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Abstract

This study examines wine trade in the United States to assess the impact of higher energy costs on the average distance of world and U.S. regional wine shipments, or wine miles, to U.S. markets. To examine this issue we calibrate a spatial equilibrium model of the U.S. wine industry. The model accounts for (i) consumer preferences for variety, (ii) monopolistic-competition/increasing-returns in the production of differentiated wine products, and (iii) transportation costs. Wine production areas are grouped into nine U.S. and seven world producing regions. U.S. markets are grouped into the 50 States plus the District of Columbia. Results indicate that U.S. consumers are willing to pay substantial transportation costs in order to consume a wide variety of wines from premier U.S. and world wine growing regions. As increasing energy costs drive up the price of freight services, wine mile impacts are limited by the degree of regional product differentiation in U.S. and world producing regions.

Introduction

Food and beverage related energy consumption represents a large and apparently growing share of the total U.S. annual energy budget (Pimental et al., 2007; Hirst, 1974). Several studies have examined potential benefits, including energy savings, of an increased reliance on local food systems to accommodate local food demand (e.g., Hinrichs, 2003; Feenstra, 1997) and the resulting food mile reductions realized by this increased reliance (e.g., Pirog et al., 2001; Weber

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[1] *The views expressed in this paper are those of the authors and do not represent the opinions of the U.S. Department of Agriculture.*

and Matthews, 2008). This paper examines the U.S. wine industry as a case study to consider the food miles issue.

A wine industry case study highlights consumer issues concerning the viability of realizing substantial reductions in food miles in the U.S. food system. More than most industries, the wine industry is defined by its premier growing regions. While it is feasible to grow wine grapes in many areas throughout the world, the growing regions that possess the ideal combinations of climate, precipitation, soil attributes and topography suitable for consistently producing high quality wine grapes is a considerably smaller area. Even so, wine is consumed throughout the world and the premier wine growing regions ship their products to all major markets worldwide. The United States is the world's fourth largest wine producer and U.S. wine production has been increasing. Although the industry has also seen its exports grow, a vast majority of U.S. wine is still consumed in the country and the United States remains a net importer of wine. California is home to almost half of all the U.S. wineries and the region that supplies about 95 percent of all domestically-grown grapes crushed for wine. Washington, New York, and Oregon together account for approximately 20 percent of the wineries and about 4 percent of the total grapes crushed for wine each year. Several new wine growing regions in the United States have emerged over the past years and have posted substantial gains in wineries and in grape acreage, but still represent a small share of the domestic supply. To achieve substantial reductions in wine miles through increases in purchases from local sources, all regions east of the pacific coast States would need to greatly expand their existing wine industry capacity. How receptive are consumers to this outcome?

To examine this issue we calibrate a spatial equilibrium model of the U.S. wine industry. Using published and estimated wine industry data from 1997 and 2002 and wine shipment data from the Department of Transportation, we estimate market clearing trade flows. Technology and behavioral parameters are obtained by reconciling industry data to our hypothesized model of wine market structure. We then re-estimate spatial equilibrium under alternative energy market assumptions and examine the outcomes with deference to the average wine mile shipments of world and U.S. regional wines to U.S. wine markets.

The paper is organized as follows. Section I presents an overview of the U.S. wine industry and wine trade in the United States to assess the capacity of accommodating a reduction in wine miles. This is followed in section II by a brief discussion of the salient research explaining intra-industry trade—overlapping trade of similar goods between countries or between sub-national regions—and presentation of a framework for a study of the U.S. wine industry. Section III presents the empirical model and the approach for a numerical calibration. In section IV, the baseline 1997 and 2002 equilibrium trade flow results and model parameter estimates are presented along with alternative estimates based on more price sensitive behavioral assumptions. Next, an energy induced trade tariff is examined and a new spatial equilibrium is computed. Results are compared to the baseline outcome and distributional impacts across world and U.S. wine producing regions are considered. The paper concludes with discussion of implications for U.S. regional wine producing regions and for U.S. wine consumers. An appendix describes data sources and model calibration.

I. U.S. Wine Industry Overview

The U.S. wine industry is the leader among New World wine producers.[2] Mostly concentrated in California, the wine industry is evolving, experiencing rapid production growth and the proliferation of many new wineries in recent years. As recently as 2007, there were over 4700 producing wineries in the country, more than double the number that existed in 1995, based on

[2] Producers of wine outside the traditional wine-growing areas of Europe, in particular comprised of Argentina, Australia, Canada, Chile, New Zealand, South Africa, Mexico, and the United States.

U.S. Department of Treasury's Alcohol and Tobacco Tax and Trade Bureau (TTB) data presented in the Wine America website. Heightened positive publicity during the 1990s surrounding the health benefits of moderate red wine consumption, along with gains in premium quality domestic wines, has fueled the growth in demand for U.S. wines here and abroad. While this growth in demand has led to expanding domestic production, the United States continues to gain presence in the world import market for wine.

Producing about 8 percent of the world's wine, the United States is the world's fourth largest wine producer, next to Old World wine leaders—France, Italy, and Spain (FAOSTAT). Even with a large production base, the United States remains a net importer of wine, sourcing about half the volume of foreign wines from the top three Old World producers and also a substantial share from New World producers. U.S. imports grew at an average annual rate of 8 percent since the 1990s, tripling in volume to 227.6 million gallons in 2007 (based on data from U.S. Department of Commerce, U.S. Census Bureau). Viewed from a global perspective, the United States has evolved as the third largest market for wine, importing 9 percent of the world's wines and surpassing import volumes in France, Russia, and Germany, once bigger markets for foreign wines and countries that are mostly heavier consumers of wine.

With wine imports growing in the United States, sourcing of product is shifting from Old World European producers to New World producers. Combined imports from Australia, Argentina, Chile, New Zealand, the Republic of South Africa, and Canada now account for over 40 percent of all the foreign wines marketed in the United States, up from only 6 percent in 1990. This shift in import market share indicates a growing preference in the United States for New World wines which offer affordable high-quality table wines that are often variety specific and present consistent taste across different vintages. Old World wines present more mystery to American consumers because the wines are often blends of different varieties of grapes, require aging to reach full potential, and sold with a geographic indicator (Goodhue, Green, Heien, and Martin). U.S. wine imports from Old World European countries continue to increase and hold a major share of total import volume. However, the competitive position of European-produced wines in the U.S. market has diminished with European shipments accounting for 56 percent of total imports in 2007, down from 90 percent.

Although small relative to imports, U.S. wine exports have also shown remarkable growth since the early 1990s. The move toward more use of high-end wine varieties enabled the domestic wine industry, especially in California, to offer more premium quality wine, and this has helped U.S. wines earn more international recognition. U.S. wine exports has increased in volume by almost five folds between 1990 and 2007, setting a record of 109.9 million gallons and valued at $872 million, also at an all-time high. U.S. wine exports is seventh largest in the world trailing international shipments from Italy, France, Spain, Australia, Chile, and South Africa in 2005 (FAOSTAT). The U.S. wine industry is slowly gaining share of the international market with export volume representing between 4 and 5 percent of world total, up from 2 percent in the early 1990s. More than three fourths the volume of U.S. wine exports are sold in the United Kingdom, Canada, Italy, Germany, and Japan.

Despite strong international demand, a vast majority of the wines produced in the United States are consumed domestically. Wine is a high-value by-product of grapes, the highest valued fruit crop in the United States. Due to high transport cost for grapes, wine production in the United States generally occurs where grapes are produced. Most wine producers in the United States grow their own grapes, but the very large wineries typically would have a contract with growers to buy their grapes.

California holds a distant lead in U.S. wine production. Wine grape acreage in California grew over 40 percent since 1990 to 471,887 acres in 2007. Of that total, an estimated 94 percent was productive. The top varieties of wine grapes in 2007, based on crush figures reported by the California Department of Food and Agriculture, include Cabernet Sauvignon, Zinfandel, Merlot, Syrah, and Pinot Noir for red varieties, and Chardonnay, French Colombard, Sauvignon Blanc, and Chenin Blanc among the white varieties. The total crush for these top nine varieties statewide increased from 1.5 million tons in 1990 to 2.5 million tons in 2007. Chardonnay, by far, continue to be the most produced wine grape in California, accounting for 20 percent of wine grape bearing acreage and 16 percent of total crushed volume in 2007. However, as demand for red wines has grown, there has been more rapid acreage expansion for the top red varieties, especially for Cabernet Sauvignon and Merlot since the early-1990s. Acreage for French Colombard and Chenin Blanc has declined throughout the 1990s and into the new century as production regions in California's North and Central Coast shifted more acreage to premium red varieties. French Colombard and Chenin Blanc are now mostly produced in the inland regions and are typically used for making low-priced jug wines (Volpe, Green, Heien, and Howitt).

A compilation of TTB monthly state-level production data shows that California's production of bottled wines (includes still wines and effervescent wines) rose 36 percent from 1997 to 469.9 million gallons in 2006, accounting for 87 percent of the U.S. total. Current production levels are met by approximately 2,025 producing wineries in the State of California, more than double the number that existed in 1995.

Industry expansion is also occurring in other parts of the country. The number of States with reported wineries has increased from 34 in 1975 to 47 in 1997. Today, wineries may be found in 50 States across the country and nearly 60 percent of these wineries are established outside of

California. Many of these wineries are small, family owned enterprises that market locally and promote rural tourism by offering wine tours and wine tasting.

Even with the exclusion of California, the western region of the country leads in U.S. wine production, making up about 3 percent of total bottled wine production and 20 percent of the wineries. The rapid growth in this region, excluding California, may be reflected by the increase in the number of wineries by more than three folds from 1995 to 2007 and the doubling of bottled wine volume from 1997. Winery numbers grew very strong across the region but remain small for several of the States in the region. Washington and Oregon together produce 4 percent of all the U.S. grapes crushed for wine and from within the western region, excluding California, the two States account for 75 percent of the winery establishments and over 90 percent of production volume. Winery numbers more than doubled in Oregon and increased almost five fold in Washington. Both these States have substantial gains in grape bearing acreage, with emphasis on premium wine grape varieties. Washington ranks third in U.S. bottled wine production accounting for about 3 percent of total volume while Oregon stands in as fourth, producing less than 1 percent.

The Northeast is the second biggest region in the country for bottled wine production, producing about 7 percent of total volume and housing 11 percent of all the wineries. The industry is heavily concentrated in the State of New York with about 95 percent of the region's production and almost half the number of wineries in the region. New York has over 30,000 acres of grapes yielding over 150,000 tons a year. Over 20 percent of the State's annual grape crop is crushed for wine production while the bulk of the harvest is destined for the juice processing sector. New York ranks second in U.S. wine production, accounting for about 7 percent of total volume of bottled wine produced annually. Production within the State only grew 2 percent from 1997 to 2006 but gains in the number of wineries were more significant. New York accounts for nearly half the number of all the wineries in the Northeast region. Similar to the Western region, the number of wineries rose more sharply in most other parts of the region that have far less of these establishments.

Wine production in the Midwest and South regions each account for one percent of U.S. bottled wine production. Wine production in the South region grew about 70 percent between 1997 and 2006 and in the Midwest, production rose about 40 percent. There are now over 600 producing wineries in each of these regions, exceeding those in the Northeast. Back in 1995, the Northeast had 65 more wineries than the South and 55 more wineries than the Midwest. Wineries are reported in 12 of the Midwest States and 16 of the southern U.S. states. The number of wineries in these States, except one (Mississippi in the South region) grew substantially since 1995. Michigan and Ohio together account for over 35 percent each of the midwest region's wine production and wineries. In the South, Virginia has the most number of wineries and the largest production of grapes crushed for wine. However, wine production data from TTB indicate Florida and Texas as larger producers. As with the other regions, many of the wineries are small producers who concentrate on rural tourism for the majority of their sales.

II. A Framework to Examine the U.S. Wine Industry

Intra-industry trade—overlapping trade of the same or very similar goods between countries or between sub-national regions—is widely observed in the trade statistics of numerous industries, from auto's to wine, to home furnishings, to name a few. Theoretical models that explain intra-industry trade are well established. Helpman (1999) reviews this literature pertaining to international trade, and Krugman (1998) reviews the economic geography literature. There has been little application of these models in empirical research. The empirical model most often employed to explain patterns of intra-industry trade has been the gravity equation (Isard, 1998).

Many variants of the gravity equation exist, but the core parameters characterizing these variants are the relative sizes of the supply and demand markets in the trading regions (e.g., income, population, industry output, personal consumption), and the 'distance' products must travel between buyer and seller. A gravity equation is used to assign unobserved trade flows consistent with known control totals, such as regional production and regional consumption, or to explain observed trade flows in terms of the gravity parameters. In either case, once parameters are assigned, the gravity model predicts that a spatial equilibrium in the trade of industry products is achieved by the minimum impedance in the transport of product, where impedance is defined by the size and distance parameters.

Several economic explanations of the gravity equation have been proposed. Anderson (1979) derives the gravity equation from the properties of an expenditure system with a hypothesis that products are differentiated by place of origin. Bergstrand (1989) shows how the gravity equation fits in with the increasing returns, monopolistic competition models of intra-industry trade proposed by Krugman (1991) and Helpman (1987). Economic properties of these approaches have been tested at the macro level. Bergstrand examines sector level trade data to test factor intensity properties of international trading partners. Hummels and Levinsohn (1995) examine volume of total trade and the share of intra-industry trade between countries to test economic properties of the monopolistic competition model for international trade. Noting that the reduced form empirical equations of this model resembles a gravity equation; their research findings were inconclusive, noting that several unrelated models of trade were effective in explaining bilateral trade flows.

At the industry level, gravity equation studies of interregional trade have not been closely linked to economic foundations such as derived demand and industry supply expressions. For example, Lindall, et. al. (2006) estimate NAICS based interregional industry trade between U.S. States using industry specific market size parameters and an index of transportation impedances between all potential interregional bilateral transactions. By constraining the calibration with a set of regional out-flow and in-flow control totals that are exogenously estimated (the doubly constrained gravity equation), a unique set of log-linear coefficients to the 'size' and 'distance' parameters are calibrated. Although this approach produces a complete system of interregional trade, it is neither informed by, nor directly informs the measurement of behavioral supply and demand parameters which limit the ability to conduct policy experiments.

Our approach for the study of the U.S. wine industry is to derive a system of supply, demand, and market clearing equations that are calibrated to detailed industry statistics of the wine industry. Trade flows are estimated by a gravity type equation derived from a monopolistic-competition/increasing-returns model with shipping costs for facilitating interregional trade. By deriving an explicit equilibrium system of equations, this data intensive approach allows for extensive use of wine industry data to inform the calibration model parameters.

To start, consider a national economy that is comprised of R distinct regions. Following the monopolistic competition framework of Dixit and Stiglitz (1979), let each regional household, r Є R, derive utility , u_r, from consumption of a numeraire good, $x_{0,r}$, representing the aggregation of all non-wine commodities available for consumption, and from consumption of a variety of wines. Households maximize utility subject to an expenditure budget, I_r:

1) $$u_r = U(x_{0,r}, y_r)$$

2) $$x_{0,r} + q_r y_r = I_r$$

3) $$y_r = \Big(\sum_{e \in E} \alpha_{e,r}^{1/\sigma} x_{e,r}^{(\sigma-1)/\sigma}\Big)^{\sigma/(\sigma-1)} \qquad where \sum_e \alpha_{e,r} = 1$$

4) $$q_r = \Big(\sum_{e \in E} \alpha_{e,r}\, p_{e,r}^{(1-\sigma)}\Big)^{1/(1-\sigma)}$$

where $x_{e,r}$ denotes region r demand for wines from establishment e. Assume U is homothetic in its arguments. Maximization of (1) subject to (2) leads to regional wine expenditure budgets:

5) $$q_r y_r = I_r s(q_r) = M_r \ ,$$

where $0 < s(q_r) < 1$ is a wine budget share equation with a price elasticity less than one and potentially negative. Equation (3) specifies a constant elasticity of substitution, σ, between any wine variety pairs. The $\alpha_{e,r}$ expressions measure household capacity to gain utility from the use of wine variety 'e'. Maximization of (3) conditional on (5) leads to regional household demand expressions for each of the wine varieties. An interregional demand expression is obtained through aggregation of the establishment demand expressions[3]:

6) $$x_{s,r} = \sum_{e \in s} x_{e,r} = \frac{n_s \alpha_{s,r} M_r}{p_{s,r}^{\sigma} \bullet \sum_{s \in S} (n_s \alpha_{S,r} p_{s,r}^{1-\sigma})},$$

where n_s denotes the number of wine establishments in region s and $p_{s,r}$ is the price paid in region r for wines from region s.

Each establishment sells a differentiated wine product, X_e for e=1,…,E, using the same increasing returns technology and with equal access to the same production factors: [4]

7) $$l_e = \beta_0 + \beta_1 X_e,$$

where X_e is total establishment output, l_e is total wine production inputs, β_0 is the fixed input requirement, and β_1 is the variable input requirement per unit of output. The wine industry faces a downward sloping demand for their products and firms assume their decisions do not affect decisions of other firms. The variable factor inputs are mobile so all establishments pay the same rent per unit of input. Free entry of new establishments eliminates excess profits and optimal establishment output is (see derivation on page 488-89 in Krugman, 1991):

[3] This aggregation is facilitated by the assumption that preferences are uniform for varieties within a selling region.
[4] Technology and consumer preferences push the wine industry towards a uniform scale of production for each differentiated wine establishment.

8) $$X_e^* = \frac{\beta_0(\sigma - 1)}{\beta_1}$$

There are S regions selling wine products to the R regional households. Wine shipments require freight services at a cost of γ per ton-hours of service between s and r:

9) $$p_{s,r} = p_s(1 + \gamma h_{s,r}) \text{ where } 0 > d > -1$$

III. Spatial Equilibrium Model and Empirical Approach

To determine how well this framework explains spatial equilibrium in the U.S. wine industry, the model is calibrated for 1997 and 2002 market years. To facilitate the calibration of key demand parameters, divide both numerator and denominator in (6) by the total number of establishments across all selling regions to produce the share expressions, $\eta_s = n_s/N$:

10) $$x_{s,r} = \eta_s \alpha_{s,r}(M_r / \overline{P}_r) \times \left(\frac{p_{s,r}}{\overline{P}_r}\right)^{-\sigma}, \quad \overline{P}_r = \sum_{s \in S}\left(\eta_s \alpha_{s,r} p_{s,r}\right)$$

where, by assumption:

11) $$\sum_s \eta_s \alpha_{s,r} = 1$$

To the extent that establishments adopt a uniform scale of production across regions, η_s is approximated by the regional share of total wine sales to U.S. households.

Regional wine production is predetermined, as are Regional household wine expenditures. Market clearing conditions are:

12) $$X_s = \sum_{e \in s} X_e = \sum_r x_{s,r}$$

13) $$M_r = \sum_s p_{s,r} x_{s,r}$$

Define the 'standardized unit' as the national average quantity of wine selling for \$1. Allowing the quantity of a \$1 unit of wine to vary by selling region (contrary to the long-run spatial equilibrium outcome), the price equation for a standardized unit is:

14) $$p_{s,r} = \rho_S(1+\gamma h_{s,r}),$$

where ρ_s is the seller price per unit of wine sales in region s, which has an expected value of one. The cumulative transportation costs for all bilateral transactions must add up to the observed national wine industry freight service payments, including international shipping charges:

15) $$\sum_s \sum_r (p_{s,r} - \rho_s)x_{s,r} = T$$

Commodity flow data and wine industry statistics, however incomplete they may be, can be incorporated to narrow the bounds of feasible solutions to this system.[5] This is done by including the appropriate accounting constraints.

Gaps in the available data sets leave this model (equations 10 to 15) under determined, such that the $\alpha_{s,r}$, ρ_s and γ parameters must be solved numerically. The model describes a wine industry that tends towards a long-run spatial equilibrium where producer prices become uniform across regions ($\rho_s = \rho = 1$) and the accumulation of information pushes the consumption parameters towards symmetry ($\alpha_{s,r} = \alpha$ for all s,r). Therefore, we seek the value of γ that provides the minimum weighted least squared deviation from this long-run outcome and is consistent with the short-run equilibrium described in (10) to (15):[6]

16) $$\underset{\gamma}{Min} \sum_s \left(\eta_s[\rho_s(\gamma)-1]^2\right) + \sum_s \sum_r \left(\eta_s[\alpha_{s,r}(\gamma)-1]^2\right)$$

[5] For example, a 1998 publication of the Texas Wine Institute reports that 95-percent of Texas wine industry sales in 1997 were within the State. The 2002 Commodity Flow Survey reports mean and standard error estimates for the average distance of wine shipments by State of origin.

[6] Treyz and Bumgardner (2000), after imposing symmetry to eliminate the α terms, apply an objective function similar to this to estimate short-run equilibrium trade flows in Services for the State of Michigan in which ε_s and γ determine a non-pecuniary price wedge between buying and selling regions.

Model aggregation of wine producing regions is depicted in figure 1. Due to the variation in production scale of wine producing regions, the California industry is grouped into four regions, while regions outside of California are Statewide (Oregon, Washington, New York) or multi-State aggregations. Imported wines are country totals for major wine producing countries and an aggregation of country data for all other countries shipping wine to U.S. market. Markets for wine in the U.S. are represented by each of the U.S. States plus D.C. Data sources and model calibration procedures are presented in the appendix.

IV Results

{Data for a 2002 calibration is currently being compiled, and those results are forthcoming}

As a basis for comparison, we first carry out a control model that simply calibrates the minimum combined ton/hours of freight services necessary to meet all observed regional consumption from the observed sales to the U.S. market from the 16 model regions. This model assumes wine is a non-differentiated industry that minimizes total distribution costs. Figure 2 summarizes key control results for the U.S. market and for two regional markets—California and New Jersey.[7] For the nation, the control scenario indicates that wine shipments average 2,500 miles nationally. The California market is served entirely by wines from within the State while the New Jersey market served entirely by wine shipments from France. Looking at the destinations of wines from California and from France, we find that roughly half of California wines are shipped to the four largest markets outside of the northeast region, while wines of France are shipped exclusively to four mid-Atlantic coastal States.[8]

[7] The California market is located in the heart of the major domestic wine producing regions while New Jersey is in close proximity to the largest port of entry for international wine shipments to the U.S.

[8] While wines from France enter through several U.S. ports, the model uses a single weighted average shipping time across all transportation modes and ports of entry, as computed for each U.S. State (see appendix).

Next, the monopolistic completion model was estimated under two scenarios. Scenario I (base) uses a regional price elasticity of 1.81, as derived from the U.S. wine industry data and equations (7) and (8). Scenario II (price sensitive) increases the price elasticity parameter to 3.31. Figure 3 provides the same details presented in figure 2 when the control model is replaced by the monopolistic competition model under the base scenario. Instead of sourcing their wines exclusively from one or a few least cost sources, figure 3 shows how regional consumption draws from a wide variety of sources. Three quarters of the wine marketed in California come from within the State, with an additional 15-percent sourced from France and Italy. A non-negligible share is also sourced from Washington State. New Jersey sources a slightly lower share of its wines from California (68 percent) and a slightly higher share of its wines from their 3rd and 4th largest sources—U.S. east and Italy. Figure 3 also depicts the re-estimation of U.S. shipping destinations for wines from California and France. In contrast to the control model solution (figure 2), estimates of destinations for wines of both regions are far more diverse, with the top four destinations receiving 42 and 38 percent to total shipments from these top two producing regions. Overall, the national average wine miles are nearly 15-percent higher in comparison to the undifferentiated (least cost) control model. With an estimated 8.6 million tons of wine traveling on the U.S. freight system in 1997,[9] these additional wine miles represents a substantial cost in freight services incurred to accommodate household preferences for a variety of regional wines. The overall cost in freight services to distribute wines to the U.S. markets exceeded $450 million in 1997 (see appendix).

A more detailed summary of key results concerning wine producing regions are reported in table 1, where the 16 wine production regions of the model are reported for 7-regional groupings. Section A of table 1 summarizes the value of shipments to the U.S. market by wine production

[9] The 1997 Commodity flow survey indicates 7.2 million tons of domestically produced wine was shipped in the U.S. Assuming imported wines added an additional 20 percent; the total is about 8.6 million tons.

regions. The row reporting shipments to all U.S. destinations represents the total value of wines shipped to U.S. markets, reported in 1997 producer prices. Nearly 70 percent of this total comes from California, with an additional 18.3 percent from France, Italy, and Spain. Overall, the model predicts that around 80 percent (producer value) of the wines shipped to U.S. markets go to areas outside of the State/Country of origin. However, notable among these results are the very small share of wines from 'Other U.S. States' that are sold outside of their home markets. Under the price sensitive scenario, a slightly smaller share of the California wine production leaves the State. The top three destinations for wines shipped outside of their home market are New York, Florida, and California, so after excluding the California wines shipped within the State, it still ranks third in destinations for wine shipments to U.S. markets. These three markets attract about one quarter of all wine shipped outside the State/Country of production. While this one-quarter figure is also true for wines shipped from California to it's top three domestic destinations, the wines from other U.S. and world regions show substantially higher concentrations going to their three top destinations, ranging from around one third for the three international regions to 38 percent for the New York/Oregon/Washington regional grouping. Under the more price sensitive scenario, the difference between California and the other regions is far less pronounced.

Sections B and C of table 1 report the same analysis as section A, but with the unit of measurement changing to shipping distance (B) and shipping costs (C). Whereas the total value of shipments and total shipping costs to U.S. markets were exogenous in the model, total shipping distances were not. Model estimates of total distance shipped for wine sold in U.S. markets averaged 2,861 miles. Under the price sensitive scenario, this estimate decreased by 24 miles, implying roughly 200-million less annual ton-miles shipped for wine destined to U.S. markets. Shipments from Argentina, Australia, and Chile averaged over 9,000 miles. Not surprisingly, shipping cost margins from these regions were highest, averaging about 10 percent. Average shipping distance and cost margins for California wines were lower than the overall average;

about 1,800 miles and 3.7 percent respectively. Wines from other U.S. States had considerably lower distance and cost margin averages. Wines shipped to the top three destinations outside of the home markets were shipped an average of over 4,200 miles according to base model forecast. This average falls substantially under the price sensitive scenario, to about 3,600 miles.

The variable in the model estimation that is most responsible for reconciling a consumers' price sensitivity with their preference for wine variety is the $\alpha_{s,r}$ coefficients. In the consumer theory of household production (see Stigler and Becker, 1977), this expression describes the conversion of a standard unit of input (wine) into a measure of output (utility form wine consumption). As a technology (as opposed to taste) parameter, it can be exogenously changed, for example with access to more information about the products attributes. In this context, the results in section D of table 1 report the average household capacity to derive utility from the purchase of wines from each of the producing regions—we denote this parameter the household productivity index (HPI). When the averages are reported across all destinations, it is not surprising to find the highest value, 1.6, in the 'Other U.S. States' region, where commodity flow accounting constraints keep larger percentages of wine production within the home market. To reconcile this constraint to the model, households of the home regions are assigned a high HPI, thus keeping the wine products largely in-State. When home market consumers are excluded from this average, the HPI in this region is considerably lower at 0.4. The two California regions exhibit consistently high HPI, as does the Washington, Oregon, New York region except for outside market consumers under the price sensitive scenario.

Table 2 summarizes key findings of the wine consuming regions—all U.S. States—with only the base scenario reported. Total value of shipments into each State are reported in column 1 and are computed by the model calibration. They reflect the exogenous total in-shipments at producer prices and the endogenous transportation margins. They do not reflect retail trade margins. The

California market ($1.9 bil.) is more than double the next largest market (New York at $868 mil.). California also has the smallest estimated percentage of it's wine shipments coming from out-of-State sources, at 26 percent. Other than Texas, estimated at 85 percent, all other States obtain over an estimated 90 percent of their wine from out-of-State sources. Aside from Alaska and Hawaii (both over 4,000 miles), the top five States in terms of average wine in-shipment distances were all New England States; Maine, New Hampshire, Massachusetts, Vermont, and Rhode Island. Excluding in-State shipments, California had the highest average in-shipment distances at 6,275 miles. Average freight costs for in-shipments ranged from a low of 2.6 percent in California to a high of 6.7 percent in New Hampshire. It is worth noting that freight costs are not perfectly correlated with distance. New Hampshire is in the congested New England region and is more reliant on expensive modes of transportation than, for example, Hawaii. Average HPI's are generally uniform across State, particularly when excluding home region shipments.

An Energy Induced Trade Tariff

From the numerical solutions for the γ, ρ_s, and $\alpha_{s,r}$ parameters, we now have a fully determined system of wine market equations. To facilitate policy experiments, we implement the following assumptions; (i) a global energy price spike doubles the price per ton-hour of freight services, (ii) the average fob price for wine changes at the same rate as the price of the numeraire good (dq=0), (iii) regional nominal incomes remain unchanged, and (iv) short-run variable input supply to the wine industry is at a constant elasticity with two scenario's considered—a 'flex' scenario with a 0.4 supply elasticity and a 'rigid' scenario with a 0.04 supply elasticity. Combined with the 'base' and 'price sensitive' scenarios of the model calibration, we consider a total of four policy simulations: base/flex, base/rigid, price-sensitive/flex, and price-sensitive/rigid.

The spatial equilibrium system is comprised of the regional demand (10) and consumer price (14) equations, calibrated alternatively to the base and price-sensitive parameter values. In addition, the monopolistic competitive supply (X_s) and price (p_s) equations are needed:

$$17) \qquad p_s = \frac{\sigma}{\sigma - 1} \beta_1 w_s$$

$$18) \qquad X_s = p_s \times [L_s^0 \times w_s^{\xi} - \beta_0] / \beta_1 \, ,$$

where w_s is the region s local 'rental' rate, L^0_s is the current (pre-policy) region s variable factor input level, and the remaining parameters have already been defined.[10] Equilibrium is attained at the local rent level in which equations 18 and 10 (summed across all States) are equal. After verifying this compiled system replicates the initial spatial equilibrium outcomes, 'base' and 'price sensitive', the final step is to resolve this system under the new energy induced global trade tariff (τ) regime:

$$14t) \qquad p_{s,r} = p_S (1 + \tau\gamma h_{s,r}) \, ,$$

where τ is set to a value of 2.0.

Figure 4 revisits the in-shipment outcomes for California and New Jersey under to new freight tariff regime. The overall reduction in the f.o.b. value of shipments to these two regions is due to the assumption that nominal wine budgets are unchanged while shipping costs have substantially increased. Even so, we find that there is a shift in the sourcing of wines that favor the regions in closer proximity. This result reflects the extent to which regional consumers are willing to trade off their preferences for regional variety for cost savings that can be realized by purchasing fewer wine miles. The bottom panel in the figure reports the overall drop in wine miles by U.S. wine consumers to offset the increased freight costs. Wine mile reductions under the 'base' and 'price sensitive' scenarios were 2.5 and 3.1 percent respectively with implied wine mile price elasticities

[10] This model is compiled by initially setting w_s such that p_s equals the solution to ρ_s from the previously estimated price (equation 15). Then L^0_s is set such that equation 18 replicates the initial regional supply.

of 0.025 and 0.031 respectively. These figures are an effective demonstration of the barriers to realizing substantial food mile savings through policies directed to the products that are know to be highly differentiated by location of production.

Table 3 provides greater detail of the impacts from the freight tariff, where the 16 regions of the model are reported for 7-regional groupings. Average transportation margins across all shipments to U.S. markets rose 4.5 percent in all four scenarios. This increase amounts to slightly less than the trade tariff increase since pre-tariff average transportation margins averaged 4.7 percent. Across production regions the results are uneven. Trade margins increased by less than the tariff in California, Washington, Oregon, and New York, and increased by equal or greater amounts in all other regions. Differences in these results are very similar across all four scenarios.

For average shipping distances, the scenario choice did affect the outcome. Overall, a reduction in average shipping distances ranged between 63 and 89 miles depending on the scenario, which helps to explain why the impact of the trade tariff was less than proportional. Somewhat surprising is the result that the greatest average reductions occurred under the 'base' scenarios as opposed to the price sensitive scenarios. The highest reductions occurred for the 'base/rigid' scenario, where the variable input supply was rigid, so limited the ability of producers to lower prices through wage cost reductions. A possible explanation why a more price sensitive consumer doesn't shorten the average distances as much may be that the initial spatial equilibrium in these scenarios already reflected shorter average shipments, so fewer further opportunities existed. Beyond this, it was already noted that shipping cost changes are largely the same under all scenarios. We have already noted above that distances don't perfectly correlate with shipping costs, so this may also help explain this result.

Nominal regional incomes were pegged and the price of wine assumed to mirror price changes of the numeraire good, so it is not especially interesting that overall wine shipments to U.S. markets decreased. What is interesting is the relative changes across production regions. Imported wines are disproportionately affected by the trade tariff, with shipment values declining an average of 7.5 and 9.9 percent, depending on the scenario. California wine shipment values decline by roughly 3-percent, while shipments from other U.S. regions declined by smaller percentages. This would indicate that California's dominance in both variety offerings and strong household productivity index numbers (the $\alpha_{s,r}$ parameters) are partially offset by the increasing costs of shipping their products to distant markets. This result holds even for the base scenarios, where the regional price elasticities are relatively low. Had regional nominal incomes been assumed to increase slightly, shipments from these emerging U.S. production regions would have grown with declines occurring in shipments to U.S. markets out of California and the import regions.

V Conclusions

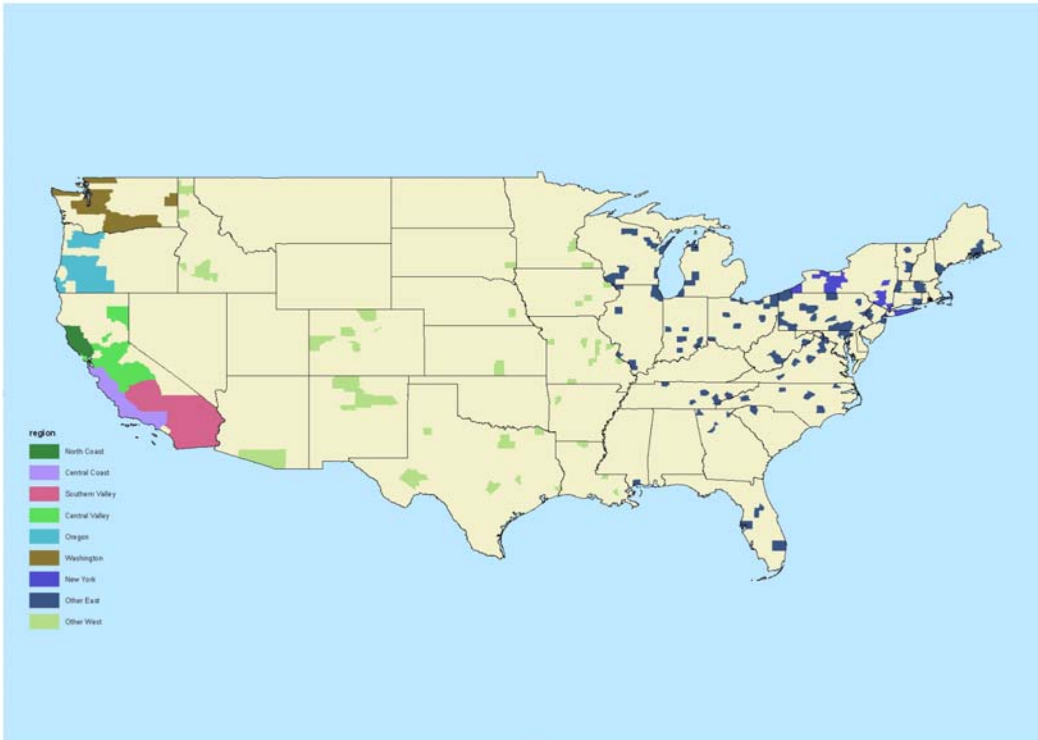
This study used a model of intra-industry trade with market structure assumptions that are consistent with observed features of the wine industry; regionally differentiated products marketed to consumers that value variety and pay substantial shipping charges to obtained wines from around the world. Using publicly available wine industry data, we were able to numerically calibrate the spatial equilibrium system of equations to obtain key behavioral and technology parameters. In doing so, commodity flow statistics where incorporated into the calibration using an efficient information processing criteria that helped inform the estimation of these parameters. By deriving our system of equations from a fully specified economic model, we were able to conduct policy experiments to determine how the spatial equilibrium would adjust to changes in the cost of global freight services.

Both the baseline calibration and the policy scenario analysis provided useful insights about the wine industry. The dominance of the California wine industry in shipping substantial quantities of their products to all U.S. wine markets is shown to be largely driven by a very broad variety of wine products offered, and by higher than average demand parameters that measure the perceived consumption attributes of wines by region of origin. To a lesser extent, these factors helped make numerous international wine regions competitive across all U.S. wine markets, even as these wines required substantially higher freight charges to reach these markets. The silver lining in these findings for the emerging U.S. wine regions is the apparent willingness of U.S. consumers to increase their shares of wine purchase from these emerging regions as shipping costs from all regions increase—particularly at the expense of international wine imports. While such a finding is intuitive, analysis provided in this study demonstrates the extent of this potential shift.

Results from the analysis of an energy induced global tariff on freight services demonstrates the potential barriers to realizing substantial food mile savings through policies directed to the products that are know to be highly differentiated by location of production. Implied wine mile price elasticities, measured from the percentage change in average wine miles brought on by a 100-percent increase in shipping costs, were found to be between 0.025 and 0.031. Consumers may more readily seek local food alternatives for less differentiated foods such as fresh fruits and vegetables when the cost of purchasing food miles increases. But unlike wine, which is far less perishable, supply seasonality's of fresh produce is another form of regional product differentiation that may limit food mile tradeoffs when consumers desire year-round supplies of these products. An analysis of this issue would require an extension of our spatial equilibrium model to capture the seasonality of supply.

Beyond the analysis of the wine industry, this study demonstrates a potentially important use for transportation statistics. Historically, commodity flows data has been viewed as being too limited to inform studies of interregional and intra-industry trade. In this report, the information provided by the commodity flows survey had an important role in informing the numerical calibration of the behavioral and technical parameters of the model. In addition, results from this type of approach can be used as a tool to assess the strengths and limitations of the transportation data.

FIGURE 1: U.S. AND WORLD MODEL REGIONS



WORLD MODEL REGIONS

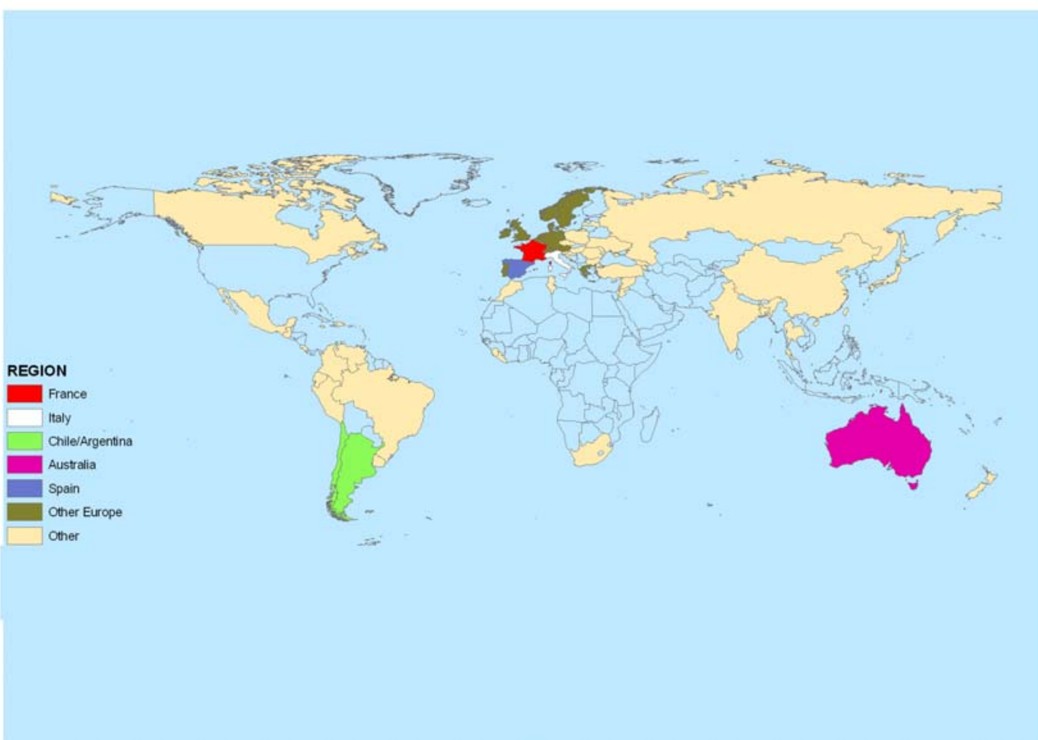


Figure 2:

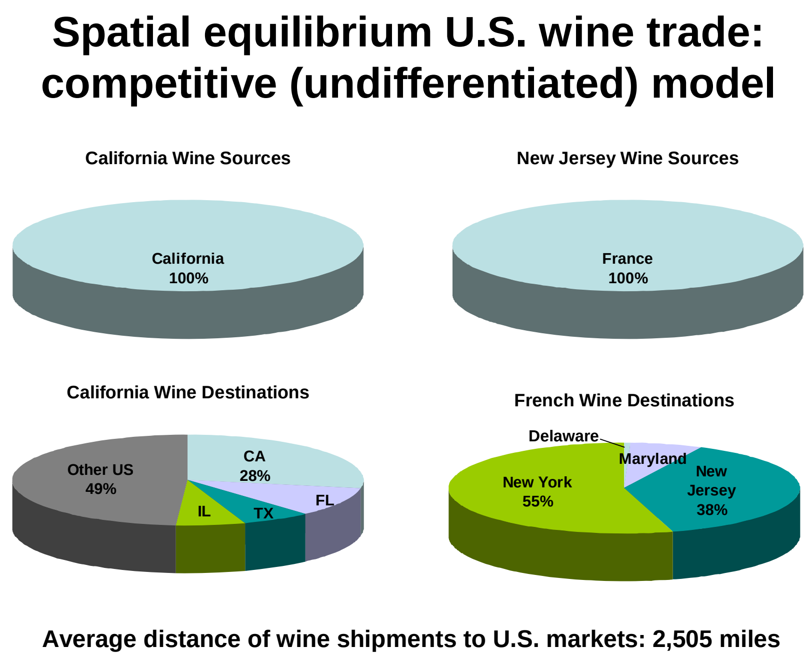


Figure 3:

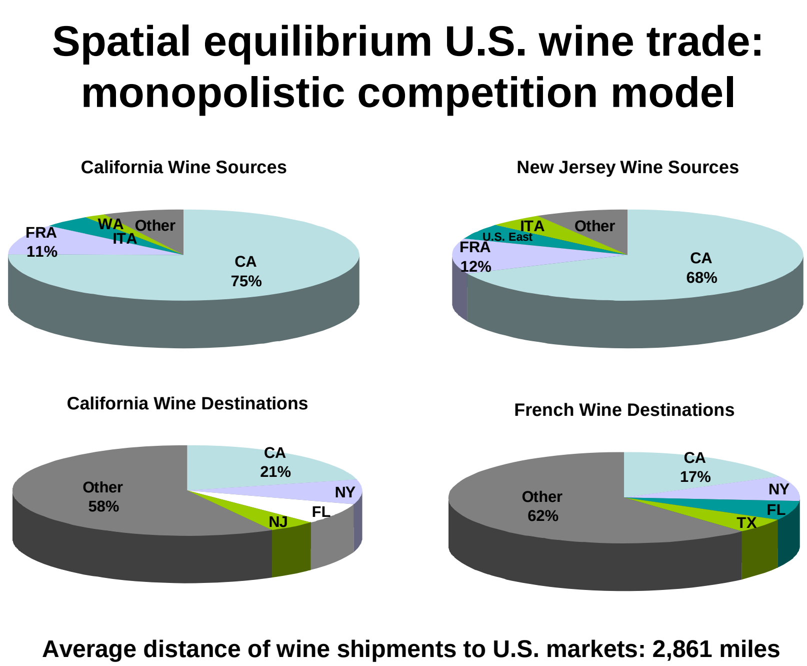
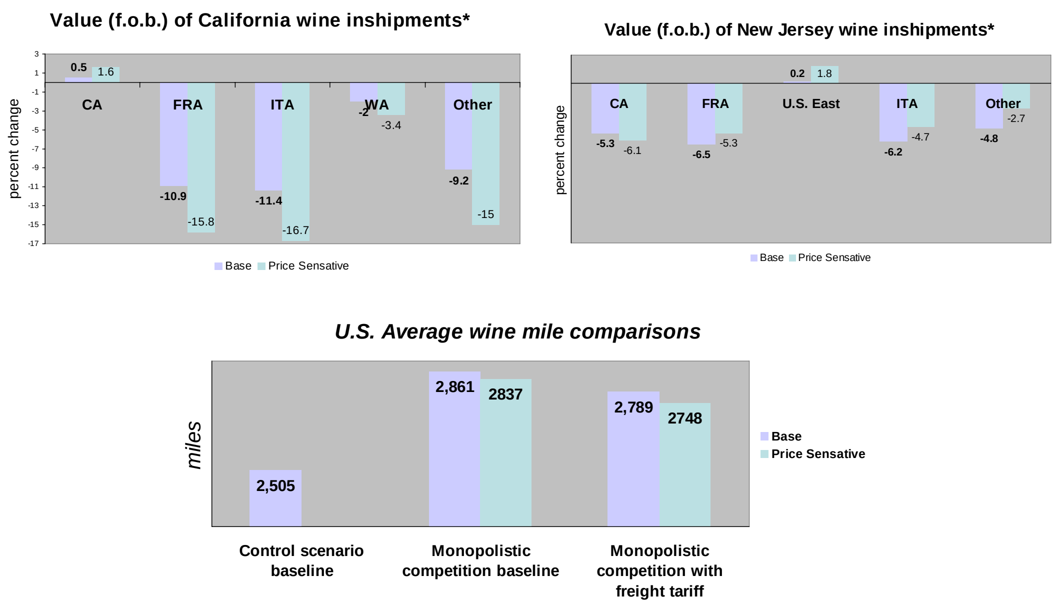


Figure 4:

Trade Impacts of an Energy Induced Worldwide Trade Tariff, 1997



* **Scenario**: variable input supply elasticity: 0.4; regional price elasticity: 1.81; freight service trade tariff rate: 100-percent

Table 1. Model Results: Spatial Equilibrium Wine Trade in the United States by Origin of Production, 1997

	Regional Price Elasticity (σ)	Total	CA, Coastal	CA, Other	WA OR NY	Other U.S. States	France Italy Spain	Argentina Australia Chile	Rest of World
		WINE PRODUCING REGION							
A. Value of shipments		***Value of Wine Shipments ($ million)***							
All U.S. Destinations		9,597	3,491	3,172	356	429	1,756	223	171
All out-of-State/Country destinations	1.81	7,749	2,759	2,507	313	21	1,756	223	171
	3.31	7,664	2,725	2,455	313	21	1756	223	171
Top three U.S. destinations outside of home-market (State abbr.)	1.81	1,920 NY FL CA	735 NY FL NJ	668 NY FL NJ	118 CA FL OR	4 DC UT MT	581 CA NY FL	74 CA NY FL	57 CA NY FL
	3.31	1,873 NY FL NJ	740 NY FL NJ	679 NY FL NJ	101 CA FL OR	5 HI OK UT	507 CA NY FL	65 CA NY FL	49 CA NY FL
B. Distance of shipments		***Average Distance Shipped (Miles)***							
All U.S. Destinations	1.81	2,861	1,830	1,830	1,271	752	6,430	9,237	6,732
	3.31	2,837	1,806	1,797	1,281	762	6,402	9,230	6,710
All out-of-State/Country destinations	1.81	3,465	2,256	2,256	1,427	1,555	6,430	9,237	6,732
	3.31	3,470	2,251	2,256	1,436	1,603	6,402	9,230	6710
Top outside destinations	1.81	4,243	2,766	2,766	1,610	1,423	6,622	9,315	6,901
	3.31	3,597	2,766	2,766	1,567	1,401	6,593	9,282	6,880
C. Cost of shipping		***Average transportation margins (percent of producer price)***							
All U.S. Destinations	1.81	4.7	3.7	3.7	2.6	1.7	8.8	9.8	9.1
	3.31	4.7	3.6	3.6	2.6	1.8	8.9	9.9	9.1
All out-of-State/Country destinations	1.81	5.7	4.5	4.5	2.9	3.4	8.8	9.8	9.1
	3.31	5.7	4.5	4.5	2.9	3.5	8.9	9.9	9.1
Top outside destinations	1.81	6.6	5.3	5.3	3.0	3.2	9.1	9.8	9.3
	3.31	6.0	5.4	5.4	2.9	4.2	9.1	9.9	9.3
D. Household Regional Preferences		***Average Consumer Productivity Index ($\alpha_{s,r}$)***							
All U.S. Destinations	1.81	1.07	1.06	1.06	1.14	1.60	0.97	0.97	0.97
	3.31	1.08	1.07	1.10	1.05	1.72	0.93	0.94	0.93
All outside destinations	1.81	1.02	1.05	1.05	1.01	0.44	0.97	0.97	0.97
	3.31	1.02	1.05	1.07	0.95	0.47	0.93	0.94	0.93

Table 2. Model Results: Spatial Equilibrium Wine Trade in the United States by Destination of Use, 1997								
	In-Shipments		Average Distance (*miles*)		Average Freight Costs (*percent of fob price*)		Average Household Productivity Index ($\alpha_{s,r}$)	
	All Sources (*$mil.*)	Outside Sources (*Percent*)	All Sources	Outside Sources	All Sources	Outside Sources	All Sources	Outside Sources
Alabama	102	100	3,092	3,092	5.5	5.5	1.06	1.06
Alaska	26	100	4,426	4,426	5.1	5.1	0.99	0.99
Arizona	184	91	2,197	2,301	3.6	3.6	1.15	1.02
Arkansas	37	95	2,882	2,999	5.0	5.2	1.01	1.00
California	1,900	26	1,803	6,275	2.6	8.7	1.05	0.89
Colorado	192	91	2,535	2,713	4.3	4.5	1.14	1.02
Connecticut	203	94	3,573	3,758	5.9	6.2	1.02	1.03
Delaware	41	100	3,554	3,554	5.8	5.8	1.00	1.00
Dist. of Columbia	57	100	3,520	3,520	5.9	5.9	1.02	1.02
Florida	740	95	3,489	3,626	5.6	5.8	1.02	1.03
Georgia	227	94	3,185	3,350	5.7	6.0	1.02	1.03
Hawaii	59	100	4,036	4,036	4.6	4.6	1.02	1.02
Idaho	48	95	2,425	2,482	4.2	4.3	1.02	1.00
Illinois	437	94	2,901	3,040	4.7	4.9	1.02	1.03
Indiana	155	94	2,984	3,148	5.2	5.5	1.02	1.02
Iowa	42	95	2,897	3,015	4.9	5.0	1.01	1.00
Kansas	38	95	2,752	2,866	4.5	4.7	1.01	0.99
Kentucky	65	100	3,170	3,170	5.8	5.8	1.03	1.03
Louisiana	107	93	3,080	3,249	4.9	5.1	1.08	1.03
Maine	52	94	3,854	4,043	6.3	6.5	1.01	1.01
Maryland	193	94	3,401	3,588	5.8	6.1	1.02	1.02
Massachusetts	388	94	3,686	3,860	6.0	6.3	1.02	1.03
Michigan	248	94	3,119	3,282	5.5	5.8	1.02	1.03
Minnesota	149	92	3,085	3,283	5.2	5.5	1.11	1.03
Mississippi	27	94	2,992	3,130	5.3	5.5	0.99	0.99
Missouri	139	92	2,943	3,137	4.8	5.1	1.10	1.03
Montana	29	100	2,632	2,632	4.9	4.9	1.00	1.00
Nebraska	38	95	2,719	2,828	4.6	4.7	1.01	0.99
Nevada	122	100	1,988	1,988	3.3	3.3	1.06	1.06
New Hampshire	80	100	3,799	3,799	6.7	6.7	1.06	1.06
New Jersey	472	94	3,493	3,662	5.8	6.0	1.02	1.03
New Mexico	46	95	2,386	2,475	4.1	4.2	1.02	1.00
New York	868	98	3,590	3,670	6.0	6.2	1.06	1.06
North Carolina	203	94	3,351	3,532	6.1	6.4	1.02	1.03
North Dakota	9	100	2,908	2,908	5.5	5.5	0.99	0.99
Ohio	253	94	3,122	3,292	5.5	5.7	1.02	1.03
Oklahoma	54	100	2,678	2,678	4.6	4.6	1.01	1.01
Oregon	192	99	2,461	2,475	3.7	3.8	1.11	1.11
Pennsylvania	261	94	3,376	3,556	5.9	6.2	1.02	1.03
Rhode Island	54	94	3,657	3,847	5.8	6.1	1.01	1.01
South Carolina	105	94	3,304	3,485	5.9	6.2	1.02	1.02
South Dakota	11	96	2,784	2,868	5.5	5.7	1.00	1.00
Tennessee	107	94	2,999	3,162	5.4	5.7	1.03	1.02
Texas	452	85	2,855	3,232	4.5	5.0	1.46	1.02
Utah	35	100	2,191	2,191	3.6	3.6	1.00	1.00
Vermont	32	94	3,670	3,851	6.6	6.9	1.00	1.00
Virginia	279	94	3,399	3,580	5.9	6.2	1.02	1.03
Washington	296	92	2,682	2,893	3.8	4.1	1.19	1.04
West Virginia	22	94	3,278	3,455	5.9	6.2	1.00	1.00
Wisconsin	165	94	2,961	3,108	5.2	5.4	1.03	1.03
Wyoming	9	100	2,444	2,444	4.5	4.5	1.00	1.00

Table 3. Model Results: Trade Impacts of an Energy Induced Worldwide Trade Tariff by Origin of Production, 1997									
		WINE PRODUCING REGION							
Input Supply Elasticity (ξ_L)	Regional Price Elasticity (σ)	Total	CA, Coastal	CA, Other	WA OR NY	Other U.S. States	France Italy Spain	Argen-tina Australia Chile	Rest of World
		Change in Average Transportation Margins (percent of producer price)							
0.40	1.81	4.5	3.5	3.5	2.5	1.8	8.8	10.0	9.3
	3.31	4.5	3.6	3.6	2.4	1.7	8.8	9.8	9.1
0.04	1.81	4.5	3.5	3.5	2.4	1.7	8.8	9.8	9.1
	3.31	4.5	3.5	3.5	2.4	1.7	8.8	9.9	9.1
		Change in Average Distance Shipped (miles)							
0.40	1.81	-72	-24	-24	-35	-4	-8	-32	-8
	3.31	-63	-24	-24	-33	-4	-8	-27	-7
0.04	1.81	-89	-33	-34	-59	-7	-17	-42	-15
	3.31	-73	-34	-34	-58	-7	-17	-32	-14
		Change in Value of Wine Shipments (percent)							
0.40	1.81	-4.1	-3.1	-3.1	-2.0	-0.7	-8.3	-9.3	-9.3
	3.31	-4.2	-3.3	-3.3	-2.4	-1.4	-7.6	-8.3	-7.8
0.04	1.81	-4.1	-2.9	-2.9	-1.5	-0.1	-8.8	-9.9	-9.1
	3.31	-4.1	-3.3	-3.3	-2.3	-1.2	-7.5	-8.3	-7.8
	3.31	-73	-34	-34	-58	-7	-17	-32	-14

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APPENDIX: Data Sources and Numerical Calibration

The U.S. benchmark input-output accounts provide the most complete accounting of the U.S. wine industry. Released by the Bureau of Economic Analysis (BEA) every five years with a 5-year lag in statistical year coverage, the two most recent publications (BEA, 2008; BEA, 2003) cover the 1997 and 2002 calendar years. Table A.1 summarizes the relevant U.S. wine industry information from this resource, where the wine industry classification is based on the 1997 and 2002 North American Industry Classification System (NAICS), so covers table wine, brandies from grapes, and blending wines. We seek to spatially enhance these national industry accounts from the underlying geographic data these accounts are based on.

U.S. regional wine production and employment data are published in the 1997 and 2002 Census of Manufacturing (COM). Complete establishment counts are published at the County level. Employment and output wine industry data have extensive data suppressions. For employment, data ranges are provided and allow for calculations of preliminary mean and variance estimates of all suppressed data elements. The COM has both an industry and geographic hierarchy. Industry statistics are reported from the 2-digit to the 6-digit NAICS level and for U.S., State, and county totals. Higher level data such as two and three digit NAICS data, or U.S. and State totals, are less likely to be suppressed than are the more detailed industry and county data elements. Taking advantage of this structure, we employ a mathematical programming procedure to reconcile our preliminary estimates of suppressed data elements with all published hierarchical data elements. An example of this approach is found in Canning and Wang (2005).

Wine imports by country of origin are published by the International Trade Division of the U.S. Census Bureau. Specifically, monthly trade statistics by U.S. port district and mode of transportation are summed to their annual totals. International freight impedances are based on bilateral trade data by U.S. port district, international vessel shipping distance tables from the

U.S. Army Corps of Engineers and international airport distance tables developed from the Digital Aeronautical Flight Information File, a product of the National Imagery and Mapping Agency of the U.S. Department of Defense.

Wine exports by State must be netted out to obtain total availability by origin of production. For the major producing States (CA, OR, WA, NY), estimates of each States share of national exports are obtained from Walker (2000). Export data for Texas is reported by the Texas Wine Marketing Research Institute (1998). Remaining unallocated exports are assigned to others States in proportion to State production.

Interregional freight distance and impedance[11] estimates between domestic regions and by transportation mode are obtained from Oak Ridge National Laboratory (http://cta.ornl.gov/transnet/). For international imports, the weighted average impedances from all ports of entry to each U.S. State are added to the estimated impedances from each country to the different ports of entry. This produces a single average impedance estimate between each importing country and each U.S. State. Mean and variance data on the average distance of wine shipments by State of origin are available from an unpublished research data product of the 2002 Commodity Flow Survey (CFS). These data allow for the inclusion of inequality constraints that narrow the bounds of feasible solutions to the model calibration. Regional wine trade publications provide State export statistics and summary geographic information of market sales. To ensure consistency across the different regional accounts, all data is normalized to the Make and Use tables of the 1997 and 2002 U.S. Benchmark Input-Output accounts.

[11] Here, impedance approximates the time and cost of transporting freight between origin and destination—it has a non-linear relationship to the distance between origin and destination.

Regional household wine expenditure data are obtained from the Adams Wine Handbook (1998 and 2003) combined with age based population data from the Census Bureau. These statistics report wine volumes and so are used to allocate national expenditures to States excluding any transportation costs, or the free on board (f.o.b.) value of shipments.

To implement, estimates of the parameters β_0 and β_1 in equation (7) are obtained from wine industry data. Optimal firm size is computed as the product of the median establishment employee size and the median output per employee, and from equation (8) we obtain σ. For each production region, the η_s parameters are set to the regional f.o.b. value share of total wine supply for the U.S. market. Remaining model parameters are drawn directly from the data described above.

Model variables to be solved numerically include ρ_s, $\alpha_{s,r}$ and γ plus composites of these variables. The first two are initialized to a value of 1, which is their hypothesized long-run equilibrium value, while the latter is initialized to a value equal to the national average freight cost margin (4.717 percent) divided by the national average domestic shipping distance for wine reported in the 1997 commodity flows survey. These initial values are then optimally adjusted to satisfy the equality constraints in equations 10 to 16 such that the solution to equation 16 is minimized. The model is implemented with GAMS mathematical programming software (www.gams.com) using the CONOPT3 nonlinear programming solver. The model programming code is available from the authors upon request.

Appendix Table A.1—U.S. Wine Industry Statistics, 1997 1/				
Account	**SUPPLY**		**USE**	
	f.o.b. value	freight charges 2/	f.o.b. value	freight charges
	$million			
Domestic	7,797.2	321.7	9,597.3	442.7
Imports	2,148.8	131.1		
Exports			348.7	10.1
Total	9,946.0	452.8	9,946.0	452.8

1/ Source: Bureau of Economic Analysis, 2003. "1997 Benchmark Input-Output Accounts of the U.S." www.bea.gov
2/ Freight charges on imports are based freight charge statistics reported by the Census Bureau, International Trade Division (http://www.census.gov/foreign-trade/www/), normalized to BEA benchmark import statistics that are reported as freight inclusive values.