coefficients are d_k $(k = 1, \ldots, 6)$, where d_1 is associated with a distance of 375 miles or less, d_2 is associated with a distance of 375 to 750 miles, and so on (a spline approach). We also account for whether two countries share a border (b), share membership in a trade agreement (e_h), and have a common language (l). Finally, we include an overall destination effect (m_n) that proxies for openness to imports, i.e., trade costs that are more likely to be controllable (as opposed to the geographic trade costs with more permanence). Substituting these in for $\ln d_{ni}$ in equation (11)

[8] This is the share if the potential source countries include only the twenty-three countries of our sample. The share is 85.5% if the potential source countries include all countries of the world.

Table 1. Bilateral Trade Equation

Description	Coefficient	Estimate	p-value	Coefficient	Estimate	p-value
Dist [0,375]	$-\theta d_1$	−5.52	<0.01			
Dist [375,750]	$-\theta d_2$	−5.86	<0.01			
Dist [750,1500]	$-\theta d_3$	−7.03	<0.01			
Dist [1500,3000]	$-\theta d_4$	−8.20	<0.01			
Dist [3000,6000]	$-\theta d_5$	−9.96	<0.01			
Dist [6000,max]	$-\theta d_6$	−10.26	<0.01			
Border	$-\theta b$	0.38	0.38			
Language	$-\theta l$	0.98	<0.01			
NAFTA	$-\theta e_1$	1.48	0.27			
EU	$-\theta e_2$	1.41	0.02			
Mercosur	$-\theta e_3$	−0.81	0.36			
Argentina	S_1	3.93	<0.01	$-\theta m_1$	2.70	<0.01
Australia	S_2	1.82	<0.01	$-\theta m_2$	2.27	<0.01
Brazil	S_3	3.23	<0.01	$-\theta m_3$	2.63	<0.01
Bulgaria	S_4	−1.22	<0.01	$-\theta m_4$	−4.05	<0.01
China	S_5	2.51	<0.01	$-\theta m_5$	1.73	<0.01
Ethiopia	S_6	0.90	0.01	$-\theta m_6$	1.87	<0.01
France	S_7	1.92	<0.01	$-\theta m_7$	3.23	<0.01
Greece	S_8	−2.62	<0.01	$-\theta m_8$	−0.99	0.07
Hungary	S_9	−1.54	<0.01	$-\theta m_9$	−1.18	0.03
Italy	S_{10}	−1.30	<0.01	$-\theta m_{10}$	0.03	0.96
Japan	S_{11}	−2.21	<0.01	$-\theta m_{11}$	−0.86	0.10
Mexico	S_{12}	−0.39	0.28	$-\theta m_{12}$	−0.70	0.20
Morocco	S_{13}	−0.65	0.07	$-\theta m_{13}$	0.59	0.27
Peru	S_{14}	−3.22	<0.01	$-\theta m_{14}$	−3.55	<0.01
Romania	S_{15}	−1.35	<0.01	$-\theta m_{15}$	−2.29	<0.01
Russia	S_{16}	0.00	1.00	$-\theta m_{16}$	−0.75	0.16
South Africa	S_{17}	0.47	0.19	$-\theta m_{17}$	1.70	<0.01
Spain	S_{18}	−1.24	<0.01	$-\theta m_{18}$	1.11	0.04
Turkey	S_{19}	0.02	0.95	$-\theta m_{19}$	0.85	0.11
Ukraine	S_{20}	0.51	0.16	$-\theta m_{20}$	−2.52	<0.01
United States	S_{21}	5.42	<0.01	$-\theta m_{21}$	5.88	<0.01
Uruguay	S_{22}	−1.92	<0.01	$-\theta m_{22}$	−3.42	<0.01
Zimbabwe	S_{23}	−3.06	<0.01	$-\theta m_{23}$	−4.29	<0.01

Note: Estimated by feasible generalized least squares with 506 observations. Adjusted R^2 is 0.70.

gives:

$$(12)\quad \ln\left(\frac{X_{ni}}{X_{nn}}\right) = S_i - S_n - \theta m_n - \theta d_k - \theta b - \theta l - \theta e_h + \theta \xi_{ni}.$$

The dummy variable associated with each effect in equation (12) is suppressed for notational simplicity. The error term is $\xi_{ni} = \xi^2_{ni} + \xi^1_{ni}$. ξ^2_{ni} affects two-way international trade and has variance σ_2^2, with $\xi^2_{ni} = \xi^2_{in}$. ξ^1_{ni} affects one-way international trade and has variance σ_1^2. Under this error structure, diagonal elements of the variance-covariance matrix are $E(\xi_{ni}\xi_{ni}) = \sigma_1^2 + \sigma_2^2$, while certain off-diagonal elements are $E(\xi_{ni}\xi_{in}) = \sigma_2^2$. This allows for "reciprocity" in geographic barriers, i.e., for the possibility that the disturbance concerning shipments from n to i is positively correlated to the disturbance concerning shipments from i to n. To avoid the dummy variable trap, we impose $\sum S_i = 0$, $\sum m_n = 0$, and no overall intercept.

In our estimation, we work with a cross section for 2001, since that is the only year for which complete data (including fully reconciled trade flows) are available for our analysis as a whole. Data on 2001 bilateral crop purchases (X_{ni}) for twenty-three countries are from the GTAP database (Dimaranan and McDougall 2007). The GTAP data have the key advantage of being fully reconciled across each exporter i and importer n. Among these countries, imports from the other twenty-two countries as a share of total imports are 76% on average.

Table 1 reports the results of estimating equation (12) with generalized least squares for

506 observations. The fit is good, as the adjusted R^2 is 0.70 and most of the coefficients are statistically nonzero at the 1% level. The coefficients in the upper part of table 1 indicate how distance, border, language, and trade agreements affect trade volumes. The coefficients on the distance effects are particularly large. For example, the coefficient on distances less than 375 miles, −5.52, is larger in absolute value than any nondistance coefficient. The negative signs and successively larger magnitudes on the distance dummies suggest that freight costs, and possibly other aspects of transport costs, may be a particularly important impediment to trade in crop markets.[9]

The coefficients on border, language, the North American Free Trade Agreement (NAFTA), and the European Union are all positive, which implies that these reduce trade costs, as expected. In looking at the country-specific effects, the countries most open to imports are the United States and France, with $-\theta m_n$ estimates of 5.88 and 3.23, respectively. The countries least open to imports are Zimbabwe and Bulgaria, with estimates of −4.29 and −4.05, respectively.

The lower-left portion of table 1 reports our estimates of competitiveness (S), that is, productivity adjusted for input costs. The United States is the most competitive country (5.42), followed by Argentina, another important exporter (3.93). Peru and Zimbabwe are the least competitive, at −3.22 and −3.06, respectively.

Some country-specific results are plotted in figures 1 and 2. Figure 1 plots estimated openness to imports ($-\theta m_n$) against per capita GDP, and figure 2 plots competitiveness against per capita GDP. Rich countries appear to be somewhat more open to imports, which could reflect a variety of factors: better infrastructure and risk-handling institutions or lower tariffs and nontariff barriers. Rich countries also appear to be more competitive, reflecting factors such as better access to new technologies (figure 2). On the other hand, both of these relationships are somewhat dependent on extreme points, such as Zimbabwe on the low end, and the United States on the high end. Ideally we would have a larger sample to verify the above points, but we have already maximized sample size with respect to constraints imposed by other parts of our empirical approach.

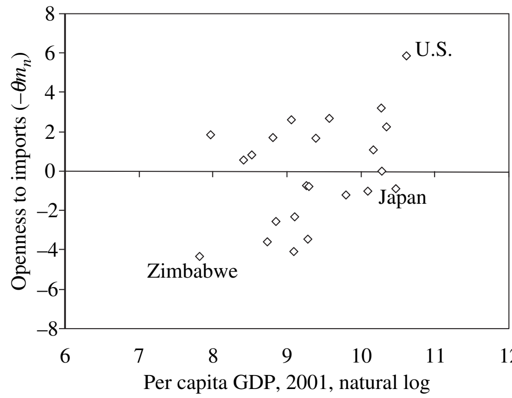

Figure 1. Scatterplot of estimated openness and per capita GDP

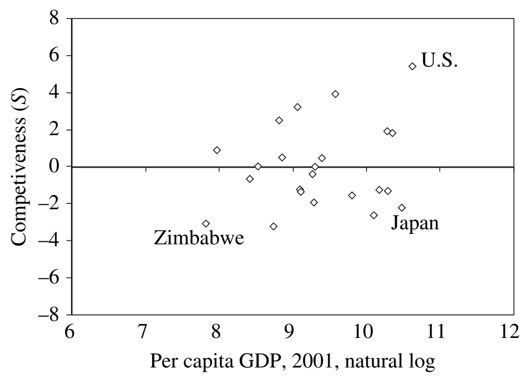

Figure 2. Scatterplot of estimated competitiveness and per capita GDP

Estimation of Remaining Parameters

The above regression provides us with baseline estimates of the d_{ni}^{θ} parameters. We develop three alternative approaches to estimating the θ and T_i parameters. The first two approaches involve directly estimating the parameters of equation (4), a yield equation, using yield data on multiple crops.[10] Approach 1 is a generalized method of moments (GMM) technique.

[9] Other aspects of transport costs might include insurance, holding costs for goods in transit, inventory cost due to buffering the variability of delivery dates, and preparation costs associated with shipment size (Anderson and van Wincoop 2004).

[10] An anonymous reviewer points out that estimating these parameters from yield data is strictly valid only under autarky. Otherwise, the model predicts that each country obtains each crop from only one source, and we would not observe the yield in countries that import that crop. Given that our estimates suggest that the world is not far from autarky, however, our approach is probably a good approximation. Note that Donaldson (2009), by contrast, assumes that each crop comes in a unit continuum of varieties, and

Since there are ($2N$) first- and second-order raw moments but only ($N+1$) unknown parameters (since θ is not indexed by i), the GMM model is overidentified. To deal with this. we replace the second-order raw moments with a single second-order central moment equation (a full description is available in a supplementary appendix online). Approach 2 is a maximum likelihood estimation (MLE) technique. An empirical likelihood function based upon equation (4) is:

$$(13) \quad L\left(\theta, T_i | z_{ij}\right) = \prod_{i=1}^{N} \prod_{j=1}^{J} \theta T_i z_{ij}^{-\theta-1} \times \exp(-T_i z_{ij}^{-\theta}).$$

Approach 3 differs from the above two approaches because estimation of θ is done separately from T_i, and equations (6) and (7) are used instead of equation (4). To determine θ, we follow EK (p. 1753), who link the model to data on prices by first dividing equation (6) by the analogous expression for the share of country i producers at home and then substituting in equation (7):

$$(14) \quad \frac{X_{ni}/X_n}{X_{ii}/X_i} = \left(\frac{p_i d_{ni}}{p_n}\right)^{-\theta}.$$

If we take the logarithm of both sides, it is straightforward to estimate θ using ordinary least squares (OLS). EK recommend calculating the logarithm of the right-hand side as:

$$(15) \quad \ln\left(\frac{p_i d_{ni}}{p_n}\right) = \max 2\,\{\ln p_n(j) - \ln p_i(j)\} - \frac{\sum_{j=1}^{J}\{\ln p_n(j) - \ln p_i(j)\}}{J}.$$

We now consider data requirements. Approaches 1 and 2 are estimated using FAO yield data for twenty-three countries and six crops produced in each of these countries (barley, maize, oats, rice, soybeans, and wheat). This set of countries and crops was chosen to maximize the total number of observations in the sample. To make the yields of different crops comparable, we normalize country i's yield of crop j by j's worldwide average yield, using national acreages as weights. This gives less weight to niche producers of a given crop. We end up with six comparable observations on yields for each of the twenty-three countries.[11] In Approach 3, the dependent variable of equation (14) is constructed using GTAP data on bilateral crop purchases. The right-hand side of equation (14) is constructed using FAO data on producer prices for the six crops listed above.

We first discuss our estimates of θ, which measures the breadth of the yield distributions and the potential role for comparative advantage. The approach 1 (GMM) estimate of θ is 2.83 with standard error of 0.0001. The approach 2 (MLE) estimate of θ is 2.52 with standard error of 0.25. The approach 3 estimate of θ is 4.96 with standard error 1.37. These estimates are on the low end of the 3.60–12.86 range of estimates that EK report for the manufactures sector. However, this is consistent with their observation that a lower θ should be expected, since productivity in agriculture is more heterogeneous across countries than productivity in manufacturing (p. 1768). There are large differences in temperature, precipitation, growing season, and soil type across the world. Applied agricultural research therefore tends to be specific to particular regions. Furthermore, agricultural innovations with broad applicability are not always adopted around the world due to other constraints, such as imperfectly functioning input markets.

We now turn to discuss our estimates of T_i, which reflect the average level of yields in i. The approach 1 (GMM) estimates range from 0.01 for Morocco to 2.24 for France and are reported in table 2 along with estimator standard errors. Note that high estimates of T_i do not automatically imply greater competitiveness in international markets, since land rental rates may be higher in those countries. The approach 2 (MLE) estimates of T_i are quite similar and have a 0.93 correlation with the GMM estimates. The approach 3 (OLS) estimates of T_i are taken to be the average yield by country, normalized by weighted average world yield. Estimates are

thus each region would be expected to produce at least some varieties of each crop. He is then unable to use the yield data to estimate the parameters as done here.

[11] Note that while we estimate individual crop yield distributions for Ethiopia and Ukraine, the GTAP database combines these into a regional composite: XSS ("Rest of Sub-Saharan Africa") and XSU ("Rest of former Soviet Union"), respectively (Dimaranan and McDougall 2007). For simplicity, we refer to Ethiopia and Ukraine in the analysis, but in reality the results below refer to these regional composites.

Table 2. Key Parameters

	Approach 1: $\hat{\theta} = 2.83$			Approach 3: $\hat{\theta} = 4.96$		
Country	$\hat{T}_i$(std. err.)	$\hat{w}_i$	$\hat{L}_i$	$\hat{T}_i$(std. dev.)	$\hat{w}_i$	$\hat{L}_i$
Argentina	0.48 (0.02)	0.19	40,188	0.95 (0.09)	0.45	17,273
Australia	0.43 (0.02)	0.39	5,613	0.95 (0.33)	0.69	3,188
Brazil	0.24 (0.01)	0.19	41,047	0.76 (0.21)	0.49	16,126
Bulgaria	0.27 (0.01)	0.97	7,425	0.85 (0.38)	1.24	5,827
China	0.69 (0.03)	0.36	126,262	1.12 (0.35)	0.62	74,055
Ethiopia	0.08 (0.00)	0.30	31,239	0.59 (0.40)	0.75	12,625
France	2.24 (0.10)	0.67	6,353	1.76 (0.69)	0.76	5,636
Greece	0.73 (0.03)	2.25	286	1.14 (0.39)	1.74	370
Hungary	0.70 (0.03)	1.52	535	1.15 (0.40)	1.40	578
Italy	1.14 (0.05)	1.66	2,790	1.32 (0.31)	1.37	3,372
Japan	0.51 (0.02)	1.72	9,691	1.03 (0.35)	1.57	10,615
Mexico	0.46 (0.02)	0.87	5,280	1.04 (0.52)	1.09	4,218
Morocco	0.01 (0.00)	0.28	8,693	0.38 (0.28)	0.94	2,583
Peru	0.12 (0.01)	1.48	697	0.61 (0.25)	1.73	594
Romania	0.19 (0.01)	0.89	3,022	0.79 (0.39)	1.25	2,161
Russia	0.13 (0.01)	0.48	10,976	0.64 (0.25)	0.91	5,797
South Africa	0.17 (0.01)	0.45	2,731	0.69 (0.24)	0.85	1,464
Spain	0.67 (0.03)	1.34	2,037	1.11 (0.37)	1.31	2,086
Turkey	0.42 (0.02)	0.73	3,818	0.92 (0.17)	0.98	2,850
Ukraine	0.26 (0.01)	0.52	59,537	0.82 (0.32)	0.87	35,685
USA	0.97 (0.05)	0.15	228,092	1.23 (0.22)	0.35	95,308
Uruguay	0.19 (0.01)	1.09	519	0.73 (0.29)	1.38	408
Zimbabwe	0.38 (0.02)	2.10	131	1.18 (0.85)	1.92	144

reported in table 2 along with the standard deviations.

Once we have our T_i and θ estimates by either approach 1, 2, or 3, we infer the values of w_i and L_i from identities in the model. Using $S_i \equiv \ln T_i - \theta \ln w_i$, we calculate the land rental rate in country i as:[12]

$$\text{(16)} \quad \hat{w}_i = \exp\left([\ln \hat{T}_i - \hat{S}_i]/\hat{\theta}\right).$$

Note that since land is the only factor of production, $\hat{w}_i$ can be thought of as returns to the entire bundle of resources associated with a unit of land. Using this estimate, baseline cropland estimates can be solved from the land market identity that relates total cropland domestic product and land rental rates:

$$\text{(17)} \quad \hat{L}_i = \left(\sum_{n=1}^{N} X_{ni}\right) \Big/ \hat{w}_i.$$

[12] EK (p. 1776) use actual wages to estimate wages for the baseline, while using the model itself to solve for intermediate input prices. We ignore intermediate inputs and use the model itself to solve for land rental rates.

Values of $\hat{w}_i$ and $\hat{L}_i$ are reported in table 2 for approaches 1 and 3. The $\hat{L}_i$ are not necessarily in recognizable units such as hectares or acres given how $\hat{w}_i$ is calculated in equation (16). We can nonetheless get a sense of the validity of $\hat{L}_i$ by evaluating whether it gets the ranking of countries by cropland area correct. In this respect, the estimates are quite reasonable. A simple linear regression of FAO cropland areas on $\hat{L}_i$ yields an R^2 of 0.76 and 0.80 for approaches 1 and 3, respectively. Since $\hat{L}_i$ is a function of $\hat{w}_i$ yet has a good fit, this suggests that $\hat{w}_i$ must also be quite reasonable. Note that approach 3 generates a smaller, and therefore possibly more realistic, range of $\hat{w}_i$ than does approach 1. This occurs mainly because there is less variation in the estimates of T_i.

The final parameter to estimate is α. We first calculate this for individual countries, then find a unified α by taking a GDP-weighted average. We get $\hat{\alpha} = 0.21$, with a standard deviation is 0.05.

Counterfactuals are evaluated according to several criteria. One is the change in land rental rates, $w'_n - w_n$, where w'_n denotes the new land rental rate that solves equation (8) under the

Table 3. Counterfactuals 1 and 2: Large Changes in Trade Costs

	Baseline to Autarky: % Change in Net Welfare		Baseline to Zero Gravity: % Change in Net Welfare	
	Approach 1	Approach 3	Approach 1	Approach 3
Argentina	−2.6	−4.4	50.6	30.6
Australia	−0.6	−0.5	37.1	20.0
Brazil	−0.3	−0.2	27.7	15.8
Bulgaria	−0.0	−0.0	37.5	17.9
China	−0.2	−0.2	15.9	8.5
Ethiopia	−0.2	−0.1	28.4	15.3
France	−2.5	−2.0	28.4	15.3
Greece	−4.7	−4.4	66.2	32.1
Hungary	−0.8	−1.4	57.0	30.2
Italy	−3.3	−2.5	45.3	22.1
Japan	−0.2	−0.1	39.1	16.5
Mexico	−3.9	−2.9	37.9	19.0
Morocco	−0.4	−0.3	43.0	22.5
Peru	−1.3	−1.2	69.2	32.9
Romania	−0.3	−0.8	44.5	23.3
Russia	−0.1	−0.1	35.3	18.1
South Africa	−1.6	−1.3	43.5	22.8
Spain	−5.5	−3.6	43.2	21.5
Turkey	−1.6	−1.8	42.1	21.7
Ukraine	−0.0	−0.0	22.4	10.4
USA	−0.5	−0.6	19.1	11.7
Uruguay	−1.8	−1.4	59.4	29.6
Zimbabwe	−0.3	−0.3	76.3	37.6

Note: Approach 1 uses $\hat{\theta} = 2.83$ and $\hat{T}_i$ from table 2. Approach 3 uses $\hat{\theta} = 4.96$ and $\hat{T}_i$ from table 2. The percentage change in world trade is −100, −100, +1,393, and +1,151 in the four scenarios, respectively.

counterfactual simulation. Higher land rental rates are positively correlated with welfare, since this reflects increases in income on the supply side. Another criterion is the change in crop prices $(P'_n - P_n)$, where P'_n denotes the new price that solves equation (7) in the counterfactual simulation. This price reflects the costs of purchasing on the demand side and has a negative relation to welfare. We can also define "welfare" as the real GDP of the sector, denoted $W_n = Y_n/P_n^{\alpha}$. The percentage change in welfare is:

$$(18) \quad 100 \times \left[\frac{W'_n}{W_n} - 1\right] = 100 \times \left[\frac{Y'_n}{P_n'^{\alpha}}\frac{P_n^{\alpha}}{Y_n} - 1\right] = 100 \times \left[\frac{w'_n L_n + Y_n^O}{w_n L_n + Y_n^O}\left(\frac{P_n}{P'_n}\right)^{\alpha} - 1\right].$$

Note that noncropland value added (Y_n^O) remains fixed throughout. Further note that for mobile land, only the price effect is operative in equation (18). Instead of looking at changes in land rental rates, we will look at changes in cropland area.

Main Results

Counterfactual 1: We have provided some measures of openness to imports at the country level (table 1). We now calculate overall global openness in the crop sector. To begin doing so, we first report the results of raising trade barriers to their autarkic levels. We let d_{ni} go to infinity for $n \neq i$ such that countries are forced to equate their production and consumption. Results are reported in table 3 and are not as extreme as one might expect. We discuss the results for approach 1 first. While every country suffers a small loss in net welfare, the maximum fall is only 5.5% (Spain), and the median reduction in welfare is only 0.6% (Australia). (In Bulgaria and Ukraine, the losses round to zero.) These numbers suggest that in terms of net welfare, existing trade costs are high enough to approximate a state of autarky. Net welfare change is plotted against per capita GDP in figure 3. The largest falls in

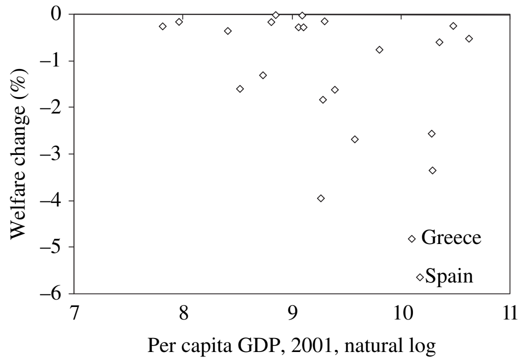

Figure 3. Move to autarky: Scatterplot of welfare change and per capita GDP

net welfare tend to occur on the high end of the income distribution.[13] In particular, there are a number of rich countries that import a large share of their consumption but are not especially competitive. Italy, Spain, and Greece are the most extreme examples. According to the GTAP data, they import an average 31% of their grains and oilseeds consumption, while the average for all twenty-three countries is 11%. Their crop prices go up by an average 56% in Counterfactual 1, while the average for all twenty-three countries is a 10% increase (not reported in the table). This result is hardly specific to these three countries, as suggested by figure 3, but is the most pronounced for them.

We also consider Counterfactual 1 under an alternative set of parameter estimates, given by approach 3 in table 2. One of the changes is that $\hat{\theta} = 4.96$, which means that yield distributions are broader and a country's relative strengths and weaknesses across crops within the crop sector are less pronounced. The median change is about the same as before (−0.8% for approach 3 versus −0.6% for approach 1), although the maximum change is somewhat smaller (−4.4% for Greece in approach 3 versus −5.5% for Spain in approach 1).

Counterfactual 2: The results for Counterfactual 1 suggest that existing trade barriers are quite high. We can get a better sense of this by considering the opposite experiment: an elimination of all trade costs and barriers. In this case, we set $d_{ni} = 1$ in equation (2) for all n and i. This creates a situation of what might be called zero gravity. The effect on trade volumes is much more extreme: The volume of world trade increases 1,393% for approach 1. This suggests that the volume of trade would increase approximately fifteen times if all forms of trade costs could be eliminated. Every country has a substantial gain in net welfare, with a median of 42.1% (Turkey) and a maximum of 76.3% (Zimbabwe). Clearly, international crop markets are very far removed from the frictionless trading system envisioned in many traditional models of international trade.

We also consider Counterfactual 2 under an alternative set of parameter estimates, given by approach 3 in table 2. In this case, world trade grows by 1,151% as trade costs are eliminated, which is a smaller amount than under the parameters of approach 1. The median and maximium welfare gains are also more subdued, at 21.5% (Spain) and 37.6% (Zimbabwe), respectively. This is primarily because $\hat{\theta}$ is higher in approach 3, which means that yield distributions are broader. Since a country's relative strengths and weaknesses across crops within the crop sector are less pronounced, comparative advantage exerts less of a force, and trade does not rise by as much as it did in approach 1.

If we repeat the general idea of Counterfactuals 1 and 2 for different changes in bilateral trade costs (reducing each of the 506 d_{ni} parameters by the same proportion), we are able to estimate the elasticity of trade volumes with respect to trade costs. We find that a 1% reduction in overall trade costs increases world trade volumes by 2.0–2.5% (based on simulations which we lack space to report).

Counterfactual 3: The previous two counterfactuals suggest that "globalization" has not really come to the world crop sector, if the metric is global volume of trade. We now focus on import trade costs (as represented by m_n) that are more likely to be reducible. We reduce the import trade costs of each country to the level of the country that is most open in this regard. This happens to be the United States, for which $-\theta m = 5.88$. All other trade costs in equation (12) are retained. We report results for approach 1 only.

Changes in net welfare, crop prices, and land rents are in columns 1–3 of table 4. Every country experiences an increase in welfare, with a median of 17.9% (Bulgaria). The net welfare changes mask much larger changes in crop prices and rental rates for land. All countries except Argentina, Brazil, and the

[13] A note of caution is in order. Since the model concerns only the agricultural sector, the welfare results might in general be of greater importance in poorer countries, all else the same. First, agriculture has a greater share of the economy of poorer countries. Its share of GDP has a −0.73 correlation with per capita GDP. Second, food has a greater share of the consumption bundle in poorer countries. Its share of final consumption has a −0.81 correlation with per capita GDP. These points are not taken into account in our welfare results.

Table 4. Counterfactuals 3 and 4: Liberalized Import Policy

	Land is fixed by agricultural sector			Land is mobile across agricultural sectors		
Country	Net welfare	Crop prices	Land rental rates	Net welfare	Crop prices	Cropland area
Argentina	13.4	57.7	78.3	1.1	−4.7	306.7
Australia	5.0	−24.4	−6.2	7.0	−26.4	−33.3
Brazil	3.0	14.2	26.6	4.7	−18.7	16.3
Bulgaria	17.9	−56.9	−9.4	25.3	−64.0	−63.0
China	4.6	−39.5	−29.3	10.7	−37.0	−68.7
Ethiopia	6.4	−27.6	−4.0	10.2	−35.6	−43.9
France	7.8	−25.2	5.0	12.0	−40.2	−32.6
Greece	77.4	−93.7	−24.7	107.6	−96.3	−80.7
Hungary	45.0	−59.8	69.4	26.9	−66.0	396.5
Italy	32.0	−75.7	−20.6	52.3	−85.1	−65.1
Japan	14.4	−69.9	−57.0	29.0	−68.4	−95.3
Mexico	25.3	−74.7	−47.1	51.5	−84.8	−96.8
Morocco	13.3	−38.3	8.0	18.4	−53.5	−16.4
Peru	38.6	−88.6	−74.0	77.6	−92.6	−99.7
Romania	40.0	−60.1	57.3	26.1	−65.0	322.6
Russia	22.5	−46.1	30.9	19.6	−55.5	72.7
South Africa	8.2	−41.2	−20.1	20.4	−56.9	−76.7
Spain	25.5	−64.0	1.0	30.9	−70.5	−9.2
Turkey	21.2	−58.6	−1.3	28.1	−67.4	−5.3
Ukraine	9.8	−35.4	−1.3	15.4	−47.8	−24.7
USA	5.9	70.0	72.9	0.0	0.0	175.1
Uruguay	43.2	−87.7	−53.1	79.4	−92.9	−96.5
Zimbabwe	38.4	−87.6	−59.1	68.3	−90.5	−98.4

Note: Values are percentage changes. In both counterfactuals, import trade costs for each country are lowered to the level of the country that is most open in this regard (the United States). Approach 1 parameters are used. World trade increases 775% and 1,102% in the left and right scenarios, respectively. Crop prices refer to those faced by buyers.

United States experience a fall in crop prices. In these three countries, crop prices rise by 57.7%, 14.2%, and 70.0%, respectively, because they have sufficient competitiveness to respond in a major way to new opportunities in foreign markets (table 1). Greece, Peru, Uruguay, and Zimbabwe experience more than an 80% drop in crop prices because they were initially among the least open countries (table 1). This gives Greece the largest increase in net welfare (77.7%), also in part because it is one of the least competitive countries (S estimated to be −2.62) (table 1).

Every country faces a drop in land rental rates except for nine, including Argentina, Brazil, and the United States. Since their crop sectors expand under falling trade barriers, they might be called natural exporters. Brazil, however, has the smallest increase in net welfare (3.0%). The benefit of rising land rental rates (26.6%) is offset by the higher prices that consumers pay (14.2%).

France's crop prices for buyers fall by 25.2% due to the import liberalization, while land rental rates increase by 5.0% (table 4). Note that unlike the previous examples, this cannot be explained by the well-known three-panel diagram of international trade because it would assume that there is one good that is consumed and produced. The consequence is that if the domestic price falls, then producers must be worse off. In our model, France as a nation can consume a much broader mix of crops than the crops specialized in by France's producers. As a result, the price index for crop buyers is not the same as the price index for producers. The consumer price index can fall while producers nonetheless receive higher prices for the subset of crops that they produce, due to demand from foreign markets. The latter effect manifests itself in the form of higher land rental rates.

Counterfactual 4: In previous simulations, land area was held fixed by sector. We now repeat Counterfactual 3 but allow land to be mobile across agricultural sectors, with land rental rates held fixed (L_i is now endogenous, while w_i is now exogenous). Although reality lies somewhere in between these two extremes, of course, this provides a sensitivity check on the results. Results are provided in columns 4–6 of table 4. Since land rental rates no longer change, all welfare changes arise from changes in crop prices. The United States is the only country to experience no change in welfare (crop prices do not change, since U.S. openness does not change, and land is mobile). For every other country, there is an increase in welfare, with the median being 25.3% (Bulgaria). The positive change in welfare is similar to the result under fixed cropland area (Counterfactual 3). However, in 78% of the countries, the welfare increase is larger (Counterfactual 4). This is largely due to the ease by which land can be shifted toward crop production in key producing countries. Increases in cropland area in Argentina, Brazil, Russia, and the United States more than make up for the contraction in cropland experienced in most other countries. This is verified by the fact that crop prices fall for all countries (except, as noted, the United States), which is the source of the welfare gain. Despite a fundamental difference in the setup, Counterfactuals 3 and 4 have many similarities—for instance, the correlations between welfare and crop prices across Counterfactuals 3 and 4 are 0.87 and 0.95, respectively. In spite of these similarities, we feel that the fixed cropland assumption is a better approximation of reality.

Counterfactual 5: In the next two counterfactuals, we examine how an event in one country is transmitted to others. Counterfactual 5 considers how trade can be a vehicle by which the benefits of new technologies are spread. Consider, for example, a pledge by the Monsanto Company to develop seeds that will double the yields of corn, soybeans, and cotton by 2030 (Pollack 2008). There can be severe limits to the internationalization of such technologies, however, due to agro-climatic differences across countries, licensing restrictions, and imperfectly functioning input markets. Many consumers will therefore benefit through only importation of the grain itself. Are trade costs, however, low enough for the benefits of such innovations to be spread?

We consider the effect of a hypothetical 30% increase in the overall yields of the United States (T_{USA}). Results are reported in table 5 (cropland area is fixed). One effect of the change is a 4.4% increase in world trade volume. U.S. welfare increases 2.2%, due largely to a 6.2% drop in crop prices caused by an increase in supply. In addition, there is a 2.8% increase in land rental rates as the U.S. crop sector expands to supply foreign markets. U.S. exports increase by 12.5%, while imports fall by 13.5%. All other countries have a fall in crop prices, which benefits consumers. This happens because they increase their imports (between 1.4% and 12.3%). Only Argentina has a welfare decrease, and it is slight, at 0.1%. This happens because Argentina is a close competitor of the United States, with nearly as high a competitiveness (table 1) and of comparable distance to major Asian and European markets. The welfare of every other country increases.

Looking more closely, the benefits are spread unevenly across countries. For example, crop prices fall by 4.0% in Mexico but fall by only 0.3% in Russia. This cannot be due to our proxy for general openness, since Mexico and Russia have a very similar $-\theta m$ coefficient (-0.70 and -0.75, respectively). It may be due to the fact that Mexico and the United States share a border and are in NAFTA. On the other hand, the difference may be explained by distance. Based on the relative size of these coefficients in table 1, Russia's lengthy distance appears to explain why it benefits less. In short, geography matters.

Counterfactual 6: Another plausible means by which countries can gain from trade—consumers in particular—is when one country expands its area in agricultural production. Brazil, for example, currently farms about 175 million acres and is said to have room to double its available cropland to equal the scale of the United States, without clearing any more of the Amazon rainforest (Barrionuevo 2007). As an illustration of how this might affect the welfare of other nations, we consider a hypothetical 30% expansion of acreage in Brazil.

The right three columns of table 5 report the effects on welfare, crop prices, and land rental rates (cropland area is fixed). The largest impact is in Brazil, with a net welfare gain of 5.9%. Crop prices drop by 17.4% and land rental rates drop 17.8%. Overall world trade increases by 1.5%, with Brazil's exports increasing by 70.9%. The effects are fairly minor for other countries. The United States experiences a small, 0.8%, drop in exports and a larger, 12.9%, rise in imports. However, due to the large size of the U.S. crop sector, U.S. crop prices, land rental rates, and welfare are essentially unaffected.

For certain aspects of the results, an interesting pattern emerges. Changes in crop prices on distance are plotted in figure 4. The relationship shows that countries located close to Brazil (Peru, Argentina, Uruguay) benefit the most from its expansion. This suggests that while tariffs and nontariff barriers are

Table 5. Counterfactuals 5 and 6: Diffusion of an Event Across Countries

	Yield increase: T_{USA} increases by 30%			Cropland expansion: L_{BRA} increases 30%		
Country	Net welfare	Crop prices	Land rental rates	Net welfare	Crop prices	Land rental rates
Argentina	−0.1	−0.9	−0.9	−0.1	−1.3	−1.2
Australia	0.1	−1.5	−1.2	0.0	−0.4	−0.3
Brazil	0.0	−0.5	−0.4	5.9	−17.4	−17.8
Bulgaria	0.0	−0.2	−0.2	0.0	−0.1	−0.1
China	0.0	−0.4	−0.3	0.0	−0.2	−0.2
Ethiopia	0.0	−0.4	−0.4	0.0	−0.2	−0.2
France	0.1	−1.8	−1.4	0.1	−1.0	−0.7
Greece	0.2	−1.5	−1.2	0.1	−0.8	−0.6
Hungary	0.0	−0.8	−0.7	0.0	−0.4	−0.3
Italy	0.1	−1.4	−1.1	0.1	−0.7	−0.5
Japan	0.0	−0.5	−0.4	0.0	−0.2	−0.2
Mexico	0.4	−4.0	−3.1	0.0	−0.3	−0.2
Morocco	0.0	−0.9	−0.7	0.0	−0.4	−0.4
Peru	0.0	−0.6	−0.5	0.1	−1.5	−1.2
Romania	0.0	−0.5	−0.5	0.0	−0.2	−0.2
Russia	0.0	−0.3	−0.2	0.0	−0.1	−0.1
South Africa	0.2	−2.4	−1.8	0.1	−0.7	−0.6
Spain	0.2	−1.6	−1.3	0.1	−0.9	−0.7
Turkey	0.1	−1.5	−1.1	0.0	−0.6	−0.5
Ukraine	0.0	−0.1	−0.1	0.0	0.0	0.0
USA	2.2	−6.2	2.8	0.0	−0.4	−0.3
Uruguay	0.0	−0.5	−0.4	0.1	−0.8	−0.7
Zimbabwe	0.0	−0.6	−0.5	0.0	−0.2	−0.1

Note: Values are percentage changes. Approach 1 parameters are used. World trade increases by 4.4% and 1.5% in the left and right scenarios, respectively. Crop prices refer to those faced by buyers.

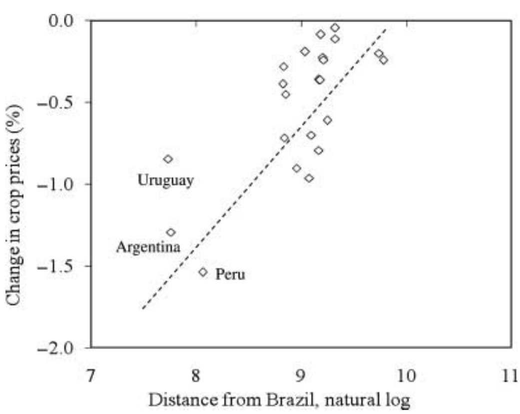

Figure 4. Brazil expansion: Scatterplot of change in crop prices on distance

important in world agricultural trade, the role of distance should not be overlooked. Even if countries could eliminate all policy-based barriers to trade, the penalty imposed by geographical trade costs limits the benefit from an increase in supply elsewhere. Geography has an important impact on the gains from trade.

Conclusions

In this study we propose a new framework for the analysis of international agricultural trade. We carry out six counterfactual scenarios for twenty-three countries to illustrate basic points about the model and the world trading system for grains and oilseeds. The existence of large international differences in crop yields, crop prices, and land rental rates suggests that there should be large gains from international trade in this sector. We find, however, that trade costs are close to those associated with autarkic equilibria, and very little of the potential gains are being reaped. The volume of world trade would increase fifteen times if all trade costs could be eliminated, including those that are difficult to reduce, such as freight costs, and those that are more easily reduced, such as tariff and nontariff policy barriers.

Even if we restrict our focus to the elimination of just those trade costs that are in principle reducible, the welfare gains are quite high from freer trade. For example, if all countries were to reduce trade costs to the level of the country most open to imports, the median fall in consumer prices is 56.9%. Such reductions can have large effects on the volume of trade, as a 1% reduction in overall trade costs would increase world trade volumes by 2.0–2.5%. For this reason, even small rises in trade costs can be very harmful. The introduction of export restrictions by some crop exporters in 2007–2008 was an example of this, and highlighted the thinness of many crop markets.

The results differ systematically across countries. Distance inhibits the extent to which an event in one country is transmitted to other countries. The level of economic development, as proxied for by per capita income, is also related to many results. Countries with high average productivity are more likely to be found on the high end of the global income distribution. Countries with high import trade costs, by contrast, are more likely to be found on the low end of the global income distribution. The insulation associated with high import trade costs may shield countries somewhat from adverse changes in other countries. However, it also means they may gain less when other countries are able to increase their supply. Regardless of these tendencies, it appears that all countries are very far from reaping the potential gains from trade in international crop markets. The framework offers a means for future researchers to determine the gains from trade from new policy directions.

Funding

The authors acknowledge financial support from the Oregon Agricultural Experiment Station and the USDA Cooperative State Research, Education and Extension Service.

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