Agricultural Payments and Land Concentration: A Semiparametric Spatial Regression Analysis

Michael J. Roberts and Nigel Key

Over the last twenty years, both crop production and agricultural payments have shifted toward larger operations. This study examines whether payments from federal farm programs contributed to increased concentration of cropland and farmland. Using zip code–level data constructed from the microfiles of the 1987–2002 agriculture censuses we examine the association between government payments per acre and subsequent growth in land concentration. A semiparametric generalized additive model (GAM) controls for location and historical concentration, sales per acre, and ratio of cropland area to zip code area. Findings indicate, both with and without nonparametric controls, government payments are strongly associated with subsequent concentration growth.

Key words: farm structure, generalized additive model, agricultural payments, spatial regression.

Over the last twenty years, agricultural production has become increasingly concentrated on larger farms. According to Census of Agriculture data, farms from 1,000 to 10,000 acres increased in number by 14.3% between 1982 and 2002 and total farmland controlled by these large operations increased by 20.6%.[1] In contrast, over this period farms with fewer than 1,000 acres declined in number and amount of farmland controlled. Increasing concentration of agricultural production has coincided with an increasing share of government payments going to large farms: between 1982 and 2002 the share of all payments going to farms from 1,000 to 10,000 acres increased from 41.1% to 49.5%.

In recent years interest groups, politicians, and newspaper editorials have expressed concern that payments unfairly advantage large operations and have argued that government payments are a key factor contributing to the growth in concentration and farm sizes (e.g., Williams-Derry and Cook 2000; Becker 2001; Nelson 2002). Concerns about the link between agricultural payments and farm size have helped motivate congressional efforts to tighten payment caps on large-scale producers (U.S. Department of Agriculture 2003).[2]

Claims that government payments unfairly advantage large farms are usually supported with statistics showing a steady growth in farm size and the strong association between farm size and payment levels. However, while government payments and production have both become increasingly concentrated, this concurrence of trends does not necessarily imply a causal link between payments and farm size. The design of government agricultural programs is such that payment levels are tied to the amount of land farmed and the land's production history. Thus, regardless of what caused farms to increase in size, payments would have become more concentrated on larger farms (MacDonald, Hoppe, and Banker 2005).

To what extent are government agricultural programs and their associated payments contributing to the concentration of production? Most studies that have attempted to explain changes in the size and survival of individual

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[1] The statistics cited in this paragraph are described in more detail in the third section.

[2] In 2002, a Senate amendment to cap payments at $275,000 per farm was dropped in conference with the House. Efforts to limit payments continued in 2003, when the Grassley-Dorgan payment limits bill that would have limited annual farm subsidy payments to $250,000 ($500,000 for a couple) was introduced (and later dropped). In 2005, President Bush proposed payment caps legislation similar in scope to Grassley-Dorgan bill.

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farms have focused on characteristics of the farm operator or farm, not on the role of government payments (Sumner and Leiby 1987; Hallam 1993; Zepeda 1995; Kimhi and Bollman 1999; Weiss 1999). Exceptions are two recent studies by Key and Roberts (2006; 2007) that found government payments positively and significantly associated with the survival rate and duration of individual farm businesses, as well as farm size conditional upon survival. These studies, however, consider effects of payments on the growth or survival of individual farms, which cannot predict the effects of an increase in payments on aggregate farm structure. This is because studies of individual farms cannot account for how induced changes on one farm affect other, neighboring farms, or how payments influence the size and number of entering farms. For example, consider a hypothetical case where payments cause consolidation of two neighboring farms of equal size and equal payment levels. At the level of an individual farm, the average payment effect on size may appear to equal zero: one farm increased in size by 100% while the other declined in size by 100%. Nevertheless, the aggregate effect on land concentration is substantial.

Some past studies have estimated the effect of agricultural payments on aggregate measures of farm structure, including the national agricultural bankruptcy rate (Shepard and Collins 1982), the total number of farms (Tweeten 1993), and average farm size (Huffman and Evenson 2001). While taking very different approaches, these studies treat government payments as exogenous and have used current payments to explain current indicators of farm structure. A problem with this approach is that it is difficult to attribute a causal mechanism to an observed cross-sectional association between payments and farm size. To do so requires confidence that determinants of farm structure, other than agricultural payments, are adequately accounted for. A particular concern is the heterogeneity of land and farms across regions in the United States. A finding that farms are larger in areas with higher payments might be explained by the fact that government programs target field crops (e.g., corn, soybeans, and wheat), which require more land to be profitably farmed. Another concern is the endogeneity of payments: farm acreage decisions influence payment levels, so causation may go in the opposite direction.

This study compares zip codes with different per-acre payment levels to subsequent percentage *changes* in land concentration. That is, it examines whether concentration growth rates are higher in areas with higher historical payments per acre relative to areas with lower payments per acre. Even if programs happen to target regions where farms are larger because of the crops grown, we see no obvious reason to expect programs to target regions inclined to subsequently experience faster growth in concentration over time—by examining growth rates we control for time-invariant factors associated with concentration. In other words, a correlation between payments and the subsequent change in land concentration is less likely to result from reverse causality.

The study supplements the simple comparisons described above with a semiparametric generalized additive model (GAM) to control for location, historical concentration, historical sales per acre, and the share of land in agriculture in a flexible way. These variables control for time-varying factors that may create a spurious relationship between payments and concentration growth.

Concentration is measured at the zip code level. Farmland concentration is defined as the acre-weighted median farm size: the farm size such that half the farmland within each zip code resides on larger farms and half resides on smaller farms (cropland concentration is analogously defined). We focus on this measure, rather than the more commonly used mean or median farm size, because these measures are extremely sensitive to the definition of a farm, which has changed implicitly or explicitly over time, and are heavily influenced by a growing number of small "hobby" farms. In table 1, notice the growth in the number of smallest farms (0–50 acres) and larger farms (1,000–10,000 and 10,000 + acres) and the marked decline in the number of middle-sized farms (150–500 and 500–1000 acres).

The analysis uses microdata from the 1987, 1992, 1997, and 2002 agricultural censuses and includes all U.S. zip codes with at least three farms in all four censuses. The zip code analysis improves upon national, state, or county-level analyses by providing more observations and more variation across observations in both concentration and payment levels. Sufficient variation at a local level is important when using an empirical technique that controls for factors that vary geographically. The census data are the only data available for such a

Table 1. Farmland Operated and Number of Farms by Farm Size Category, 1982–2002

Farmland Categories	1982	1987	1992	1997	2002	Percentage Change 1982–2002
0–50 Acres						
Farmland[a]	12.70	11.61	10.87	11.46	15.52	22.1
(Percent of total)	(1.33)	(1.25)	(1.19)	(1.27)	(1.66)	24.4
Farms	629,962	588,632	546,955	556,330	738,113	17.2
(Percent of total)	(28.45)	(28.57)	(28.81)	(29.54)	(34.77)	22.2
50–150 Acres						
Farmland[a]	52.38	47.49	43.14	43.92	49.18	−6.1
(Percent of total)	(5.49)	(5.10)	(4.73)	(4.88)	(5.25)	−4.4
Farms	571,330	517,388	470,880	482,340	548,062	−4.1
(Percent of total)	(25.81)	(25.11)	(24.81)	(25.61)	(25.82)	0.0
150–500 Acres						
Farmland[a]	179.05	162.62	144.85	136.33	133.45	−25.5
(Percent of total)	(18.78)	(17.47)	(15.88)	(15.16)	(14.26)	−24.1
Farms	656,800	595,808	530,961	502,820	498,524	−24.1
(Percent of total)	(29.67)	(28.91)	(27.97)	(26.69)	(23.48)	−20.8
500–1,000 Acres						
Farmland[a]	138.12	136.15	126.99	119.93	112.38	−18.6
(Percent of total)	(14.48)	(14.63)	(13.93)	(13.34)	(12.00)	−17.1
Farms	200,601	196,705	183,207	172,660	161,450	−19.5
(Percent of total)	(9.06)	(9.55)	(9.65)	(9.17)	(7.60)	−16.1
1,000–10,000 Acres						
Farmland[a]	324.04	335.80	349.88	365.12	390.88	20.6
(Percent of total)	(33.98)	(36.08)	(38.37)	(40.61)	(41.76)	22.9
Farms	147,615	154,535	158,492	162,223	168,730	14.3
(Percent of total)	(6.67)	(7.50)	(8.35)	(8.61)	(7.95)	19.2
10,000 + Acres						
Farmland[a]	247.27	237.13	236.16	222.41	234.68	−5.1
(Percent of total)	(25.93)	(25.48)	(25.90)	(24.73)	(25.07)	−3.3
Farms	7,641	7,492	7,739	7,218	8,096	6.0
(Percent of total)	(0.35)	(0.36)	(0.41)	(0.38)	(0.38)	10.5
Total farmland[a]	953.56	930.80	911.87	899.16	936.08	−1.8
Total farms	2,213,949	2,060,560	1,898,234	1,883,591	2,122,975	−4.1

Source: Census of Agriculture. Farmland is defined in the Census as the quantity of land owned plus land rented in minus land rented out.
[a]Farmland measured in millions of acres.

fine-scale analysis: the census attempts to collect information on every U.S. farm business with expected sales of at least $1,000.

Determinants of Concentration: Farm Size and Survival

As the amount of U.S. farmland and cropland has remained relatively stable, changes in concentration from one period to the next depend on the size distribution and growth rate of surviving farms, and on the sizes of entering farms (Vesterby et al. 2006). The literature on firm size and survival therefore provides some insight into the determinants of farm structure. In this literature, the relationship between firm size and survival is often modeled as a dynamic process wherein firms (or entrepreneurs) are uncertain about their own competitiveness at startup (Jovanovic 1982; Ericson and Pakes 1992; and Pakes and Ericson 1998). In these models, firms gradually learn about their abilities over time and the longer they operate, the more they learn about their competitiveness. As managers revise their perceptions of their firm's ability upward, they tend to expand, while those revising downward tend to contract or exit. Thus, the longer a firm has existed, the bigger it will become and the less likely it will be to fail. Empirical studies generally confirm these theoretical predictions (Dunne, Roberts, and Samuelson 1988; Baldwin and Gorecki 1991; Audretsch 1991; Audretsch and Mahmood 1995; among others).

Theory does not provide unambiguous predictions as to how a change in government payments would influence farm growth and survival. Consider, for example, a model of a representative farm where the quantity of agricultural land is fixed, but labor and capital are mobile between agricultural and nonagricultural sectors (Kislev and Peterson 1982). In this model, farm size is a function of the ratio of wages to the cost of capital. An increase in government payments increases returns to farming, but these additional profits are capitalized into the price of land. Hence, a change in government payments has no clear direct effect on the cost of labor relative to capital, and therefore has no effect on farm size.

In more complex economic models that allow for transaction costs and a range of farm sizes, there arise a variety of mechanisms through which payments could influence farm structure. For example, if *per-acre* payments are unequally distributed across farms of different sizes then an increase in payments could alter farm structure. Such a pattern may arise if there are fixed transactions costs associated with program participation, so that larger farms have a stronger incentive to participate than smaller farms. Higher payments per acre for a particular farm size group would allow this group to expand and bid up the prices of fixed resources—especially land—and cause other size farms to shrink or exit.

An unequal distribution of per acre and/or total payments might also influence farm size and survival through capital or labor market mechanisms. Borrowing constraints could cause a farm's cost of capital to depend on its net worth: farms with greater net worth face lower borrowing costs because they have more resources with which to secure a loan (e.g., Hubbard 1998). If this were the case, an increase in income from government payments would raise the net worth of a farm, making it less costly for a farmer to obtain financing to increase farm size. Similarly, anticipated payments may give farm operators more leverage with agricultural lenders. Because larger farms presumably require more capital, both per-acre and/or total payments may influence borrowing costs. If large farms are credit constrained and small farms are not—a counterintuitive but distinct possibility given increasing returns to scale and the fact that larger farms tend to be more leveraged—then an increase in payments causes large farms to expand and increase in number, which bids up land prices and causes small farms to shrink and decline in number (Key and Roberts 2005). If both large and small farms are credit constrained, then the effect of an increase in government payments on farm size and survival is ambiguous.

Total payments may also influence farm size and survival by altering farm operator labor-leisure decisions via a wealth effect combined with transactions costs. Payments could encourage farmers receiving them to work less; and if there are transaction costs associated with hiring labor or finding employment, higher payments may cause a reduction in the supply of farm labor (Lopez 1984; Strauss 1986). Less farm labor could mean less production and a smaller farm. However, under certain conditions, a higher shadow wage for farm labor could mean greater capital utilization and thus an increase in farm size, as in Kislev and Peterson.[3]

Trends in Concentration and Government Payments

Census of Agriculture data illustrates the increasing concentration of production in U.S. agriculture. Table 1 shows a marked increase in the prevalence of farms with between 1,000 and 10,000 acres.[4] Between 1982 and 2002, these large farms increased from 6.7 to 8.0% of all farms and increased their share of total farmland from 34.0 to 41.8%. Growth in the number of these large farms came mainly at the expense of farms between 150 and 500 acres, which declined as a share of all farms from 29.7 to 23.5%. The number of farms with fewer than 50 acres increased markedly, as did their share of farmland. Although these farms comprised 37.8% of all farms by 2002, they made up only 1.7% of all farmland. Very large farms—those with more than 10,000 acres of farmland—increased slightly in number and declined slightly in their share of all farmland.

Table 2 presents four measures of representative farm size from 1982 to 2002 for all farms, and for farms with fewer than 10,000 acres. For all farms, mean farm size increased by 2.4%, from 431 acres in 1982 to 441 acres in 2002. However, median farm size actually declined by 22.1% over this period: falling from 122 to 95 acres. The decline in median farm size

[3] Kislev and Peterson assume fixed labor supply per-farm in order to obtain the result that farm size was linked only to the relative costs of labor and capital.

[4] The Census of Agriculture defines farmland as the quantity of land owned plus land rented in minus land rented out.

Table 2. Representative Farm Size, Various Measures, 1982–2002

Farmland	1982	1987	1992	1997	2002	Percentage Change 1982–2002
All farms						
Mean (acres)	430.7	451.7	480.4	477.4	440.9	2.4
Median (acres)	122	125	125	120	95	−22.1
Weighted mean (acres)	48,955	46,998	51,742	95,482	95,945	96.0
Weighted median (acres)	1,620	1,700	1,925	2,000	2,190	35.2
Farms < 10,000 Ac.						
Mean (acres)	321.4	339.3	359.5	362.5	333.7	3.9
Median (acres)	121	125	125	120	94	−22.3
Weighted mean (acres)	1,776.8	1,831.5	1,957.6	2,035.9	2,144.8	20.7
Weighted median (acres)	864	954	1,054	1,143	1,225	41.8

Source: Authors' calculations from the Census of Agriculture. Farmland is defined in the Census as the quantity of land owned plus land rented in minus land rented out.

reflects the growing proportion of very small farms mentioned above.[5]

The acre-weighted mean and the acre-weighted median are alternative indicators of land concentration. The weighted mean farm size averages farm sizes over acres rather than over farms. It can be thought of as the expected farm size associated with a randomly chosen acre of farmland.[6] The acre-weighted median is the size of a farm such that half of all farmland is operated by larger farms and half by smaller farms. Both of these measures emphasize the production unit (acre), rather than the farm, as the unit of interest. This emphasis makes sense when focusing on land concentration, because we want a statistic that measures the farm size associated with a typical production unit. The weighted median and particularly the weighted mean are much larger than the unweighted measures, reflecting the fact that large farms control most farmland. Table 2 shows that for all farms, the weighted mean increased by 96.0% between 1982 and 2002, while the weighted median increased by 35.2%. The weighted median row indicates that in 1982 half of all farmland was operated by farms larger than 1,620 acres; by 2002, half of all farmland was controlled by farms larger than 2,190 acres.

Comparing all farms to farms with fewer than 10,000 acres (bottom of table 2), we find similar patterns over time for the mean, median, and weighted median (the levels are smaller but the changes over time are similar). However, the weighted mean increased by a smaller amount.

The analysis of changing land concentration in the next section uses the weighted median as the measure of land concentration because it tracks concentration better than the mean and median when the farm size distribution is highly skewed, and because it is less sensitive to outliers than the weighted mean.[7] The weighted mean is more sensitive to outliers than the weighted median for the same reason a simple mean is more susceptible to outliers than a simple median. The weighted median is a standard measure of concentration within the industrial organization literature (e.g., Hart and Clarke 1980, p. 43).

Government Payments

Table 3 reports trends in the level of government payments and payment per acre (all reported in 2002 dollars) by farm size category beginning in 1987, when payments data are first available from the census of agriculture. Government payments are defined as total payments received for participation in Federal farm programs net of payments received for

[5] The decline in median farm size, despite the increasing concentration of farmland on large operations, might be explained in part by the USDA's definition of a farm as: "Any place from which $1,000 or more of agricultural products (crops and livestock) were sold or normally would have been sold during the year under consideration." The $1,000 figure has remained unchanged since the 1974 Census. If adjusted for inflation using the CPI, the comparable number for 2002 would be $3800. Subtle changes in how the Census defines a farm might also help explain the declining median farm size (see http://www.nass.usda.gov/Census_of_Agriculture/index.asp for additional information).

[6] Mathematically, the acre-weighted mean is the sum of acres-squared divided by the sum of acres.

[7] Using the weighted mean in the analysis in the next section yields results similar to those reported for the weighted median.

Table 3. Government Payments and Government Payments-Per-Acre of Farmland by Farm Size Category, 1987–2002

Farmland Categories	1987	1992	1997	2002	Percentage Change 1987–2002
0–50 Acres					
Mean payment ($)	182	108	183	227	24.4
Median payment ($)	0	0	0	0	0.0
Mean payment/acre ($/acre)	32.9	22.1	28.0	10.1	–69.3
Total payments[a]	107	59	102	127	18.6
(Percent of total)	(0.7)	(0.9)	(1.8)	(1.9)	171.6
50–150 Acres					
Mean payment ($)	981	438	632	812	–17.2
Median payment ($)	0	0	0	0	0.0
Mean payment/acre ($/acre)	6.4	3.6	6.2	7.5	17.3
Total payments[a]	508	206	305	373	–26.6
(Percent of total)	(3.4)	(3.2)	(5.5)	(5.7)	68.2
150–500 Acres					
Mean payment ($)	6,262	2,389	2,390	2,904	–53.6
Median payment ($)	0	0	0	43	–
Mean payment/acre ($/acre)	13.6	6.5	7.7	9.7	–28.6
Total payments[a]	3,731	1,269	1,202	1,330	–64.4
(Percent of total)	(24.9)	(19.4)	(21.7)	(20.3)	–18.4
500–1,000 Acres					
Mean payment ($)	21,676	8,553	7,403	8,062	–62.8
Median payment ($)	12,831	4,464	4,284	3,500	–72.7
Mean payment/acre ($/acre)	19.7	9.5	9.4	11.2	–43.3
Total payments[a]	4,264	1,567	1,278	1,255	–70.6
(Percent of total)	(28.5)	(24.0)	(23.1)	(19.2)	–32.6
1,000–10,000 Acres					
Mean payment ($)	39,840	20,589	15,665	19,331	–51.5
Median payment ($)	23,469	11,540	9,206	9,738	–58.5
Mean payment/acre ($/acre)	14.5	8.6	7.5	9.6	–34.2
Total payments[a]	6,157	3,263	2,541	3,237	–47.4
(Percent of total)	(41.1)	(50.0)	(45.9)	(49.5)	20.4
10,000 + Acres					
Mean payment ($)	28,605	21,355	14,636	27,481	–3.9
Median payment ($)	0	0	0	4,000	–
Mean payment/acre ($/acre)	1.1	1.0	0.8	1.7	53.8
Total payments[a]	214	165	106	222	3.6
(Percent of total)	(1.4)	(2.5)	(1.9)	(3.4)	137.3
Total payments[a]27	14,981	6,529	5,533	6,543	–56.3

Source: Census of Agriculture.
Note: All government payments are in 2002 dollars. Payment information is not available prior to 1987.
[a]Total payments measured in millions of dollars.

participation in the Conservation Reserve Program and the Wetlands Reserve Program.[8] In 2002, farms with 1,000–10,000 acres, received a median payment of $9,738—almost three times the median payment received by farms with 500–1,000 acres, and about 200 times the median payment received by farms from 150 to 500 acres. In contrast, farms with more than 10,000 acres received a median payment of just $4,000, and over half of all farms with less than 150 acres receive no government payments—a fact that has not changed since 1987. Note that many farms have low payments or no payments at all, and that mean payments generally equal double (or more) median payments. Thus, while the nature and level of farm payments has changed over time, the level of payments received by most large

[8] The 1987, 1992, and 1997 censuses asked respondents for the "total amount received for participation in Federal farm programs (not including CCC loans)." Respondents were also asked to provide "how much was received for participation in the Conservation reserve program and Wetlands Reserve Program (CRP and WRP)?" The latter was subtracted from the former to obtain the measure of payments used in this study. In 2002, the amount received for participation in Federal farm programs other than CCC loans, CRP or WRP was asked directly. It is not possible from the Census data to determine whether payments are tied to land rented in or to land owned (either rented out or farmed).

farms specializing in key program crops continues to equal a sizable proportion of farm household income.

The relationship between payments per acre and farm size generally displayed an inverted U-shape.[9] For farms larger than 50 acres, payments per acre increased with farm size, peaking in the 500–1,000 acre category, and then decreased. Whether or not payment limits have anything to do with this pattern is not clear from these data, but there are other reasonable explanations.[10] For example, the largest farms had substantially lower per acre payments, probably reflecting a higher proportion of pasture and range land, which do not typically receive payments. An exception to the inverted U-shape was the smallest farm size category—this group had the highest average payments per acre, probably because it includes operators with little or no production who received substantial payments from land rented out.

As large farms produced an increasing share of total output, they also received an increasing share of government payments. The share of total payments going to farms with between 1,000 and 10,000 acres rose by 9.1 percentage points between 1987 and 2002. About seven-eighths of this increase is due to the increase in the share of large farms and the remainder (1.2 percentage points) is due to an increase in the share of payments per large farm.[11] In contrast, the share going to farms with between 500 and 1,000 acres declined by 9.3 percentage points, and the share going to farms with between 150 and 500 acres declined by 4.9 percentage points. The other farm size groups slightly increased their share of total payments.

[9] The time trends in mean payments per-acre differed somewhat from time trends mean payments because of changes in the size distribution of farms in each category and the relationship between farm size and payments. For example, in the smallest farm size category the mean payments per farm increased from 1987 to 2002 while payments per-acre decreased. This can be explained by an increase in the portion of relatively large farms that received relatively high payment farms. The relatively high payments increased mean payments, but the relatively large size of these farms caused mean payments per-acre to decline.

[10] From census data we cannot link payments to specific government programs and crops, which would be needed for a more careful consideration of payment limitations. An excellent study by Kirwan (2007) uses administrative data on payments by crop to analyze possible effects of payment limitations.

[11] This breakdown can be gleaned through inspection of tables 1 and 2. In 1987, medium-sized farms (500–1000 acres) made up 9.06% of farms and received 28.5% of payments. By 2002, these farms made up 7.06% of farms and received 19.2% of payments. If farms in this category received the same share of payments per share of farms in 2002 as 1987, they would have received 23.9% of payments in 2002. So the remaining decline of 4.7 percentage points is due to a decline in payments per farm in this category relative to farms in other size categories.

Empirical Methods

The essence of our empirical strategy is to compare farmland and cropland concentration growth rates across zip codes with different initial levels of government payments per acre. At the zip code level, we consider two measures of payments: total payments divided by total cropland or farmland area. Defining the payment level on a per-acre basis creates a standardized measure that is not sensitive to zip code size—which varies widely across the United States. Zip codes are assigned to six discrete categories based on payments per acre of cropland or farmland in the initial year. The discrete categories allow for possible nonlinear associations between payments and concentration growth and mitigate the statistical influence of any single observation or group of observations, making estimates more robust.

To measure the simple relationship between concentration growth and the payments per-acre category we estimate the following model using least squares

$$(1) \qquad \Delta c_i = \mathbf{X}_i \beta + \varepsilon_i$$

where subscript i (omitted below to simplify notation) indexes zip codes, Δc is the percentage change in concentration between censuses $((c_1 - c_0)/\tfrac{1}{2}(c_1 + c_0))$, c_0 and c_1 denote concentration in the beginning year and final year, respectively, $\mathbf{X}$ is a matrix of indicator variables denoting initial-year payment-per-acre categories (one element of each row equals 1 and the other elements equal 0), β is a vector of payment-category effects and ε is the error.

Growth in concentration is expressed as a percentage change in order to scale the growth measure relative to initial concentration levels.[12] Differencing $(c_1 - c_0)$ controls for time-invariant heterogeneity at the zip code level. Most importantly, it controls for the fact that government programs target field crops like corn, wheat, cotton, and rice, which tend

[12] This frequently used measure of percent change (also used when calculating an arc elasticity) is more robust and symmetric when dealing with discrete changes that can be very large—as with the zip code measure of concentration. For example, a change from 10 to 1000 acres is a 9900% increase while a change from 1000 to 10 acres is a 99% decline, using the "standard" percent change measure $((c_1 - c_0)/c_0)$. With the measure of percent change used in this study these numbers are +196% and −196%. An alternative specification (not reported here) produced similar results using the standard percent-change with robust statistical methods. Similar results were also obtained using the difference in log concentration as the dependent variable.

to be grown on larger farms than fruit, tree, or vegetable crop farms.

We estimate (1) separately for each two-year panel (1987–92, 1992–97, 1997–2002) and for a "long" panel—a two-period panel consisting of 1987 and 2002 data. The long panel allows us to examine how payments in 1987 relate to changes in concentration between 1987 and 2002 (a twenty-year difference rather than just five years).

A Generalized Additive Model

Although a comparison of changes in land concentration controls for time-invariant factors that might lead to noncausal associations between farm size and payments, the approach is not infallible. The main concern is that climate, soils, distance from markets, and urban competition for land all make location a critical feature of agricultural production, and that these factors create a noncausal link between payments and concentration growth. It could be that corn, wheat, and cotton and other crop farms traditionally targeted by agricultural programs have coincidently experienced greater growth in concentration for reasons other than government programs. For example, there may have been more technological change in cultivation of these crops as compared to nonprogram crops.

To address this concern we use a semiparametric regression, called a GAM (Hastie and Tibshirani 1990; Hastie 1992), that controls for zip code location (defined by the longitude x and latitude y of the zip code centroid), initial concentration (c_0), initial crop sales per acre of cropland (s_0), and initial ratio of cropland area to zip code area (a_0).[13] The GAM has been used in a similar fashion by Gibbons (2004) to estimate the costs of urban property crime and by Pope et al. (2002) to estimate health effects of long-term exposure to fine particulate air pollution, among many other applications. To our knowledge there have been no applications of this model in agricultural economics.With controls, the model is

$$(2) \qquad \Delta c_i = \mathbf{X}_i\beta + f(x_i, y_i) + g_c(c_{0i}) + g_a(\alpha_{0i}) + g_s(s_{0i}) + \varepsilon_i$$

where $f(x, y)$ is a smooth function of zip code centroids (x, y), and $g_c(c_0)$, $g_a(a_0)$, and $g_s(s_0)$ are smooth functions of c_0, a_0, and s_0, respectively. The payment effects are captured by the parametric component of the model, $\mathbf{X}_i\beta$, to facilitate interpretation and comparison with the simple model (1). Although the payment effects are parametric, because we have divided observations into six discrete ordered payment groups, the form of the relationship is flexible. The additive separability of the nonparametric effects constrains the functional form, but it remains much more flexible than a standard linear model with fixed effects.

One may think of the spatial surface $f(x, y)$ as representing smoothed location fixed effects. State fixed effects create arbitrary discontinuities along state borders, which reduce efficiency and may induce bias. The smooth nonparametric surface eliminates these sharp discontinuities along regional boundaries. The smooth functions of the other control variables allow for nonlinearities in a flexible way. Results reported in an online appendix (Roberts and Key 2007) show that the GAM has a substantially better overall model fit than a standard linear model with state fixed effects.

With respect to the control variables (location, initial concentration, sales per acre, and the ratio of cropland to zip code area) the GAM is very flexible. A potential shortcoming to using such a flexible model is that the large number of effective parameters may limit statistical power or prevent identification of the model altogether. This is not a problem in the current application because the sample is large. Because the purpose of using nonparametric controls is to check the robustness of our estimates, making the controls as flexible as possible lends greater credibility to the estimated effects of payments. Moreover, since our focus is on payment effects, a numerical interpretation of the effects of the controls is less important.

The smooth functions are estimated using a local polynomial regression ("loess") that repeatedly estimates weighted linear regressions using observations local to each fitted point. Details about the model estimation methods are presented in an online appendix (Roberts and Key 2007). The online appendix also reports estimates from linear models with state fixed effects and nine separate long-panel regional GAM models with payment quintiles defined separately for each region. The linear models do not fit the data as well as the GAM models summarized below, but obtain similar

[13] The model is called the *generalized* additive model because it can be implemented for any error distribution in the exponential family, much like the *generalized linear model* in the statistics literature. Thus, it can be estimated for models having binomial, Poisson, or otherwise discrete dependent variables.

payment effects. For example, the R^2 values for the long-run GAM models for cropland and farmland concentration growth are 0.20 and 0.27 respectively; for the analogous linear models with state fixed effects, the R^2 values are 0.15 and 0.20. The regional GAM models have smaller nonparametric bandwidths and thus a better overall fit, but also give similar overall payment effects.

Sources of Payment Variation

There are likely two principal sources of variation in payments per acre across zip codes that identify the relationship between payments and concentration growth. One source is broad regional differences in crop mix and yields stemming from climatic and soil variations. Due to the way agricultural programs are designed some crops have higher associated payments than other crops. In addition, even with the same crop mix, areas with historically higher yields receive higher payments than areas with historically lower yields. The nonparametric functions of location, initial concentration, and initial sales per acre likely remove most variation in payment levels caused by cross-sectional differences in crop mix and yield.

Payments per acre may vary across nearby and similar zip codes because of differences in historical patterns of participation in government programs and differences in base-crop yields between 1981 and 1985. In the late 1980s, program participation came with many restrictions: it required farmers to limit their plantings to a share of acres historically planted to program crops (called 'base acres') and required a certain portion to be set aside (left fallow). Farmers with environmentally fragile land (e.g., highly erodible) were also required to follow certain management practices to limit environmental damages stemming from their cropping activities.[14] These costly restrictions limited program participation somewhat. In addition, some farmers may have strategically chosen not to participate in order to "build base" (payment-qualifying) acres in anticipation of higher future payments. Because payments are tied to historical plantings, and participation required farmers to limit plantings, some may have chosen not to participate in order to expand acreage and increase expected future payments. As payments in future years were tied to historical plantings, historical plantings were tied to participation decisions, and participation varied somewhat across producers, so did payments.[15] Base acres could also vary due to chance variation in rotations between 1981 and 1985, particularly since soybeans were not considered a program crop at that time.

The second local source of variation in payments per acre is differences in base yields, which affect payment levels. Base yields were determined by realized yields between 1981 and 1985. While yields are clearly tied to land quality, they also vary widely from year-to-year and across space, due to weather outcomes. Indeed, summary statistics reported by Roberts, Key, and O'Donoghue (2006) indicate that field-level yields are typically from 30% to 50% above or below their mean, and the county-level yield shock accounts for only about half the field-level shock. Thus, some variation in base yields, even locally, is arguably random.[16]

The second source of identification—local variation in payments—differs markedly from the first broader source and, to our knowledge, has no obvious links to nonpayment drivers of concentration growth. The simple model (1) captures the response to broad and local variation in payments, while the GAM approach (2) removes most variation caused by broad regional differences in crop mix and yield. By estimating the relationship between payments and concentration growth with and without the controls, we are able to consider both broad and local sources of identification.

Data

Measures of land concentration and government payments are constructed at the zip code level using individual farm-level data from the census of agriculture. The zip code is used as the unit of analysis because it is the smallest geographic area that can be associated with individual farms. The data include all zip codes recorded in the Census of Agriculture that had at least three farms in each of the four census

[14] See Claasen et al. for a discussion of cross compliance provisions.

[15] See Young et al. for a description of government programs and how they have evolved over the last twenty years.

[16] We do not observe base yields or base acres in the Census data so we cannot use these as instrumental variables.

years examined (1987, 1992, 1997, and 2002).[17] The analysis begins in 1987 because that is the first year farm-specific data on government payments are available.

An important consideration when using zip code regions as observational units is that zip codes can change over time (Blodgett 2005). Most zip code changes have occurred in relatively urban areas that have experienced rapid population growth and where agriculture is less prevalent, which somewhat mitigates the importance of the issue for our analysis. Zip codes usually change by splitting into two or more zip codes, with one of the new areas retaining the old code and the other(s) assigned a new code. Because we restrict our analysis to zip codes appearing in all four censuses, farms in areas where zip codes changed are omitted. Some farms in our analysis may be in zip codes that were split, and therefore decreased in size, between 1987 and 2002. However, these changes in zip code size should not be systematically related to payments per acre or the land concentration measure.

The Census of Agriculture reported farms in 32,959 zip codes in 1987, 34,202 in 1992, 34,408 in 1997, and 33,548 in 2002. Our data include 23,293 zip codes with three or more farms reporting in all four censuses.[18] Of these zip codes, we drop observations with undefined variables or extreme outliers and end up with 21,524 zip codes.[19] Although our sample drops about one-third of all zip codes, it drops a much smaller share of the total number of farms.[20]

[17] More precisely, every zip code was included where at least three farm operators responded to the Census in each of the four Census years. To protect the confidentiality of farmers' responses, the data were analyzed on site at the USDA's National Agricultural Statistical Service (NASS), the agency that administers the Agricultural Census. More information about the Census of Agriculture can be found at: http://www.nass.usda.gov/census/.

[18] These counts compare to a nationwide total of about 43,000 zip codes currently in the United States.

[19] Our per-acre control variables (sales and cropland area) and measure of cropland concentration are undefined for a few observations reporting zero cropland. We drop observations with extreme outliers: initial cropland concentration greater than 20,000 acres, a cropland to zip code area ratio greater than 10,000 (acres/square-miles), and sales-per-acre greater than $10,000 (1997 dollars). Eliminating these observations reduces our sample of zip codes by 7.6%, our sample of farms by 1.6%, and total 1987 cropland acres by 1.9%. These numbers vary slightly for the different census years we consider with the number of zip codes ranging from 21,500 to 21,524 (see table 6).

[20] Our sample includes 1,716,814, 1,524,783, 1,541,547, and 1,341,306 farms in the four sequential Census years, compared to 1,799,926, 1,621,263 1,653,098 and 1,486,895 farms in the raw Census files. These numbers refer to actual Census observations. Published Census estimates of farm numbers are higher because these estimates account for nonresponse probabilities. Nonresponse weights were used in computing tables 1–3.

For each zip code, concentration is measured by the acre-weighted median farmland or cropland (defined earlier). Across zip codes, farmland and cropland measures can differ substantially because total farmland includes range, pasture, and woodland in addition to cropland.[21]

Figure 1 shows zip code frequency distributions of farmland and cropland concentration for each of the Census years from 1987 to 2002. The horizontal axis is the natural logarithm of the weighted median (cropland or farmland), and the vertical axis is the estimated density.[22] We use the logarithm of land size because the size distribution of farms is highly skewed and the logarithm is more closely bell-shaped, which makes it easier to discern changes in the higher end of the distribution. Over time, the distributions shift markedly to the right, particularly above 5 (equivalent to about 150 acres), illustrating the shift in farming to larger operations. The shift in distributions is more pronounced for cropland than for farmland. Since payments target cropland rather than rangeland or pasture, the relatively larger shift in cropland concentration is the first indication that government programs might play a role in concentration growth. For relatively small farm sizes, the distribution changes little. These farms are mainly "residential lifestyle" farms with little production and little or no government payments.

For all panels, zip codes are sorted into six groups according to payments per acre in the initial year. The first group includes those zip codes with zero government payments per acre; the remaining zip codes are sorted into five equal-sized quintiles. In the online appendix we report summary statistics for each panel and each payment quintile (Roberts and Key 2007).

Results

Ordinary least squares (OLS) results in table 4 show how initial government payments per acre are associated with subsequent changes

[21] Cropland comprises 46.3% of farmland and pasture and range comprise 42.1%; remaining farmland is in woodland and conservation uses. See table 8 of the U.S. summary table for the 2002 Census of Agriculture, http://www.nass.usda.gov/census/.

[22] The distributions were estimated with a kernel density estimator using the public-domain software program 'R' (R Core Development Team, 2005; http://r-project.org/). The estimates use the default bandwidth of the function "density," which is 0.9 times the minimum of the standard deviation and the inter-quartile range divided by 1.34 times the sample size to the negative one-fifth power.

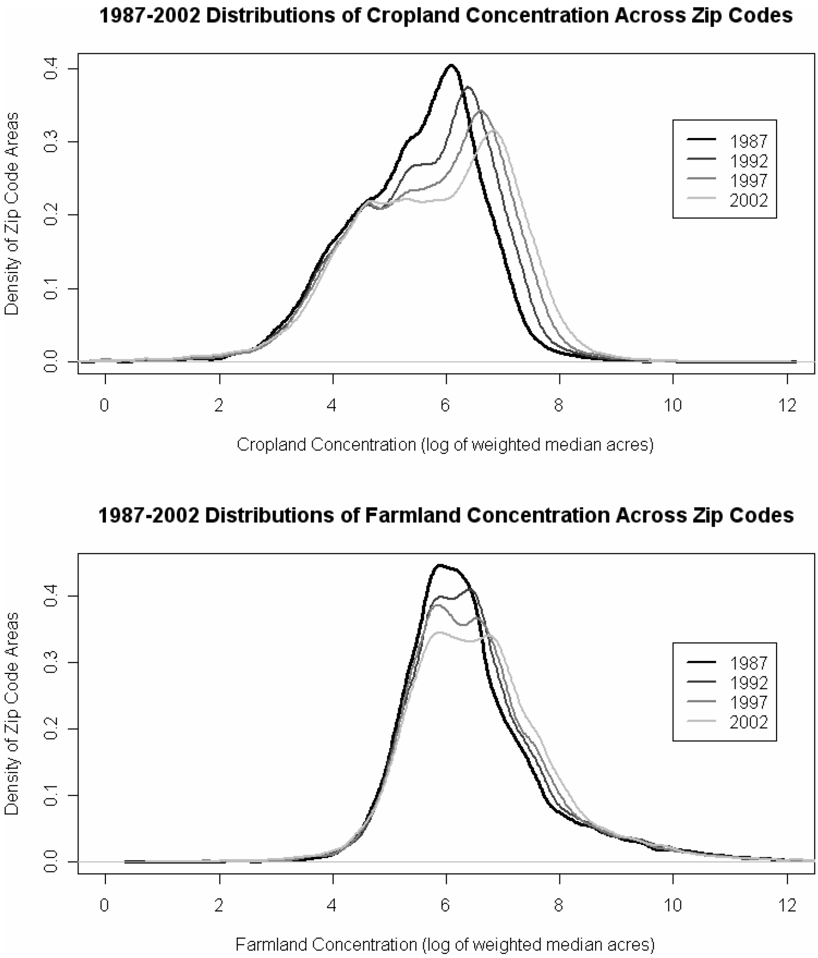

Figure 1. Smoothed frequency distributions of zip code concentration

in cropland and farmland concentration for the four panels. The first row reports average cropland concentration changed between 1987 and 1992 for each 1987 payments per-acre category (no payments, and each of five quintiles of payments per acre), weighted by the cropland in each zip code. The long panel results correspond to 1987 payment categories and average concentration growth from 1987 to 2002. All panels generally indicate increasing concentration growth for higher payment levels, and the relationship is strongest and clearest in the long-run analysis. In the long-run analysis, 1987 payments are relatively more exogenous to the subsequent long-run change. In addition, short-run idiosyncratic concentration changes tend to average out, increasing the overall fit.[23] Consequently, the long panels might provide the most reliable information about the relationship between payments and concentration growth.

Table 5 reports estimated concentration growth rates for the same panels and groups as table 4 using the GAM that incorporates the nonparametric controls for location, beginning-year concentration levels, crop sales per acre, and the ratio of cropland to zip code area. The adjusted estimates are derived by

[23] In a separate analysis (not reported) we constructed payment-per-acre categories for the long panels using the average of payments in 1987, 1992, and 1997 and obtained similar results. Averaging payments over the three years makes it more likely that zip codes are accurately classified by expected payments since payments can vary from widely from year to year. This averaging comes at the cost of potentially introducing more endogeneity, since changes in cropping decisions may influence both future payment levels and future measures of concentration. We also obtained similar results when we used only 1997 payments to generate payment categories, which were almost exclusively "lump-sum" payments, scheduled in advance (1996), and had very few links to 1997 production decisions.

Table 4. Percentage Change in Land Concentration by Payments Per-Acre Category

	Payments per Acre of Cropland in Beginning Year					
Panel Years	No Payments	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Cropland						
1987–92						
Concentration change (%)	−8.8	4.2	9.3	19	24.8	27.9
(Standard error)	(1.7)	(0.8)	(0.7)	(0.5)	(0.4)	(0.4)
1992–97						
Concentration change (%)	−9.9	4.5	10.8	15.6	18.3	18.7
(Standard error)	(1.5)	(0.8)	(0.6)	(0.5)	(0.4)	(0.4)
1997–2002						
Concentration change (%)	−21.2	2.8	7.9	14.8	16.5	16.1
(Standard error)	(2.0)	(0.9)	(0.7)	(0.6)	(0.5)	(0.5)
Long panel (1987–2002)						
Concentration change (%)	−9.8	14.0	28.0	47.8	56.6	61.4
(Standard error)	(2.0)	(1.1)	(0.9)	(0.7)	(0.6)	(0.5)
Farmland						
1987–92						
Concentration change (%)	−12.5	−13.6	−2.0	4.8	9.7	14.0
(Standard error)	(1.6)	(1.0)	(0.8)	(0.6)	(0.5)	(0.4)
1992–97						
Concentration change (%)	−41.1	−10.3	−4.6	1.4	6.8	10.3
(Standard error)	(2.2)	(1.0)	(0.8)	(0.6)	(0.5)	(0.4)
1997–2002						
Concentration change (%)	−14.7	−7.5	0.2	7.4	12.7	17.2
(Standard error)	(1.7)	(1.1)	(0.9)	(0.6)	(0.5)	(0.4)
Long panel (1987–2002)						
Concentration change (%)	−35.3	−18.1	0.0	13.0	28.8	40.9
(Standard error)	(2.3)	(1.3)	(1.1)	(0.9)	(0.6)	(0.5)

Notes: Concentration is defined as the area-weighted median cropland or farmland in each zip code. This measure marks the farm size for which half the land area (cropland or farmland) lies on farms with more and half with less. For each zip code and panel, the percentage change in concentration is calculated as 100 times the change in concentration divided by average concentration in the two years considered. For the long panels (1987–2002), the percentage change is calculated as the sum of percentage changes for the individual panels. Payment quintiles are calculated using payments per acre of cropland or farmland in the beginning panel year for all zip codes reporting positive government payments in the beginning year. For the long panels, quintiles are calculated using payments per acre in 1987. Because zip codes are sometimes classified into different payment categories in different panels, the percentage change for the long panel need not equal the sum of the individual panels.

using the estimated model to predict average concentration growth when all observations are set to the column's payment category. Like the simple comparisons in table 4, estimates are weighted by the land area in each zip code. Compared to table 4, these estimates restrict comparisons between proximate zip codes that have similar initial concentration rates, sales per acre, and cropland density. The addition of controls changes the estimates somewhat, but a similar pattern emerges. For the long panel, the estimated difference in cropland concentration growth between the highest and lowest payment quintiles is 47.4 percentage points without controls (table 4) and 22.7 percentage points with controls (table 5). For farmland concentration growth, the estimated difference in concentration between the fifth and first quintiles is 59.0 percentage points without controls and 24.9 with controls.

Summaries of all fitted models are reported in table 6, excluding the parametric payment effects, which are reported in table 5. The F-statistics indicate that the null hypothesis that the smoothed functions should not be included in the model is strongly rejected.[24] Figures A1 and A2 in the online appendix (Roberts and Key 2007) show the fitted smooth curves and spatial surface for the long panel of cropland concentration growth; that is, the estimated effects of these variables holding other variables constant. The figures are discussed in the appendix. For all specifications, the spatial surface accounts for more than half the variance of the fitted values ($\hat{\Delta c}$).

[24] The F-tests use "nonparametric degrees of freedom" which may be interpreted as the equivalent number of parameters required for the estimated smooth function. More formally, the smooth function can be formulated as a linear combination of the observed responses so that for some matrix A, $\hat{\Delta c} = A\Delta c$. Because the matrix A serves the same role the projection or 'hat' matrix in linear regression, nonparametric degrees of freedom for the model are defined as the trace of A.

Table 5. The Percentage Change in Land Concentration with Controls

	Payments Per Acre of Cropland in Beginning Year					
Panel Years	No Payments	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Cropland						
1987–92						
Concentration change (%)	−4.3	2.9	9.8	15.7	21.4	22.1
(Standard error)	(1.7)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)
1992–97						
Concentration change (%)	−5.3	3.3	7.5	12.3	14.7	15.2
(Standard error)	(1.7)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)
1997–2002						
Concentration change (%)	−11.4	−0.7	4.3	10.1	13.4	7.1
(Standard error)	(1.7)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)
Long panel (1987-2002)						
Concentration change (%)	11.2	23.6	29.9	39.7	46.3	46.3
(Standard error)	(1.8)	(2.0)	(2.0)	(2.3)	(2.3)	(2.4)
Farmland						
1987–92						
Concentration change (%)	−14.4	−5.6	−5.9	−4.5	−1.2	3.4
(Standard error)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)
1992–97						
Concentration change (%)	−21.1	−10.6	−11.6	−7.1	−3.4	0.3
(Standard error)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)	(1.8)
1997–2002						
Concentration change (%)	−12.3	−4.3	−7.8	−2.8	3.7	8.7
(Standard error)	(1.7)	(1.8)	(1.8)	(1.9)	(2.0)	(2.0)
Long panel (1987–2002)						
Concentration change (%)	−19.2	−5.5	−7.3	−2	9.5	19.4
(Standard error)	(1.6)	(1.9)	(2.0)	(2.1)	(2.2)	(2.1)

Note: See the notes to table 5 for definitions. This table reports estimated effects of payment quintiles with nonparametric controls for location and beginning-year concentration, sales per acre, and ratio of cropland area to zip code area (see text for details).

Table 6. Summary of GAM Estimates

		Nonparametric Function									
		Initial Concentration		Sales Per Acre		Ratio of Cropland to Zip Code Area		Spatial Surface		Goodness of Fit	
Regression	Sample Size	F Stat	DF	F Stat	DF	F Stat	DF	F Stat	DF	R^2	MSE
Cropland											
1987–1992	21,524	82.7	36.9	3.41	36.8	14.6	36.9	17.8	70.7	0.162	0.287
1992–1997	21,500	93.6	36.7	5.87	36.9	16.6	36.9	14.1	70.8	0.143	0.295
1997–2002	21,517	81.5	36.3	5.02	37.1	15.5	36.8	11.3	70.8	0.138	0.371
Long panel (1987–2002)	21,524	65.2	46.6	4.18	46.4	17.7	46.6	18.0	87.3	0.209	0.47
Farmland											
1987–1992	21,524	131.3	37.8	2.70	36.8	1.99	36.9	26.5	70.7	0.174	0.242
1992–1997	21,500	141.1	38.0	2.02	36.9	4.43	36.9	25.7	70.8	0.188	0.247
1997–2002	21,517	126.5	38.1	1.32	37.1	1.77	36.8	25.6	70.8	0.162	0.288
Long panel (1987–2002)	21,524	150.0	47.6	2.61	46.4	3.6	46.6	36.5	87.3	0.273	0.349

Notes: Estimates and standard errors for the parametric components of the models (the payment per-acre categories) are reported in table 6. All reported F statistics, except sales per acre for the 1997–2002 farmland regression, are statistically significant at the 1% or smaller significance level. MSE is the mean squared error.

Assuming we can interpret the association between payments and concentration growth as causal, how much of observed cropland and farmland concentration would be attributed to payments from agricultural programs? To answer this question, we estimate how much concentration would have grown without payments using our GAM model. This is shown in table 5, which reports the predicted overall growth in concentration with payments for all observations set to each of the six payment categories. If there were no payments, then between 1987 and 2002 average predicted cropland concentration growth is 11.2% and average predicted farmland concentration growth is −19.2%. These predicted growth rates compare to average fitted growth rates (with payments set at observed levels) of 41.5 and 1.5% for cropland and farmland, respectively.[25] These estimates may be misleading because there are relatively few zip codes with no payments, and these zip codes are likely quite different from those with small positive payments.

A more conservative way to predict concentration growth in the absence of payments is to compare predicted growth at observed payment levels with growth predicted if payments are assigned to the first payment quintile rather than zero payments. With payments for all observations set to the first payment quintile, predicted growth is 23.6% for cropland concentration and −5.5% for farmland concentration. These more conservative comparisons still indicate that nearly one-half of overall cropland concentration growth occurring between 1987 and 2002 might be attributed to government payments.[26]

Conclusions

Agricultural structural change over the last few decades can be characterized, in part, by crop production shifting to larger operations. The share of total cropland and farmland controlled by large-scale operations has steadily increased, while the share controlled by medium-scale operations has declined. Though many factors likely contribute to increased land concentration, including changes in technology and factor prices, concerns have been expressed that government payments to farmers have contributed to this phenomenon.

To our knowledge, this study is the first to document a large, extensive, and robust link between payment levels and subsequent land consolidation in agriculture. It does so using a newly constructed fine-scale regional (zip code) panel data set. The analysis attempts to exploit two plausibly exogenous sources of variation in government payments: (1) broad regional variation in crop types and yields caused by soil and climate variation, and (2) local variation resulting from differences in "base acreage" (program participation) and "base yields." The very large data set the sample of all agricultural zip codes with three or more farms permits comparisons across similar regions using a semiparametric spatial regression analysis that controls for location and initial land concentration. We examine concentration growth rates rather than levels to control for time-invariant factors that might be correlated with government payments and structural change. While payments could be correlated with farm size for a number of reasons, it is less likely that payments would be spuriously correlated with farm size growth, especially after controlling for location, initial concentration, historical sales per acre, and the share of land historically cropped. However, despite efforts to control for factors that might cause spurious association between government payments and structural change, it is not possible to know with certainty whether there remain factors that have not been controlled for. This is a standard caveat to measuring program effects when program participation is not randomly assigned.

Findings indicate that both broadly and locally, there is a strong positive association between government payments and the subsequent change in farm concentration (as measured by the acre-weighted median cropland and farmland). The evidence is striking, particularly because the marginal association between payments and concentration growth remains even when comparing nearby zip codes having similar initial concentration, sales per acre, and cropland density measures. If the association is in fact causal, then from a third to more than half of the observed concentration growth from 1987 to 2002 is due to government payments.

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[25] Because the GAM model is nonlinear, average fitted growth rates do not equal average observed growth rates, which were 50.1 and 9.5% for cropland and farmland, respectively.

[26] The acre-weighted average zip code farmland concentration growth in our sample (9.1%) between 1987 and 2002 is somewhat smaller than the individual farmland concentration (weighted median) growth implied in table 2 (30.2%). The difference arises mainly because acre-weighted average of weighted medians across zip codes does equal the overall acre-weighted median. Overall Cropland concentration growth is much less sensitive to our sample selection.

Because the relationship between payments and concentration growth is maintained after including flexible nonparametric controls, it is difficult to imagine what omitted variables might confound a causal interpretation of these results. In particular, *changes* in factor prices and technological change were likely similar in most parts of the country, so these standard economic explanations are unlikely to explain why concentration growth would be so much greater in areas with greater payment levels. However, it is equally difficult to pin down the fundamental economic forces that appear to create a link between payments and concentration growth, particularly one as large as we find. One possible explanation is that there are significant increasing returns to scale in agricultural production and that government payments—which provide cash and perhaps also increase leverage for loans—relieve borrowing constraints and allow some farms to transition more quickly to an efficient scale. This explanation would be consistent with studies finding increasing returns to scale (e.g., Morrison Paul et al. 2004; Morrison Paul and Nehring 2005) and liquidity constraints in agriculture (e.g., Hubbard and Kashyap 1992; Bierlen and Featherstone 1998; Barry, Bierlen, and Sotomayor 2000; Roberts and Key 2002).

As this is the first study to examine the relationship between payments and subsequent concentration growth, it is prudent to consider alternative explanations for these findings. For example, some local variation in payments may be due to local variation in program "base yields," which were fixed in 1985. Areas with higher base yields probably also have better land quality (flatter, more fertile soil, etc.). If scale-enhancing technological change favored higher quality land relative to lower quality land for same crop, this could provide an alternative explanation for our findings at the local level. However, this does not explain why technological change would favor higher-valued field crops relative to lower-valued crops (e.g., cotton over corn over wheat), which is required to explain the observed association at the broader level. A technological effect of this kind would seem coincidental, particularly because it would need to be associated with payment levels in a consistent and gradual way in order to explain the steadily higher rates of concentration growth across the five payment quintiles. Moreover, historical crop sales per acre would seem to be a reasonably good control for local variation in land quality, and controlling for historical sales nonparametrically had little influence on the results. Given the magnitude and novelty of the findings, there is clearly a need for further research to develop a better understanding of how payments lead to higher concentration levels.

If the findings are not spurious—that is, if there is indeed a causal effect of payments on subsequent concentration growth—they suggest that an enforceable cap on total payments would reduce the rate of land concentration and growth of farm sizes. However, the normative implications of such a policy (if it could be enforced) remain unclear. For example, if liquidity constraints coupled with increasing returns to scale provide the fundamental explanation for these findings (one of several possible explanations), then a payment cap would likely reduce production efficiency. The prudence of a payment cap must balance the loss in efficiency against any perceived social benefits, including a reduction in concentration growth. Although our findings may indicate the magnitudes of some potential tradeoffs, they do not measure the social benefits of such a policy.

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