International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 5, No. 42017, pp.41-61

FOODBORNE OUTBREAKS AND FARM STRUCTURE: AN EXAMINATION OF VEGETABLE AND MELON FARMING

Ioana (Julia) Marasteanu[1]
US Food and Drug Administration 10903 New Hampshire Ave, Silver Spring, MD 20993, USA, Email: Ioana.Marasteanu@fda.hhs.gov

Travis Minor
US Department of Agriculture, Economic Research Service, USA

Abstract

This paper examines the association of foodborne outbreaks with farm and labor density. Using a novel data set, comprised of state level agricultural statistics from the US Census Bureau combined with foodborne outbreak information compiled by the Centers for Disease Control and Prevention from 2004 to 2014, we find that, within the vegetable and melon industry, raw outbreaks do not appear to be significantly correlated with a decrease in farm numbers. However, taking into account the severity of an outbreak suggests a negative long-term correlation between farming establishments in an affected state. Labor also appears to be correlated with outbreaks, positively in the near-term but negatively overall. Finally, spatial results suggest that nearby markets may be impacted by vegetable and melon outbreaks, and that states tend to be surrounded by neighbors with dissimilar outcomes.
Keywords: *Foodborne Diseases, agribusiness, Food Safety, Produce, Spatial Distribution*
***JEL* Classification Codes:** *Q13; Q18; R11*

1. Introduction

Foodborne outbreaks in the US have become of increasing concern to consumers, producers, and public health officials. The CDC estimates that 9.4 million people get sick every year from foodborne diseases, 56,000 of which are hospitalized, and 1,400 of which die (Scallan, et al., 2001). Studies estimate that the direct cost of foodborne illness to the United States to those afflicted is somewhere between $15 and $36 billion (Hoffman & Anekwe, 2013; Minor, et al., 2015).

Foodborne illness has been addressed by policy work and scholarly research. Most recently, the Food and Drug Administration (FDA) published the Food Safety Modernization Act (FSMA), which gives the FDA the ability to implement improved safety controls across the food system. Most scholarly research on foodborne outbreaks focuses on public health outcomes and preventative measures. However, the impact of these outbreaks is typically felt beyond those outcomes which have traditionally been examined, potentially affecting long-term consumption patterns, production, and industry make-up. To date few resources have been devoted to the broader impact of foodborne outbreaks on farms or adjacent markets.

[1] The views expressed here are those of the authors and cannot be attributed to FDA, ERS, or the U.S. Department of Agriculture. We thank Linda Calvin, Erik Lichtenberg, and attendees of the AAEA session, for helpful comments and suggestions that greatly improved the paper. All mistakes are solely our own.

It is important to analyze the impact of foodborne outbreaks from a farm perspective, given the fact that food safety regulations such as FSMA are frequently met with concern from farms and agribusinesses. Farms and agribusinesses may be interested to know how foodborne outbreaks affect the structure and performance of the industry. Policy makers, on the other hand, may be interested to know if there is already a strong market response to foodborne outbreaks.

In this paper, we attempt to answer the following question: Is being in an area affected by a foodborne outbreak associated with a change in farm or labor numbers in the area? To do this, we examine foodborne outbreaks linked to vegetable and melon consumption, which provides a good case study as it covers many produce items and multiple outbreak events resulting from different pathogens with a wide range of measurable impact. Additionally, vegetable and melons are interesting to examine, as they represent an important sector of food safety concern. For example, one of the main rules in FSMA, specifically addresses produce, which, according to Sivapalasingam et al. (2004), has become an increasingly common culprit in the incidence of foodborne outbreaks. In the same year, McCabe-Sellers and Beattie (2004) identify fresh produce as a commodity that has been "added to the traditional list of food requiring careful selection and handling to prevent foodborne diseases".

Our findings indicate that, within the vegetable and melon industry, raw outbreaks do not appear to be significantly correlated with a decrease in farm numbers. However, taking into account the severity of an outbreak suggests a negative long-term correlation between farming establishments in an affected state. Labor also appears to be correlated with outbreaks, positively in the near-term but negatively overall. Finally, results of our spatial models suggest that nearby markets may be impacted by vegetable and melon outbreaks, and that states tend to be surrounded by neighbors with dissimilar numbers and sizes of vegetable and melon farms.

The rest of this paper is organized as follows. Section 2 discusses the existing literature on foodborne outbreaks. Section 3outlines our empirical methodology, and Section 4 describes the data used for this study. Section 5 presents results, and Section 6 concludes.

2. Literature Review

The current literature on foodborne outbreaks has primarily taken one of three forms. The first examines the impact of individual foodborne outbreaks on the consumer. These typically take the form of case studies, or trace back studies, which examine the outbreak and try to link it to a particular source or cause(Naimi, et al., 2003; Sauer, Majkowski, Green, & Eckel, 1997).

The second branch of literature examines the trends and economic implications in foodborne outbreaks. This is primarily comprised of studies which evaluate the changes in historical data. Papers such as Bean and Griffin (1990) and Sivapalasingam et al. (2004) each highlight trends in foodborne outbreaks over time and even highlight certain pathogens or commodities which appear to be increasing in prevalence. Greg and Ravel (2009) show how international outbreak data points towards some expected pathogen and food commodity parings but also highlight the need for more uniformity across countries in their reporting techniques. And Painter et al.,(2013) further attribute complex food outbreaks to their most probable source based on historical associations of food and pathogen information.

The third branch of literature attempts to apply some economic measure to evaluate the burden of foodborne outbreaks. These papers, such as (Hoffmann, Batz, & Morris, 2012; Minor, et al., 2015) show the impact of foodborne outbreaks or illnesses on 'society'. However, many times these studies are limited to the outcomes of consumption or the consumer, who is made ill.

This study fits most closely into this third branch of literature; however, instead of examining the impact on consumers or patients, we seek to determine the effect, if any, that a foodborne outbreak has on the decisions and composition of farming operations in the affected area. In doing so, we attempt to quantify an economic effect of foodborne outbreaks that has not been widely discussed in the literature.

Farm level decisions have been studied fairly extensively in the economics literature. Although the geographical regions may vary due to data availability, the bulk of this literature generally examines the drivers of farm exit. The primarily cited drivers are size of the operation, retirement decisions (Glauben, 2006), development of rural land, and low unemployment rates (Foltz, 2004). However, none of these studies have attempted to show how sudden, one-time shocks to public health, such as a foodborne outbreak, may enter into that decision process. In addition to these standard drivers of farm-level decisions, some studies have begun to look at policy impacts. Kazukauskas et al. (2013) find that passage of Common Agricultural Policy lowered disinvestment for affected EU farms, with some notable exceptions of livestock farms and farms already in the process of exiting. This study is important for our work, as it shows a onetime event's change on the decisions of farmers, as modeled in a quasi-experimental framework. We take a similar approach in modeling outbreaks, as they are unlikely to be a recurring factor in most farmers' everyday decision process.

We attempt to extend the current literature by examining the impact of foodborne outbreaks on farm-level decisions, such as entry and exit and labor hiring.

3. Methodology

To examine the effect of outbreaks on multiple state-level outcomes, we first use Ordinary Least Squares to estimate:

$$Y_{s,t} = \alpha_1 + a_2 Outbreak_{s,t-N} + \alpha_3' Z_{s,t} + \mu_s + \nu_t + \varepsilon_{s,t} \qquad (1)$$

where $Y_{s,t}$ is one of two examined outcome measures (number of farms or hired labor) in state, *s*, in year, *t*; $Outbreak_{s,t-N}$ is one of three measures (number of outbreaks, number of illnesses, and cost of illnesses) of the vegetable and melon-related outbreak that occurred during time, *t-N*, in state, *s*; because we do not expect that farms will react contemporaneously with a foodborne outbreak, we examine a number of lags, in the presented results N is equal to 1 through 5 allowing us to see how farms deal with a foodborne outbreak up to five years after its initial occurrence; $Z_{s,t}$ represents a vector of state specific control variables; μ_s represents state fixed-effects; ν_t represents year fixed-effects; and $\varepsilon_{s,t}$ represents the idiosyncratic error term. The coefficient of interest is a_2 as it should show the association of a given foodborne outbreak with the state's farm structure in subsequent years.

Because it is likely that outbreaks are not completely contained state-level events, we need to account for the fact that $Outbreak_{s,t-N}$ may affect a larger geographical region than (1) allows for. To do this, we use a Spatial Durbin Model, defined as follows (Lesage, 1998):

$$Y_{s,t} = \alpha_1 + a_{0w} W Y_{r \neq s,t} + a_2 Outbreak_{s,t-N} + \alpha_3' Z_{s,t} + a_{2w} \mathrm{W} Outbreak_{s,t-N} + \alpha_{3w}' \mathrm{W} Z_{s,t} + \mu_s + \nu_t + \varepsilon_{s,t} \qquad (2)$$

where all previous variables are defined as before except for ε which is now distributed $N(0,\sigma^2 I_n)$, and W is an inverse distance weighting matrix, in which the weight between two states is equal to the inverse of the distance between their centroids (LeSage 1998, Anselin, 1999).This method of defining weights accounts for the fact that spatial spillovers likely get weaker the farther away you are from the source. Other methods of defining weighting matrices exist; however, LeSage and Pace (2010) explain that estimations of spatial models may not be very sensitive to the specification of the weighting matrix. The interpretation of a_2 and a_3 remain the same as in equation (1). The coefficients on the spatially lagged variables (a_{0w}, a_{2w} and a_{3w}) show how changes in the values of the variables in one state are associated with the outcome measure in neighboring states. The indirect effects refer to the sum of the effects of a variable on observations outside of its state ($\sum_{j\neq i} \partial Y_{j,t}/\partial WZ_{i,t}$), the direct effects refer to the effect of a variable on observations inside its state ($\partial Y_{s,t}/\partial Z_{s,t}$) (LeSage and Pace, 2009). Equation (2) estimated using Maximum Likelihood Estimation in Stata (Belotti et al., 2013).

4. Data

To examine the relationship between foodborne outbreaks and farm structure we create a unique data set comprised of agricultural industry data coupled with foodborne outbreak and growing condition information which spans from 2004 through 2014. Summary Statistics for the complete set of the observed variables in our data are presented in Table 1. Because of the proprietary nature of our data, we have several missing observations for *Farms* and *Employees*. *Farms* has fewer missing observations, which can be accounted for by dropping the states of Wyoming and South Dakota. *Employees* has 131 missing observations across the data set, likely due to non-reporting and disclosure concerns at the state and individual farm level. To account for this, we use a multiple imputation method. First, we draw from the closest 5 neighbors to generate 50 imputations of *Employees* based on $Outbreak_{s,t-1}$ and $Z_{s,t}$ (changing the number of imputations and nearest neighbors yields similar results); we then obtain linear predictions of $Employees$ from $Outbreak_{s,t-1}$ and $Z_{s,t}$; finally we match missing values with a set of non-missing observations that have the most similar predicted values, from which we select the most appropriate imputed value. The multiple imputation estimate of the missing value is the average of the multiple imputations (Stata, 2013 and Carlin et al., 2003). Appendix 3 shows a side by side graph of the kernel distribution of just the observed values of *Employees*, and the observed values plus imputed values of *Employees*. Because the distributions are similar, we assume that the imputed values are appropriate.

The data for the state-level outcome variables, *Farms* and *Employees* (including their location quotients, which are discussed further in Table 1), come from the Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages, and pertain to establishments that fall into the NAICS 111219 category. NAICS 111219 represents establishments that primarily focus on growing melons and/or vegetables (with the exception of potatoes, dry peas, dry beans, field silage, seed corn and sugar beets), producing vegetable and/or melon seeds, and growing vegetable and/or melon bedding plants (Census, 2016). Table 1 shows a mean of 72 vegetable and melon farms across states each year, which ranges from 1 to 989 farms in a given state in a given year. On those farms, there are an average of about 2,000 workers in each state, which again can range from 5 to almost 35,000 workers in a particular state in a particular year.

Figure 1 shows how the values of the outcome variables and the outbreak variables (discussed in the next paragraph) change over time. We see that the number of vegetable and melon farms in the Unites States decreases between 2004 and 2005, plateaus between 2005 and 2006, and drops between 2006 and 2007. This is then followed by a steady increase through 2014. Employment on vegetable and melon farms sees a steady decrease until 2006, and then plateaus between 2006 and 2008. It then drops in 2009, and then rises until 2013 and drops again in 2014. The figure shows only the observed numbers; however, the imputed values show similar trends (see Appendix 3). Foodborne illness outbreaks associated with vegetables and melons have regular ups and downs, with a noticeable drop in 2010. The number of foodborne illnesses associated with vegetables and melons also has regular ups and downs. There is a notable spike in 2008, followed by an overall decreasing trend through 2014. The cost of foodborne illnesses associated with vegetables and melons have appears to be steady, with a notable spike in 2011, which is likely due to the Jensen Farms listeria outbreak in cantaloupes (CDC, 2017).

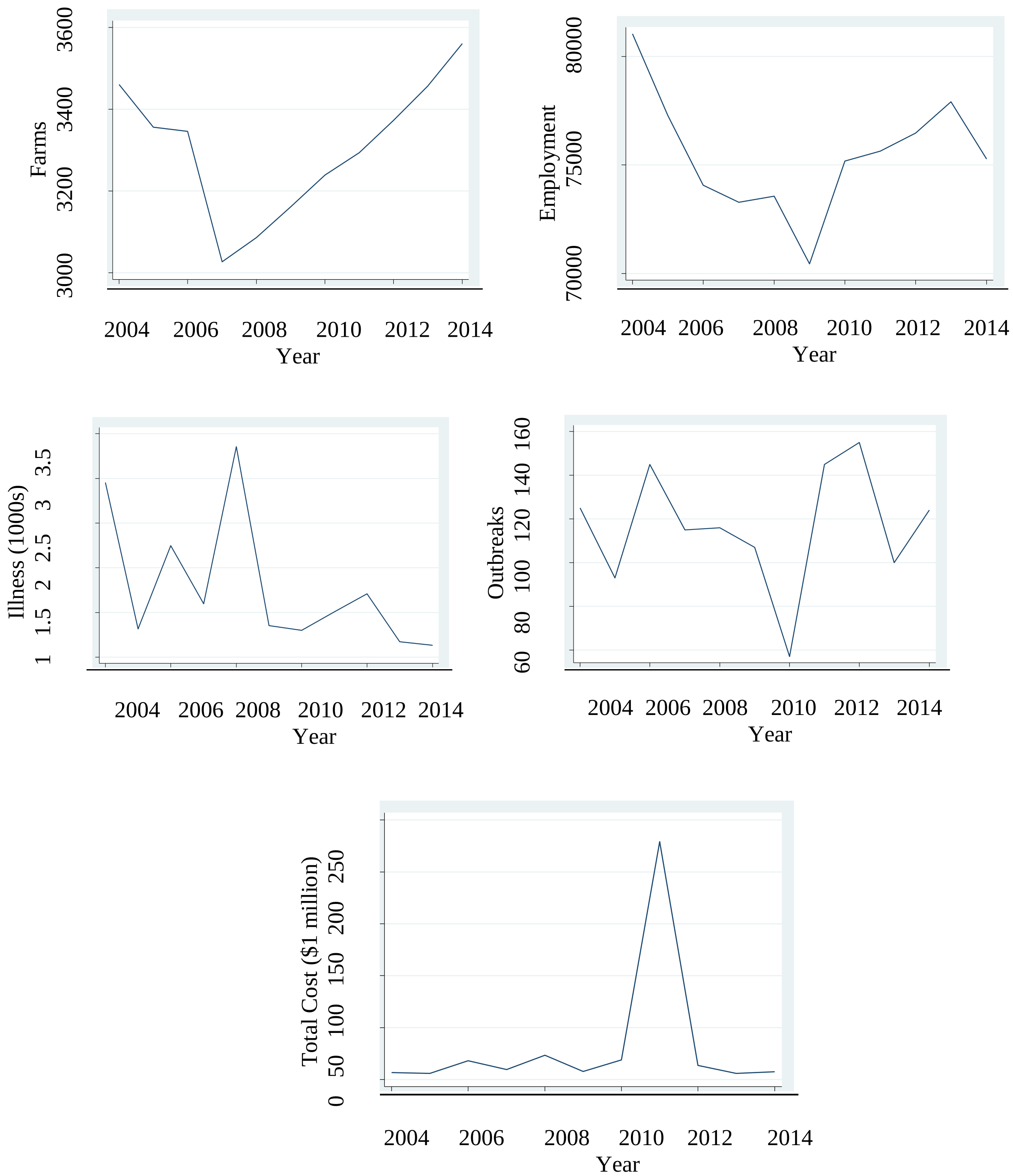

Figure 1. Outcomes and Outbreaks by Year

Table 1. Summary Statistics

	Mean	Standard Deviation	Minimum	Maximum	Data Source
Outcome					
Farms	71.86	138.3	1	989	BLS
Employees	2,225.57	5,885.74	5	34,831	BLS
Key Explanatory Variables					
Outbreaks	2.53	2.60	0	13	CDC
Illnesses	38.82	66.32	0	731.76	CDC
Cost of Illnesses (1,000s)	$683.65	$3638.76	$0	$63001.98	CDC
Control Variables					
LQ Farms	0.86	0.75	0.04	3.15	BLS
Temperature (^{0}F)	53.1	7.67	38.1	72.4	NOAA
Precipitation (in.)	38.81	14.83	6.73	70.4	NOAA
Population (1,000,000s)	6.57	6.84	0.62	38.79	BEA
GDP (per capita)	45,791.61	7,938.86	30,673	69,745	BEA
Income (per capita)	39,217.28	6,885.81	25,257	64,864	BEA
Below Poverty Level (%)	13.45	3.51	5.4	25.75	BEA
Acres (1,000,000s)	18.33	22.082	0.07	131.9	NASS
Acres (per farm)	453.25	521.86	56	2,610	NASS
Land value (S/acre)	3,838.38	3,283.62	260	16,800	NASS

***Notes*:** All summary statistics are comprised of 506 observations, with the exception of *Number of Employees,* which is comprised of 373. To minimize the number of missing values, Alaska, Hawaii, Wyoming and South Dakota are dropped from the data set. The data span the years 2004 through 2014. LQs are calculated in three steps: first, divide local industry employment by the all-industry, all-ownerships total of local employment, then divide national industry employment by the all industry, all ownerships total for the nation, and finally the local ratio is divided by the national ratio. The greater the LQ, the higher the local concentration

The data on the state-level key explanatory variables, *Outbreaks*, *Illnesses,* and *Cost of Illnesses,* come from the Centers for Disease Control and Prevention's (CDC) FOOD tool. The data pertain only to foodborne illnesses attributed to products that fall into the vegetable and melon category. The data shows an average of 2.5 outbreaks per state per year, which on average consist of approximately 39 illnesses. These numbers are both highly variable, ranging from zero to 13 outbreaks per state, per year and 0 to 732 illnesses per state, per year. *Cost of illnesses*, is calculated using pathogen cost estimates presented in Minor et al., (2015) multiplied by the CDC data on annual illnesses by pathogen. Like *outbreaks* and *illnesses*, *cost of illnesses* is highly variable ranging from zero to $63 million per state per year, with an average impact of approximately $700,000. The data for the remaining state-level control variables (all of which are state-wide values, and not restricted to NAICS 111219) come from the National Oceanic and Atmospheric Administration (NOAA), Bureau of Economic Analysis (BEA), U.S. Census, and the National

Agricultural Statistics Service. These variables control for state size, income, GDP, climate, and general farm size and value.

Table 2. Summary Statistics

	Number of Outbreaks	**Number of Illness**	**Cost per Illness**
Single Pathogen			
Bacillus Cereus	18	217	$254
Campylobacter	10	139	$4,456
Clostridium Botulinium	9	24	$1,637,084
Clostridium Perfringens	34	1,118	$257
Cryptosporidium	2	13	$2,825
Cyclospora	6	300	$4,540
E-Coli non-STEC	4	357	$803
E-Coli STEC non-O157	26	109	$2,371
E-Coli STEC O157	152	1,185	$12,165
Giardia	2	65	$6,410
Hepatitis A	4	66	$46,971
Listeria	28	153	$1,574,736
Norovirus	256	6,617	$452
Salmonella (non-Typhoidal)	442	4,967	$6,268
Salmonella (Typhoidal)	108	1,288	$6,232
Sapovirus	1	33	$474
Shigella	4	432	$3,594
Staphylococcus	4	97	$465
Unknown[1]	156	2,210	$429
Multiple Pathogens			
B. cereus; C. perfringens	11	165	$255
B. cereus; Staph.	2	11	$359
Staph.; Norovirus	1	66	$459

[1] Unknown includes pathogens labeled as "other," and pathogens labeled as "pesticide" or "plant toxin" (2 observations).

Table 2 breaks up the CDC data by pathogen and presents the cost per illness associated with each pathogen. The table shows that, from 2004 through 2014, non-Typhoidal Salmonella was responsible for the highest number of outbreaks attributed to vegetables and melons (442), followed by Norovirus (256), Unknown (156), and E-Coli STEC O157 (152). The highest number of illnesses attributed to vegetables and melons was due to Norovirus (6,617), followed by non-Typhoidal Salmonella (4,967), Unknown (2,210), and Typhoidal Salmonella (1,288). Of the pathogens associated with foodborne illnesses attributed to vegetables and melons, the most costly per case is Clostridium Botulinium, followed by Listeria, both of which cost over $1.5 million per case. Hepatitis A and E-Coli STEC O157 are the next most costly pathogens, with the cost per case in the tens of thousands of dollars.

Table 3. Weighting Matrix

Matrix	Values
Dimensions	46 x 46
Values	
min	0.0000000
min>0	0.0003760
mean	0.0015277
max	0.0258539

The information for the weighting matrix comes from the U.S. Census. Summary statistics for the weighting matrix are presented in Table 3. The matrix is 46X46 because we are looking only at the continental United States, and because we drop Wyoming and South Dakota in order to account for some of the missing observations in the data set. Each state's weight with itself is equal to 0. The weights between two different states are calculated as the inverse of the distance between the centroids of the two states.

5. Results

The results of the Ordinary Least Squares Regressions and the Spatial Durbin Models examining the association between outbreaks and farm numbers are presented in Table 4. These tables only present the coefficients on the key explanatory variables. For full model results, refer to Appendix Tables 1 and 2. Examining Table 4 from the top right, we see that the number of outbreaks are positively associated with farm numbers up to three years after outbreaks occur, suggesting that there may be entry into the market after outbreaks occur. When these estimates are examined spatially, we again observe a significant positive association up to three years after the outbreaks, as well as a similar, but dwindling effect in year four. There is no significant estimated effect on neighboring states, as indicated by the estimated coefficient on indirect.

Next we examine outbreaks as the sum of illnesses rather than the sum of outbreaks; this measure is more likely to capture severity than outbreaks summed uniformly. OLS results suggest that the number of illness is negatively associated with farm numbers three, four and five years after those illnesses occur. The magnitudes are smaller than outbreaks, as expected, since many illnesses make up a single outbreak, and the signs are more intuitive, suggesting that in the long run foodborne illnesses within a particular state are associated with lower levels of producers in that state. Spatial models suggest a similar relationship, where negative direct impacts are observed in years three, four, and five after a series of foodborne illnesses. The magnitudes of the direct effects in the spatial models are somewhat larger than those estimated by OLS. Additionally, the spatial estimates of the indirectly affected states suggest that there is a positive association between outbreak illnesses and the number of neighboring farms in the third, fourth and fifth years following those illnesses. These results seem to indicate that although it takes some time to occur, severe outbreaks do negatively affect the number of farming operations within a state where those illnesses occur, and there is some indication that neighboring states are positively affected in the long run.

International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 5, No. 42017, pp.41-61

Table 4. Outbreaks and Farms

	OLS					*Spatial*				
	Lag 1	*Lag 2*	*Lag 3*	*Lag 4*	*Lag 5*	*Lag 1*	*Lag 2*	*Lag 3*	*Lag 4*	*Lag 5*
Outbreaks										
Direct	0.640** (0.284)	1.208*** (0.268)	1.000*** (0.285)	0.400 (0.269)	0.104 (0.272)	0.554** (0.229)	1.129*** (0.241)	1.021*** (0.259)	0.531** (0.236)	0.239 (0.236)
Indirect						1.187 (0.834)	-36.016 (22.252)	7.219 (22.173)	16.753 (19.038)	22.126 (19.213)
ρ						-13.873*** (3.559)	-13.752*** (3.541)	-13.461*** (3.537)	-15.708*** (3.839)	-15.113*** (4.250)
R^2	0.389	0.409	0.398	0.392	0.374	0.291	0.251	0.218	0.138	0.111
Illnesses										
Direct	-0.004 (0.008)	0.009 (0.007)	-0.013** (0.005)	-0.018*** (0.005)	-0.027*** (0.005)	-0.003 (0.006)	0.009 (0.006)	-0.013*** (0.005)	-0.021*** (0.004)	-0.029*** (0.004)
Indirect						0.032 (0.036)	-0.031 (0.033)	0.052** (0.026)	0.053** (0.022)	0.087*** (0.021)
ρ						-13.380*** (3.551)	-13.693*** (3.566)	-13.382*** (3.540)	-15.512*** (3.836)	-14.634*** (4.242)
R^2	0.382	0.384	0.389	0.410	0.431	0.340	0.309	0.371	0.182	0.121
Cost of Illnesses										
Direct	-0.120 (0.121)	-0.059 (0.121)	-0.026 (0.122)	-0.383 (0.284)	-0.823** (0.319)	-0.129 (0.099)	-0.048 (0.109)	-0.044 (0.110)	-0.225 (0.255)	-0.650** (0.286)
Indirect						0.074 (0.596)	0.630 (16.596)	-23.507 (17.043)	89.574** (37.178)	83.092** (36.943)
ρ						-13.470*** (3.544)	-13.490*** (3.544)	-13.474*** (3.545)	-15.409*** (3.851)	-14.561*** (4.248)
R^2	0.383	0.382	0.382	0.391	0.386	0.355	0.328	0.343	0.125	0.103
Obs.	506	506	506	460	414	506	506	506	460	414

***Notes*:** Standard Errors are presented in parenthesis.

Table 5. Outbreaks and Employees

	OLS					*Spatial*				
	Lag 1	*Lag 2*	*Lag 3*	*Lag 4*	*Lag 5*	*Lag 1*	*Lag 2*	*Lag 3*	*Lag 4*	*Lag 5*
Outbreaks										
Direct	42.051*** (9.480)	53.003*** (8.954)	52.359*** (9.514)	32.354*** (9.023)	22.203** (8.626)	38.421*** (7.729)	50.802*** (7.325)	49.347*** (7.718)	31.120*** (7.454)	22.077*** (6.860)
Indirect						-44.553* (22.818)	-44.907** (22.859)	-39.071 (29.232)	-39.115 (24.250)	3.019 (22.616)
ρ						-1.132 (2.649)	-1.388 (2.662)	-0.972 (2.636)	-1.694 (2.914)	-2.268 (3.269)
Illnesses										
Direct	0.028 (0.255)	0.511** (0.247)	0.24 (0.187)	0.102 (0.166)	-17.385* (10.031)	0.070 (0.206)	0.476** (0.199)	0.243 (0.149)	0.116 (0.136)	0.075 (0.120)
Indirect						0.257 (1.122)	-0.440 (1.081)	0.070 (0.923)	0.104 (0.877)	0.415 (0.983)
ρ						-1.537 (2.703)	-1.482 (2.685)	-1.495 (2.692)	-1.748 (2.878)	-1.880 (3.175)
Cost of Illnesses										
Direct	2.634 (4.109)	2.594 (4.047)	5.942 (4.214)	-3.119 (10.361)	0.040 (0.151)	2.310 (3.345)	2.421 (3.220)	6.069* (3.521)	-2.635 (8.834)	-19.789** (8.291)
Indirect						11.348 (11.276)	2.001 (11.604)	2.408 (13.371)	-6.193 (57.126)	-64.251 (43.560)
ρ						-1.774 (2.705)	-1.546 (2.697)	-1.709 (2.746)	-1.683 (2.878)	-3.470 (3.391)
Obs.	506	506	506	460	414	506	506	506	460	414

***Notes*:** Standard Errors are presented in parenthesis. Because this is estimated using imputation, R2 is not calculated

Finally, we examine the association between farms and outbreaks, measured as the total annual estimated cost of foodborne illnesses. Here again, we are trying to capture severity of the outbreaks, rather than counting them uniformly. This model may be superior to outbreaks and illnesses as it will prioritize the most harmful impacts and capture any changes associated with the most severe foodborne outbreaks. OLS estimates show that the estimated cost of illnesses is negatively associated with farm numbers five years following the foodborne event. These results, like illnesses, suggest that foodborne illnesses are negatively associated with farm numbers in the longer term. Spatial models, show similar direct results, but suggest that effects may start to materialize as soon as four years after the foodborne outbreak for neighboring states. Indirect effects are estimated to be positive and much larger in magnitude, suggesting that some operations may be pushed out of the implicated state while neighboring states may re-allocate to fill the affected production.

Table 5 presents the association between outbreaks and the number of employees estimated via OLS and Spatial Durbin Models. OLS results, measuring outbreaks uniformly, show that outbreaks are positively associated with employment in all five years following a foodborne outbreak event. The effect is estimated to rise in year two and then taper off through year five. Spatial models suggest a direct effect very similar to OLS results, but also suggest that neighboring states are negatively affected in the first two years following an outbreak event. The opposite signs on direct and indirect coefficients suggest that there may be labor flight from the neighboring state to the affected state in the short term.

Defining outbreaks in terms of illnesses yields somewhat different results. OLS estimates suggest that there is a small positive association with employment two years following a foodborne outbreak, but a large negative association five years after the outbreak. Spatial models however, suggest only the small positive direct impact, two years after a foodborne outbreak. OLS models measuring outbreaks in terms of the total estimated cost reveal no significant association between outbreaks and employment. Spatial models show a positive association three years following a foodborne outbreak event and a much larger negative association five years following the event. Taken wholly, these models seem to suggest that in the near-term employment may increase in a state affected by foodborne outbreaks. This may make sense if workers are brought in to address possible issues with production or labor, but this effect is not permanent, and in the long run employees may be more likely to leave those states affected by a foodborne outbreak.

Finally, in all of the models, the coefficient on the spatially lagged outcome is negative and significant. This means that states with higher measures of vegetable and melon farming (*Farms* or *Employment*) are surrounded by states with lower of vegetable and melon farming outcome values.

6. Conclusion

The results of our study point to a significant association between foodborne outbreak sand industry make-up for vegetable and melon farming. They show foodborne outbreaks are correlated with decreased farm numbers within this industry three to five years after a more severe event has occurred. Additionally, employment, which is more fluid in the near-term, may increase in the near-term but ultimately decline in severely affected states. Spatial analyses suggest that the effects of foodborne outbreaks on industry make-up may also spillover across state lines, and that states tend to have neighbors with dissimilar values of vegetable and melon farms and employees.

More specifically, our results may indicate that some industry consolidation in the implicated state, as farm numbers contract despite a temporary swell in employment. Additionally, because the indirect effect is most strongly observed on farm numbers, there is some indication of markets restructuring from the outbreak implicated state to neighboring states with the same or similar growing conditions. Considering the relatively long term decision for a farmer to enter or exit a particular market, it is perhaps not surprising that labor supply reacts much more quickly to an outbreak than something like land, machinery, or other relatively fixed costs which would all be involved in the start-up or shut-down of an entire farming operation.

This study adds to foodborne illness literature, as it focuses on how foodborne outbreaks are associated with the structure of affected industries, rather than on how they impact public health or on prevention measures. Our results may be of interest to farms and agribusinesses that primarily focus on the vegetable and melon industry, as they point to potential changes within the industry structure and particularly how labor moves in response to sudden market-changing events. Policy makers focused on food safety may also find our results interesting, as they show how the industry naturally responds to foodborne outbreaks.

Further exploration of this topic may benefit from access to foodborne illness data at a level smaller than the state-level. Annual farm-level output data would also be beneficial, as it would allow farm characteristics to be controlled for, as well as farm entry and exit to be recorded. Investigating the impact of foodborne illness on farm entry and exit, while controlling for spatial spillovers between neighboring farms would give us an even stronger idea of how foodborne outbreaks impact affected industries.

References

Akaike, H. (1981). "Likelihood of a model and information criteria." Journal of econometrics 16: 3-14.

Anselin, L. (1999).“Spatial Econometrics.” Center for Spatially Integrated Social Science, University of California, Santa Barbara.

Bean, N., & Griffin, P. (1990). Foodborne Disease Outbreaks in the United States, 1973-1987: Pathogens, Vehicles, &Trends. Journal of Food Protection , 53(9); 804-817.

Carlin, J., Li, N., Greenwood, P., & Coffey, C. (2003) "Tools for analyzing multiple imputed datasets." The Stata Journal 3, no. 3: 226-244.

Centers for Disease Control and Prevention. “Multistate Outbreak of Listeriosis Linked to Whole Cantaloupes from Jensen Farms, Colorado (FINAL UPDATE).” (accessed November 2, 2017)

Foltz, J. (2004). Entry, Exit, &Farm Size: Assessing an Experiment in Dairy Price Policy. American Journal of Agricultural Economics , 86 (3): 594-604.

Glauben, T. T. (2006). Agriculture on the move: Exploring regional differences in farm exit rates in Western Germany. Review of Regional Research , 26: 103.

Greig, J., & Ravel, A. (2009). Analysis of foodborne outbreak data reported internationally for source attribution. International Journal of Food Microbiology , 130(2); 77-87.

Hoffman, S., & Anekwe, T. (2013). Making sense of recent cost-of-foodborne-illness estimates. United States Department of Agriculture, Washington, DC, USA.

Hoffmann, S., Batz, M., & Morris, J. (2012). Annual cost of illness and quality-adjusted life year losses in the United States due to 14 foodborne pathogens. Journal of Food Protection, 75(7):1292–1302.

Kazukauskas, A. N. (2013). Disinvestment, Farm Size, & Gradual Farm Exit: The Impact of Subsidy Decoupling in a European Context. American Journal of Agricultural Economics , 95 (5): 1068-1087.

McCabe-Sellers, B., & Beattie, S. (2004). Food safety: Emerging trends in foodborne illness surveillance & prevention. Journal of the American Dietetic Association, 104(11); 1708-1717.

Minor, T., Lasher, A., Klontz, K., Brown, B., Nardinelli, C., & Zorn, D. (2015). The Per Case & Total Annual Costs of Foodborne Illness in the United States. Risk Analysis, 35: 1125–1139.

Naimi, T., Wicklund, J., Olsen, S., Krause, G., Wells, J., Bartkus, J., . . . Hedberg, C. (2003). Concurrent Outbreaks of Shigella sonnei and Enterotoxigenic Escherichia coli Infections Associated with Parsley: Implications for Surveillance & Control of Foodborne Illness. Journal of Food Protection, 4; 535-709.

Painter, J. A. (2013). Attribution of foodborne illnesses, hospitalizations, & deaths to food commodities by using outbreak data, United States, 1998–2008. Emerging Infectious Disease, 19(3), 407-415.

Sauer, C., Majkowski, J., Green, S., & Eckel, R. (1997). Foodborne Illness Outbreak Associated with a Semi-Dry Fermented Sausage Product. Journal of Food Protection , 12; 1612-1617.

Scallan, E., Hoekstra, F., Angulo, R., Tauxe, M., Roy, S., Jones, J., & Griffin, P. (2001). Foodborne Illness Acquired in the United States—Major Pathogens. Emerging Infectious Disease, 17(1); .

Sivapalasingam, S., Friedman, C., Cohen, L., & Tauxe, R. (2004). Fresh produce: a growing cause of outbreaks of foodborne illness in the United States, 1973 through 1997. Journal of Food Protection, 67(10); 2342-2353.

Stata Multiple-Imputation Reference Manual. 2013. https://www.stata.com/manuals13/mi.pdf (accessed April 30, 2017)

United States Census. http://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-people.html(accessed September 1, 2017)

International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 5, No. 42017, pp.41-61

Appendix 1. Ordinary Least Squares with Time and Individual Fixed Effects Full Results

	Average Annual Establishments	Average Annual Number of Employees	Average Annual Establishments	Average Annual Number of Employees	Average Annual Establishments	Average Annual Number of Employees
Illnesses	-0.004 (0.008)	0.028 (0.255)				
Estimated Impact (1,000s)			-0.120 (0.121)	2.634 (4.109)		
Outbreaks					0.640** (0.284)	42.051*** (9.480)
LQ Farms	26.563*** (2.590)	106.540 (95.630)	26.429*** (2.591)	109.343 (95.567)	26.391*** (2.577)	95.894 (93.959)
Precipitation (in.)	0.014 (0.082)	-1.496 (2.863)	0.010 (0.081)	-1.464 (2.852)	0.005 (0.081)	-1.848 (2.800)
Population (1,000,000s)	-8.782*** (1.512)	-514.230*** (51.147)	-8.638*** (1.509)	-516.504*** (51.097)	-8.629*** (1.500)	-508.472*** (49.924)
GDP (per capita)	0.000 (0.000)	0.070*** (0.016)	0.000 (0.000)	0.070*** (0.016)	0.000 (0.000)	0.064*** (0.015)
Income (per capita)	-0.001 (0.001)	-0.029 (0.021)	-0.001 (0.001)	-0.030 (0.021)	-0.000 (0.001)	-0.023 (0.021)
Below Poverty Level (%)	-0.033 (0.325)	-8.756 (11.444)	-0.065 (0.326)	-8.096 (11.481)	-0.039 (0.323)	-8.950 (11.215)
Acres (1,000,000s)	-1.778 (1.711)	26.463 (58.933)	-1.664 (1.715)	23.371 (59.110)	-1.600 (1.703)	40.959 (57.672)
Acres (per farm)	0.001 (0.005)	-0.322* (0.177)	0.001 (0.005)	-0.316* (0.177)	0.002 (0.005)	-0.298* (0.175)
Land value (S$/acre)	-0.002*** (0.001)	-0.048* (0.025)	-0.002*** (0.001)	-0.048* (0.025)	-0.002*** (0.001)	-0.055** (0.024)
Constant	144.665*** (35.075)	1,048.793 (848.400)	142.031*** (35.170)	1,078.717 (850.875)	-0.007 (-0.005)	910.144 (833.990)
R-squared	0.382		0.383		0.389	

International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 5, No. 42017, pp.41-61

Appendix 2. Spatial Durbin Model with Time and Individual Fixed Effects Full Results (Marginal Effects)

Average Annual Establishments					
	Main				
Illnesses	-0.001 (0.007)	**Wx**	**Direct**	**Indirect**	**Total**
LQ Farms	27.101*** (2.446)	0.782 (0.983)	-0.003 (0.006)	0.032 (0.036)	0.029 (0.035)
Precipitation (in.)	-0.008 (0.076)	203.318 (254.362)	27.691*** (2.775)	-6.711 (9.099)	20.980** (9.146)
Population (1,000,000s)	-9.958*** (1.504)	-3.386 (4.487)	0.005 (0.088)	-0.141 (0.199)	-0.136 (0.168)
GDP (per capita)	0.000 (0.000)	-249.187 (310.937)	-9.496*** (1.462)	-8.042 (11.573)	-17.537 (11.410)
Income (per capita)	-0.000 (0.001)	0.017 (0.030)	0.000 (0.000)	0.001 (0.001)	0.001 (0.001)
Below Poverty Level (%)	0.072 (0.299)	-0.016 (0.013)	-0.000 (0.001)	-0.000 (0.001)	-0.001 (0.001)
Acres (1,000,000s)	-1.149 (1.647)	24.012 (29.615)	0.033 (0.312)	0.986 (1.221)	1.019 (1.234)
Acres (per farm)	-0.002 (0.005)	-21.113 (226.630)	-1.131 (1.656)	-1.426 (7.915)	-2.557 (7.881)
Land value (S$/acre)	-0.003*** (0.001)	-0.578 (0.781)	-0.001 (0.004)	-0.024 (0.028)	-0.025 (0.029)
ρ	-13.380*** (3.551)	0.037 (0.027)	-0.003*** (0.001)	0.003** (0.001)	-0.000 (0.001)
σ^2	61.659*** (3.873)	.			
R^2	0.340				

Average Annual Number of Employees					
	Main	**Wx**	**Direct**	**Indirect**	**Total**
Illnesses	0.076 (0.238)	3.192 (17.229)	0.070 (0.206)	0.257 (1.122)	0.327 (1.120)
LQ Employees	147.044 (93.599)	-4,760.114 (7,746.256)	155.205 (102.283)	-356.564 (491.147)	-201.358 (507.888)
Precipitation (in.)	-1.542 (2.784)	61.861 (100.211)	-1.419 (2.995)	3.432 (7.052)	2.013 (6.484)
Population (1,000,000s)	-470.431*** (49.320)	24,539.936*** (6,893.803)	-475.848*** (50.258)	1,546.739*** (443.761)	1,070.891** (450.978)
GDP (per capita)	0.066*** (0.014)	-1.170 (0.858)	0.069*** (0.014)	-0.072 (0.054)	-0.004 (0.055)
Income (per capita)	-0.033* (0.017)	0.341 (0.394)	-0.034* (0.018)	0.023 (0.028)	-0.010 (0.029)
Below Poverty Level (%)	-9.019 (11.197)	-150.759 (887.262)	-8.255 (11.578)	-1.667 (57.050)	-9.922 (57.909)
Acres (1,000,000s)	81.683 (58.649)	16,419.040** (7,234.135)	75.867 (56.299)	950.400** (466.361)	1,026.267** (472.036)
Acres (per farm)	-0.223 (0.175)	18.731 (20.217)	-0.251 (0.177)	1.234 (1.328)	0.983 (1.374)
Land value (S$/acre)	-0.054** (0.026)	0.929 (0.854)	-0.055** (0.025)	0.062 (0.053)	0.007 (0.054)
ρ	-1.537 (2.703)				
σ^2	75,538.085*** (5,121.897)				

International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 5, No. 42017, pp.41-61

Average Annual Establishments					
	Main	**Wx**	**Direct**	**Indirect**	**Total**
Estimated Impact (1,000s)	-0.123 (0.109)	-0.161 (16.463)	-0.129 (0.099)	0.074 (0.596)	-0.055 (0.570)
LQ Farms	27.147*** (2.449)	229.944 (253.176)	27.686*** (2.773)	-5.750 (8.957)	21.936** (9.004)
Precipitation (in.)	-0.010 (0.076)	-2.574 (4.392)	0.000 (0.088)	-0.107 (0.195)	-0.107 (0.164)
Population (1,000,000s)	-9.815*** (1.501)	-237.355 (311.687)	-9.372*** (1.460)	-7.618 (11.505)	-16.990 (11.351)
GDP (per capita)	0.000 (0.000)	0.018 (0.030)	0.000 (0.000)	0.001 (0.001)	0.001 (0.001)
Income (per capita)	-0.000 (0.001)	-0.018 (0.013)	-0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Below Poverty Level (%)	0.050 (0.299)	23.725 (29.685)	0.011 (0.312)	0.986 (1.223)	0.997 (1.232)
Acres (1,000,000s)	-1.013 (1.656)	-6.166 (227.248)	-1.021 (1.651)	-0.923 (7.894)	-1.945 (7.887)
Acres (per farm)	-0.002 (0.005)	-0.626 (0.789)	-0.001 (0.004)	-0.026 (0.028)	-0.027 (0.029)
Land value (S$/acre)	-0.003*** (0.001)	0.042 (0.026)	-0.003*** (0.001)	0.003*** (0.001)	0.000 (0.001)
ρ	-13.470*** (3.544)				
σ^2	61.554*** (3.867)				
R^2	0.355				

Average Annual Number of Employees					
	Main	**Wx**	**Direct**	**Indirect**	**Total**
Estimated Impact (1,000s)	2.431 (3.842)	170.205 (180.602)	2.310 (3.345)	11.348 (11.276)	13.657 (10.894)
LQ Employees	158.785* (93.358)	-1,653.962 (8,113.177)	166.077 (101.336)	-145.535 (502.750)	20.541 (521.468)
Precipitation (in.)	-1.578 (2.769)	59.273 (98.504)	-1.464 (2.987)	3.268 (6.838)	1.805 (6.249)
Population (1,000,000s)	-470.971*** (49.299)	26,080.411*** (6,986.118)	-478.121*** (50.573)	1,632.790*** (444.043)	1,154.669** (450.179)
GDP (per capita)	0.068*** (0.014)	-0.919 (0.863)	0.070*** (0.014)	-0.056 (0.054)	0.014 (0.055)
Income (per capita)	-0.036** (0.017)	0.164 (0.422)	-0.037** (0.018)	0.012 (0.029)	-0.025 (0.031)
Below Poverty Level (%)	-7.792 (11.253)	110.434 (902.771)	-7.114 (11.589)	15.381 (57.016)	8.267 (57.996)
Acres (1,000,000s)	85.520 (58.971)	17,651.323** (7,191.946)	78.600 (56.245)	1,017.879** (461.627)	1,096.479** (464.811)
Acres (per farm)	-0.220 (0.174)	18.341 (19.641)	-0.249 (0.176)	1.184 (1.283)	0.935 (1.328)
Land value (S$/acre)	-0.052** (0.026)	1.291 (0.869)	-0.054** (0.025)	0.087 (0.055)	0.033 (0.055)
ρ	-1.774 (2.705)				
σ^2	75,251.213*** (5,110.463)				

Average Annual Establishments					
	Main	**Wx**	**Direct**	**Indirect**	**Total**
Outbreaks	0.631** (0.253)	39.193* (22.275)	0.554** (0.229)	1.187 (0.834)	1.741** (0.790)
LQ Farms	27.049*** (2.421)	244.201 (251.352)	27.588*** (2.759)	-5.504 (8.779)	22.084** (8.796)
Precipitation (in.)	-0.010 (0.075)	-4.396 (4.434)	0.005 (0.088)	-0.175 (0.194)	-0.170 (0.164)
Population (1,000,000s)	-9.931*** (1.487)	-328.226 (308.810)	-9.285*** (1.447)	-10.687 (11.337)	-19.972* (11.172)
GDP (per capita)	0.000 (0.000)	0.011 (0.030)	0.000 (0.000)	0.000 (0.001)	0.001 (0.001)
Income (per capita)	-0.000 (0.001)	-0.016 (0.013)	-0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Below Poverty Level (%)	0.043 (0.296)	21.786 (29.342)	0.006 (0.311)	0.901 (1.189)	0.907 (1.199)
Acres (1,000,000s)	-1.260 (1.634)	-58.935 (224.948)	-1.163 (1.655)	-2.750 (7.746)	-3.913 (7.697)
Acres (per farm)	-0.001 (0.005)	-0.463 (0.775)	-0.000 (0.004)	-0.020 (0.027)	-0.020 (0.028)
Land value (S$/acre)	-0.003*** (0.001)	0.015 (0.029)	-0.003*** (0.001)	0.002* (0.001)	-0.001 (0.001)
ρ	-13.873*** (3.559)				
σ^2	60.492*** (3.813)				
R^2	0.291				

Average Annual Number of Employees					
	Main	**Wx**	**Direct**	**Indirect**	**Total**
Outbreaks	38.427*** (8.946)	-650.350* (343.887)	38.421*** (7.729)	-44.553* (22.818)	-6.132 (21.438)
LQ Employees	137.880 (92.286)	-3,734.316 (7,608.192)	145.201 (100.805)	-290.619 (494.531)	-145.419 (511.682)
Precipitation (in.)	-1.614 (2.725)	76.698 (96.879)	-1.494 (2.931)	4.544 (6.958)	3.050 (6.412)
Population (1,000,000s)	-467.485*** (48.442)	23,322.086*** (6,822.438)	-470.533*** (49.126)	1,495.856*** (445.570)	1,025.323** (452.877)
GDP (per capita)	0.061*** (0.014)	-1.245 (0.810)	0.063*** (0.014)	-0.078 (0.053)	-0.015 (0.054)
Income (per capita)	-0.028 (0.017)	0.314 (0.388)	-0.029* (0.017)	0.021 (0.028)	-0.008 (0.029)
Below Poverty Level (%)	-8.987 (11.064)	-360.999 (871.977)	-8.208 (11.405)	-16.485 (57.388)	-24.694 (58.411)
Acres (1,000,000s)	94.576 (57.636)	16,056.868** (7,057.426)	90.098 (55.433)	958.340** (469.039)	1,048.439** (474.312)
Acres (per farm)	-0.211 (0.173)	13.348 (20.009)	-0.237 (0.175)	0.895 (1.348)	0.659 (1.395)
Land value (S$/acre)	-0.056** (0.026)	1.126 (0.841)	-0.058** (0.025)	0.076 (0.054)	0.018 (0.055)
ρ	-1.132 (2.649)				
σ^2	72,654.747*** (4,962.169)				

International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 5, No. 42017, pp.41-61

Appendix 3. Imputed Numbers