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Technical Barriers to Interstate Trade: Noxious Weed Regulations

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We focus on regulations controlling the spread of noxious weeds, especially the trade effects of regulatory differences across U.S. states. We specify a gravity model for each state's seed, nursery product, and commodity trade with each other state. Within the gravity model, we examine the role of cross-state regulatory congruence arising from ecological and agronomic characteristics and interest-group lobbying. A spatial-autoregressive Tobit model is estimated with a modified expectation-maximization algorithm. Results show that weed regulatory congruence positively affects interstate trade. By fostering cross-state regulatory differences, consumer and commodity-producer lobbying reduce the value of interstate trade by about two percent per annum.

Key Words: interstate trade, invasive species, rent-seeking

JEL Classifications: F1, H7, Q5

Human activity, especially cheaper and expanded transportation, in the United States has exacerbated invasive species (IS) problems (Burt et al., 2007; Margolis, Shogren, and Fische, 2005). Over the past few decades, invasive plants, insects, and microbes have created up to $100 billion in ecological and economic damage (Pimentel, Zuniga, and Morrison, 2004). To prevent the introduction and spread of invasive plants, especially weeds, the federal government has established two major regulations. The first is a noxious weed seed (NXWS) list under the Federal Seed Act (FSA) of 1939 and its amendments, which prohibits or restricts the interstate and international trade of agricultural products containing noxious weed seeds. The second, arising from the Plant Protection Act (PPA) of 2000, bars importation and interstate movement of plants recorded in a noxious weed (NXW) list. The latter requires, in effect, that nursery and greenhouse shipments be free of listed noxious weeds. Both federal lists establish either a zero (prohibited) or a defined (restricted) tolerance level for each weed species. In addition to the two federal lists, states are authorized by the FSA and the PPA to establish their own NXWS and NXW list, respectively, based on local ecological and environmental conditions.

Substantial size and compositional differences in noxious weed regulations (NXW and NXWS lists) are observable across states. For example, California had 119 noxious weeds in its 2002 NXW list, whereas many Eastern states had no NXW list at all. Differences among state noxious weed regulations likely are motivated to protect local ecosystems and reduce agricultural

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production costs, but can also create significant barriers to interstate trade. That is, a NXWS list is expected to respond to local climatic and ecological conditions but may also be impacted by interest groups' rent-seeking activities. For instance, seed producers may have an incentive to lobby their legislature for an especially stringent NXWS list to protect the local seed market. From consumers' viewpoints, increasing IS protection reduces agricultural product supply, raising prices and impairing welfare; but to the extent it also protects the ecosystem, welfare may be enhanced. Like consumers, commodity producers face a tradeoff between increased input (e.g., seed) prices and reduced weed intrusions into their state. Questions about the sources of interstate weed regulatory differences, and whether such differences have affected interstate agricultural trade, remain unanswered.

The objective of this article is to estimate the effects of weed regulations (NXW and NXWS lists) on interstate agricultural trade while accounting for regulatory endogeneity. A number of analysts have investigated the link between trade and environment (Copeland and Taylor, 2003). Although trade's influence on the environment has been highlighted, environmental regulations' impact on trade has received limited attention (Antweiler, Copeland, and Taylor, 2001; Costello and McAusland, 2003). We address the latter gap by investigating the trade effect of environmental barriers implicit in weed regulations of U.S. states, which otherwise freely exchange goods.

For this purpose we have assembled, from the 1997 and 2002 Commodity Flow Surveys of the U.S. Department of Transportation, a database on interstate trade of agricultural products. Our estimates show that trade among U.S. states in seeds, nursery products, and selected agricultural commodities are valued at approximately \$5, \$1, and \$50 billion, respectively. We also have compiled all 50 states' NXWS and NXW lists in 1997 and 2002 along with data on respective ecological and environmental conditions. Together with the data on state-level demand characteristics, we specify an interstate trade equation for three agricultural products: seeds, nursery products, and agricultural commodities. A spatial autoregressive Tobit model of interstate trade is estimated with a modified expectation-maximization algorithm (Anselin, Florax and Rey, 2004; LeSage, 1999; Maddala, 1983; LeSage and Pace, 2004).

To achieve our objective, we specify a gravity model of interstate trade in seeds, nursery products, and commodities (Feenstra, 2004). The gravity model relates trade between two countries to the size of the individual or combined markets and the distance between them, in which the latter proxies trade friction arising from geography and policies. Within the gravity model, we examine the distinct role of cross-state weed regulatory congruence arising from dissimilarities among states' ecosystems, agronomic conditions, and interest-group behaviors. Three economic interest groups are considered in each state: consumers, seed producers and nursery growers, and commodity producers. Using the fitted regulatory congruence values, we then estimate the effects of noxious weed regulatory similarities on interstate agricultural trade, paying attention to the lobbying effects of the three interest groups. The trade distortion arising from lobbying has implications for resource reallocation in seed, nursery, and commodity production across U.S. states.

A Gravity Framework for Interstate Trade

Our focus is on distortions created by weed regulations in the interstate trade of seeds, nursery products, and commodities. In the following, we first use a standard gravity-type equation to model interstate trade. Here, each (base) state's trade with another (comparator) state is specified as a function of their weed-regulatory similarities, controlling for market, endowment, agronomic, and ecological characteristics. Within the gravity framework, we then model the endogenous trade friction arising from weed regulations, which depend on states' ecosystems, agronomic conditions, and interest group behavior. Finally, we use the gravity model to identify the interstate trade effects of weed regulatory differences arising from interest group activity.

The gravity model is highly popular in the empirical modeling of trade flows because of its strong explanatory power. Originally proposed by Tinbergen (1962), the gravity model suggests that trade between any two countries is directly and inversely proportional to the size of and distance between the two markets, respectively. Anderson (1979) is the earliest attempt to model the theory underlying such gravity models followed by Bergstrand (1985) and Helpman and Krugman (1985). Feenstra (2004) and Frankel (1997) provide a good overview of the theoretical and empirical issues related to gravity trade models. We adapt the gravity models of international trade flows to the case of U.S. interstate trade.[1]

We begin with the specification of trade between base (i) and comparator state (j), Q_{ij}^{g}, as:

$$Q_{ij}^{g} = Q_{ij}^{g}(L_{ij}, \mathbf{A}_{ij}, \mathbf{I}_{ij}, \mathbf{T}_{ij}^{g}), \tag{1}$$

where $g = s,n,m$ denotes seeds (s), nursery products (n), and commodities (m); L_{ij} is the indicator of weed regulatory similarities or congruence between i^{th} and j^{th} states; I_{ij} and A_{ij} is a vector each representing ecosystem and agronomic dissimilarities between the two states; and $\mathbf{T}_{ij}^{g}$ is a vector representing gravity-type variables: distance, common border, and relative size (gross domestic product [GDP]) and endowment. Our specification of interstate trade in Equation (1) includes not only variables commonly found in gravity models ($\mathbf{T}_{ij}^{g}$), but regulatory differences (inverses of L_{ij}) as well. In the gravity specification, we also consider ecosystem and agronomic characteristics because, together with endowments, they determine production and trade patterns among states.

Although most variables on the right-hand side of Equation (1) are likely predetermined (e.g., distance, border, ecosystem characteristics), regulatory congruence (L_{ij}) is likely endogenously determined (Copeland and Taylor, 2003; Goldberg and Maggi, 1999). Min et al. (2008) present a simple political–economic framework to derive weed regulatory congruence as an interplay of the demand and supply of such regulations. Demand arises from two sources. First, scientifically based concerns exist about the integrity of the local ecosystem if foreign species are introduced. Second, economic interest groups view weed regulations as a way to increase private rents. The supply of weed regulation is provided by policymakers empowered to erect barriers against products containing invasive species. Following Min et al. (2008), we specify L_{ij} as:

$$L_{ij} = L_{ij}\,(\mathbf{I}_{ij}, \mathbf{A}_{ij}, \omega_{ij}^{c}, \omega_{ij}^{s}, \omega_{ij}^{m}),\ \forall i,j\ k = c,s,m. \tag{2}$$

where $k = c,s,m$ denotes consumers (c), seed and nursery producers (n), and commodity producers (m).[2] Equation (2) suggests that the similarity between any two states' weed regulations is a function of dissimilarities between 1) their ecosystem and agricultural characteristics; and 2) the relative lobbying, ω_{ij}^{k}, of interest groups who seek changes in weed regulations to protect respective interests. We consider the role of three interest groups in shaping weed regulations. First, consumers face a tradeoff from decreasing regulatory congruence: reduced agricultural product supplies along with raising prices vs. welfare improvements by protecting the ecosystem. Second, seed producers and nursery growers gain both from the higher product prices and the agronomic protection embodied in weed regulations. Finally, commodity producers face a tradeoff, like consumers, between increased seed (input) prices and reduced weed intrusions into their state. Thus, the net effects of lobbying on regulatory congruence, which in turn affects intestate trade, are an empirical issue.

Substituting Equation (2) into Equation (1), we derive a general representation for the bilateral export equation:

$$Q_{ij}^{g} = h(L_{ij}^{*}(\mathbf{I}_{ij}, \mathbf{A}_{ij}, \omega_{ij}^{c}, \omega_{ij}^{s}, \omega_{ij}^{m}), \mathbf{I}_{ij}, \mathbf{A}_{ij}, T_{ij}^{g}), \quad \forall i,j;\ g = s,n,m \tag{3}$$

[1] Data from each of these industries, for example, and the American Seed Trade Association and American Nursery and Landscape Association are suggestive of market environment similar to monopolistic competition underlying gravity models. Some producers or groups may have market power, but that is beyond the scope of the present study.

[2] We model interstate trade in three products (seeds, nursery products, and commodities) but only consider the combined lobbying of seed and nursery producers in Equation (2). The reason is interstate trade data are more detailed than the lobbying contributions data available to us. See the data section for details.

Examining the relationship among ω_{ij}^{c}, ω_{ij}^{s}, ω_{ij}^{m}, and Q_{ij}^{g} in Equation (3) allows us to identify the extent of interstate trade distortion in each of the three commodities when interest groups engage in lobbying activity.

Data

The U.S Department of Transportation's Commodity Flow Survey for 1997 and 2002 is the source of our data on interstate trade flows.[3] These data include origin and destination states and value and quantity of interstate trade in our three categories of interest: agricultural seeds, nursery plants, and agricultural commodities. The seeds category contains cereal grain seeds, leguminous vegetable seeds, and miscellaneous seeds such as of grass, tobacco, trees, and ornamental flowers, whereas nursery plants include live trees and plants, bulbs, roots, flowers, and similar products. For agricultural commodities, we have data on interstate flows of five major field crops: corn, wheat, grain sorghum, oats, and barley. Trade flows by origin and destination can be represented by a 48 × 48 matrix yielding 2304 state pairs. Unsurprisingly, we encountered a large proportion of zero (export) observations. Note that by setting Q_{ij}^{g} $(g = s,n,m)$ equal to exports, we also capture the import information. For example, the i^{th} state's seed import from the j^{th} state is exactly the same as the latter's seed exports to the former. In other words, if state i imports seeds from state j, then $Q_{ij}^{s} = 0$, but Q_{ji}^{s} equals the value of seeds exported by the j^{th} state to the i^{th} state. We therefore have a censored dependent variable in which nonzeros ranged from 5% to 10% depending on commodity and year (Table 1).

We draw on Min et al. (2008) to construct a 48 × 48 matrix of regulatory congruence (L_{ij}) based on state NXW and NXWS lists in 1997 and 2002. For instance, the NXWS list regulatory congruence is represented by a 48 × 48 of the overlap matrix

$$\begin{pmatrix} AL \cap AL & AL \cap AR \ldots & AL \cap WY \\ \vdots & \ddots & \vdots \\ WY \cap AL & WY \cap AR \cdots & WY \cap WY \end{pmatrix}_{48 \times 48}$$

where AL, AR, and WY denote Alabama, Arkansas, and Wyoming. Each row gives the number of overlap occurrences of the given state's weed species with each of the 48 contiguous states, including itself. For example, the first row gives AL's list overlaps first with itself, then with each of the remaining 47 states. The matrix is therefore symmetric with diagonal elements consisting of the number of noxious weeds listed in the respective state. Because states differ in the number of weeds they list, we created a corresponding percent-overlap matrix by dividing the weed overlap numbers in each row of the 48 × 48 matrix by the diagonal element in that row. For instance, the first row of Equation (1) is divided by the number of noxious weeds in AL's list. Resulting diagonal elements are unity; off-diagonal elements vary between 0 and 1 depending on the percentage of species overlap. We have every state's noxious weed seed lists and their sublists—prohibited (NXWSP) and restricted (NXWSR)—in both years. However, 26 states in 1997 and 14 states in 2002 did not report a NXW list. Hence, the 48 × 48 matrix of NXW overlap is constructed such that the rows and columns corresponding to states lacking a weed seed list are set at zero.

We measure cross-state ecosystem differences ($\mathbf{I}_{ij}$) using Bailey's (1995) four-level hierarchical classification of U.S. ecoregions: domains, divisions, provinces, and sections. Specifically, we use the data underlying the classification such as land surface form, climate (temperature and precipitation), soil, and surface water characteristics to measure ecosystem differences across U.S. states (National Resources Inventory, 1998). All county-level data are aggregated to state-level indices using county shares of state land as weights. Seven variables are used to represent a state's ecosystem: average temperature (mean January temperature); average precipitation (days of measurable precipitation per year); variance of temperature; variance of precipitation; a land index (computed with principal component analysis of the shares of cropland,

[3] Our choice on years coincides with availability of interstate trade data from the Commodity Flow Survey conducted once every 5 years by the U.S. Department of Transportation. The choice also represents regulations before and after PPA's implementation in 2000.

Table 1. Descriptive Statistics

Dependent Variables	Observations	Censored	Unit	Mean	Standard Deviation	Minimum	Maximum
Seed trade 2002	2304	2089	$mil	1.807	14.785	0	374
Seed trade 1997	2304	2032	$mil	1.697	13.715	0	353
Nursery trade 2002	2304	2200	$mil	0.612	10.003	0	340
Nursery trade 1997	2304	2065	$mil	0.908	5.983	0	154
Commodity trade 2002	2304	2040	$mil	22.1	229.4	0	8180.1
Commodity trade 1997	2304	1910	$mil	22.6	184.4	0	3697.2
Independent variables							
Overlap of NXWS 2002 (OL02NXWSP)	2304		index	0.440	0.161	0.025	1
Overlap of NXWS 1997 (OL97NXWSP)	2304		index	0.424	0.162	0.033	1
Overlap of NXW 2002 (OL02NXW)	2304		index	0.442	0.428	0	1
Overlap of NXW 1997 (OL97NXW)	2304		index	0.505	0.443	0	1
Border dummy	2304		index	0.114	0.318	0	1
Capital cities distance	2304		mile	1019.8	629.2	0	2670.7
GDP/capita 2002– (GDP02/cap–)	2304		index	–0.090	0.140	–0.904	0
GDP/capita 2002+ (GDP02/cap+)	2304		index	0.070	0.099	0	0.475
Land-labor ratio 2002– (LLR02–)	2304		index	–12.5	71.8	–1797.5	0
Land-labor ratio 2002+ (LLR02+)	2304		index	0.342	0.398	0	0.999
GDP/capita 1997– (GDP97/cap–)	2304		index	–0.088	0.135	–0.853	0
GDP/capita 1997+ (GDP97/cap+)	2304		index	0.069	0.097	0	0.460
Land-labor ratio 1997– (LLR97–)	2304		index	–10.9	58.9	–1414.6	0
Land-labor ratio 1997+ (LLR97+)	2304		index	0.339	0.395	0	0.999

The + and – symbols next to a variable indicate the negative and positive scale of explanatory variables (dissimilarity indices).

pasture, rangeland, forest, small and large urban area, and miscellaneous land in total land area); soil index (from a principal component analysis of such soil characteristics as sandy, silty, clay, loamy, organic, and other); and water index (from a principal component analysis of such water body size classifications as less than 2, 2–40, and more than 40 acres). For each ecosystem variable, we construct a 48 $\times$ 48 dissimilarity matrix as before (Min et al., 2008).

Each row provides the percentage differences in the given ecosystem variable between the indicated state, itself, and the other 47 states. Diagonal elements of a dissimilarity matrix are zero, whereas off-diagonal elements take values between negative and positive infinity.

We use two measures of a state's agronomic characteristics ($\mathbf{A}_{ij}$): irrigated share of total cropland and field-crop share of total cropland. Field crops include corn, wheat, barley, soybeans, other grains, and cotton. These data are obtained from the 2002 and 1997 Census of Agriculture (U.S. Department of Agriculture). A 48 $\times$ 48 matrix of dissimilarity indices was constructed for each of these two variables.

To represent stakeholders' interests in weed and weed-seed regulation ($\omega_{ij}^c, \omega_{ij}^s, \omega_{ij}^m$), we obtained data on campaign contributions by industry groups in state politics (Institute on Money in State Politics, www.followthemoney.org). From these, we identified agricultural producers' political contributions, including, as a subset, seed producers'. Because seed-producer and nursery interests are similar to one another, and because nursery industry contributions alone were marked by several missing values, we combined seed-producer and nursery contributions together. A consumer-interest group was constructed by pooling contributions from a number of advocacy groups in the food-product and environmental amenities arena. Because welfare weights sum to one, we focus on each group's share in total dollar contributions. We then construct, for each of these industries, a 48 $\times$ 48 dissimilarity-index matrix showing state-by-state percentage differences in dollar-contribution shares. Note that a lobbying dissimilarity index, $\omega_{ij}^c = \left(\omega_i^c - \omega_j^c\right)/\omega_i^c$, is an increasing function of the base state's lobbying contribution.

Control variables T_{ij}^g are per-capita personal income, land-labor ratio, distance between two states' capital cities, and a dummy variable that is unity if the two states share a common border, zero otherwise. They all are commonly used in gravity-type trade flow models in international economics (Feenstra, 2004).[4] We use state-level per-capita personal incomes and land-labor ratios to, respectively, approximate income and relative endowment differences. State-level incomes are from the U.S. Department of Commerce and land-labor ratios from the U.S. Department of Agriculture. Mileages between states' capital cities are drawn from a GIS map. Descriptive statistics are presented in Table 1.

Econometric Specification and Procedures

We face three econometric issues in estimating Equation (3): endogeneity of L_{ij}^*, censored dependent variables Q_{ij}, and spatial dependency of errors. We use a two-stage approach to endogenize L_{ij}^*, in the first stage estimating Equation (2) and in the second stage using L_{ij}^*'s fitted values to estimate Equation (3). The second two econometric issues require that we simultaneously consider a limited-dependent variable model with the possibility of a spatially correlated error structure. Our interstate trade data have a large proportion of zeros, i.e., censoring at zero, for which the appropriate procedure is a Tobit model (Maddala, 1983). Suppressing index g for notational convenience, a linear specification of Equation (3) is given by:

$$(4) \qquad Q_{ij} = \alpha_0 + \beta_1^{'} \hat{L}_{ij}^* + \beta_2^{'} A_{ij} + \beta_3^{'} I_{ij} + \beta_4^{'} T_{ij} + \mu_{ij},$$

$$\text{with} \quad \begin{array}{ll} Q_{ij} = 0 & \text{if } Q_{ij}^* \le 0, \\ Q_{ij} = Q_{ij}^* & \text{if } Q_{ij}^* > 0, \end{array}$$

where Q_{ij}^* is the unobserved latent variable that equals observed trade flow only when the latter takes a positive value. Ordinary least squares (OLS) will yield biased estimates because the

[4] GDP, population, and/or per-capita GDP can be proxies for the sizes of two economies in a gravity model (Feenstra, 2004; Porojan, 2001).

left tail of the distribution of Q_{ij} is censored (Maddala, 1983).[5]

Consider now the possibility of spatial dependency in error term μ_{ij} in Equation (4). Following the general approach of Anselin (1988), a number of studies have used spatial econometric methods to examine the adjacency effect among counties, states or provinces, and regions (Anselin, 1992; Case, 1992). The empirical, gravity-type trade literature has considered spatial dependency as well (Blonigen et al., 2007; Porojan, 2001; Weinhold, 2002). For instance, Porojan's (2001) comparison of standard and spatial econometric approaches for estimating gravity trade models shows the latter improves not only the accuracy, but also the statistical significance (efficiency) of estimated parameters. In the present study, we specify a spatial error model (SEM) in which tobit errors follow a first-order spatial autoregressive process.[6] SEM is motivated by the fact that excluded effects spill across observation units and hence produce spatially correlated errors (Anselin, 2006). Adjacent states usually have similar ecological and environmental conditions and therefore similar agricultural commodities, seeds, and nursery plants. These neighborhood effects are difficult to measure and often are excluded from or inaccurately measured in Equation (4)'s independent variables. They then become a part of the error term, which thus exhibits spatial correlation.

We employ the following error specification for Equation (4)'s i^{th} panel, that is the 48×1 error-term vector for the i^{th} state:

$$(5) \qquad \mu_i = \lambda \sum_{j=1}^{48} w_{ij}\mu_j + \varepsilon_i \quad \varepsilon \sim N(0,\sigma^2),$$

where w_{ij} is the $i\text{-}j^{\text{th}}$ element in the standardized spatial weight matrix W, a 48×48 matrix of known constants to capture cross-state spatial correlation.[7] Parameter λ is the spatial autoregressive error coefficient, measuring the strength of spatial error dependency. A positive (negative) spatial correlation coefficient indicates similar (dissimilar) errors in neighboring states. Specification (5) can be extended to all 48 states.

Although tobit or spatial error models have often been individually applied, their combination with a spatial autoregressive error model is less common. This rarity derives partly from the complexity of approximating multiple integrals, tedious even in small samples (Anselin, Florax, and Rey, 2004; Kelejian and Prucha, 1999). We find three methods of addressing spatial correlation in limited and discrete dependent variable cases: LeSage's (1999) Bayesian approach or Markov Chain Monte Carlo sampling; Marsh and Mittelhammer's (2004) generalized maximum entropy estimator; and the expectation-maximization (EM) algorithm (Case, 1992; McMillen, 1992; Pinkse and Slade, 1998). All three have advantages but the EM approach is straightforward, is least computationally tedious, and has been applied to spatial Tobit models (Anselin, Florax, and Rey, 2004; LeSage, 1999).

Expectation-Maximization Algorithm

Our chosen EM algorithm for estimating Equation (4), with error structure like in Equation (5), entails two steps. The first is an E-step to calculate the conditional expected value of the latent variable given the observed variable. When the conditional expected value substitutes for the latent variable, the dependent variable is no longer censored. The next or M-step thus involves estimating a standard spatial error model by maximum likelihood methods. Parameters obtained from the M-step are then used in another E-step and the process repeated until parameters converge to the maximum likelihood estimates of the original multidimensional likelihood function. A drawback of the EM algorithm in spatial autoregressive Tobit is that when n is large, the spatial error model (M-step) is computationally intensive (Fleming, 2004; Kelejian and Prucha, 1999). To estimate Equation (4), we thus divide the M-step into two stages as follows.

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[5] We used OLS to estimate Equation (4) but the R^2 was under 1%. A fixed-effects model improved the fit, but OLS estimators are biased when the dependent variable is censored.

[6] This is the most commonly used form of spatial error dependence (Anselin, 1988; LeSage, 1999).

[7] $w_{ij} = 1$ if states i and j ($i \neq j$) are adjacent; $w_{ij} = 0$ otherwise.

E-step. In the E-step, we generate the conditional expected value of the dependent variable (interstate trade flows) to replace the unobserved latent variable. For this purpose, Equation (4) is rewritten in matrix notation as:

$$\text{(6)} \qquad \mathbf{Q} = \mathbf{X}\beta + \mu,$$
$$\mu = \lambda\mathbf{W}\mu + \varepsilon \quad \varepsilon \sim N(0,\sigma^2),$$

where $\mathbf{Q}$ is the (2304×1) vector of interstate trade flows, whereas X is the $(2304 \times k)$ matrix of independent variables and μ the 2304×1 vector of error terms. Then, Equation (6) becomes:

$$\text{(7)} \qquad \mathbf{Q} = \mathbf{X}\beta + (\mathbf{I} - \lambda\mathbf{W})^{-1}\varepsilon,$$

for which the error variance–covariance matrix is given by:

$$\mathbf{\Omega} = \sigma^2[(\mathbf{I} - \lambda\mathbf{W})(\mathbf{I} - \lambda\mathbf{W})']^{-1}.$$

Following Chib (1992) and McMillen (1992), the expected value of the latent variable in Equation (4) is:

$$\text{(8)} \quad E[Q_{ij}^{*} \mid Q_{ij} = 0] = X_{ij}^{'}\beta - \sigma_{ii}\left[\frac{\phi(X_{ij}^{'}\beta/\sigma_{ii})}{1 - \mathbf{\Phi}(X_{ij}^{'}\beta/\sigma_{ii})}\right],$$

where $X_{ij}^{'}$ is the $1 \times k$ vector containing the i-j^{th} observation on independent variables, and $\phi(.)$ and $\mathbf{\Phi}(.)$ are the density and distribution functions, respectively, of a standard normal variable. Parameter σ_{ii} is the diagonal element of the upper left 48×48 matrix of $\mathbf{\Omega}$. The zero observation of the dependent variable in Equation (6) is replaced by its expected value from Equation (8).

M-step. Given the E-step computation, the log likelihood function in the SEM model is:

$$\text{(9)} \quad \begin{aligned} Ln(L) = &-(N/2)(\ln\sigma^2 + \ln(2\pi)) + \ln|\mathbf{I} - \lambda\mathbf{W}| \\ &-(1/2)(\mathrm{Q} - \mathbf{X}\beta)'\Omega^{-1}(\mathrm{Q} - \mathbf{X}\beta). \end{aligned}$$

As noted earlier, the primary problem in obtaining the coefficients that maximize the log likelihood function is the sample size (Anselin, Florax, and Rey, 2004; Kelejian and Prucha, 1999). In our case, N and k equal 2304 and 10, respectively. The additional concern in maximizing Equation (9) is that most software uses the Newton-Raphson method, which sometimes finds only a local maximum. Therefore, like in Kelejian and Prucha (1999) and LeSage and Pace (2004), we implement the M-step in two stages. The first is to estimate spatial autoregressive parameter λ by maximum likelihood; the second is to use λ to transform the data as in Equation (7) and estimate it with OLS. These estimates are used, through Equation (8), to derive the latent variable's new conditional expected value, and the M-step is repeated until estimates converge.

The added advantage of the EM approach is that we can test the presence of error spatial autocorrelation with Moron's I test (Anselin, 1988, p. 102). Given the standardized spatial weight matrix, Moron's I statistic can be written as $I = e'\mathbf{W}e/e'e$, in which vector e represents tobit residuals and W is as defined below Equation (5), i.e., a standardized spatial weight matrix. Cliff and Ord (1981) define a standard normal variable:

$$\text{(10)} \qquad Z(I) = [I - E(I)]/V(I)^{1/2},$$

in which $E(I) = tr(\mathbf{MW})/(N - k)$ and

$$V(I) = \frac{tr(\mathbf{MWMW}') + tr(\mathbf{MWMW}) + [tr(\mathbf{MW})]^2}{(N-k)(N-k+2)}$$

are the mean and variance of the I-statistic, M is the projection matrix $(\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}')$, and tr is the trace operator. The null hypothesis is that spatial dependence does not exist in Tobit residuals. Failure to reject the null hypothesis would lead us back to the standard Tobit model in Equation (4).

Results and Discussion

We first draw on estimates of the determinants of interstate weed regulatory congruence, Equation (2), from Min et al.'s (2008, pp. 319–20; Tables 2 and 3). They provide the results of four specifications of a weed-regulatory congruence index: those based on NXWS, NXWSP, NXWSR, and XW lists. The second and third of these are sublists of NXWS regulation and refer respectively to weed species with a "zero" and a "defined" tolerance level. In general, dissimilarities among state ecosystems, agronomic conditions, and interest group activities have statistically significant effects on cross-state regulatory differences. Increasing seed producer lobbying increases cross-state weed-regulatory

Table 2. Estimates of Interstate Trade Equations, 1997

	Model I Seed Trade	Model II Seed Trade	Model III Nursery Trade	Model IV Nursery Trade	Model V Commodity Trade
Constant	–20.077[a]	–17.902[a]	7.980[a]	–2.164[a]	–379.876[a]
OL97NXWSP	65.792[a]	53.987[a]		16.195[a]	835.255[a]
OL97NXW		11.228[a]	3.137[a]	0.884[a]	91.618[a]
Border dummy	–0.611	–1.678	6.420[a]	5.013[a]	43.85[a]
Distance	0.007[a]	0.005[a]	–0.001[a]	0.001	0.047[a]
GDP97/Cap–	41.881[a]	41.073[a]	14.116[a]	12.306[a]	154.929[a]
GDP97/Cap+	–13.553[a]	–23.499[a]	–14.002[a]	–12.319[a]	–44.559
LLR97–	0.022[a]	0.007	–0.003[a]	0.005[a]	0.244[a]
LLR97+	1.620[a]	0.412	–2.913[a]	–1.103[a]	43.141[a]
Spatial coefficient	0.775[a]	0.778[a]	0.703[a]	–0.965[a]	0.829[a]
Moran's I	0.245[a]	0.246[a]	0.843[a]	0.831[a]	0.240[a]
Beta coefficient OL97NXWSP	0.665[a]	0.538[a]		0.411[a]	0.618[a]
Beta coefficient OL97NXW		0.303[a]	0.202[a]	0.080[a]	0.184[a]

[a] Indicates statistical significance at least at the 5% level.
The + and – symbols next to a variable indicate the negative and positive scale of explanatory variables (dissimilarity indexes).
Model I includes NXWS list; Models II and IV include both NXWS and NXW lists.

congruence. In other words, seed producers treat noxious weed-seed lists as export barriers so lobby for more cross-state regulatory uniformity. In contrast, consumers and commodity producers appear to prefer weed regulations' environmental and agronomic protection. That is, both groups lobby for less cross-state regulatory congruence (Min et al., 2008).

Tables 2 and 3 report the SEM parameters of interstate trade Equation (4) in 1997 and 2002.

Table 3. Estimates of Interstate Trade Equations, 2002

	Model I Seed Trade	Model II Seed Trade	Model III Nursery Trade	Model IV Nursery Trade	Model V Commodity Trade
Constant	–9.859[a]	–11.074[a]	–5.714[a]	–11.454[a]	–378.727[a]
OL02NXWSP	47.516[a]	41.464[a]		6.859[a]	939.661[a]
OL02NXW		9.145[a]	12.147[a]	11.293[a]	78.266[a]
Border dummy	12.138[a]	11.084[a]	23.279[a]	22.695[a]	27.121[a]
Distance	0.006[a]	0.006[a]	–0.001[a]	0.001	0.065[a]
GDP02/Cap–	20.993[a]	23.015[a]	15.361[a]	17.233[a]	147.654[a]
GDP02/Cap+	–55.905[a]	–47.468[a]	–89.29[a]	–88.283[a]	–329.283[a]
LLR02–	0.005	0.002	–0.046[a]	–0.045[a]	0.187[a]
LLR02+	–0.573	–0.711	–25.739[a]	–26.236[a]	2.792
Spatial coefficient	0.592[a]	0.671	–0.768[a]	–0.779[a]	0.687[a]
Moran's I	0.672[a]	0.679[a]	0.675[a]	0.674[a]	0.444[a]
Beta coefficient OL02NXWSP	0.456[a]	0.394[a]		0.062[a]	0.573[a]
Beta coefficient OL02NXW		0.253[a]	0.290[a]	0.268[a]	0.139[a]

[a] Indicates statistical significance at least at the 5% level.
The + and – symbols next to a variable indicate the negative and positive scale of explanatory variables (dissimilarity indexes).
Model I includes NXWS list; Models II and IV include both NXWS and NXW lists.

Five specifications in each of these two tables are driven by the statistically significant lobbying effects identified in the Equation (2) estimates reported in Min et al. (2008). Model I regresses interstate seed trade on NXWSP congruence, whereas Model II considers the agronomic protection provided by the NXW list to seed producers even if nurseries are not used as seed-production inputs. Similarly, Model III regresses nursery exports on NXW congruence, whereas Model IV examines the effects of NXWSP and NXW congruence. For agricultural commodities, we report only one set of results (Model V) in which, after a sequence of specification tests, we have included both weed lists.

These specifications are motivated by our earlier theoretical hypotheses about how NXWS and NXW lists both affect interstate trade. Moreover, interstate trade specifications that include both lists' congruence variables were statistically preferred to those that excluded both lists or included only one of them. Additional specification tests failed to reject the hypothesis that the direct coefficients of $\mathbf{I}_{ij}$ and $\mathbf{A}_{ij}$ in Equation (1) are zero. That is, ecological and agronomic variations affect interstate trade only through weed regulations L^*_{ij}. Over 90% of the estimated SEM parameters are statistically significant at least at the 5% level. Moran's I statistics indicate spatial correlation is present in all five Tobit models' residuals in both 1997 and 2002. Estimated spatial autoregression coefficients λ, measuring the level and direction of spatial error correlation, are also shown in Tables 2 and 3. Only one of 10 estimated autoregression coefficients is statistically insignificant.

Regulatory Congruence and Interstate Trade

In each of the Tables 2 and 3 models, we find that fitted NXWSP and NXW regulatory congruence (from Equation [2]) has a positive and significant effect on interstate trade. The higher the weed regulatory similarities between any two states, the larger is their interstate agricultural trade.

Our results on Equation (4) suggest that weed-seed regulation is a barrier to seed exports. Although the impact of weed-seed list overlap (OL97NXWSP, read overlap of 1997 NXWSP list) in Tables 2 and 3 (Model I) is slightly larger in 1997 than in 2002 (OL02NXWSP), both show that greater similarities in weed regulation are associated with larger seed exports. This is consistent with the finding of Min et al. (2008) that seed producers lobby for greater regulatory congruence. Our results indicate that NXWSP likely protect biodiversity and environment but also seem to distort interstate seed trade. Congruence in noxious weed lists (OL97NXW or OL02NXW) also has a positive and significant effect on interstate seed trade, likely because of the embodied agronomic protection (Model II, Tables 2 and 3).

Models III and IV in Tables 2 and 3, relating NXW and NXWSP regulations to interstate nursery trade, show results similar to those in the seed trade. The greater the cross-state similarities in NXW and NXWSP lists, the larger the interstate nursery trade. In 1997, the coefficient on NXWSP list overlap is greater than on NXW overlap; in 2002, the reverse is true. In 2000, moreover, the Federal Noxious Weed Act was replaced by the PPA's more stringent regulation of interstate movement in greenhouse products (Tasker, 2001). Before 2000, therefore, NXWSP lists may have had a larger impact on nursery trade than did NXW lists. However, subsequent to the PPA, nursery trade likely has been affected more by NXW than by NXWSP lists. Model V in Tables 2 and 3 shows that weed and weed-seed regulations also affect interstate commodity trade. The NXWSP list has a larger impact than does the NXW list, and both effects appear stronger in 2002 than in 1997. In general, we find that larger interstate trade in seeds, nursery products, and commodities is associated with greater similarities in weed regulations.

To further quantify the effects of NXW and NXWSP lists on interstate trade, we show the "beta coefficients" in the last two rows of Tables 2 and 3, representing the change in the dependent variable resulting from a 1-standard deviation change in an independent variable. In general, and except in Model IV of Table 3, the beta coefficients show that both NXWSP and NXW regulatory congruence significantly impacts interstate agricultural trade but that the former can bring larger interstate trade flows than do the latter.

Effects of Distance, Income, and Endowment Differences on Interstate Trade

We also control for key factors common to gravity-type models (Feenstra, 2004). Our primary control is the dummy variable capturing common-border effects. In most models reported in Tables 2 and 3, the border effect is positive and statistically significant, consistent with gravity-type trade studies (Feenstra, 2004). That is, if two states share a common border, their agricultural product trade is larger than otherwise. Exceptions are Model I and Model II in 1997 in Table 2.

Another variable to capture gravity effects is distance between capital cities. The distance effect takes the expected negative sign in the nursery trade but an unexpected positive sign in the seed and commodity trade equations. We think the unexpected sign of the distance coefficient is the result of the nature of the data and type of econometric model used to estimate the interstate trade equation. First, our censored interstate trade data show a strong tendency for goods to be exchanged between states that border one another. Because that effect is strongly captured by our border dummy variable, we have what, in more extreme situations, would be called a "dominant variable" situation: the distance variable accounts for a relatively small share of the gravity effect. Second, regulatory similarities decline as distance between states rises (Min et al., 2008, Figure 1, p. 308). Regulations thus partly mimic the distance variable. Moreover, our study is one of the first to correct for spatial autocorrelation in a Tobit model of intracountry trade. Several authors have suggested that the spatial weighting matrix (W in Equation [6]) likely captures some of the distance effects (Anselin, Florax and Rey, 2004; Porojan, 2001). For example, Porojan (2001) reports a significant drop in distance's importance as an international trade-flow barrier when spatial econometric rather than OLS or fixed-effects models are used. In short, these two phenomena combine to produce a relatively lower economic significance of the distance variable in our interstate trade equation, and a positive sign therefore can arise. For instance, when regulations have accounted for friction, distance may have a small positive trade effect because some consumers may regard exchanged products as exotic. In fact, we find the economic significance of the distance variable, i.e. the beta coefficient, to be relatively lower among all explanatory variables in our spatial-error model.

GDP or per-capita income is commonly used as a demand indicator in gravity-type models. We use income dissimilarity indices analogous to those for the ecological characteristics described in the data section. This index can take a positive or negative value. A negative (positive) one indicates the base state's income is higher (lower) than the comparator state's. The expectation is that states with more similar incomes participate in more frequent agricultural product trade. This is similar in the trade literature to a variety effect, that is intraindustry trade motivated by a wish for the other state's varieties (Feenstra, 2004). We find that the greater—in either direction—per-capita income dissimilarity between two states, the lower the trade between them: a variety effect.

Relative land-labor ratios are included in Equation (4) to capture interstate trade's endowment motivations. We obtained mixed results on the trade effects of endowment differences. Seeds and agricultural commodities are land-intensive goods, in which a higher relative land endowment implies larger interstate trade. Nursery trade, however, shows a different pattern. Most coefficients on nursery land-labor dissimilarities are negative, meaning a higher relative land endowment implies smaller interstate trade. In other words, greater relative labor endowment implies greater interstate nursery trade. The latter result may arise if nursery production is more labor-intensive than is seed or commodity production.

Interstate Trade Effects of Interest-Group Lobbying

Differences in noxious weed regulations have a scientific basis driven by ecological and climatic variations. Yet some regulatory dissimilarity might be attributable to lobbying; if so, trade distortions might be avoided, enhancing trade flows and welfare. From the decomposition of L^*_{ij} in Equation (2), we derive an interest group's lobbying effect on interstate trade as:

$$\text{(11)} \quad Contribution = \frac{\partial Q_{ij}}{\partial \hat{L}^*_{ij}} \times \left(-\frac{\partial \hat{L}^*_{ij}}{\partial \boldsymbol{\omega}_-} + \frac{\partial \hat{L}^*_{ij}}{\partial \boldsymbol{\omega}_+} \right) \times \frac{\overline{-\boldsymbol{\omega}_- + \boldsymbol{\omega}_+}}{\overline{Q_{ij}}}$$

Table 4 presents such lobbying contributions in those cases in which lobbying effect L^*_{ij} was statistically significant. Statistically insignificant contributions are reported as zeros. A given contribution can be interpreted as the interstate trade change induced by setting the respective lobbying influence to zero. Consistent with the Equation (2) estimates from Min et al. (2008), the seed-industry lobby uses support for greater congruence in NXWSP and NXW lists as a way of promoting interstate seed, nursery plant, and agricultural commodity trade. Seed lobbies affect nursery trade more than they do seed or commodity trade. In particular, they enhance interstate nursery trade by 0.038%, that is by approximately \$2 million in per-annum trade volume.

Recall that consumer lobbies reveal a preference for ecosystem preservation over food price reductions. The consumer lobby unsurprisingly has—by way of reducing NXWSP congruence—a primarily a negative impact on interstate seed, nursery, and commodity trade, ranging from –0.315% to –2.302% (Table 4). They also have small interstate trade effects through the NXW lists. The effect through NXWSP congruence reduction translates into an annual decline of up to, respectively, \$115

Table 4. Interest Groups' Lobbying Effects on Interstate Trade

	Model I		Model III	
	Seed Trade 2002 OL02NXWSP	Seed Trade 1997 OL97NXWSP	Nursery Trade 2002 OL02NXW	Nursery Trade 1997 OL97NXW
Seed producer lobby	0	0	0.038%	0
Consumer lobby	–1.084%	–2.302%	–1.320%	0.013%
Commodity producer lobby	–0.870%	0	0.119%	0.096%
	Model II			
	Seed Trade 2002		Seed Trade 1997	
	OL02NXWSP	OL02NXW	OL97NXWSP	OL97NXW
Seed producer lobby	0	0.007%	0	0
Consumer lobby	–0.946%	–0.494%	–1.889%	0.025%
Commodity producer lobby	–0.759%	0.028%	0	0.179%
	Model IV			
	Nursery Trade 2002		Nursery Trade 1997	
	OL02NXWSP	OL02NXW	OL97NXWSP	OL97NXW
Seed producer lobby	0	0.036%	0	0
Consumer lobby	–0.315%	–1.227%	–1.068%	0.004%
Commodity producer lobby	–0.396%	0.111%	0	0.027%
	Model V			
	Commodity Trade 2002		Commodity Trade 1997	
	OL02NXWSP	OL02NXW	OL97NXWSP	OL97NXW
Seed producer lobby	0	0.005%	0	0
Consumer lobby	–1.756%	–0.346%	–2.192%	0.015%
Commodity producer lobby	–1.410%	0.020%	0	0.110%

million, $13 million, and $1.1 billion in interstate seed, nursery, and commodity trade.

Commodity producer lobbying has contributed, in a mixed way, to small increases in seed and nursery trade by way of its impact on NXW congruence. However, commodity lobbying reduces NXWSP congruence and, thus, significantly reduces interstate seed, nursery, and commodity trade. The commodity trade effect, which is the most prominent, may arise from commodity producer preference for agronomic protection, for example through the use of locally grown seeds. Commodity producer lobbying impaired interstate seed and commodity trade by approximately $44 and $705 million, respectively, in 2002.

Summary and Conclusions

We have investigated noxious weed regulations' impacts on interstate seed, nursery, and agricultural commodity trade and explored trade distortions arising from interest-group lobbying. Estimable trade relationships, in the form of a gravity model, are specified for each state's net trade with each other state in each of the three goods categories.

Interstate trade data in 1997 and 2002 are taken from the Commodity Flow Surveys of the U.S. Department of Transportation organized by origin and destination states. We compiled all 48 contiguous states' noxious weed seed and noxious weed lists in each of those 2 years together with ecological, environmental, and demand characteristics. We address three major econometric issues in the estimation of the interstate trade equation: endogeneity of regulatory congruence, dependent-variable censoring, and spatial error dependency. An instrumental-variable, spatial autoregressive Tobit model—using a modified EM algorithm—is used to obtain consistent parameter estimates. Fitted regulatory congruences from the first stage enable second-stage estimation of each interest group's interstate trade contribution.

Results indicate that regulatory congruence has a positive and significant effect on interstate trade flow. The greater the regulatory similarity between two states, the greater their interstate trade in every product category. Interest-group lobbying impairs interstate trade. Some of the cross-state weed regulation differences responsible for such impairment are legitimate consequences of ecological differences and serve to protect local environments. Other differences appear to be consequences of interest-group lobbying. Although seed lobbies promote regulatory similarity, commodity and consumer lobbies promote dissimilarity, distorting trade.

Agronomic and ecosystem lobby interests are generally legitimate. Price-enhancement interests are, however, inconsistent with Section 436 of the U.S. Plant Protection Act. More seriously, they likely are inconsistent as well with Article I, Sections 8 and 9, of the U.S. Constitution prohibiting restraint of interstate commerce. Eliminating trade-distorting lobbying would enhance interstate trade by up to $1.1 billion per year, a gain of nearly 2% over present levels. Encouraging greater weed scientist and biologist participation in county and state noxious weed boards—empowered with deciding which plant species are noxious weeds—would go some way toward reducing these distortions.

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