Ricardian Model: Modern Interpretation

Workers to Make a Unit of a Good

	Cloth	Wine
England	100	120
Portugal	90	80

- Suppose wage in Portugal is 1, and in England, $\omega > 1$, i.e., unit of cloth costs 100ω in England and 90 in Portugal, and unit of wine costs 120ω in England and 80 in Portugal

- With free trade and competition, prices of cloth and wine same in each location, and lowest-cost way of producing each good

- Suppose $\omega > 90/100$, since:

$$\underset{\text{(cloth)}}{\frac{90}{100}} > \underset{\text{(wine)}}{\frac{80}{120}},$$

both goods produced in Portugal, i.e., an English wage more than 90% of Portugese wage is incompatible with employment in England

- **If English wage lies between 9/10 and 2/3, it produces cloth and Portugal produces wine**

- **Add a third good, linen, where England and Portugal each need 100 workers per unit, allowing inequality to be extended:**

$$\underset{\text{(linen)}}{\frac{100}{100}} > \underset{\text{(cloth)}}{\frac{90}{100}} > \underset{\text{(wine)}}{\frac{80}{120}},$$

- **Ordering of goods is *chain of comparative advantage*, broken by English wage ω relative to Portugese wage, e.g., ω = 0.95 breaks chain between linen and cloth**

- **Use chain to construct demand for English labor relative to world labor**

- **If ω >1, demand is vertical line at zero for good 1 (linen); at ω =1, England competitive in linen, and consumers indifferent between England and Portugal as source**

- **Demand for English labor flat (perfectly elastic) between zero, until demand for linen saturated at price of 100**

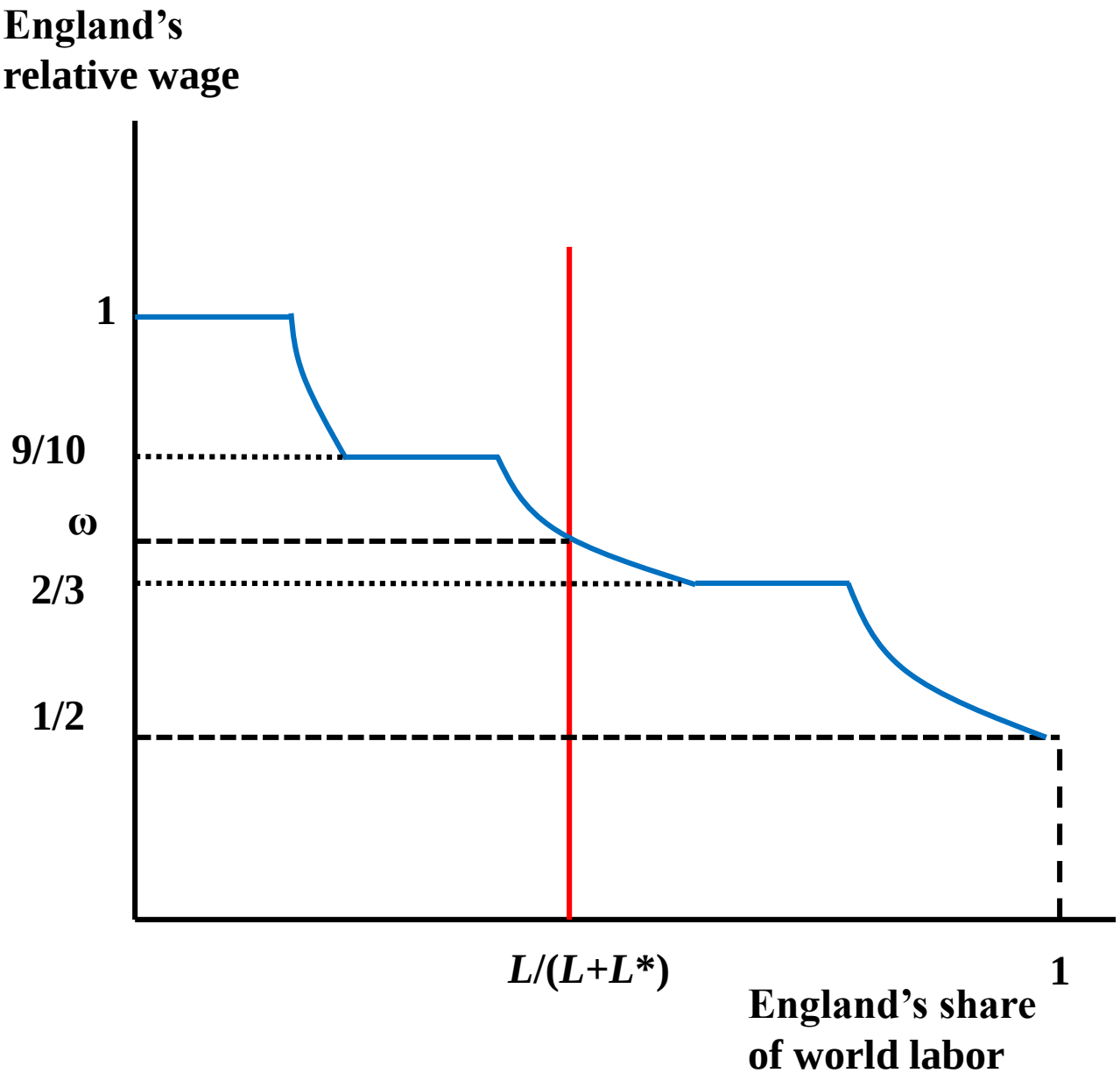
- **Decline in ω results in England being sole supplier of linen – as price is 100ω, fall in ω lowers price of linen, increasing demand and hence demand for English labor**

- **Once ω=0.9, England becomes competitive in cloth, and demand curve for labor is flat again, buyers of cloth being indifferent between England and Portugal as supplier**

- **Proceeding along chain, demand for English labor is stairway, with treads where England and Portugal share production, connected by risers where England and Portugal specialize in specific goods**

- **Equilibrium found where share of England in world labor supply $L/(L+L^*)$ cuts labor demand curve (Figure 1), England producing two goods**

Figure 1: Wage Determination in Many-Good Model



- **Along a riser, drop in ω raises demand for English goods at *intensive margin*, i.e., all English goods sold at lower prices; when ω hits tread, trade expands at *extensive margin*, i.e., England sells more goods**

- **Given technologies of constant returns, having larger share of labor force, country may have to lower its wage, i.e., either sell more of its goods or sell wider range of goods**

- **Dornbusch, Fischer and Samuelson (1977) made establishing equilibrium easier by making chain of comparative advantage a continuum**

- **Assumed set of goods correspond to all points on interval between 0 and 1, goods being sorted to form chain of comparative advantage**

- **England has strongest comparative advantage in goods near to 0, Portugal having strongest comparative advantage in goods near to 1**

- **Defined function $A(j)$ as ratio of Portugal's labor requirements to those of England for j, where $A(j)$ is smooth and strictly decreasing (see Figure 2)**

- **For any ω between $A(0)$ and $A(1)$, there is some good, $\bar{j}$ satisfying $A(\bar{j}) = \omega$, i.e., unit cost is same in England as in Portugal**

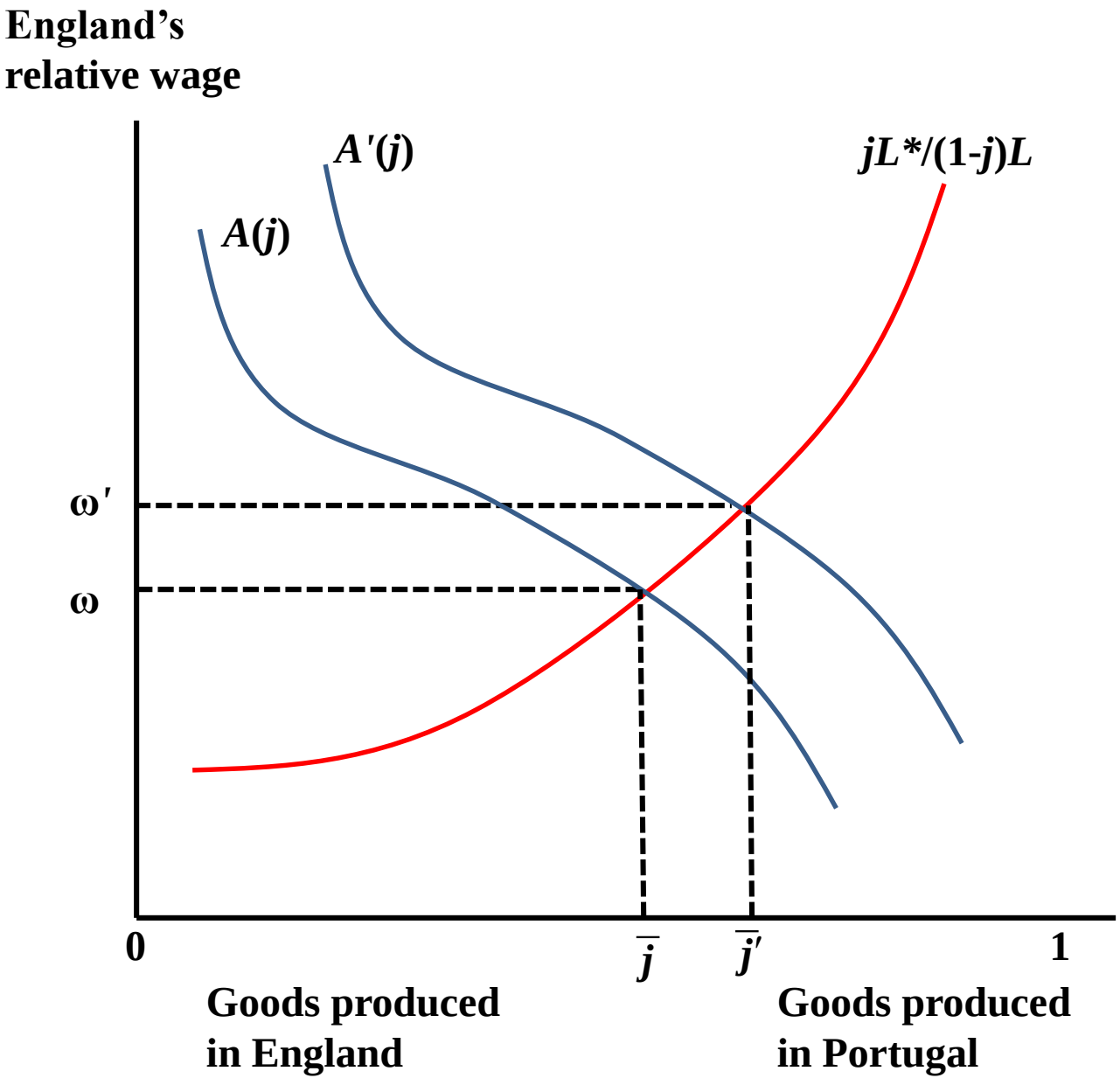
- **Therefore England produces goods $j \leq \bar{j}$, and Portugal produces goods $j \geq \bar{j}$; who produces $\bar{j}$ is irrelevant as it is a small fraction of total number of goods**

- **$\bar{j}$ is also share of goods produced in England, and if ω increases, England must reduce share of goods it produces**

- **What ω breaks chain? Need to look at demand side, where a higher $\bar{j}$ means England is producing larger share of goods, increasing demand for labor and hence its wage**

- **Equilibrium where upward sloping function cuts $A(j)$ (see Figure 2)**

Figure 2: Wage Determination with Continuum of Goods



- **Assume tastes such that consumers spread spending evenly across goods – share of goods produced in England becomes share of spending on English goods**

- **Labor market equilibrium requires full employment of workers in England at Portugal at ω, with English workers paid fraction $\bar{j}$ of world income, i.e., $\omega L = \bar{j}(\omega L + L^*)$**

- **A uniform increase in English productivity results in England getting relatively more productive in making every good, raising ω and expanding share of goods it produces**

- **Suppose iceberg transport costs *d* are introduced, where $d > 1$, implying goods get destroyed in transit, and *d* affects all goods**

- **Creates range of non-traded goods, as each country can make them more cheaply itself, but still a range of goods near 0 that England trades, and range near 1 that Portugal trades**

- **Eaton and Kortum (2002) extended multi-good Ricardian model to a multi-country setting**

- **Productivity determined by draw from probability distribution, each country having some chance of producing at lower cost than any other country**

- **Follow application to agricultural trade by Reimer and Li (2010), where land is key factor, and productivity is a function of random weather shocks across countries along with differences in climate, soil, and technology**

- ***N* countries indexed *i* and *n*, land is L_i, yield of crop *j* in *i* is $z_i(j)$, and rental rate of land is w_i, and under constant returns, cost of producing *j* in *i* is $w_i/z_i(j)$**

- **Bilateral trade where exporter is *i* and importer is *n*, and trade costs are "iceberg"-type, where cost of delivering unit of good *j* is $d_{ni} \geq 1$**

- **Crop sector modeled as continuum $j \in [0,1]$**

- **In competitive market, price *n* pays for crop *j* from *i* is:**

$$p_{ni}(j) = \frac{d_{ni} w_i}{z_i(j)} \qquad (1)$$

- **Country *n* seeking to buy crop *j* from cheapest source, pays:**

$$p_n(j) = \min\{p_{n1}(j), p_{n2}(j), p_{n3}(j), \ldots p_{nN}(j)\} \qquad (2)$$

- **Let crop yields be random variable $Z_i(j)$ in place of $z_i(j)$. As price depends on $Z_i(j)$, it is also a random variable, $P_{ni}(j)$, i.e., *n* chooses minimum price from sequence of random variables**

- **$Z_i(j)$ assumed to follow a Fréchet distribution:**

$$F_i(z) = \Pr[Z_i \leq z] = \exp(-T_i z^{-\theta}), \qquad (3)$$

where $T_i > 0, \theta > 0,$ and $z > 0$

- **Higher T_i - higher crop yields in *i*. Lower θ - yield distributions broader, and country's productivity strengths/weaknesses more pronounced**

- **Continuum of crops, in conjunction with identical cost and demand structure, index *j* dropped, focusing on crop sector in aggregate**

- **Probability that *i* supplies *n* at lowest price is:**

$$\Pr[P_{ni}(j) \leq \min\{P_{ns}(j); s \neq i\}] = \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}} \quad (4)$$

- ***N*'s probability of buying from *i* increases with higher yields in *i* (T_i), lower trade costs between *n* and *i* (d_{ni}), and lower land rental rates in *i* (w_i)**

- **Let X_{ni} be *n*'s spending on crops from *i*, with *i*=*n* when country produces good itself. Summing over all sources, $\sum_{i=1}^{N} (X_{ni} / X_n) = 1$. Due to continuum, share of *n*'s spending on crops from *i* is:**

$$\frac{X_{ni}}{X_n} = \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}} \quad (5)$$

- **Following Eaton and Kortum, normalize (X_{ni}/X_n) by home sales of buyer (X_{nn}/X_n):**

$$\frac{X_{ni}}{X_{nn}} = \frac{T_i(w_i d_{ni})^{-\theta}}{T_n w_n^{-\theta}} = \frac{T_i}{T_n}\left(\frac{w_i}{w_n}\right)^{-\theta} d_{ni}^{-\theta} \qquad (6)$$

- **Taking logs:**

$$\ln\left(\frac{X_{ni}}{X_{nn}}\right) = \ln\frac{T_i}{T_n} - \theta\ln\frac{w_i}{w_n} - \theta\ln d_{ni} \qquad (7)$$

- **Let $S_i \equiv \ln T_i - \theta\ln w_i$ (productivity adjusted for costs, i.e., competitiveness), and substitute in:**

$$\ln\left(\frac{X_{ni}}{X_{nn}}\right) = -\theta\ln d_{ni} + S_i - S_n \qquad (8)$$

- **(8) is gravity-type equation, where S_i are captured as country fixed effects, and d_{ni} are measured by variables: distance (*d*), common border (*b*), membership of free trade agreement (*e*), common language (*l*), and destination-specific effects (*m*)**

- **Reimer and Li estimate (8) with bilateral crop purchases for 2001 across sample of 23 countries – see Table 1 for results**

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.

- **With estimates of d_{ni}^{θ}, Reimer and Li then estimate θ and T_i, and solve out for w_i and L_i (Table 2)**

- **Run counterfactuals to get sense of importance of trade costs and potential gains from trade in crops:**

  (i) ***Counterfactual 1*: push model to autarky, i.e., let d_{ni} go to infinity for $n \neq i$ (Table 3)**

  (ii) ***Counterfactual 2*: push model to free trade, i.e., let $d_{ni} = 1$ for all n and i (Table 3)**

  (iii) ***Counterfactuals 3 and 4*: reduce destination-specific trade barriers to level of US, i.e., let $-\theta m = 5.88$ (Table 4)**

- **Results suggest trade costs are already high enough to almost approximate autarky, and that removing all trade costs significantly increases volume of trade in crops**

- **Welfare gains from trade remain quite high if focus is only on trade costs that are reducible**

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

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 $\delta = 2.83$ and $\hat{T}_i$ from table 2. Approach 3 uses $\delta = 4.96$ 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.

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.