Journal of Food Distribution Research
Volume 50, Issue 2

A Hard Nut to Crack: Identifying Factors Relevant to Chestnut Consumption

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Abstract

Chestnuts are popular worldwide, but they are not commonly purchased in the United States. Using a survey of over 1,000 U.S. and over 1,000 Chinese consumers, we use geospatial techniques and explore why over half of U.S. consumers have never eaten a chestnut. We test questions regarding key geographic, social, and cultural characteristics of likely U.S. chestnut consumers. Results suggest that immigration patterns weakly affect chestnut consumption but that age is a more important predictor of consumption frequency. Our empirical analysis suggests that consumers in coastal states consume the most chestnuts and that socioeconomic characteristics significantly influence consumption.

Keywords: chestnut consumption, consumer characteristic, immigration

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Introduction

Despite many cross-country consumer comparisons, little is known about cultural differences in nut consumption (Lusk, Roosen, and Fox, 2003; Loureiro and Umberger, 2007; Labrecque et al., 2006; Rozin et al., 1999). Understanding cultural differences in nut preferences is likely to become increasingly important as climate-conscious policy makers frequently campaign against meat consumption and advocate for alternate sources of protein and healthy fats (Elzerman et al., 2011; De Boer and Aiking, 2011; Aiking, 2011; Schösler, De Boer and Boersema, 2012; Beverland, 2014). Thus, identifying reasons why U.S. consumers might be averse to switching their consumption patterns toward plant-based alternatives is of increasing importance.

We contribute to the literature via data from Chinese and U.S. consumers to test institutional explanations for the disparity of chestnut consumption in the two countries. By comparing the relatively small U.S. market with the largest chestnut market in the world, we investigate the potential for U.S. chestnut producers. In 2017, China produced nearly 1.9 million tons of chestnuts, representing 80% of global production and 23 times the production scale of Bolivia, the second-largest chestnut producer (FAO, 2017). China is also the world's leading consumer of chestnuts, consuming nearly 1,651,000 tons in 2015, 80% of global consumption (IndexBox, 2018). This article highlights an interesting difference between consumption patterns in the two countries. By comparing the relationship between production and consumption regions in the two countries, we can examine the likely effects of localized supply chains on consumer behavior.

By focusing our empirical analysis on chestnuts, we also identify potential marketing paths to increase U.S. domestic chestnut consumption. While U.S. chestnut production has increased significantly over the past decade, few peer-reviewed articles have generated marketing information for the industry. Filling this gap in the literature is especially important as specialty crop producers are increasingly interested in diversification (Lancaster and Torres, 2019). Chestnuts are unique among nuts as they have a sweet, mild flavor profile and contain significant nutritional value. (Aguilar, Cernusca, and Gold, 2009; Ertürk, Mert, and Soylu, 2006; University of Missouri Center for Agroforestry, 2006). Chestnuts contain no cholesterol and only trace fats, and they are the only nut that contains a significant amount of vitamin C. They also have a high concentration of complex carbohydrates, a low glycemic index, and only one-third the calorie content of peanuts and cashews.

To assess this market opportunity, growers would benefit from understanding key characteristics of chestnut consumers. In the prior literature on chestnut demand, a few studies have focused on the influence of institutional and behavioral features. For example, Gold, Cernusca, and Godsey (2004) show that most participants were unaware of two of the most basic chestnut facts (i.e, need for refrigeration and fat content). Gold, Cernusca, and Godsey (2005) also pointed out U.S. consumers' unfamiliarity with chestnuts, including unawareness of their properties and unfamiliarity about where to buy and how to prepare them. However, these studies only revealed consumer familiarity with chestnuts; they did not explore factors likely to influence chestnut consumption. By combining participant familiarity with production location data, we seek to begin a dialogue about this relationship. Similarly, Bodet (2001) suggests that ethnic Asian and European dietary cultures are likely to be correlated with chestnut familiarity and consumption. We empirically test this assertion by focusing on the correlation between chestnut consumption, dietary cultural characteristics such as ethnicity, and each consumer's relationship with agriculture.

Every year, the average European consumer eats 1 lb (0.5 kg) of chestnuts and the average Chinese, Japanese, or Korean consumer eats 5.7 lb (2.5 kg) (Vossen, 2000). Despite this popularity overseas, the average American consumes a mere 0.10 lb (0.05 kg) per year (Vossen, 2000). Where prior studies focused on convenience samples to acquire their survey respondents (Gold, Cernusca, and Godsey, 2004; Aguilar, Cernusca, and Gold, 2009), this study is more representative, as our data for both China and the United States are nationwide and include more than 1,000 participants from each country. Additionally, nothing has been published in peer-reviewed journals that explores chestnut consumption after 2008. Instead, the literature has focused on other important nuts such as pecans (Kim and Dharmasena, 2018), making our data a timely contribution in guiding present-day chestnut marketing strategies.

As such, this article focuses on likely demand-side institutional features inherent to the chestnut market that might influence the geographic relationship between U.S. chestnut supply and demand . We explore the potential influence of ethnicity among chestnut consumption in different states, hypothesizing that states with more immigrants from high-chestnut consumption regions (e.g., Asia) are more likely to consume chestnuts. In addition, we empirically test for relationships between other likely factors such as farming experience and grocery shopping frequency.

Background

There is perhaps a historical explanation for the unusually low chestnut consumption in the United States. U.S. chestnut trees narrowly escaped extinction in the nineteenth century due to the accidental introduction of an Asian chestnut blight fungus, *Cryphonectria parasitica* (Anagnostakis, 1987). Within 50 years, the fungus killed almost all of the 4 billion American chestnut trees in the eastern forests of the United States (Roane, Griffin, and Elkins, 1986). Thanks in large part to exhaustive research efforts that identified improved cultivars of non-American chestnuts (Gold, Cernusca, and Godsey, 2006), the chestnut industry has experienced a rapid resurgence over the past few decades. The production gains for chestnut orchards have also coincided with a growing consumer interest in healthy and alternative foods (Gold, Godsey, and Josiah, 2004), creating conditions to support a growing U.S. chestnut market.

Despite this potential, most chestnuts in the United States are imported from Italy and, to a lesser extent, from Asia (U.S. Department of Agriculture, 1976). This unbalanced trade relationship is poised to change, as U.S. growers now primarily cultivate Chinese and Japanese–European hybrids, which have many superior production qualities, including reduced susceptibility to *C. parasitica* (Anagnostakis, 1987). Additionally, U.S. chestnut growers have a comparative advantage over growers from overseas as they can provide freshly harvested local chestnuts with lower transportation costs.

Prior studies have focused on chestnut demand or market opportunity, although shortcomings remain. Bodet's (2001) summary of existing chestnut literature suggests that domestic ethnic Asian and European markets have a longstanding cultural use of chestnuts; they also find that consumers who have heard about chestnuts via songs such as Nat King Cole's "The Christmas Song" might have a stronger preference for chestnut consumption. Another study on chestnut culture in California also showed that U.S. consumers are likely to be enthusiastic in their acceptance of chestnuts (Vossen, 2000). Smith et al. (2002) and a report from the University of Nebraska-Lincoln Food Processing Center (2002) also identified marketing opportunities for chestnuts by showing that restaurant chefs have substantial interest in chestnut products. Other research illustrates the potential of increasing chestnut demand as chestnuts experienced a surge in popularity in many European countries, Australia, New Zealand and the United States (Kelley and Behe, 2002). From 2007 to 2015, the average annual growth rates of chestnut consumption in many European countries, including Italy, reached over 6.0% per year (IndexBox, 2018).

Other studies of chestnut consumption have found that quality, freshness, production region, and nutrition are important features for consumer demand. The University of Nebraska-Lincoln (2002) study indicates that freshness and quality are extremely important for upscale restaurant chefs in choosing chestnut products. Similarly, chefs prefer peeled to unpeeled chestnuts and use them in a variety of dishes (Kelley and Behe, 2002). Gold, Cernusca, and Godsey (2004) assess consumer preferences among attendees at the Missouri Chestnut Roast and find that nutrition/diet/health, quality, and local production influence purchase and consumption decisions for chestnut consumers. Gold, Cernusca, and Godsey (2004, 2005) also report that U.S. consumers prefer buying chestnuts from grocery stores or farmers' markets and that organic and chestnut cultivar labeling can help capture price premiums. Aguilar, Cernusca, and Gold (2009) reanalyze survey data from Missouri Chestnut Roasts and find that festival participants ranked product quality, local production, and nutritional value as the most important attributes. Size also matters, as festival-goers showed more interest in medium-sized chestnuts. The current study builds on this previous work as we focus on a sample more representative of the U.S. chestnut market. This is especially important as chestnut consumption frequency is likely to be geographically heterogeneous.

Methods

This article explores the potential influence of institutional and behavioral factors likely to increase chestnut consumption. To accomplish this task, we use two survey datasets collected in the summer of 2017 by Survey Sampling International (SSI®), which maintains panels of likely consumers in both China and the United States. Both primary datasets were collected based on a survey written in the Qualtrics software program under the guidance of the Oklahoma State University Food Demand Survey (Lusk, 2017). We analyze the data in two ways. First, we test for correlations between chestnut production and consumption in the U.S. and Chinese markets. These relationships are likely to matter, as the notion of "place" has become increasingly important for consumer decision making (Duram and Oberholtzer, 2010). A product's "localness" has been shown to draw a premium in the United States, so it follows that production regions are likely to have a relationship with demand (Bir et al., 2019; Printezis, Grebitus, and Hirsch, 2019; Zepeda and Li, 2006). Second, we run a series of regression models to identify correlations between demographics and consumption frequency, culminating with zero-inflated negative binomial models. These models are especially helpful when a significant proportion of the sample has no observations at all. Similar zero-inflated methods have been utilized to test for policy effects on the number of craft breweries in each county (Malone and Lusk, 2016), consumer demand for tobacco (Harris and Zhao, 2007), and U.S. mushroom consumption (Jiang et al., 2017).

Data Description

To identify U.S. chestnut consumption, we evaluated responses on the Food Demand Survey (FooDS), an online survey that was conducted monthly to track consumer preferences and sentiments on food safety, quality, and price (Lusk, 2017). The survey also collected consumers' demographic information, including gender, age, education, income, marital status, and ethnicity. The July 2017 survey asked participants to identify the frequency with which they consumed an assortment of nuts, including chestnuts, using a Likert scale. In total, 1,034 U.S. consumers completed the survey. To identify consumption frequency in China, we utilize a survey of 1,000 likely Chinese food consumers collected by the Food Demand Survey team (Lusk, 2017). Table 1 reports descriptive statistics of key variables for this study. The average U.S. consumer eats chestnuts about twice per year, while Chinese consumers eat chestnuts monthly. The average U.S. consumer in our sample is slightly older and slightly more educated than the average Chinese consumer in our sample, while Chinese participants had more children on average. Nearly 77% of Chinese participants were the primary shopper for their family, while only 67% of U.S. participants were the primary shopper for their household.

Empirical Methods

Using Python, we analyzed regional differences in chestnut consumption geometrically and statistically. We then used multiple regression models to analyze the relationship between chestnut consumption and other independent variables such as gender, age, education, and race. Prior research suggests that many U.S. consumers have never consumed a chestnut (Gold, Cernusca, and Godsey, 2004). Thus, we apply the Poisson and negative binomial regression model for analysis. Assuming that chestnut consumption frequency satisfies a Poisson distribution, and so y_i, the chestnut consuming frequency of individual i given $\boldsymbol{X}_i$ is Poisson distributed with density

(1) $$f\left(y_i|\boldsymbol{X}_i\right) = \frac{\lambda_i^{y_i} \cdot \exp\left(-\lambda_i\right)}{y_i!},\ y_i = 0,1,2,\ldots,$$

where $\boldsymbol{X_i} = [\boldsymbol{x}_{1i}, \boldsymbol{x}_{2i}, \ldots, \boldsymbol{x}_{ki}]'$ is the k-dimensional vector of covariates and $\lambda_i = \exp(\boldsymbol{X_i'\beta})$, in which $\boldsymbol{\beta}$ is the vector of parameters (Cameron and Trivedi, 2013).

We estimate the log-linear equation in a Poisson regression model (Frome, 1983; Silverberg and Verspagen, 2003):

(2) $$\ln\left(E\left(y_i|\boldsymbol{X}_i\right)\right) = \sum_{j=1}^{k} \beta_j x_{ji}.$$

Table 1. Descriptive Statistics

Variables	U.S. Consumers	Chinese Consumers
Chestnut consumption frequency		
Never	62.0%	2.3%
Once per year	14.5%	8.4%
Twice per year	4.6%	8.3%
3–6 times per year	7.1%	18.5%
7–11 times per year	4.6%	19.3%
Monthly	4.5%	22.7%
Weekly or Daily	2.6%	20.5%
Male	44.0%	51.0%
Age		
18–24	11.9%	0.3%
25–34	19.6%	41.5%
35–44	17.5%	34.9%
45–54	15.2%	16.5%
55–64	17.7%	6.0%
65–74	13.5%	0.0%
> 74	4.6%	0.8%
Education		
Less than high school	0.3%	6.3%
High school	20.7%	0.0%
Some college	21.4%	0.1%
2-year college degree	8.4%	2.1%
4-year college degree	27.5%	24.4%
Graduate degree	21.8%	6.8%
Marital status (single or unmarried)	72.0%	
Family size	2.6	3.3
Have child in family	22.0%	73.0%
Prior shopper	67.0%	77.0%
Vegan	4.0%	
Farmer	2.0%	
Hispanic/Latino/Spanish origin	20.5%	
Race		
White	70.1%	
African American/American Indian	12.4%	
Asian	4.5%	
Others	13.0%	
Number of observations	1,033	1,000

Note: Except for family size, numbers in the table represent the ratio of relative populations.

We also applied the most frequently cited alternative to the Poisson regression—the negative binomial (NB) regression model—as the other benchmark model for our analysis of count data.

Since expected value and variance are equal in Poisson distribution, the NB regression might provide a better fit than the Poisson regression in the presence of Poisson overdispersion for count data, in which the variance in the Poisson model is larger than the expected value (Greene, 2003; Gardner, Mulvey, and Shaw, 1995; Land, McCall, and Nagin, 1996). By contrast, the NB model addresses the issue of overdispersion by assuming that unexplained variability exists among individuals who have the same expected value, allowing higher variability among individuals (Coxe, West and Aiken, 2009). The probability mass function (*pmf*) of the negative binomial distribution in the NB model can be specified as

$$\text{(3)} \qquad \text{Prob}(\text{y}) = \frac{\Gamma(\text{y}+\theta)}{\Gamma(\theta)y!}\mu^{\theta}(1-\mu)^{\text{y}} \quad \theta > 0, \quad y = 0,1,\ldots$$

where $\mu = \dfrac{\theta}{\theta+\lambda}$ and (θ, λ) is the parameter vector of the distribution.

We include social characteristics such as gender, age, education, marital status, and income in our model since many studies have shown that these are significant determinants of consumption (Schifferstein and Ophuis, 1998; Verbeke, 2005; Hughner et al., 2007). We also include ethnic variables (such as Latino origin and race) to estimate the possible influence of immigrant food cultures on chestnut consumption.[1] Finally, we include variables for farmers, vegans, and primary shopper designation (the person with the main responsibility of shopping in the family).

For this study, we focus on chestnut consumption frequency. Using a Likert scale, participants identified the frequency with which they consumed chestnut. Since the dependent variable is a count variable, we first estimate the Poisson regression model and the NB regression model (see Table 2). Since nearly 62% of U.S. survey participants had never eaten a chestnut, we also estimate zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB) regressions to mitigate concerns about potentially excessive numbers of zero observations.

Following the assumptions of zero-inflated count data models, the counts can be modeled in two parts: One estimates the probability that the observation is 0 while the second portion is a general count data model for analyzing regular count data. (Wagh and Kamalja, 2018). The two parts of ZIP model contain the logit model for predicting excess zeros and the Poisson count model. The ZIP model assumes that the count variable satisfies the zero-inflated Poisson distribution with *pmf*:

[1] *Latino* is the dummy variable that represents whether the individual identifies as Hispanic, Latino, or Spanish; *race* is a group variable that separates participants into four racial groups: white, African American, Asian, and other.

$$\text{(4)} \qquad \text{Prob}(y) = \begin{cases} \omega + (1-\omega)\mathrm{e}^{-\theta}, & y = 0 \\ (1-\omega)\dfrac{\theta^{y}\mathrm{e}^{-\theta}}{y!}, & y > 0 \end{cases},$$

where (θ,ω) is the parameter vector of the distribution (Mullahy, 1986).

The ZINB model is also formed with two parts: the logit model for predicting excess zeros and a negative binomial count model, but the *pmf* is quite different:

$$\text{(5)} \qquad \text{Prob}(y) = \begin{cases} \omega + (1-\omega)\left(\dfrac{1}{1+\varphi\theta}\right)^{\varphi^{-1}}, & y = 0 \\ (1-\omega)\left(\dfrac{\Gamma(y+\varphi^{-1})}{\Gamma(\varphi^{-1})\Gamma(y+1)}\right)\left(\dfrac{1}{1+\varphi\theta}\right)^{\varphi^{-1}}\left(\dfrac{\varphi\theta}{1+\varphi\theta}\right)^{y}, & y > 0 \end{cases},$$

where (θ,φ,ω) is the parameter vector of the distribution (Cameron and Trivedi, 2013).

Results

Figure 1 displays the frequency distribution of chestnut consumption in the United States and China. While almost every Chinese consumer (97.7%) had eaten a chestnut in the past year, fewer than half of U.S. consumers had ever tried a chestnut.

Differences in U.S. and Chinese consumers are key to this study. Figure 2 illustrates the frequency of chestnut consumption by province in China. On average, consumers in southeastern coastal areas and the provinces around Beijing, the capital of China, consume more chestnuts.[2]

Figure 3 displays chestnut production data for each province from the China Agricultural Database (2014). As the largest country in terms of chestnut production, chestnuts are grown in over 90% of Chinese provinces. Hubei, Shandong, Hebei, Yunnan, and Anhui provinces produce the most chestnuts.[3]

Figure 4 demonstrates the correlation between chestnut production and consumption in the Chinese provinces. Results suggest that, at least in China, chestnut consumption is positively correlated with chestnut production; consumers who live in provinces with higher yearly chestnut outputs consume chestnuts more frequently (correlation coefficient = 0.258).

[2] We also calculated the Moran's I, a statistical measure of spatial correlation developed by Moran (1950). The Moran's I of our province-level Chinese chestnut consumption data is 0.046 (*p*-value = 0.94), which indicate no statistically significant spatial autocorrelation between provinces.
[3] The Moran's I of province-level Chinese production data is −0.622 (*p*-value = 0.37), which again indicates that there is no statistically significant spatial autocorrelation at the province level.

Figure 1. Chinese and U.S. Chestnut Consumption Frequency

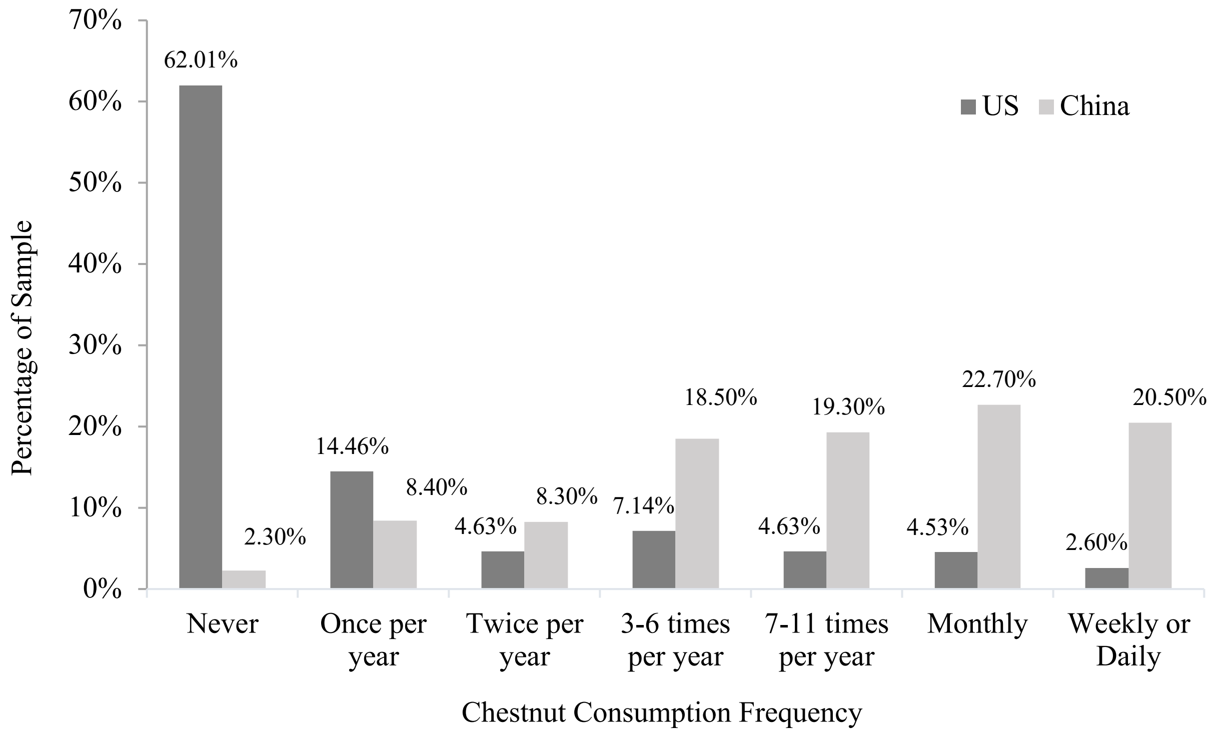
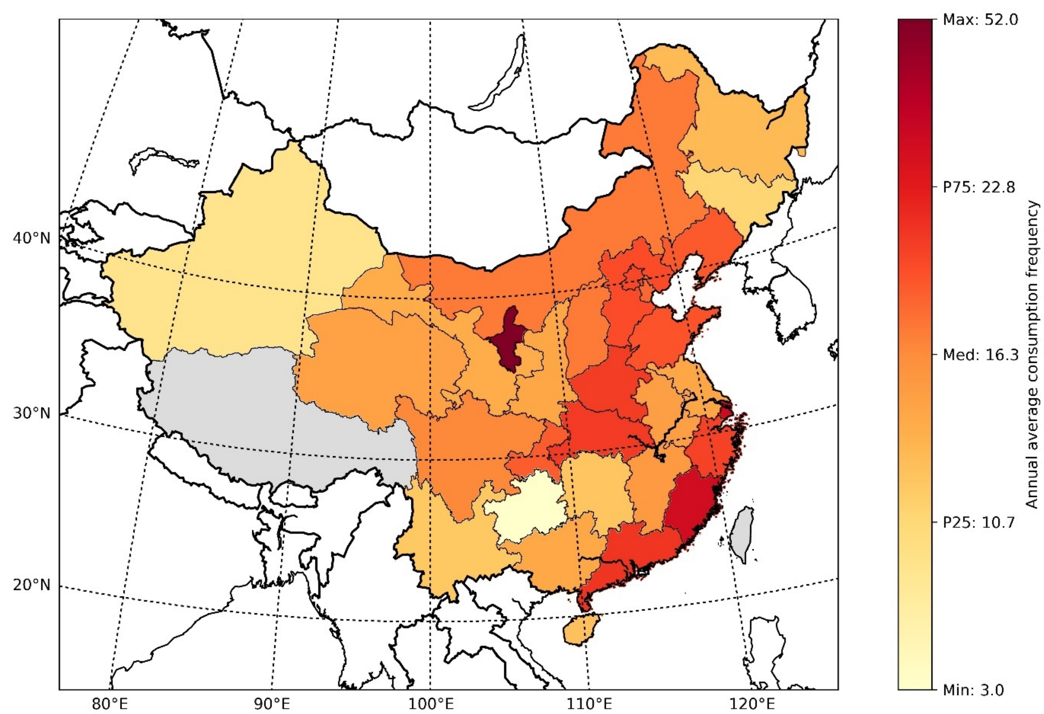
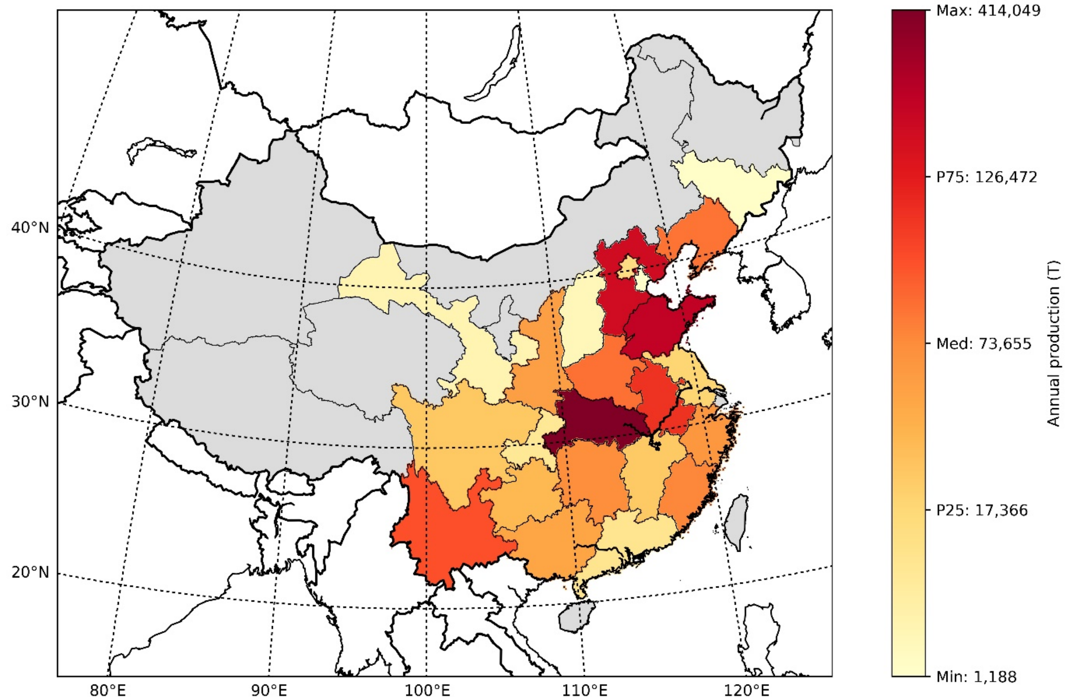


Figure 2. Chinese Chestnut Consumption, 2017



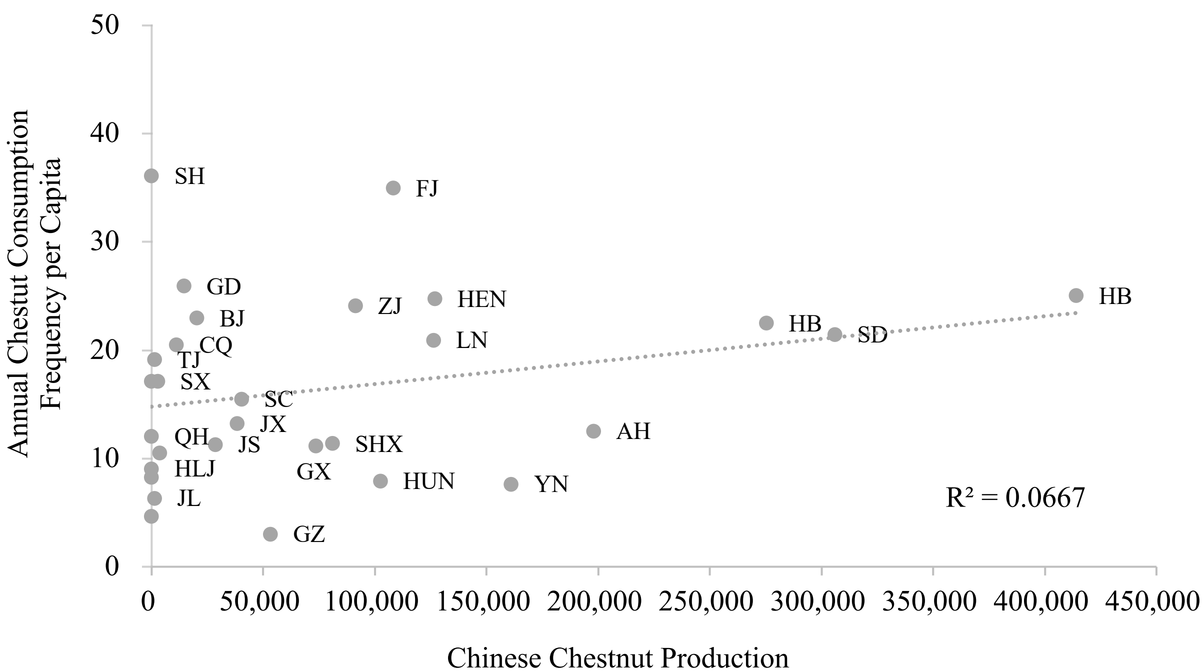
Note: Darker color reflects higher average chestnut consumption. Grey indicates provinces without observations.

Figure 3. Chinese Chestnut Production, 2014



Note: Darker color reflects higher average chestnut production. Grey indicates provinces without production data.

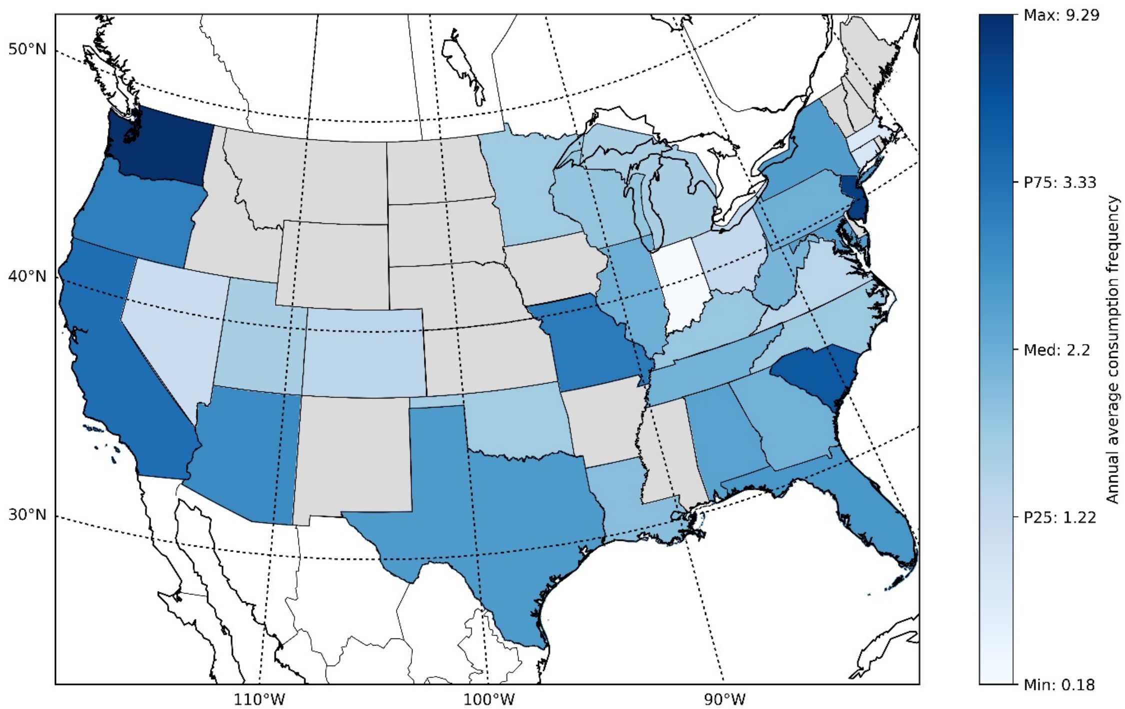
Figure 4. Chinese Chestnut Output and Consumption Frequency by Province, 2014



Note: Each point represents a province. See the appendix for full province names.

Figure 5 displays average state-level per capita U.S. chestnut consumption drawn from FooDS survey data. States near the coast are more likely to consume chestnuts.[4]

Figure 5. U.S. Chestnut Consumption, 2017



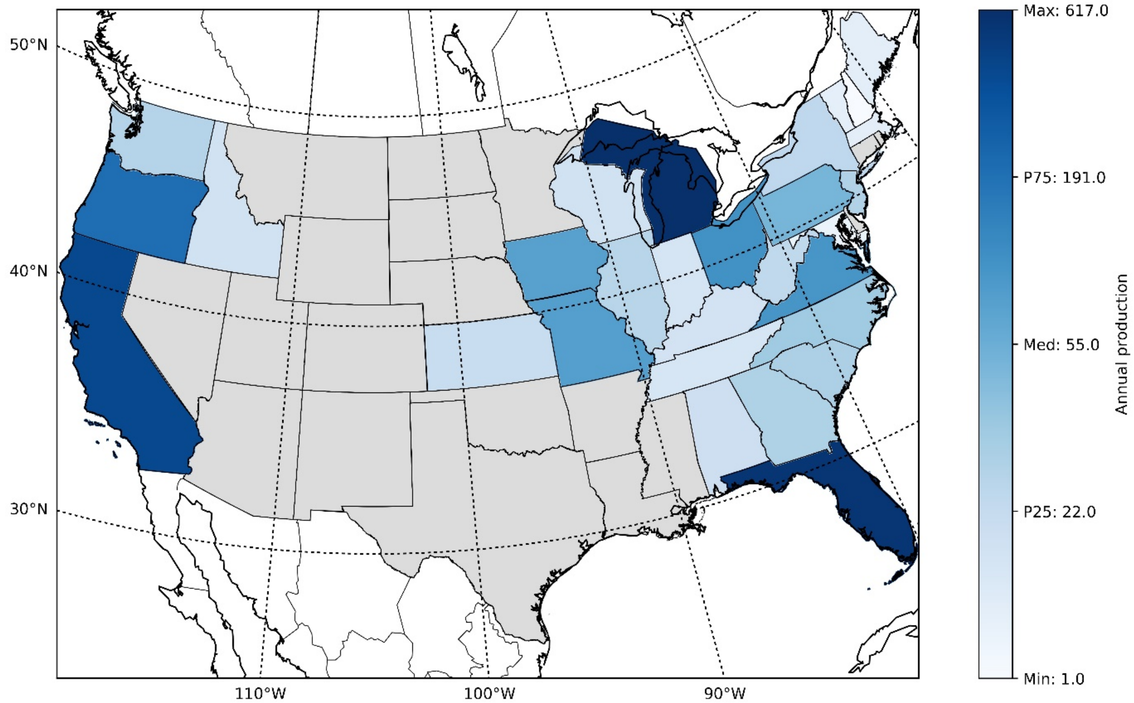
Note: Darker color reflects higher average chestnut consumption per capita. Grey indicates states with fewer than 10 observations while white indicates low average chestnut consumption per capita.

Figure 6 displays U.S. chestnut production in 2012 (U.S. Department of Agriculture, 2012). Few states actually produced chestnuts in 2012, as most chestnuts in the United States are imported.[5]

One key question is whether the positive relationship between production and consumption seen in China also exists in the United States. We find no significant correlation between chestnut consumption and production in the United States (Figure 7). This is interesting, as prior research suggests that local production is a critical component of chestnut demand.

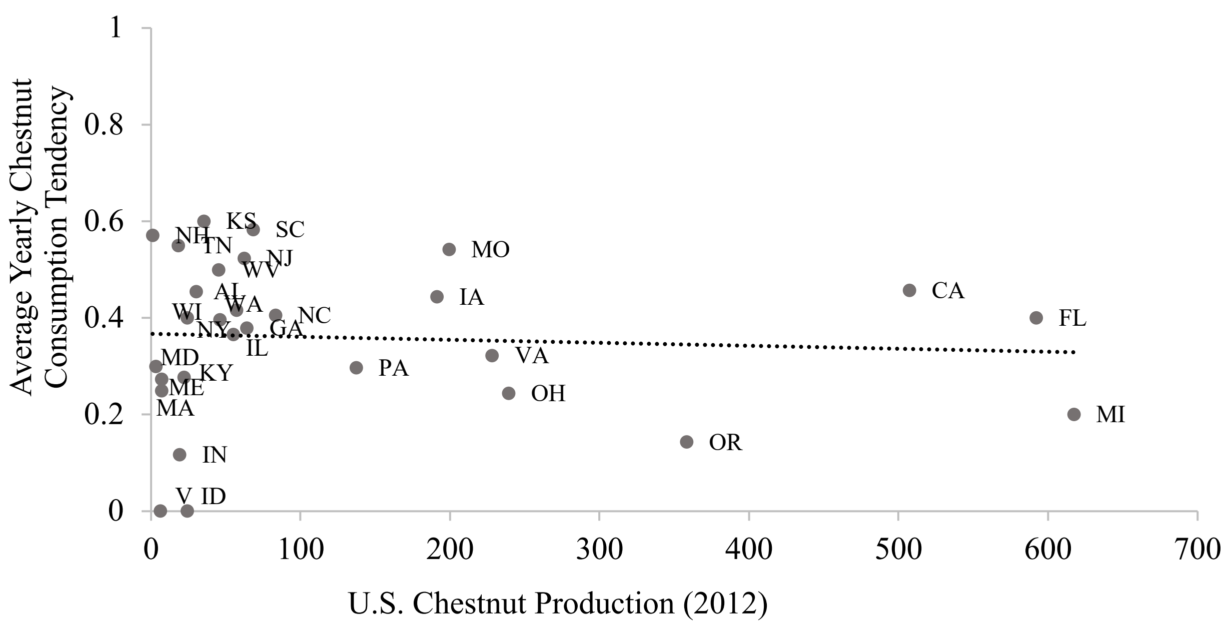
[4] The Moran's I is 0.057 (p-value = 0.42), which indicates that is no geographic autocorrelation in U.S. chestnut consumption data.
[5] Again, the Moran's I between state production is not statistically different from 0 (0.025, p-value = 0.62), which did not show significant autocorrelation in U.S. chestnut production.

Figure 6. U.S. Chestnut Production, 2012



Note: Darker color reflects higher average chestnut production. Grey indicates states with no production data.
Source: U.S. Department of Agriculture (2012)

Figure 7. U.S. Chestnut Production and Consumption Frequency by State



Note: Each point represents a state. See the appendix for full state names.

Regression Results

Table 2 reports regression results for U.S. consumers. While the Poisson distribution is not the model of best fit, we include its results for reference. Coefficients from Poisson models can be interpreted as, all other variables held constant, a 1-unit change in the variable will lead the difference in the logs of expected chestnut consumption to change by the respective coefficient. For example, according to the Poisson model in column 1 of Table 2, an increase from the age of "25–34" to "35–44" will lead to an exp(−0.275) = 0.760 − 1 = 24% decrease in the frequency of consuming chestnuts. Simply speaking, all else held constant, younger consumers are more likely to regularly consume chestnuts.

In column 2 of Table 2, the NB regression shows a significant dispersion parameter (alpha), which suggests that our data is over-dispersed, meaning the NB fits the data better than does the Poisson model. However, most of the conclusions generated using the Poisson regression do not change significantly when we use the NB model.

As previously noted, over half of Americans have never tried a chestnut; our data contain an excessive number of zeros, which limits the goodness-of-fit for a Poisson model. To control for this possible issue, we also estimated ZIP and ZINB models (columns 3 and 4 of Table 2). The insignificant log-transformed over-dispersion parameter (Lnalpha) suggests that there is no overdispersion in the zero-inflated model. The similarity between the results of the ZIP and ZINB models also implies that the parameters are robust. Results suggest that several factors that affect chestnut consumption, although some of them only influence the likelihood that a consumer has ever tried chestnuts, while others also affect consumption frequency. The logit link function includes variables for gender, age, education, ethnicity, and dummy variables for being a farmer, a vegetarian/vegan, and the primary household shopper. These variables may affect whether participants have knowledge about or experience with chestnuts, which might decide whether an individual has ever tried them. As such, those parameters can be interpreted as identifying how each variable influences the likelihood that a consumer has ever tried a chestnut.

In these models, being a farmer or having a vegetarian/vegan in the family significantly increases the likelihood the participant had tried a chestnut. For example, the odds of never having tried chestnuts decreases by exp = 2.326 times if the consumer is a vegetarian/vegan. The farmer's odds of not having tried chestnuts is exp(1.926) = 6.862 times lower than nonfarmers. This is likely because farmers and vegetarians/vegans are more aware of chestnuts. However, the Poisson portion of the ZIP model and the NB portion of the ZINB model both indicate that being a farmer or vegetarianism/veganism is not correlated with higher chestnut consumption. In contrast, being a primary shopper affects the likelihood the participant has tried chestnuts but *does* affect consumption frequency. In the ZINB model, the expected log of consumption frequency is 0.478 higher for primary shoppers than for those who are not primary shoppers.

Age and gender influence the likelihood that participants have never tried chestnuts and also the consumption frequency of chestnuts. The results from the ZIP and ZINB models suggest that younger male participants have a higher likelihood of having ever tried chestnuts as well as a

Table 2. Factors Affecting U.S. Chestnut Consumption (*N* = 1,030)

Variables	Poisson	NB	ZIP	ZINB
Intercept	−0.489* (0.281)	−0.360 (0.297)	0.356 (0.229)	0.352 (0.232)
Male	0.404*** (0.093)	0.420*** (0.113)	0.234*** (0.083)	0.236*** (0.083)
Age	−0.275*** (0.042)	−0.279*** (0.041)	−0.166*** (0.041)	−0.167*** (0.040)
Education	0.063** (0.031)	0.041 (0.038)	0.014 (0.024)	0.013 (0.025)
Income	0.035 (0.025)	0.014 (0.028)	0.018 (0.021)	0.018 (0.021)
Marital status (unmarried)	0.121 (0.130)	0.069 (0.141)	0.130 (0.117)	0.129 (0.118)
Family size	−0.008 (0.052)	0.024 (0.059)	0.067 (0.049)	0.067 (0.050)
Have child in family	0.354*** (0.135)	0.334** (0.155)	0.129 (0.117)	0.134 (0.121)
Ever farmed	−0.133 (0.149)	−0.104 (0.188)	−0.053 (0.127)	−0.055 (0.129)
Region (South)	–	–	–	–
West	−0.024 (0.112)	−0.080 (0.141)	−0.080 (0.089)	−0.081 (0.090)
Mideast	−0.082 (0.142)	−0.137 (0.162)	−0.013 (0.110)	−0.015 (0.112)
North	−0.075 (0.127)	−0.030 (0.148)	−0.010 (0.100)	−0.011 (0.101)
Latino	0.234* (0.129)	0.293* (0.168)	0.025 (0.109)	0.026 (0.110)
Race (white)	–	–	–	–
African American/Am. Indian	−0.062 (0.137)	−0.079 (0.157)	0.025 (0.104)	0.024 (0.105)
Asian	0.298* (0.170)	0.477** (0.226)	0.060 (0.151)	0.062 (0.154)
Others	−0.002 (0.233)	−0.127 (0.337)	−0.025 (0.186)	−0.024 (0.188)
Primary shopper	0.665*** (0.140)	0.666*** (0.140)	0.473*** (0.150)	0.478*** (0.154)
Vegan or vegetarian	0.428*** (0.143)	0.530** (0.221)	0.182 (0.116)	0.185 (0.119)
Farmer	0.553*** (0.156)	0.565* (0.311)	0.168 (0.140)	0.170 (0.142)
Lnalpha (Log-transformed over-dispersion parameter)		0.437*** (0.107)		−4.182 (3.115)
Logit link function				
Intercept			0.650* (0.338)	0.637* (0.346)
Male			−0.348** (0.168)	−0.346** (0.170)
Age			0.182*** (0.058)	0.181*** (0.058)
Education			−0.094* (0.051)	−0.095* (0.052)
Have child in family			−0.252 (0.181)	−0.247 (0.184)
Hispanic/Latino/Spanish origin			−0.503** (0.246)	−0.506** (0.249)
Asian			−0.897** (0.430)	−0.904** (0.441)
Prior shopper			−0.381 (0.239)	−0.374 (0.244)
Vegan or vegetarian			−0.841** (0.386)	−0.844** (0.391)
Farmer			−1.926** (0.801)	−1.950** (0.827)
Log pseudo-likelihood			−1,256.983	−1,256.918

Note: Robust standard errors are in parentheses. Vuong test of ZINB vs. standard negative binomial: z= 4.13***. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively.

higher consumption frequency. Further, more educated participants are more likely to consume chestnuts frequently, although education levels do not affect the odds of having tried chestnuts. The ZINB and ZIP models suggest that there is no relationship between participants who have children and chestnut consumption.

The variables representing immigration or food culture allow us to conclude that Asian and Latino participants are more likely to frequently consume chestnuts than White consumers. However, the ZIP or ZINB model shows that the influence of the ethnic variable is only significant in the logit model part, which indicates that Asian or Hispanic/Latino/Spanish consumers have higher odds of having tried chestnuts but that their expected consumption frequency is not significantly higher than that of non-Asian or Hispanic/Latino/Spanish consumers. This conclusion could be possibly explained by the fact that chestnuts are popular in Asian and Hispanic/Latino/Spanish food cultures.

Conclusion

This article identified key geographic, cultural, and social characteristics of U.S. chestnut consumers. First, we showed that geography has different effects on chestnut consumption in the United States and in China. This is most likely the result of the relatively low domestic production of chestnuts in the United States since most chestnuts in the U.S. market are imported. These results also provide evidence that chestnut producers might benefit from targeting markets outside their local region. Further, we find that young people, males, those with higher levels of education, primary shoppers, farmers, and vegetarians/vegans are more likely to consume chestnuts. Companies in the chestnut industry could use these social characteristics to target potential consumers.

We find that cultural characteristics have a significant influence on chestnut consumption in our ZIP/ZINB model. From the significant influence of Latino origin and Asian ethnicity in our inflated model, we might infer that food culture as a part of immigration culture affects consumption of plant-based proteins such as including chestnuts. This finding suggests some interesting next steps for research regarding on the role of immigration in food choice. It is likely that food choices have always been influenced by consumers' culture, which often leads to the development of local food identities (Malone and Flores Moreno, 2018). Future studies might consider popular foods with ethnic heritages, including edamame (Wolfe et al., 2018), quinoa (Stevens, 2017), or asiago cheese (Vecchio and Annunziata, 2011). That is, understanding how cultural identity influences food choice is likely to be an important next step for interpreting best practices for marketing strategies for chestnuts as well as other foods with a cultural heritage.

Future research on chestnut consumption might address some of the key shortcomings of this research. First, this study utilized consumption data reported via survey methods. Future work might benefit from considering scanner-level data in its analysis, which might help answer questions about how chestnut consumers classify chestnuts. Chestnuts are generally lower in protein than most nuts but higher in carbohydrates, potassium, and vitamin C. As such, the nutrient content of chestnuts is perhaps more comparable to a banana than to other tree nuts. Future studies might explore whether consumers actually substitute from chestnuts to other nuts or are more likely to substitute from chestnuts to fruits and vegetables with similar nutritional profiles. Relatedly, this study omits prices, which are likely important when consumers make decisions about substituting between chestnuts and other, similar products. Finally, we proxied immigrant food culture with participant ethnicity. Future work might reveal stronger correlations between culture and chestnut consumption if a more refined measure of immigrant food culture were utilized. Despite these shortcomings, this paper has some key implications for chestnut marketing. Rather than chasing immigrant populations as an avenue for real market growth, chestnut marketers might benefit by focusing on younger, more educated consumers.

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Appendix:
Corresponding Table of Abbreviation and Full Province/State Names

China		United States	
Full Name	**Abbreviation**	**Full Name**	**Abbreviation**
Anhui	AH	Alabama	AL
Beijing	BJ	California	CA
Chongqing	CQ	Florida	FL
Fujian	FJ	Georgia	GA
Gansu	GS	Idaho	ID
Guangdong	GD	Illinois	IL
Guangxi	GX	Indiana	IN
Guizhou	GZ	Iowa	IA
Hainan	HN	Kansas	KS
Hebei	HB	Kentucky	KY
Heilongjiang	HLJ	Maine	ME
Henan	HEN	Maryland	MD
Hubei	HB	Massachusetts	MA
Hunan	HUN	Michigan	MI
Jiangsu	JS	Missouri	MO
Jiangxi	JX	New Hampshire	NH
Jilin	JL	New Jersey	NJ
Liaoning	LN	New York	NY
Neimenggu	NMG	North Carolina	NC
Qinghai	QH	Ohio	OH
Shaanxi	SHX	Oregon	OR
Shandong	SD	Pennsylvania	PA
Shanghai	SH	South Carolina	SC
Shanxi	SX	Tennessee	TN
Sichuan	SC	Vermont	VT
Tianjin	TJ	Virginia	VA
Xinjiang	XJ	Washington	WA
Yunnan	YN	West Virginia	WV
Zhejiang	ZJ	Wisconsin	WI

Note: Some provinces/states are not listed in the table due to data limitations.