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Historical and Spacial Analysis of High-Value Crop Production in the U.S.

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By

Mei-luan Cheng, Nelson Bills, and Joseph Francis*

Abstract

This paper examines the complex relationship between urbanization and high-value crops production in the US. High-value products (HVPs) are defined to include farms producing fruit, vegetable, and greenhouse and nursery crops. Analysis of historical (1949-2002) shifts in production and redefinitions of metropolitan counties shows that HVPs production has been highly concentrated in metropolitan counties but in stable proportions, especially in the Northeast, Southeast and Pacific regions. To help understand these spatial relationships, a model of location and production is developed to emphasize how urbanization economies, agglomeration economies, and firm-specific factors affect the HVP production. The model is implemented for the greenhouse/nursery sector in the Northeast. Results show that current greenhouse/nursery production levels are positively correlated across counties. A critical element in assuring the continued economic vibrancy of greenhouse/nursery business will depend on operators adapting to increased competition for land in metropolitan areas while exploiting the marketing options offered by proximity to a growing number of non-farm residents.

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I. Introduction

Agriculture is an integral part of urban growth and population change in the US and in other modern nations. This fact is frequently unrecognized by the general public, mainstream agricultural interests, and political leaders. In many people's minds, there is the perception of a rural–urban split that results in competition for resources and separate policy tracks. Farming and farms have always defined rural life and rural communities. However, as the U.S. population shifted from residing and working in rural areas to urban areas, linkages between rural and urban communities have become more subtle. Many economic and social components of agriculture generate both tangible and intangible values for an urbanizing society. Recently, some studies have paid attention to agriculture's urban dimensions and illustrate the complex system of urban agriculture, which encompasses commodity production along with other activities along the value chain. These include processing, marketing, distribution, consumption, recreation/leisure pursuits, business entrepreneurship, environmental restoration and remediation, and community health and well-being (CAST report, 2002). This means that, today, agriculture is found in both rural and urban locations, and in a variety of forms and intensities.

The purpose of this paper is to summarize and clarify relationships between measures of urban influence and the spatial distribution of high-value crop production in the US. We elaborate on definitions of high value crops below and review literature that might allow one to assume that the production of high-value products (HVPs) has become increasingly concentrated in metropolitan areas over time. It is important to have a long-term perspective in order to understand the dynamics of agriculture adjustment to urbanization. To this end, we assembled county-level sales data for HVPs over Census intervals dating to 1949. An effort is made to overcome the impact of evolving metropolitan definitions on the thesis that HVP production, on balance, is concentrating in urbanizing counties and in reasonably close proximity to large urban cores. This is accomplished by examining long-term, secular trends in HVP production in the nation's top 300 counties, based on total population. Then, a general model is developed to determine the extent to which urbanization, spatial agglomeration, and firm-specific factors affect the spatial structure and geographical locations of HVP production.

The paper is developed in several sections. The next section summarizes and interprets key pieces of economic literature. Then, we deal with the question of measuring urban influence and assess the distribution of HVP crop production in urbanizing areas in the U.S. from 1949 forward in order to answer questions such as "Does farming persist in the city's shadow?" or "Does HVP crop production still thrive in the metro areas?" Then, the following section will introduce the model and describe the data used in the analysis. Spatial econometric methods are implemented for the densely populated northeastern US to examine the variables influencing location and production of greenhouse/nursery products.

II. A Brief Literature Review

Economic development theory for whole nations revolved around sharp distinctions between the agricultural and non-agricultural economy. Generations of economists paid close attention to conceptual frameworks advanced by Arthur Lewis, which emphasized a dual economy and the need to understand the process of urbanization and rural-urban migration. The overriding promise was that the major role of the nation's agricultural sector in a developing economy is to free surplus of labor to fuel a growing industrial sector (Lewis, 1958). Axiomatic for this theory is the perception that inefficiency and low labor productivity characterize agriculture. These models are non-spatial and therefore, have no bearing on the location of economic activities (Bhadra and Brandao, 1993).

The work of von Thünen stands in contrast because spatial relationships are explicitly recognized. The von Thünen location theory, developed some 150 years ago for urban-rural relations in Northern Germany, uses agricultural markets to illustrate the importance of location and the resulting transport costs to a central city in determining land use and land rent. It has greatly influenced the literature studying the implications of urbanization on land use. Von Thünen's idealized spatial model visualized an isolated populations settlement supplied by farmers in the surrounding countryside. He showed that competitions among farmers in commodity production will determine the gradient of land rents declining from a maximum at the town to zero at the outermost limit of cultivation. Each farmer/producer will be faced with a trade-off between land rents and transportation costs. Because crops differ in both their transportation cost and their yield per acre, a pattern of concentric rings of production will result. Thus, the high-rent land near the town would be reserved for crops with high transportation costs and/or crops yielding high value per acre such as vegetables; the outermost ring would be used to grow crops with either land-intensive or cheaper transportation costs such as wheat and cattle (Fujita et al, 1999, Krugman, 1995).

The effects of urbanization on agriculture have been analyzed in a series of models inspired by von Thuenen's work. Muth's analysis, a classic presentation of von Thunen's world, showed that as a city expands, its boundary expands through rural land conversion into urban uses (Muth, 1961). Other analysts, e.g., Katzman (1974) have elaborated on the von Thunen model to develop hypotheses about the linkages between agricultural and urban development; he concluded that, after considering gains in earnings from rural-to urban migration along with other economic and psychic costs, at equilibrium the disparity between urban and rural incomes will increase with distance from urban centers. In another words, farm income and productivity are posited to be highest near the centers of urban-industrial development.

Models of this sort provide useful insights into the spatial organization of agriculture and interesting hypothesis about the effects of proximity to urban centers on profitability of farming, but seem deficient because they assumed that agricultural enterprise in metropolitan areas does not exist (Gardner, 1994). But, as this paper will show, the data on metropolitan areas clearly indicate, there is actually a great deal of farming life in urbanizing communities. How does one understand this in terms of spatial theory? Lopez et al (1988) conceptualized the effects of “suburbanization” on agriculture. This is important because the farming activities to be investigated do not take place in central cities, but in areas surrounding them that can generally be classified as suburban or even urban. These areas are rightly placed within metropolitan areas for statistical purposes because their economic activities are heavily oriented toward center cities. As the United States continues to urbanize, the conflicts between agricultural and nonagricultural uses of land may intensify. This implies that while metropolitan agriculture survives, it continually shrinks in acreage. The gradient of agricultural systems around central cities moves further toward concentration of production on land well-suited to perishable products. However, the surprising story in the data is how well agriculture is doing in these areas. While the number of farms is declining in metro as in nonmetro areas, the rate of decline is not much higher in metro areas. The average annual rate of decline in the number of farms was 2.26 percent in the metro counties and 2.02 percent in the nonmetro counties over the period 1944-1982 (Lockeretz, 1986).

Urbanization is one of the most important factors influencing agriculture, and a prevailing opinion often is that the impacts are negative. Some observers contend that urban growth results in farm operators’ disinvestment in their agricultural operation in anticipation of their land being converted from farm to urban use, described as the “impermanence syndrome” (Berry, 1978). However, there are other voices, some suggesting that urbanizing environments offer attractive options for farm operators willing to grow their business by adapting to and exploiting the market potential associated with proximity to large population concentrations. Heimlich and Brooks (1989) argued that urban influences on agriculture have both negative and positive aspects, which simultaneously bring pressure on farmers to adapt and offer them opportunities. The net effects of urbanization on agricultural land use may depend on the type of agricultural commodity produced. Lopez et al (1988) showed that vegetable production may benefit from suburbanization while livestock production may be adversely affected.

Heimlich and Brooks (1989) built on earlier US Department of Agriculture studies and reported that the 1982 Census showed that farms in metro areas nationwide dominate in high-value products (HVP), often referred to as “specialty crops”. Farms located in metro counties accounted for more than two-thirds of the farm sales in fruit and vegetables and more than three-fourths of nursery and greenhouse sales. Hines and Rhodes (1994) reported that a higher proportion of agriculture sales in U.S. metropolitan areas came from high value production, such as diary and nurseries, while a higher proportion of agriculture sales in nonmetropolitan areas came from lower value production, such as grain, cattle and calves. Also, a 2002 report by the Council on Agricultural Science and Technology (CAST) indicated that metropolitan counties produced more than other counties in total crop sales for fruit, vegetables and nursery and greenhouse products in each of the five agricultural censuses conducted between 1978 and 1997. The CAST report also points out that, except in the central Great Plains, much of U.S agriculture occurs in counties defined as “urban influenced” (within metropolitan counties or adjacent counties); these areas contain much of the nation’s most productive agriculture and grow most of the specialty food: 79% of U.S fruits, 68% of vegetables, and 52% of dairy products are produced in urban-influenced counties (CAST, 2002).

The dynamics and proximity of urbanizing areas open up marketing opportunities not available in rural areas for supplying high-value products with service or quality dimensions and for selling products through direct marketing and other forms of access to urban consumers. Farms in metropolitan areas adapt to urban market opportunities, undertake more diverse enterprises, and produce high-value per acre products. The evidence in the empirical studies has shown that urbanization does not make agriculture disappear from urbanized areas. Labor-intensive production of HVPs in urbanized areas can make economic sense, especially when coupled with environmental amenities that farms generate for nonfarm residents (Heimlich & Barnard, 1992; Unnevehr, 1993). On the other side, farm operators have incentive to locate their HVP production close to cities where they benefit from agglomeration economies, ample markets for inputs and outputs, readily available labor, and off-farm employment. These urban agglomerations are also areas where ideas and knowledge are rapidly diffused. Metropolitan agriculture usually has a niche function in terms of time, space as well as specific social and economic conditions. While farm and farmland will continue to decrease under dense urbanization, continued expansion of suburban areas is likely to maintain or perhaps even increase the importance of agriculture suited to metropolitan areas in the U.S (Gardner, 1994). However, the present state of knowledge about these phenomena is still quite weak.

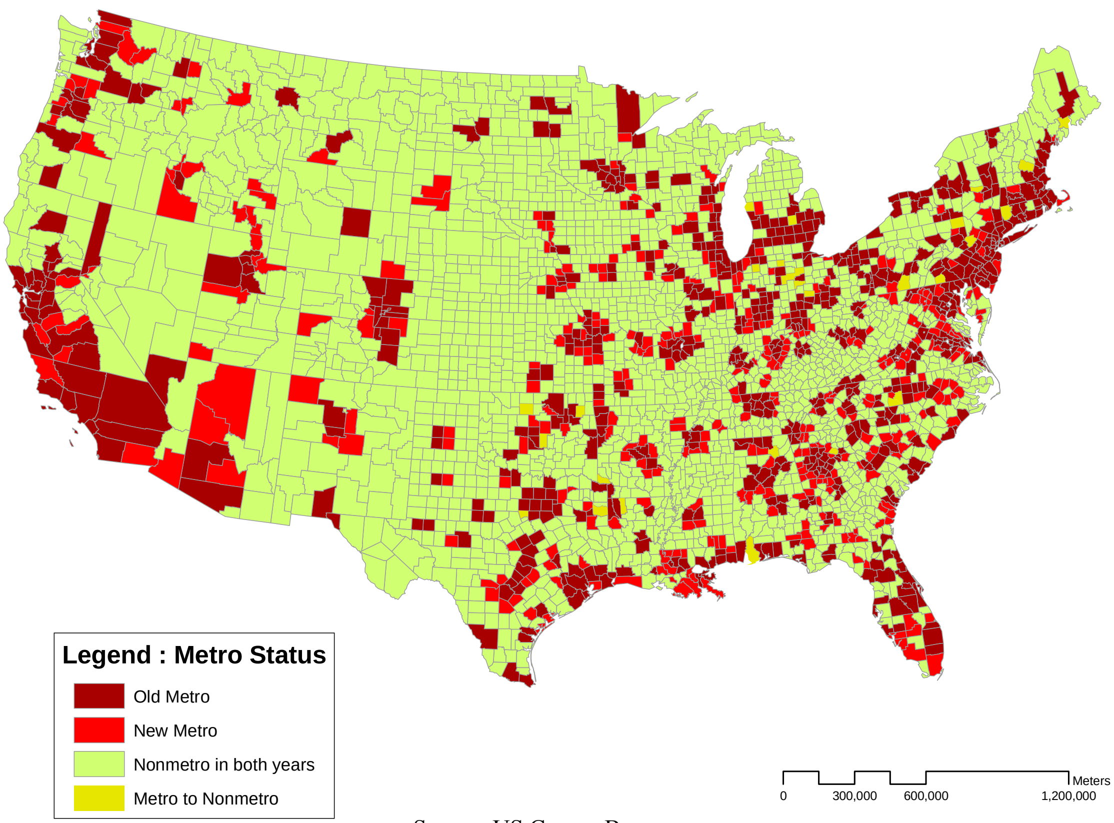
III. Agriculture and Urban Settlement

A total of 3,069 counties are reported in the five-year Census of Agriculture. These are classified into four groups of OMB-designated metro status: old metro, new metro, nonmetro in both years, and metro to nonmetro to reflect urban growth and restructuring over the past two decades (Figure 1)[2]. The group of old metro, for the purposes of this paper, is comprised of 675 counties defined as metro in both 1980 and 2003. The group of new metro includes 381 new metro counties which were reclassified and received metropolitan status between 1980 and 2003. The current metropolitan area contains about 25% of U.S land area and 80% of the U.S. population. The nonmetro area has a total of 2,013 counties. The group of nonmetro in both years includes those counties defined as nonmetro in both 1980 and 2003. The group of metro to nonmetro includes 29 counties which were metropolitan in 1980 but reclassified as nonmetropolitan in 2003.

Our data set contains fewer counties than those reported by the Census Bureau for three reasons. First, we decided to confine our analysis to the contiguous 48 states and exclude Alaska and Hawaii. Secondly, as noted above, we eliminated several cities

[2] The federal Office of Management and Budget (OMB) periodically reviews and revises the metropolitan status of US counties. The Census 2000 version used an update that classified nearly 300 formerly nonmetro counties as metro while 45 metro counties were reclassified as nonmetro. These reclassifications reflect not only urban growth and shifts in residential choices, but also modification of the rules governing metro and nonmetro status (U.S. Census Bureau, 2006).

Figure 1: Changes in Nonmetropolitan and Metropolitan Status, 1980-2003



Source: US Census Bureau

(predominantly independent cities reported for the state of Virginia) counted as county units by the Census Bureau because they were not covered in the Census of Agriculture. Finally, we eliminated 49 additional counties based on an arbitrarily selected threshold for farm numbers and acreage used for farming. Counties included in the Census of Agriculture were excluded if they contained 25 or fewer farms, fewer than 1,500 acres land in farms or both in the most recent 2002 Census report. This procedure confines our analysis to 3,020 counties in the contiguous U.S.

A Definition of High-Value Agricultural Products (HVP)

There is no single, widely agreed-upon definition of HVP crops. For the purposes of this paper, we align our definition with ongoing discussions about federal policy for “specialty crops”. A board definition, indeed the broadest, would extend to all farm commodities not designated as a “program crop” under the commodity titles of the federal Farm Bill (Bills & White, 2006). Other definitions are presently enshrined in federal law. Perhaps the most important example is the Specialty Crops Competitiveness Act of 2004 which defines the term specialty crop somewhat narrowly to mean fruits and vegetables, tree nuts, dried fruits, and nursery crops, including floriculture (Bills et al, 2006).

For the purposes of this paper, we seek a middle ground. We stop well short of using an exhaustive list of crops which are not presently eligible for federal farm program subsidy, but incorporate sales data from the Census of agriculture that uses a more expansive definition than the one specified in the Specialty Crops Competitiveness Act of 2004.

After considering access to census data at county level, the sectors of HVP or specialty crop sales for our study include the following:

- *Fruits*: including fruits, tree nuts and berries.
- *Vegetables*: including vegetables and melons, and also including potatoes and sweet potatoes in 2002 only.
- *Nursery and Greenhouse Crops*: including bedding plants, bulbs, cut flowers, flower seeds, foliage plants, mushrooms, nursery potted plants, nursery stock, live Christmas tree, tobacco transplants, sod, etc., but excluding vegetable seeds in 2002.

Agriculture and Urbanization: National Overview

Metro farms are generally smaller in land area, generate higher value per acre and more intensive farmland use than their counterparts located in nonmetro counties (Table 1). This trend becomes even more pronounced as counties have been metropolitan longer (the old metro counties). A general observation is that the need to generate higher value output on more expensive farmland in urbanizing areas leads farmers to operate more diverse enterprises and focus on higher value production. Growing population actually provides opportunities to grow new crops and market them in new ways. High-value crops, such as fresh fruit and vegetables, can be sold through specialized market niches such as restaurants and gourmet grocery outlets, or directly to consumers at road-side stands, farmers' markets, or U-pick. Land conversion to housing, along with commercial and industrial uses, offers a market opportunity to nursery and greenhouse products. Based on the North American Industry Classification System (NAICS), 56% of vegetable farms, 73% of fruit farms, and 66% of nursery and greenhouse operations in the U.S. are located in metro counties, while the majority of other types of farming is located in nonmetro counties. Many farms are not only surviving; they are thriving in the metro regions. Agriculture in metropolitan area involves more than a small minority of farm businesses. Metro counties had 24% of the nation's farmland, yet 41% of the farms are located in these counties. Moreover, in the Northeast, Southeast and Pacific regions a majority of all farms are located in metropolitan areas.

Table 1. Land in Farms and Use of Farmland by Metro Status, 2002

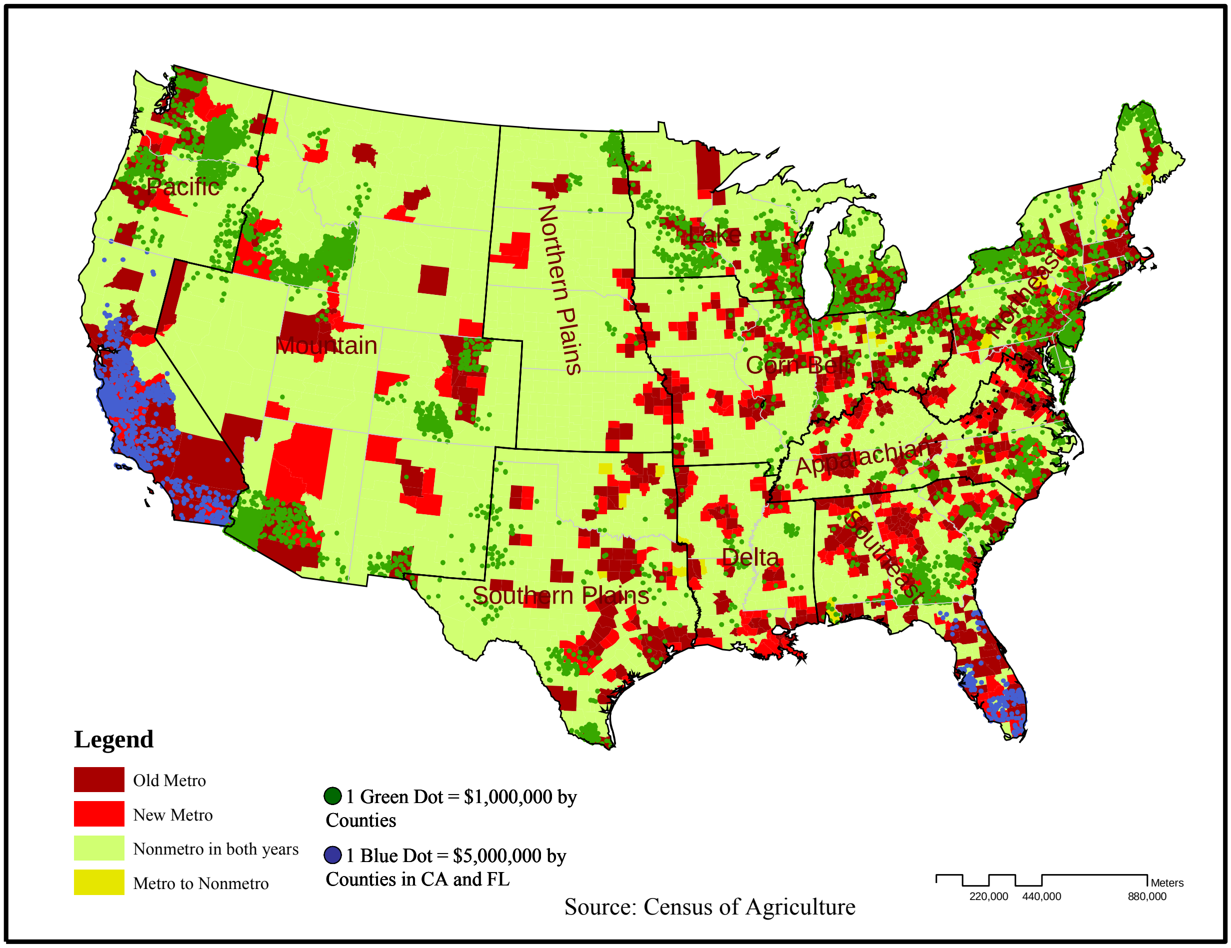
Item	Unit	Metro			Nonmetro		
		Old Metro	*New Metro*	*Total*	*Nonmetro In both years*	*Metro to Nonmetro*	*Total*
Land in farms	million acres	136	84	219	689	6	694
Number of farms	thousand	598	273	871	1219	28	1247
Average farm size	acres/ farm	227	306	252	565	199	557
Area in farms	percent	38.1%	42.7%	39.7%	51.8%	47.1%	51.8%
Value of land and buildings	dollar / acre	2,539	1,791	2,254	919	2,215	929
Value of agricultural products sold	dollar / acre	426	293	375	168	301	170
Use of farmland							
Harvested cropland	percent	41.3%	36.4%	39.5%	30.7%	52.3%	30.9%
Other land in farms	percent	58.7%	63.6%	60.5%	69.3%	47.7%	69.1%

HVP Production in Metropolitan Areas

The general characteristics of agricultural production in metropolitan areas are central to specialty crop sectors in US Agriculture. Metro farms specialize in high-value crop production. A majority of specialty crop production sales are reported by metro farms, including 66% of vegetable sales, 83% of fruit sales, and 75% of nursery and greenhouse product sales in 2002. According to the 2002 Census of Agriculture, in terms of total production of vegetables, the top five States are California (37% of U.S total), Florida (7.9%), Washington (6.3%), Idaho (5.9%) and Arizona (5.9%). However, in 1997, the top five vegetable production states are California (53% of U.S total), Florida (6%), Arizona (4%), Washington (4%), and Wisconsin (4%). Changes in the ranking of top production States between 1997 and 2002 could be due to the effect of altered definition of the vegetable category--in 2002 it included the nation's potato production, contrary to earlier census years.

Figure 2 shows a map of vegetable production in 2002 in which one green dot represents one million dollars in sales and one blue dot, shown in California and Florida, five million dollars. Mapping at two different scales yields more insight on vegetable production. From Figure 2 we observe three things: (1) overall sales of vegetables by dollar volume are concentrated in metro counties; (2) that nonmetro counties might produce more vegetable sales than metro counties in the Lake and Delta regions; (3) the production by metro status across regions is not homogeneously like the national trend which indicates 66.3% of total production in the metro areas. In the Northeast, Southeast, Mountain, and Pacific regions, metro areas produce more sales than nonmetro areas. In the Lake, Appalachian, and Delta regions, nonmetro counties produce more vegetable sales. For the remaining regions, we are not sure the status of production due to missing data.

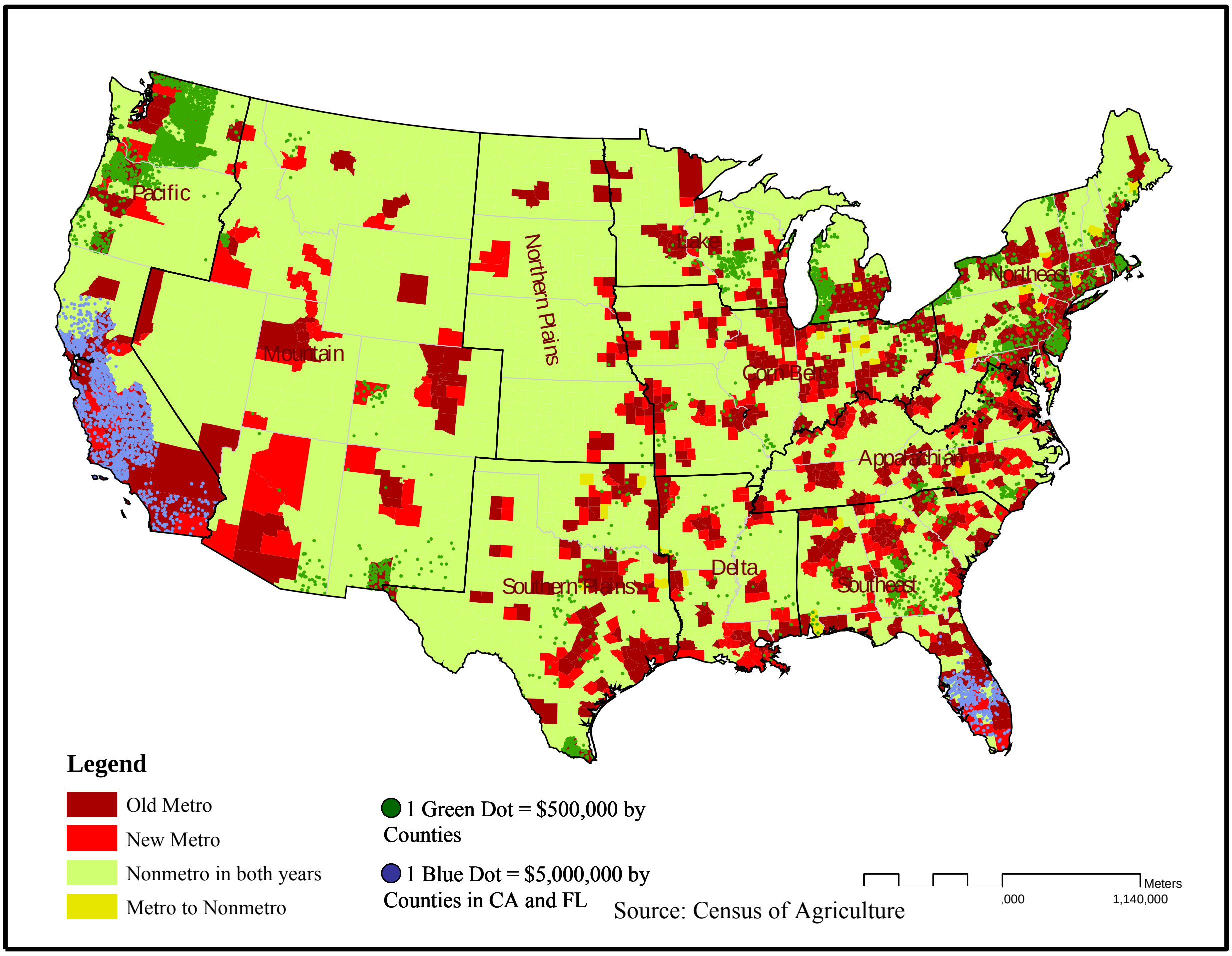
Figure 2: Market Value of Vegetable Production Sales: 2002 by Metro Status



In the case of fruit production, the top five States are California (63.3% of U.S total), Florida (11.7%), Washington (9.8%), Oregon (2.0%), and Michigan (1.3%). The 2002 fruit production sales are presented on Figure 3 with one green dot as five hundred thousand dollars and one blue dot, shown only in California and Florida, as five million dollars. As Figure 3 shows, fruit production in the country is extremely concentrated in the Pacific region, and accounted for 75% of the U.S total. The spatial pattern on the map across other regions shows considerable spatial heterogeneity and seems not to verify that metro counties produce much more fruit sales than nonmetro counties whereas the national trend indicates metro farms nation-wide produce about 80% of fruit sales

In the case of nursery and greenhouse production, the top five production states are California (22.4% of U.S total), Florida (12.6%), Oregon (5.5%), Pennsylvania (5.0%), and Texas (4.8%). See Figure 4. The 2002 nursery and greenhouse production sales are presented on the map with one green dot as one million dollars and one blue dot, shown only in California and Florida, as $2.5 million. The spatial distribution of sales of nursery/greenhouse production seems to be homogeneously concentrated in the metro counties across regions (Figure 4). In general, metro counties produce more nursery and greenhouse sales than nonmetro counties across regions.

Figure 3: Market Value of Fruit Production Sales: 2002 by Metro Status



Trends in HVP Production

Understanding trends in the spatial distribution of production of high-value agricultural products is made more problematic because of continual revisions in metro geography due to changes in metro definitions. In the past few decades, the U.S. has experienced a substantial spatial expansion of urban areas and a growth of population in these areas. As a result, an increasing number of American farms are operating in communities under urban influence because of reinterpretations of the nation's geography.

Based on these re-definitions, number of counties included in MSA's increased 287% between 1950 to 2003, from 273 to 1,056 counties, and the metro land area increased about three fold (303%) during the same period (Table 2). The population residing in the metro counties still increased 15 to 21% between 1990 and 2005.

Figure 4: Market Value of Nursery and Greenhouse Production Sales: 2002 by Metro Status

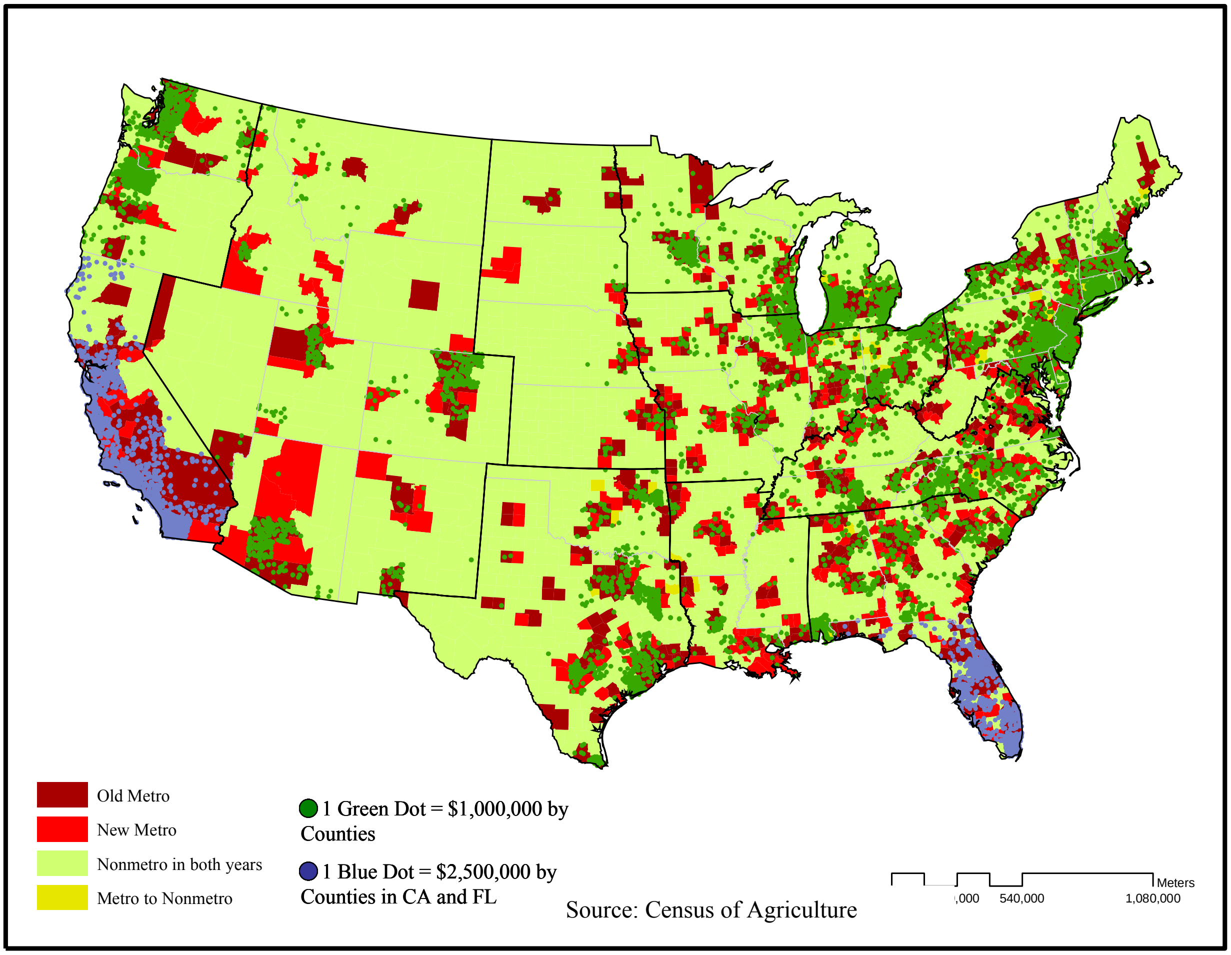


Table 2: Number of Counties, Land Area and Population of MSA's as Defined at Specific Dates, 1950-2005

Metropolitan definition	MSA's	Land area	Population 1990	Population 2000	Population 2005
	Number of counties	*Sq.miles*	*- - - Million persons - - -*		
1950	273	213,876	138.5	153.2	159.0
1960	343	315,949	153.1	171.9	180.1
1971	462	395,030	166.2	187.9	197.7
1980	704	575,665	186.2	212.0	224.3
1990	729	589,430	189.6	216.1	228.9
2003	1,056	862,750	199.5	228.2	242.0

Source: Derived from Heimlich and Brooks, US Census Bureau, 2006a and 2006b.

Fractions of commodity sales originating in metro counties are shown in Table 3 for each category of HVPs. To determine the long view, census data were assembled for five-year agricultural census intervals dating to 1949. Results for counties characterized as metropolitan are amazingly consistent over the last half-century, with fractions of total US sales hovering in the range of 80% of all HVP sales. This holds for all three HVP categories-- vegetables, fruit, and nursery/greenhouse products. A seemingly anomalous result for vegetables in 2002 is explained by an arbitrary change in data aggregation. For the first time, the Census included sales generated by potato production with sales of other vegetable commodities. Since potatoes are a major cash crop, this change in commodity aggregation is dramatic and distorts comparisons of vegetable sales with earlier census years.

To some extent, all considered, these results could be viewed as somewhat counterintuitive. While growers in urbanizing situations have a number of special business challenges, the overriding conventional wisdom is that survival rates for businesses centered on HVPs should be higher than those for other, more traditional lines of crop and livestock production in urbanizing settings. This optimism usually arises from both demand and supply considerations. As mentioned elsewhere in this paper, proximity to urban population concentration opens up opportunities for differentiating markets for both fresh and processed HVPs. Consumption of these products has increased markedly over the years as well, due not only to population growth but dramatic increases in consumption due to changes in dietary preferences and purchasing habits (Lucier and Jeraldo, 2006; Pollack and Perez, 2005; Jeraldo, 2006)

On the supply side, HVPs, by definition, generate relatively small land requirements. Technological developments and shifts in agronomic practices have reinforced this relationship with the land. For just one example, tree fruit producers have achieved enormous increases in per acre production with newer tree varieties that allow higher tree planting densities. Finally, urban proximity often leads to appreciating farm real estate values and enhanced equity position of HVP producers.

As emphasized above, the trends issue is clouded by movements in urban definition, which systematically results in large amounts of territory being reclassified as metropolitan. One possibility to overcome this limitation is to consider HVP production inside and outside the nation's high population counties. For purposes here we arbitrarily selected the top 300 counties in terms of total population and compared HVP sales there and with sales and remaining US counties. This tactic greatly reduces the variation in urban geography over time the. Results are also shown in Table 3.

Surprisingly, those ratios are exceedingly stable as well, suggesting that counties with highest population have also maintained a relatively constant fraction of HVP sales over time. On the other hand, this result largely eliminates the possibility that substantial shifts in the quantity of land mass assigned metro underpins the stability identified for HVP production in metropolitan and nonmetropolitan counties.

Table 3: Spatial distribution of HVP sales, contiguous US, selected years, 1949-2002

Year	Contiguous U.S	Top 300 counties	Old metro	New metro	Total metro	Non metro	Missing Sales
	Sales ($1000)	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
			All vegetable crops				
1949	606,470	52.3%	65.8%	14.7%	80.5%	19.5%	-
1954	644,704	55.8%	67.1%	13.5%	80.5%	19.5%	-
1959	736,093	56.4%	67.4%	13.5%	81.0%	19.0%	-
1964	982,432	56.6%	68.4%	13.8%	82.2%	17.8%	-
1978	3,247,065	60.1%	67.5%	13.6%	81.1%	15.8%	3.0%
1982	4,126,094	60.9%	67.5%	15.0%	82.1%	15.1%	2.4%
1987	4,671,518	57.5%	63.6%	16.2%	79.4%	18.2%	1.9%
1992	6,374,274	59.8%	63.1%	16.5%	79.2%	18.0%	2.4%
1997	8,367,272	61.5%	62.1%	16.6%	78.8%	18.5%	2.7%
2002	12,785,898	46.2%	49.4%	16.6%	66.0%	27.7%	6.3%
			All fruit crops				
1949	791,410	60.9%	72.1%	12.4%	84.5%	15.5%	-
1954	1,197,946	60.7%	70.8%	14.2%	85.0%	15.0%	-
1959	1,393,396	61.0%	70.6%	14.8%	85.4%	14.6%	-
1964	1,668,306	62.8%	71.9%	14.2%	86.2%	13.8%	-
1978	4,556,616	59.6%	64.3%	18.4%	82.7%	15.1%	2.2%
1982	5,724,711	63.0%	67.0%	18.0%	83.3%	13.4%	1.5%
1987	6,926,674	61.4%	65.1%	17.7%	81.0%	15.5%	1.7%
1992	9,041,278	61.5%	63.3%	17.4%	79.3%	17.9%	1.4%
1997	12,485,667	67.0%	68.3%	14.5%	82.8%	16.3%	0.9%
2002	13,770,603	64.8%	67.8%	13.2%	81.0%	14.0%	5.0%
			All nursery/greenhouse crops				
1949	390,563	61.1%	79.3%	4.4%	83.7%	16.3%	-
1954	453,558	62.7%	79.8%	4.9%	84.7%	15.3%	-
1959	604,705	66.2%	79.7%	5.5%	85.2%	14.8%	-
1964	691,753	67.4%	79.9%	5.7%	85.6%	14.4%	-
1978	2,841,602	67.4%	73.9%	3.9%	77.8%	8.8%	13.4%
1982	3,782,186	68.0%	75.1%	4.8%	79.1%	8.6%	11.5%
1987	5,712,316	67.0%	73.6%	6.6%	79.4%	10.0%	9.8%
1992	7,546,790	64.7%	71.1%	7.2%	77.4%	12.7%	9.0%
1997	10,849,640	63.3%	69.8%	8.3%	78.1%	14.0%	7.9%
2002	14,686,390	62.0%	67.7%	6.9%	74.6%	13.9%	11.5%

Source: Census of Agriculture

VI. Determinants of HVP Production: Nursery/Greenhouse Sales in the Northeast

Theoretical Model:

Following recent work by Murat (2004), we derive a model of firm location and production to examine the spatial structure of HVPs production. Assume that the firm produces output Q using inputs M_j and supplies the output to an output market. Each competitive firm i, input market j, and output market k has a location given by Cartesian coordinates (x, y). The output of each firm i is given by a stochastic quasi-concave production function

$$Q_i = f(M_{ij}, \ldots, M_{ij}, \xi_i, \delta_i, \varepsilon) \tag{1}$$

where ε is the stochastic variable indicating impacts of biophysical factors such as weather and soil conditions, ξ_i the firm-specific factors affecting production, and δ_i the external or agglomeration factors, including the extent of production in neighboring firms (i.e., $\delta_i = \delta_i(Q_l),\ \forall\, i \neq l$). It is assumed that $f_{Mj} > 0$ and $f_{MMj} < 0$. The sign of $f_{\delta i}$ determines how the external and agglomeration factors affect the firm's output. The profit of each firm i is

$$\pi_i(M, P, w, c, \delta | (x_i, y_i)) = (P - bh_{ik})Q_i - \sum_{j=1}^{J} (w_j + r_j s_{ij}) M_{ij} - c(x_i, y_i) \tag{2}$$

where P is the output price, w_j is the input price, and $c(x_i, y_i)$ is the fixed cost associated with the production and operations at (x_i, y_i), b is the transport rate per unit distance on the firm's output Q, h_{ik} is the distance between the output market k and firm i 's location, and r_j is the transport rate per unit distance on the jth input, s_{ij} is the distance from the firm i to the input market j. Let h_{ik} and s_{ij} be the Euclidean distance as

$$h_{ik}((x_i, y_i), (x_k, y_k)) = ((x_i - x_k)^2 + (y_i - y_k)^2))^{1/2} \tag{3}$$

$$s_{ij}((x_i, y_i), (x_j, y_j)) = ((x_i - x_j)^2 + (y_i - y_j)^2))^{1/2} \tag{4}$$

The firm is assumed to have a von Neuman–Morgenstern utility function, $U(W)$ defined on wealth W with $U_W > 0$ and $U_{WW} < 0$. The wealth is represented by the sum of the initial wealth (W_0) and the profit given in (2). The objective of each firm is to maximize the expected utility as

$$EU(W_0 + \pi_i(M, P, w, c, \delta | (x_i, y_i))) \tag{5}$$

where E is the expectation operator defined over ε. The choice variables in (5), the firm's input levels M_{ij} and its location (x_i, y_i), are characterized by the first-order conditions

$$\frac{\partial EU}{\partial M_{ij}} = EU_w\left[(P - bh_{ik})f_{M_{ij}} - (w_j + r_j s_{ij})\right] = 0 \quad (6)$$

$$\frac{\partial EU}{\partial x_i} = EU_w\left[(-bh_{ik\,x_i})f(\cdot) - r_j s_{ij\,x_i} M_{ij} - c_{x_i})\right] = 0 \quad (7)$$

$$\frac{\partial EU}{\partial y_i} = EU_w\left[(-bh_{ik\,y_i})f(\cdot) - r_j s_{ij\,y_i} M_{ij} - c_{y_i})\right] = 0 \quad (8)$$

The second-order conditions are satisfied under risk aversion and a quasi-concave production function. The optimal input mix is given by

$$M_{ij}^* = M_{ij}^* \,(P, b, h_{ik}, w_j, r_j, s_{ij}, \delta_i, \xi_i, U \mid (x_i, y_i)). \quad (9)$$

The firm's optimal location is determined from (7) and (8) depending on M_{ij}^*. It is implicitly given by

$$x_i^* = x_i^* \,(M_{ij}^*, P, b, h_{ik}, w_j, r_j, s_{ij}, c, \delta_i, \xi_i, U) \quad (10)$$

$$y_i^* = y_i^* \,(M_{ij}^*, P, b, h_{ik}, w_j, r_j, s_{ij}, c, \delta_i, \xi_i, U). \quad (11)$$

The first-order conditions imply that the firm i locates its operation where it obtains the highest expected utility. The optimal output, depending on (M^*_{ij}) and (x_i^*, y_i^*), is defined as

$$Q_i^* = f(M_{i1}^*, \ldots, M_{ij}^*, \delta_i(Q_l^*), \xi_i, \varepsilon \mid (x_i^*, y_i^*)). \quad (12)$$

Note that the optimal outputs of all the firms are simultaneously determined since each firm's output (Q_i^*) depends on the agglomeration factors ($\delta_i(Q_l^*)$) resulting from the existence of production in neighboring firms. The supply of HVPs will expand as the relative output price increases, as technology favoring HVP production improves rapidly, as input prices for HVP production drop, as local sector and industry infrastructure improves. Drawing from the industry location literature (Roe et al 2002; Murat, 2004; Goetz,1997), we consider several categories of variables affecting HVP location and production: (i) agglomeration economies that affect δ_i, w_i, c, and s_{ij}, (ii) firm productivity and specialization indicators that associated with ξ_i to capture profits (iii) urbanization indicators that affect P, h_{ik}, b, r_j, w_i and c, (iv) local socioeconomic conditions that impact affect P, w_i and c, and (v) biophysical factors such as land quality and climate conditions.

Econometric Model

The above theoretical model is applied to location and production data for the greenhouse/nurserygreenhouse/nursery sector in the Northeast. Total sales of greenhouse/nursery products in a county are used as a proxy for the optimal output in estimation of determinants of greenhouse/nursery production in that county. We want to explore the role that neighboring counties play in determining the greenhouse/nursery production in a given county. Thus, the important feature of our model is the inclusion of spatial interaction (spatial dependence) among the county-level greenhouse/nursery production that stems from the hypothesized intra-sector agglomeration economies. The existing spatial dependence implies that each firm's optimal output decisions depend on the neighboring outputs. Therefore, the county-level data of greenhouse/nursery sales will no longer satisfy "independence of observations", assumed in the traditional statistical methods. The commonly used ordinary least squares (OLS) regressions, therefore, are inappropriate for this purpose and lead to misleading results. In Anselin and Griffith (1988), it is shown in some detail how the results of data analyses may become invalid if spatial dependence is ignored.

Spatial dependence has two roots: measurement error and structural dependence. First, when using area data, measurement error associated with the spatial boundaries themselves may occur if the aggregation level is not the same as the level at which the process under study acts. The result of this mismatch is spatial dependence in the error terms. This dependence can be thought of as "nuisance" dependence. Second, the spatial dimension of the study may be an important aspect of the underlying model. Regional science and economics both emphasize that location – in terms of natural resources, distances to or from markets, and infrastructure - plays a role in determining the success or failure of an area (LeSage, 1999). Spatial lag models deal with "questions of how the interaction between economic agents can lead to emergent collective behavior and aggregate patterns" (Anselin, 2002).

Therefore, our empirical model incorporates spatial dependence by using a spatial lag model. The models parameterize the spatial lag structure by means of a spatial autocorrelation parameter and a spatial weight matrix (Anselin & Bera,1998). Each element of the spatial weight matrix corresponds to the relative magnitude of the spatial dependence between pairs of observations (i.e., counties). The explicit spatial interaction among the dependent variable is then formalized by

$$D = \rho VD + \beta Z + \mu \tag{11}$$

where D is a vector of the logarithm of the endogenous greenhouse/nursery sales, ρ is the scalar spatial lag coefficient, V is the spatial weight matrix, Z is the matrix of exogenous variables, β is the parameter vector to be estimated, and μ is the vector of normally distributed error terms with mean zero and variance σ^2.

The spatial lag operator, *VD,* uses the average neighboring sales of the dependent variable for each county as an explanatory variable; the parameter ρ thus reflects the spatial dependence inherent in the sample data (LeSage, 1999). At a given county, the spatial weight matrix averages the sales at nearby locations. Constructing weights in the spatial weight matrix V used in (11) is an important issue that needs further evaluation. There are various ways to define the spatial weight matrix (Anselin & Bera, 1998; Anselin, 2002). In this study, an inverse distance function is used to assign the weights in the spatial weight matrix as: $v_{ij}= 1/d_{ij}$, where d_{ij} is equal to the centroid-to-centroid distance in miles between counties i and j. Beyond some distance, the effects of greenhouse/nursery production should no longer affect local activities. For this reason, a critical distance is typically chosen as a point beyond which all the weights are equal to zero. We estimate the model with the critical distance of 50 miles. For diagnostics of spatial dependence in the models, we test the spatial dependence using Moran's *I* statistics and specifically test spatial dependence in the error terms using Lagrange multiplier test statistics.

Data

County-level agricultural and economic data are obtained from the 2002 U.S. Census of Agriculture and the US Census Bureau. The dependent variable is the natural logarithm of a county's total sales of greenhouse/nursery products. All sale values add "1" before taking the natural logarithm to avoid problems of an undefined number for counties with zero values. We consider several categories of variables that affect the firm's optimal greenhouse/nursery production level such as firm-specific factors, agglomeration economies, urbanization, and socioeconomic factors. At this stage of development, biophysical factors such as land quality and climate conditions are ignored in the econometric model.

Greenhouse/nursery production is a highly intensive enterprise requiring substantial labor and capital inputs. To take into account the firm-internal economies of scale and production cost in a county, we calculate the ratio of hired labor expenses to the total farm expenses (*Labor*) and include areas of greenhouse/nursery production under glass or other protection (*Glass*). Along with firm-internal economies of scale, which are a driving force in the greenhouse/nursery production, there exist economies of scale that are external to the firm but internal to the greenhouse/nursery sector. Existence of such agglomeration economies would imply that the performance of a greenhouse/nursery operation will improve when other greenhouse/nursery operations are located nearby. We capture agglomeration economies within the greenhouse/nursery sector by including a spatial lag (*Spacelag*) in the model which accounts for sales of greenhouse/nursery in neighboring counties within a given distance of the county of interest. The agglomeration economies can also arise from a more general infrastructure in place that facilitates all crops production. Such benefits may arise because many related sectors locate near to one another. They can often draw from the same pool of workers, technicians and services suppliers whose skills are specific to the entire crop production industry. A variable, as a proxy for industry-level (inter-sector) agglomeration economies, is constructed to measure the county's receipts of all crops except greenhouse/nursery production (*Agglom*).

The existence and size of cities are typically explained by positive external benefits that are generated by the spatial concentration of businesses and households within a local economy. These externalities, also known as urbanization economies, bring pressure on farmers to adapt and also offer them opportunities. We use county population (*Pop*) and the rate of county's population growth between 1997 and 2002 (*Popgrowth*) as proxies for this urbanization effect. Population in a county is not an indicator of urbanization, but also an indicator of market size for marketing greenhouse/nursery products. Direct market access to urban consumers may also affect the prevalence of greenhouse/nursery production in metropolitan areas. We include the number of farms that sold agricultural products directly to individuals for human consumption (*Directmkt*). To gauge the specific effect of land conversion, we include the per capita number of building permits issued in 2002 (*Permit*) as reported by the US Economic Census and the per-acre value of the land and buildings (*Landval*) reported for farmland in 2002 Census of Agriculture.

Local economic conditions and socioeconomic factors of a county may affect the extent of greenhouse/nursery production in that county. These factors may be indirectly related to urbanization economies. All else equal we would expect higher property taxes within a county to discourage new location of greenhouse/nursery production facilities and expansion of existing production. We include the taxes per-dollar value of the land in each county (*Taxes*) as a proxy for the property taxes. Furthermore, it may be easier to locate a large-scale facility in a larger county merely because there may be more tracts of land available for purchase. Hence, we include a measure of a county's total land mass (*Land*).The average income (*Income*) and the percentage of people having at least a high school education (*Edu*) in each county are also included to account for the impacts of local economic conditions, local demand and the workforce for the greenhouse/nursery production. We also consider the average participation by county farm operators in non-farm occupations (*NonfarmOcc*). As a farm-based population becomes more involved in nonfarm occupations, the opportunity cost of farm operators' labor and management probably increases. We hypothesize that management of large-scale greenhouse/nursery operations becomes less likely in counties with large proportions of farmers working off farm. However, smaller scale production may be compatible with off farm employment.

Results and Discussion

We estimate the model with a focus on agglomeration economies as well as urban influences in determining the spatial patterns of greenhouse/nursery production. Table 4 summarizes variables used in estimation of the spatial lag model of greenhouse/nursery sales in the Northeast. Table 5 presents the parameters of the estimated spatial lag model, along with the results of the common least square regression. The estimated model fits the data quite well. The adjusted-R^2, as the degree of correlation between the predicted and observed greenhouse/nursery production in 2002 in each county, is 0.72. Also, the estimated model shows no signs of spatial dependence of residuals as indicated by the Lagrange multiplier and Moran's I test statistics.

The agglomeration economies are important for the spatial structure of greenhouse/nursery production in the Northeast. The estimated spatial lag variable (*Spacelag*) is positive and statistically significant at the 1% level. This indicates that the production level of greenhouse/nursery is positively correlated across counties. The concentrations of greenhouse/nursery production in neighboring counties are also associated with other crop enterprises (*Agglom*). For the estimated model, the effect of other crop enterprises (*Agglom*) is positive and statistically significant on the production level of greenhouse/nursery. This is because the existence of crop industry infrastructures would improve diffusion of production and marketing information as well as the availability of production inputs, labor, and technical services for the greenhouse/nursery sector.

Table 4: Summary Statistics of the Data Used in the Estimation

Variable	Description	Mean	Standard Deviation
GhNurs	Sales of greenhouse and nursery products ($million)	7.845	21.320
Agglo	Sales of other crops ($million)	9.237	13.870
Labor	Ratio of hired labor expenses to total farm expenses	0.152	0.092
Glass	Areas greenhouse/nursery under glass or other protection (1000 sq.ft)	569.91	1572.80
Pop	Population (1000 persons)	167.867	238.389
Popgrowth	Population growth, 1997-2002 (%/100)	0.022	0.045
Directmkt	Number of farms selling agricultural products directly to individuals	74	57
Permit	Per-capita number of building permits issued	4.5	3.6
Landval	Per-acre value of land and building ($1000)	4.155	4.848
Tax	Property taxes per 1000 dollar value of land and building	7.548	4.058
Land	Land area (1000 acres)	442.387	390.588
Income	Average income ($1000)	27.704	7.465
Edu	Population with high school degree (%/100)	0.810	0.061
Nonfarmocc	Farm operators in nonfarm occupation (%/100)	0.458	0.076

Table 5: Estimation of Spatial Lag Model of Greenhouse/nursery Production

	OLS				Spatial Lag Model			
Variable	Coefficient	t-Statistic	Probability		Coefficient	t-Statistic	Probability	
				Agglomeration Variables				
Spacelag					0.40	6.462	0.000	***[1]
Agglo	1.48E-02	2.360	0.019	**	1.24E-02	2.113	0.035	**
				Firm-Specific variables				
Labor	7.82	7.200	0.000	***	6.34	5.947	0.000	***
Glass	4.61E-04	4.228	0.000	***	3.71E-04	3.621	0.000	***
				Urbanization Variables				
Pop	8.21E-04	1.830	0.068	*	7.16E-04	1.702	0.089	*
Popgrowth	2.75	1.206	0.229		2.95	1.379	0.168	
Directmkt	7.07E-03	4.474	0.000	***	5.75E-03	3.835	0.000	***
Permit	-1.26E-02	-0.442	0.659		-4.74E-02	-1.762	0.078	*
Landval	-7.67E-03	-0.296	0.768		-3.86E-02	-1.554	0.120	
				Local Socioeconomic Condition Variables				
Tax	-3.22E-03	-0.144	0.886		-3.30E-02	-1.522	0.128	
Land	-3.02E-04	-1.439	0.151		1.62E-04	0.799	0.424	
Income	9.81E-03	0.477	0.634		2.16E-03	0.112	0.911	
Edu	9.03	4.672	0.000	***	6.99	3.807	0.000	***
Nonfarmocc	-4.21	-3.714	0.000	***	-3.02	-2.821	0.005	**
Constant	-0.261	-0.208	0.835		-1.22	-1.034	0.301	
				Regression Diagnostics				
N	280				280			
Adj R^2	0.700				0.724			
Likelihood	-426.7				-414.6			
				Diagnostics for Spatial Dependence				
Moran's I Test[2]		4.78	0.000	***		1.03	0.301	
Lagrange Multiplier Test[3]		14.6	0.000	***		0.10	0.755	

1: *, **, *** denotes statistical significance at the 10, five, and one percent levels, respectively.
2: Moran's I test the spatial autocorrelation in residuals.
3: Lagrange multiplier test, distributed as a chi-square with one degree of freedom, that tests the null hypothesis: the model's residuals are not spatially correlated.

As addressed before, urbanization has both positive and negative consequences for agriculture. Higher land prices imply higher costs of farm products; but lower transportation costs imply higher prices of farm products for metropolitan areas. The greenhouse/nursery production generally requires less land than most agricultural activities (Shield & Willits, 2003), and products have high transportation costs and high perishability. Those attributes, one can argue, give greenhouse/nursery products a comparative advantage in metro areas. However, there is a counter argument that some farm input and product transactions costs are relatively high in metro areas. The greater concentration of agriculture activities in rural areas creates economies of scale and scope that are not available in metro areas where nonagricultural activities congest the infrastructure for input delivery and bulk output marketing. Therefore, it is not clear the effects of urban economics on greenhouse/nursery production level. Some insights do emerge from our estimated model. As expected, population (*Pop*) has a significant, positive effect on greenhouse/nursery production within a county. Population growth (*Popgrowth*) also has a positive effect but not statistically significant. Shield and Willits argued that slower population growth in the Northeast relative to the Pacific and southern states may affect the nature and rapidity of the greenhouse/nursery's future development in the Northeast.

While the greenhouse/nursery sector in California and in the southern states is driven largely by exports, the Northeastern situation is largely seasonal and locally focused. Urban populations open up marketing opportunities for supplying greenhouse/nursery products with quality and service in the Northeast. Direct market access to consumers *(Directmkt)* has significantly positive impacts upon the greenhouse/nursery production within a county. Various innovative direct marketing strategies such as farmers markets, roadside stands, U-picks, restaurants, community supported agriculture, internet, and direct mail services have been recognized as a key to successful small scale farm business.

Greenhouse and nursery have blossomed as the past several decades of economic development have seemingly put a home improvement store or a garden center just about every mile. The region's residents have created massive demand for plants, flowers and all other necessary landscaping shrubs and trees. However, the per-capita number of building permits issued in each county (*Permit*) is found to be negative and statistically significant at the 10% level for our model. This suggests that the current greenhouse/nursery production levels are relatively high in counties where less development occurs in the Northeast, while holding population and population growth constant. We suggest that the expansion of urban growth boundaries could threaten the long-term health of the greenhouse/nursery sector. *Ceteris paribus,* counties with lower land value (*Landval*) seem to have larger greenhouse/nursery production, though this relationship is not statistically significant.

With regards to input variables to account for the firm-internal economies of scale, the proportion of hired labor expenses (*Labor*) positively affects greenhouse/nursery production level. The greenhouse/nursery production is highly labor intensive and depends heavily on a reliable and skilled work force. Counties in which a lower percentage of farmers declare a nonfarm occupation as their primary livelihood (*NonfarmOcc*) are associated with higher greenhouse/nursery production. Furthermore, production tends to be larger when counties have larger specialized operation areas under glass or other protection (*Glass*). These areas may also be an indicator of production efficiency for greenhouse and nursery in terms of higher value added per acre. Several local factors considered may contribute to the historical patterns of production levels. Education levels of residents (*Edu*) in a county have positive influence in the current greenhouse/nursery production level. Education levels can be a proxy of consumer demand or local available quality workforce for the greenhouse/nursery production. Coefficients on the variable of property taxes, total land areas, and income are not statistically significant. Note that property taxes have significantly negative impacts on the spatial structure of the dairy production in the U.S. and the hog production in several states (Roe et al 2002; Murat, 2004). However, property taxes are not a significant factor affecting the greenhouse/nursery production in our model.

V. Conclusions

Considering changes in HVP production levels over more than a half century, our review of Census data shows that counties characterized as metropolitan are amazingly stable since the late 1940s, with fractions of total US sales hovering in the range of 80% of all HVP sales. This holds for all three HVP categories-- vegetables, fruit, and nursery/greenhouse products considered in this study.. These results are somewhat counterintuitive and out of step with some of the conventional wisdom. While growers in urbanizing situations have a number of special business challenges, we expected an upward trend for HVPs production in metro areas. The trends issue could be clouded by movements in metropolitan definition, however, which systematically result in large amounts of territory being reclassified as metropolitan. To overcome this limitation, we looked at HVP production inside and outside the nation's top 300 counties, based on total population. Surprisingly, the results suggest that counties with highest population have also maintained a relatively constant fraction of HVP sales over the last 50 years. These trends imply that the dynamics of agricultural adjustment to urbanization are subtle and might have a steady state mix of agricultural and non-agricultural activities in many cases. Overall, the evidence in our historical analysis indicates that, while farms and farmland continue to succumb to urbanization, continued expansion of urban areas is not likely to diminish the importance of HVP production in the U.S.

High-value crop production in the U.S has been faced with significant challenges in scale, structure, and geographical location of production. Our econometric model examines the impacts of agglomeration economies, urbanization economies, and firm-internal scale economies in determining county-level greenhouse/nursery production in the densely populated northeastern US. The analysis, confined here to greenhouse/nursery production in the Northeast, suggest that production of these commodities present agglomeration economies at both the intra-sector and at inter-sector levels. These patterns are important in modeling greenhouse/nursery location to estimate the effects of nonspatial factors, while identifying potential sites for development, concentration or diffusion. We suggest that public policies aimed at encouraging spatial concentrations of greenhouse/nursery production would enhance the positive externalities created by agglomeration economies. Another important focus of this model is on determining the urbanization factors affecting the greenhouse/nursery production in the Northeast. We found that counties with higher populations and lower building activities, other things equal, tend to increase greenhouse/nursery production. Also, the presence of direct market accesses to consumers is important in determining the location of greenhouse/nursery production. This empirical study is provisional and a precursor to a broader application to the HVPs production at the national level.

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