What drives the difference between self-reported land value and land price? A county level analysis

Daniel P. Bigelow

Margaret Jodlowski

daniel.bigelow@ers.usda.gov

mcj47@cornell.edu

Paper prepared for presentation at the 165. EAAE Seminar
'Agricultural Land Markets –
Recent Developments, Efficiency and Regulation'

Humboldt-Universität zu Berlin, Germany, April 4-5, 2019

What drives the difference between self-reported land value and land price? A county-level analysis

Daniel P. Bigelow and Margaret Jodlowski

Abstract (max. 100 words)

Estimates for the asset value of agricultural land come from direct elicitation of farm operators' own assessment of the value of their land. We use data from actual sales transactions to evaluate the extent to which these estimates accurately correspond to the observed market value, or sale price, of land at the county level. We form a short panel at the county-level and compute the difference between the average sales price and the value of land to estimate a county-level fixed effects model. We find that increasing temperatures exacerbates the difference, while increasing population has the opposite relationship. (98 words)

Keywords: land value, agricultural land, land markets, elicited value, land price

JEL Code:

What drives the difference between self-reported land value and land price? A county-level analysis

Daniel P. Bigelow*

Margaret Jodlowski†

March 3, 2019

*U.S. Department of Agriculture, Economic Research Service

†Cornell University Charles H. Dyson School of Applied Economics and Management; mcj47@cornell.edu; address: 362 Warren Hall, 137 Reservoir Avenue, Ithaca, NY 14853

‡The findings and conclusions in this preliminary publication have not been formally disseminated by the U.S. Department of Agriculture and should not be construed to represent any agency determination or policy. This research was supported in part by the intramural research program and Pathways intern program of the U.S. Department of Agriculture, Economic Research Service.

Abstract

Estimates for the asset value of agricultural land come from direct elicitation of farm operators' own assessment of the value of their land; these estimates are then aggregated and widely used for analysis by the United States Department of Agriculture (USDA) and other research entities. We use data from actual sales transactions to evaluate the extent to which these estimates accurately correspond to the observed market value, or sale price, of land at the county level. The sales data, provided by CoreLogic, contain information on the size and price of every land transaction in the United States. We form a short panel over the three most recent years of the Census of Agriculture (2002, 2007, 2012) at the county-level and compute the difference between the average and median sales price and the elicited value of land. These differences are the dependent variables in a county-level fixed effects model, with a comprehensive set explanatory variables related to demographic change, weather, and agricultural suitability. We find that increasing temperatures exacerbates the difference in the two measures of land value, while increasing population has the opposite relationship.

1 Introduction

The vast majority of the United States farm sector's asset base is in the value of its farmland, making it the primary asset for the sector as a whole and for many individual farm operators. Historically, evaluating the value of this asset has relied on surveys in which farm operators provided their estimates of the value of their land. These opinion-based surveys then form the basis for the United States Department of Agriculture's (USDA) official annual estimates of farmland values across the country (see, for example, USDA-NASS (2016)). The bulk of research on agricultural land values, whether done by government or academic researchers, has, to some extent, relied on these values to inform their analysis, although very little is known about how these self-assessed values correspond to the market's assessment of land value. Widespread use of self-reported values in analysis of farmland markets comes despite the fact that economists typically consider observed sales transaction prices to be the "gold standard" (e.g., Banzhaf and Farooque, 2013). Given the role that farm real estate values play as a barometer of the financial health of the U.S. agricultural sector, it is important to understand how competing measures of value may differ from one another.

Until recently, data limitations hampered comparison of land survey value estimates with farmland sales prices from actual property transactions. For example, the first micro-scale study to compare farmland sales prices from actual sales transactions to official USDA estimates of land value from surveys, Bigelow et al. (2017), was restricted to New York State and was limited in its ability to match the two sources of information on land values, either geographically or by matching on observable characteristics. A comprehensive assessment of which factors, whether demographic, environmental, agricultural, or otherwise, drive the differences in these two distinct sources of information about the value of US farmland remains an open question.

We address this question by matching county-level estimates of land value, which are produced by USDA's National Agricultural Statistics Service (NASS) in each year of the US Census of Agriculture with county-level aggregates of sale prices for agricultural land, available from the CoreLogic database of property transactions. The CoreLogic data include sales information, obtained from county tax assessors' offices and other sources, about every property transaction that has occurred in the United States. Although the data include sales records as early as 1900, the data are considered most reliable and virtually comprehensive beginning in 2002, covering at least three Agricultural Census years (2002, 2007, 2012). The data are at the parcel level, and each record contains information on the size, seller, and sales price of each parcel, which can be aggregated up to the sales level, for instances in which one sale contains multiple parcels. Crucially for our work, the data also contain land use codes, allowing us to limit our records to land designated for agricultural use, as well as GPS coordinates for the parcel centroid, facilitating aggregation up to the county level.

Using the CoreLogic data to form a panel of county-level aggregates of farmland sales prices over time, we estimate a model that relies on within-county variation to explain the differences between the estimated land values produced by USDA and the sales price from property transactions. We include important drivers of this difference as independent variables in a fixed effects model in which the dependent variable is the county-level difference in different measures of aggregate sales and the mean value of agricultural land from the Census of Agriculture. These independent variables are comprehensive, accounting for agricultural characteristics, crop prices, land market activity, climatic variables, and measures of a county's socio-economic development, including population and income growth. By including county fixed effects in our model, we minimize the presence of bias due to omitted variables and measurement error (e.g., stemming from differences in inherent land productivity or sales price data collection methods across counties). Year fixed effects in our baseline model control for country-wide macroeconomic and policy factors, while our most restrictive model includes state-by-year fixed effects to capture state-specific conditions in each of the Census survey years. We find that weather, especially increasing temperatures, is the most salient feature for agriculture land values, while increasing population has the strongest relationship with agricultural land prices. The difference between the two measures contracts as population increases, implying a potential impact of a "fattening" land market. However, the difference expands within counties experiencing a higher number of hotter days, albeit in a specification that does not control for state-by-year time trends.

This study provides the first comprehensive, nation-wide evaluation of how self-reported farmland value estimates compare to actual transaction prices observed in US farmland markets. Knowing the extent to which such differences exist, and what drives those differences, is valuable for researchers attempting to understand the dynamics of the historically very thin farmland market. For example, most of the Ricardian climate impact literature relies on self-reported farmland value estimates to derive measures of future damages to the agricultural sector from anticipated climate change. If survey-based estimates of farmland value systematically undervalue (or overvalue) the effects of climate, existing climate impact estimates may be biased. Further, knowing how observed farmland prices differ from the self-assessed values is important for policymakers, especially those who are navigating conflict around the expansion of cities and their outskirts in rural counties on the border of urban areas, in addition to other debates on land use and perceived development potential.

2 Background

In an efficient market, the sale price of a parcel should approach the true value; with perfectly rational and informed farm operators evaluating the value of their land, that evaluation should also approach the true value and thus the sale price. However, it is more than likely that neither the assumption of a perfectly efficient market nor that of a perfectly rational survey-taking farm operator will be met. Rather, differences in self-assessed and market-assessed land values may arise for many reasons. First, agricultural land markets are thin, with a 2014 survey suggesting that just over 2% of farmland was expected to be exchanged between non-relatives over 2015–2019 (Bigelow et al., 2016). Land, especially agricultural land, is not a homogeneous good, and asymmetric information about the idiosyncrasies of a particular parcel could also drive differences in the self-assessed value of land and the market price. In addition, most USDA surveys elicit land value assessments from farm operators, who may not own the land they farm; in fact, 40% of US farmland is operated by tenant farmers (Bigelow et al., 2016). Farm operators, therefore, may capitalize different characteristics of their parcels than the market does. For instance, the market may weigh potential development of the land for non-agricultural use very heavily, while the operator may restrict their evaluation to the land's agricultural potential, especially given the context in which the valuation is done: that is, via a survey from the USDA.

These issues, of course, pertain to other types of real estate value assessment as much as they do to farm real estate and so have been evaluated in the non-farm real estate literature more broadly. In early papers in this literature, Kish and Lansing (1954) and Kain and Quigley (1972) both found that homeowners' evaluations of their homes' value matched those done by professional appraisers: more recent papers found that homeowners' estimates were significantly higher than the revealed value of the property from the market transaction price (Goodman Jr and Ittner, 1992; Kiel and Zabel, 1999). This latter finding supports skepticism in the social sciences, including economics, around the accuracy of people's responses to hypothetical questions, including questions that ask about the perceived value of property, as that implies a hypothetical market transaction Dickie et al. (1987). In a comprehensive meta-analysis reinforcing this skepticism, List and Gallet (2001) highlight the numerous factors that can inflate stated valuations of one's private goods: responses are sensitive even to different methods of elicitation, as one example. Banzhaf and Farooque (2013), however, find that indices based on self-reported residential housing values correlate well with those based transaction prices, but with the latter being more tightly linked to local public goods.

Although differences in stated and revealed valuation for agricultural land have yet to be systematically quantified and analyzed on a national scale, there is a literature that compare different sources of data on agricultural real estate values. Bigelow et al. (2017) are the first to compare actual farmland sales data with micro-scale USDA survey values, as discussed above. They are the closest, empirically, to our current work although they are limited in geographic scope to just New York State. Earlier work relies on indexed land value measures and aggregated transaction data: for example, Scott Jr and Chicoine (1983) compare the USDA Land value Index with an Illinois farmland sale price index and conclude that caution should be exercised when using the Land Value Index, as it tracks the direction of the sale price index reliably but fails to capture a wide heterogeneity in magnitude. Another early paper limited to a particular state, Gertel (1995), find similar heterogeneity in the magnitude of the difference between sales data and values from opinion surveys. He concludes that much of this heterogeneity can be explained by proximity to urban areas. Shultz (2006), in a follow-up of sorts to Gertel, found similar systematic undervaluation of farmland value compared to actual sales price from land transactions data in North Dakota. He concludes that while survey valuations are acceptable approximations of actual land value for a state, they are unlikely to be at all valuable at the county or other sub-state levels.

A related literature compares land values from assessments done for tax reasons to farmland transaction data. Because tax assessment data often provide parcel-level characteristics, the strength of this literature is in evaluating which of these characteristics drive the tax assessment value and which drive the price a parcel receives in the market. The conclusion from this literature is that the characteristics that determine of each measure of value do differ. Characteristics undervalued by tax assessment valuations include the value of surrounding natural amenities (Ma and Swinton, 2012) and the added value of irrigation in drought-prone regions (Grimes et al., 2008). It bears mentioning, however, that farmland tax assessments are generally based on an estimate of "use value", as opposed to market value, making the results of these analyses unsurprising (Anderson and England, 2014). In contrast to tax assessment values, the survey values collected by the USDA are intended to reflect the full market value of land.

We build on both strands of this literature. First, we compare opinion-based survey values with transaction data, like Bigelow et al. (2017) and others, but we do so on a larger scale and with the ability to geographically match values and prices at the county level. Second, we use a set of county characteristics, including those that reflect both agricultural and non-agricultural use value, to systematically explain the observed differences in the two measures. This is the first such nationwide study, and the first with sufficient power to explain variation in land values, land prices, and the difference between the two within a particular county.

3 Data and empirical strategy

3.1 Data

3.1.1 Dependent variables

Farm real estate value

Data on farm real estate value come from the USDA's Census of Agriculture. Conducted every five years, the Census is the most comprehensive survey of US farm operators. The Census collects information on land use, farm production, input use, production practices, operation finances, and operator characteristics, among other things. Of primary relevance to our study are the Census questions concerning the "current market value of land and buildings" used in the farm operation. The Census data is unique in that it provides representative estimates of farm real estate value at the county level. Annual USDA survey estimates based on the June Area Survey, in contrast, are aggregated to the state level.

Table 1 provides summary statistics for the county-level measures of per-acre farm real estate value from the 2002, 2007, and 2012 Censuses. All values are adjusted for inflation to \$2016 using the GDP implicit price deflator.[1] The counties used in computing these summary statistics are limited to those for which we have sufficient sales transaction information from Core Logic. Between 2002 and 2012, the real value of farm real estate has increased by 26.5%.

Figure 1 illustrates the large amount of county-level variation present in the self-reported Census values. The geographic pattern of real estate values is relatively constant across 2002 (Figure 1a), 2007 (Figure 1b), and 2012 (Figure 1c). Farm real estate values are generally highest along both coasts and in the Corn Belt. The Pacific coast, along with Florida, is characterized by high-valued orchard and vineyard production, which drives up the value of farmland. Farmland values in the heavily populated northeastern coastal area, on the other hand, are driven more by future development potential. The Corn Belt, including Iowa and Illinois, is where much of the most valuable farmland for commodity crop production is located. Real estate values tend to be lower in the Plains and Mountain West regions, where land tends to be used for wheat and lower-valued pasture and range purposes, with generally little non-agricultural development potential. Not coincidentally, these are the areas where the bulk of the counties with insufficient transaction price data are located, suggesting that farmland values and overall market activity tend to be positively correlated.

[1] The deflator is compiled by the Federal Reserve and available at: https://fred.stlouisfed.org/series/GDPDEF.

Table 1: Farm real estate value

Year:	mean	SD	n
2002	$ 3,473.99	$ 4,145.28	1350
2007	$ 4,217.26	$ 4,914.60	1767
2012	$ 4,396.44	$ 3,310.12	2055
Total	$ 4,094.44	$ 4,150.39	5172

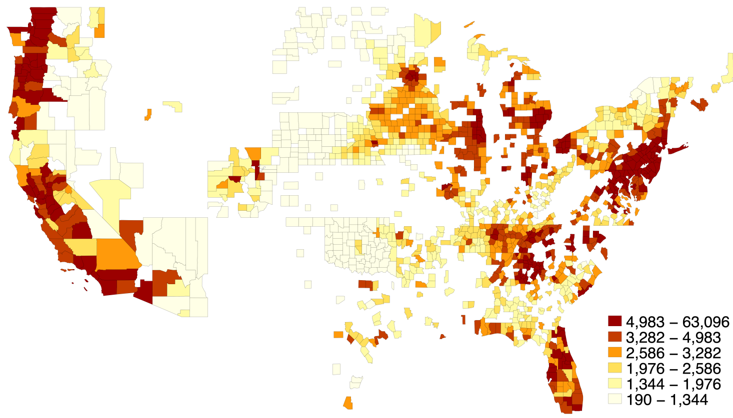
[a] Source: USDA Census of Agriculture

Farmland sales transaction data

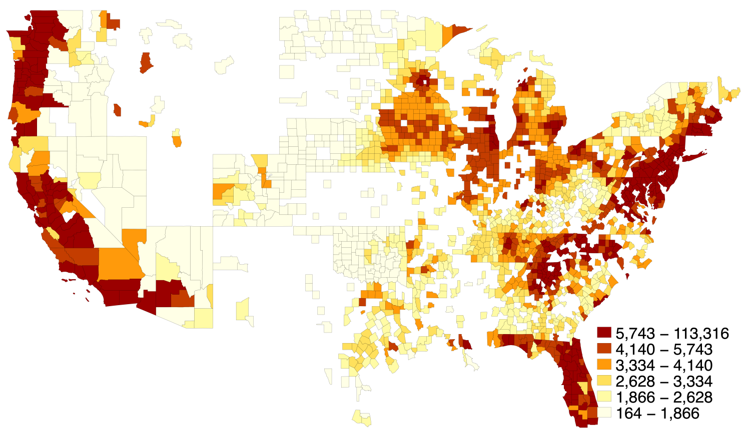
Farmland sales transaction data come from a database of all property transactions compiled by the private company CoreLogic and purchased by USDA. We use land use codes recorded for each parcel to identify sales of agricultural land from the universe of land transactions. The raw data are at the parcel level, and, to account for multi-parcel transactions, are grouped to the sale level through a combination of sale identification numbers, record identifiers, sale date, and seller information, including name. Each sale record includes sale price, size of the parcels sold in acres, number of parcels per sale, and date sold. All parcels are geo-referenced with latitude and longitude.

Since the Census of Agriculture is conducted once every five years, but land transactions occur every year, the transaction samples for 2002–2012 are assembled using a rolling five-year grouping. For example, the sales sample for 2012 comprises all transactions that occurred from 2008–2012 (inclusive). Like the Census-based values the sales prices are adjusted for inflation to $2016 using the GDP implicit price deflator. To account for changes in the real value of land within a sales year grouping, we regress the inflation-adjusted prices on a set of year fixed effects. The estimated coefficients are then used to detrend the prices. For example, transaction prices in the 2012 sales grouping are regressed on a set of 2008-2011 year fixed effects. The coefficient on the 2008 fixed effect, for instance, measures the discrepancy in the real value of 2008 prices, relative to 2012. We therefore use this coefficient to detrend the 2008 prices to the 2012 base year, and follow a similar procedure for 2009, 2010, and 2011.

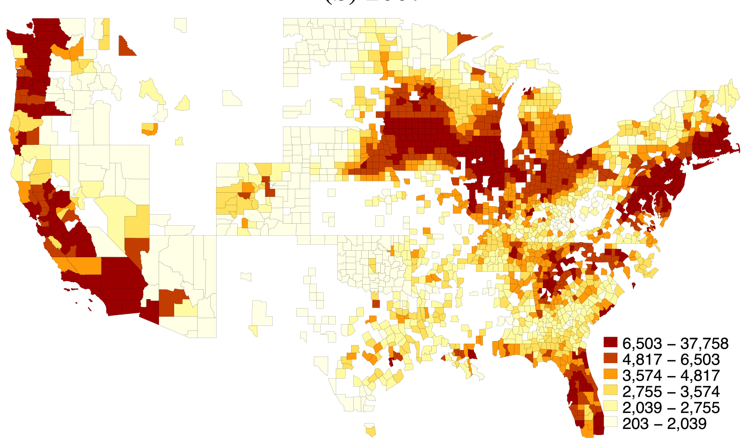
Table 2 shows summary statistics for the CoreLogic sales price data, aggregated to the county level. To measure the influence of small, high-priced parcels, we present two sets of summary statistics, one based on the raw sales observations and another in which sales transactions are weighted according to the acreage of the land sold. Comparing the unweighted average to the acreage-weighted average and the median, both weighted and unweighted, shows the influence of outliers on the average sale price. For instance, the unweighted mean for 2012 is $3,099 larger than the corresponding weighted mean, a 59% difference. The discrepancy between the unweighted mean and unweighted and weighted medians is even larger, amounting to differences of $3,155 (61%) and $4,546 (119%), respectively. Weighting parcel sales by acreage has a clear downward effect on summary measures of farmland prices, suggesting a inverse relationship between transaction price and acreage. The "small parcel premium" has been documented in past work, and is generally considered to be due to the relative ease of developing smaller parcels (Brorsen et al., 2015).



(a) 2002



(b) 2007



(c) 2012

Figure 1: Per-acre farm real estate value estimates from the Census of Agriculture, 2002–2012 (inflation adjusted to $2016)

Table 2: Land transaction prices

	2002 mean / SD	2007 mean / SD	2012 mean / SD	Total mean / SD
Average sales price, unweighted	$ 8,181.65	$ 12,505.40	$ 8,356.69	$ 9,728.01
	$ 18,682.41	$ 34,338.11	$ 19,953.96	$ 25,609.11
Average sales price, weighted	$ 5,004.29	$ 7,458.64	$ 5,257.81	$ 5,943.27
	$ 13,121.41	$ 22,264.21	$ 17,617.46	$ 18,401.66
Median sales price, unweighted	$ 4,943.04	$ 7,745.85	$ 5,201.34	$ 6,002.94
	$ 13,175.25	$ 32,089.33	$ 18,002.84	$ 22,960.09
Median sales price, weighted	$ 3,585.78	$ 5,115.48	$ 3,810.50	$ 4,197.49
	$ 12,246.12	$ 14,914.47	$ 17,282.06	$ 15,300.86
n	1354	1769	2056	5179

[a] Source: CoreLogic

Visual inspection of Tables 1 and 2 reveals that, in addition to reducing the mean and median prices, weighting also brings the summary measures closer to those of the self-reported values from the Census. To formally analyze the Census-sales differences, Table 3 displays the average county-level differences for each of the four summary price measures displayed in Table 2. Differences between the Census values and average sale prices are quite large, ranging from $3,957 to $8,099. Weighting by acreage reduces the mean-based difference by a substantial margin, 62–78%, in all three study years. The weighted median is by far the most comparable summary price measure, removing at least 91% of the year-by-year discrepancy resulting from the simple average, and resulting in a minuscule difference of just over $1 when taken over the entire study timeframe. While this is admittedly a simple analysis, weighting clearly has a profound effect on the comparability of sales and survey-based land value summary measures, a finding that echoes the results of Bigelow et al. (2017) for New York State.

Table 3: Differences between farm real estate value and land transaction prices

Difference between farm real estate value and:	2002 mean / SD	2007 mean / SD	2012 mean / SD	Total mean / SD
Average sales price, unweighted	$ 4,649.79	$ 8,099.69	$ 3,957.35	$ 5,552.82
	$ 16,834.80	$ 31,924.88	$ 19,066.37	$ 23,869.71
Average sales price, weighted	$ 1,444.40	$ 3,044.80	$ 856.97	$ 1,757.52
	$ 11,390.49	$ 19,180.05	$ 17,207.52	$ 16,673.18
Median sales price, unweighted	$ 1,400.88	$ 3,332.05	$ 800.48	$ 1,821.81
	$ 11,514.12	$ 30,087.81	$ 17,404.88	$ 21,569.40
Median sales price, weighted	-$19.16	$698.72	-$591.05	-$1.26
	$ 10,448.25	$ 10,796.02	$ 17,190.94	$ 13,637.89
n	1350	1766	2055	5171

[a] Source: USDA Census of Agriculture; CoreLogic

3.2 Methods

Our empirical approach is designed to explain variation in the difference between the farm real estate value collected from the Census of Agriculture and the actual prices for agricultural land transactions recorded in the data from CoreLogic. The first set of models we estimate are designed to explain within-county variation in different measures of farmland values over 2002-12. We estimate two specifications for each of five outcomes variables. The first specification may be written as:

$$v_{ct} = \boldsymbol{X'}_{ct}\boldsymbol{\beta}_1 + \boldsymbol{Z'}_{ct}\boldsymbol{\beta}_2 + \alpha_c + \gamma_t + \varepsilon_{it}. \tag{1}$$

The dependent variable in equation (1), v_{ct}, reflects one of five separate measures of land value for county c in time t: (1) self-reported farm real estate value, (2) average sale price, (3) weighted average sale price, (4) median sale price, or (5) weighted median sale price. Unobserved heterogeneity across counties is captured by county fixed effects α_c. Time fixed effects, represented by γ_t, account for the extent to which common macro-level trends (e.g., Farm Bill changes) influenced the trajectory of land values over our study timeframe.

There are two sets of explanatory covariates in the model.[2] The first, denoted by $\boldsymbol{X'}_{ct}$, accounts for a variety of factors related to agricultural use value, including the mix of agricultural land uses (cropland or pasture), extent of irrigation, and weather. Importantly, by including α_c our model also implicitly controls for a number of other factors that would affect cross-sectional differences in land value (e.g., soil quality and long-run climate). We also account for capitalized future development potential through the variables that comprise $\boldsymbol{Z'}_{ct}$, which include population, income per capita, and farmland acres. We note here that within-county variation in farmland acreage could reflect the loss of farmland to alternative uses (e.g., development), new land coming into production (e.g., forest-to-agriculture transitions), or some combination of the two.

An implicit restriction embedded in estimation of (1) is that, conditional on $\boldsymbol{X'}_{ct}$ and $\boldsymbol{Z'}_{ct}$, we assume that land values follow similar trajectories across the US. This is unlikely to be true for a number of reasons, such as the differential effect that changes in Farm Bill policy may have on different areas of the country. To relax this assumption, we also estimate an enhanced model of the following form:

$$v_{ct} = \boldsymbol{X'}_{ct}\boldsymbol{\beta}_1 + \boldsymbol{Z'}_{ct}\boldsymbol{\beta}_2 + \alpha_c + \theta_{s(c)t} + \varepsilon_{it}. \tag{2}$$

Equation 2 is identical to (1) in all respects apart for how it accounts for unobserved time-varying influences. In (2), we allow for differential year effects according to the state, s, in which each county is located. These state-year fixed effects are accounted for by $\theta_{s(c)t}$.

Estimation of (1) and (2) for different outcome variables allows us to gauge the extent to which farmland value sources differ in terms of which factors they capitalize. A more direct way to estimate what drives the difference in self-reported values and transaction prices is to estimate

[2] Table A1 in appendix A shows the summary statistics for these covariates.

models which feature the year-specific county-level difference as the outcome variable. These models may be written as:

$$\tilde{v}_{ct} = \boldsymbol{X'}_{ct}\boldsymbol{\beta}_1 + \boldsymbol{Z'}_{ct}\boldsymbol{\beta}_2 + \alpha_c + \gamma_t + \varepsilon_{it} \tag{3}$$

and

$$\tilde{v}_{ct} = \boldsymbol{X'}_{ct}\boldsymbol{\beta}_1 + \boldsymbol{Z'}_{ct}\boldsymbol{\beta}_2 + \alpha_c + \theta_{s(c)t} + \varepsilon_{it}. \tag{4}$$

The specification in equations (3) and (4) features as the dependent variable one of four possible land value differences for county c in time t: (1) self-reported value - mean sale price (2) self-reported value - weighted mean sale price, (3) self-reported value - median sale price, or (4) self-reported value - weighted median sale price. All other terms in (3) and (4) are defined analogously to those in equations (1) and (2).

4 Results

4.1 *Farm real estate value*

Table 4 presents results of equations 1 and 2 in columns (2) and (3) respectively, where v_{ct} is equal to self-reported land values from the Census of Agriculture. Column (1) reports a naive estimation of these equations without county fixed effects: these coefficients reflect the correlates of land values between, rather than within, counties. Comparison of coefficients between column (1) and columns (2) and (3) demonstrate the importance of controlling for time-invariant county characteristics: for example, in the between county analysis, both population and income per capita are positively related to farmland values. This relationship disappears in the within county analysis: population and wealth changes have no effect on land values within a particular county. County-level soil characteristics are one important time-invariant characteristic that is absorbed by the county fixed effects; counties with better soil tend to also have higher land values and vice versa.

Table 4: Results: Correlates of farm real estate value

	(1) Farm real estate value per acre	(2) Farm real estate value per acre	(3) Farm real estate value per acre
County characteristics			
Population	.00246***	-.000372	.0018
	(.000668)	(.00155)	(.00171)
Income per capita	.213***	.082***	.00714
	(.0153)	(.0177)	(.0193)
Cropland acres	.00624***	.0115***	.0088***

	(.00213)	(.00188)	(.0021)
Pasture acres	.00556***	.00471***	.00594***
	(.00187)	(.00168)	(.00169)
Irrigated acres	.00385***	-.0115***	-.00043
	(.0011)	(.00299)	(.00325)
Farmland acres	-.00664***	-.0103***	-.00935***
	(.00207)	(.00177)	(.00195)
Land area (acres)	.0000666		
	(.000109)		
Weather			
Degree days below 29°C	-10.1***	-5.19	6.06
	(2.45)	(5.67)	(6.28)
Degree days above 29°C	-11**	-76.9***	-55.8**
	(4.82)	(20.1)	(27.2)
Precipitation (mm)	-14.5***	-2.37	-8.13
	(4.17)	(6.47)	(5.63)
Annual precipitation (mm)	.0283***	.13***	.0261
	(.00701)	(.0344)	(.0352)
Growing season precipitation (mm)	.0922**	-.146**	.0123
	(.0426)	(.0709)	(.0621)
Annual minimum temperature (°C)	4.24**	-43.5***	-14.9
	(2.07)	(9.2)	(12.9)
Growing season minimum temperature (°C)	8.78**	36.5***	5.06
	(3.51)	(10.8)	(13.1)
Annual maximum temperature (°C)	-2.29	29.1***	32**
	(2.12)	(8.07)	(12.6)
Growing season maximum temperature (°C)	8.11***	-13.6*	-26.6**
	(2.91)	(8.15)	(11.8)
Soil characteristics			
Water capacity	-29.4		
	(46.1)		

Percent clay	-36.3***		
	(8.11)		
Minimum permability	91.3		
	(71.5)		
K-factor of topsoil	-2,666***		
	(936)		
Best soil class (%)	8.58**		
	(3.38)		
Constant	6,811***	-15,224	-3,661
	(2,158)	(12,264)	(20,555)
County FE	NO	YES	YES
Year FE	YES	YES	YES
State-Year FE	NO	NO	YES
Observations	4,705	4,705	4,705
Number of counties	2,060	2,060	2,060

Standard errors robust to correlation at the county level in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Within a particular county and controlling for time trends at the state level, weather, particularly hot weather, has the most significant relationship with land values. As the number of degree days above 29 increases, land values fall significantly; we see a similar relationship between land values and the maximum temperature (also measured in) and land values. Taken together, these results indicate that, within a county, farmland values are falling when county temperatures increase. As the weather in a county becomes more adversarial for farming, farmers appear to be more likely to lower their estimations of the value of land there.

4.2 *Land transaction prices*

We then estimate equations 1 and 2 with average land prices as the dependent variable; Table 5 includes these results, in which odd-numbered columns have the unweighted average sales price as the outcome of interest and even columns use the average sales price weighted by the number of acres in the sale. As above, we also estimate a naive, between-county specification; these results are displayed in columns (1) and (2). Columns (3) and (4) introduce county fixed effects, corresponding to equation 1 and columns (5) and (6) introduce state-by-year fixed effects in addition to county fixed effects. Generally, the strong positive relationship between land values and soil quality described above holds for land prices as well, albeit at lower levels of both magnitude and significance.

Table 5: Results: Correlates of average farmland sales price

	(1)	(2)	(3)	(4)	(5)	(6)
	Average price per acre					
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
County characteristics						
Population	.00971**	.0054***	-.0802***	-.035***	-.0681***	-.0297***

	(.00423)	(.00201)	(.0168)	(.011)	(.0152)	(.0102)
Income per capita	1.29***	.73***	.19	.242**	-.0507	.122
	(.138)	(.1)	(.137)	(.116)	(.182)	(.123)
Cropland acres	-.0118	-.0054	.0377**	.0133*	.0255	.0105
	(.00876)	(.0057)	(.016)	(.00716)	(.018)	(.00896)
Pasture acres	-.00766	.00227	.014	.00126	.0212	.00104
	(.00845)	(.00523)	(.0179)	(.00665)	(.0168)	(.0084)
Irrigated acres	.0122*	.00592	-.0618**	-.0235**	-.0252	-.00955
	(.00726)	(.00366)	(.0309)	(.0114)	(.0307)	(.011)
Farmland acres	.00566	-.00204	-.0432**	-.0117*	-.0387**	-.0082
	(.00853)	(.00516)	(.0188)	(.00635)	(.0187)	(.00831)
Land area (acres)	.000589	-.000297				
	(.000673)	(.000244)				
Weather						
Degree days below 29°C	-2.71	-5.36	-84.6	-11.4	-16.6	12.5
	(9.85)	(6.69)	(57.9)	(37.3)	(60.3)	(34.5)
Degree days above 29°C	-1.62	1.98	476***	198**	132	73
	(17.6)	(11.5)	(151)	(82.8)	(194)	(119)
Precipitation (mm)	-46.8*	-39.3*	4.97	-9.03	-107	-53
	(28.3)	(22)	(80.2)	(46.5)	(117)	(65.2)
Annual precipitation (mm)	-.0512	.00215	.646*	-.0568	.55*	.0284
	(.036)	(.0239)	(.333)	(.19)	(.322)	(.217)
Growing season precipitation (mm)	.613**	.426*	-.531	.171	.0164	.218
	(.309)	(.226)	(.584)	(.454)	(.767)	(.553)
Annual minimum temperature (°C)	34.7***	12.5*	-177***	-44	-101	-13.1
	(12.5)	(6.68)	(62.6)	(43.7)	(101)	(65.9)
Growing season minimum temperature (°C)	-32.2*	-5.49	290***	75.9	141	23.1
	(17.7)	(10.5)	(84.8)	(55.8)	(94.8)	(67)
Annual maximum temperature (°C)	-2.77	-12.2*	159**	-13.2	-32.5	-31.7
	(10.5)	(6.34)	(72.2)	(47.9)	(94.4)	(67.8)
Growing season maximum temperature (C)	6.64	16.6**	-125*	-18.1	17.4	-11.1
	(13)	(7.59)	(67.7)	(42.3)	(97.9)	(60.1)
Soil characteristics						
Water capacity	583*	124				

	(327)	(178)				
Percent clay	-45.5	-21.7				
	(48.7)	(34.7)				
Minimum permeability	1,295**	574*				
	(523)	(297)				
K-factor of topsoil	5,579	1,569				
	(4,581)	(3,281)				
Best soil class (%)	6.07	5.73				
	(19.3)	(12.3)				
Constant	-14,795	-13,458**	26,316	45,499	469	48,280
	(9,648)	(6,718)	(71,088)	(43,150)	(128,499)	(95,869)
County FE	NO	NO	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
State-Year FE	NO	NO	NO	NO	YES	YES
Observations	4,705	4,705	4,705	4,705	4,705	4,705
Number of counties	2,060	2,060	2,060	2,060	2,060	2,060

Standard errors robust to correlation at the county level in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Unlike for land value, however, we observe no relationship between land prices and weather. Using our preferred specification, that is, equation 2 with weighted average sales price, shown in column (6) no measure of weather has a significant relationship with land prices. In fact, the only county characteristic that has a significant relationship with weighted average land prices in this specification is population: agricultural land is cheaper as the population increases in a county. This coefficient is largely unchanged by the state-year time trends, but the opposite relationship is observed between counties, where counties with higher populations also have higher agricultural land prices. Therefore, the relationship between urban development, population expansion, and land values may not be a straightforward one. In some places where such developments are occurring, land prices may be lower due to a glut of land on the market, explaining this negative relationship within any particular county.[3]

4.3 *Difference between average value and average price*

In order to understand what drives the difference between farmland's surveyed value and transacted price within a particular county, we estimate equations 3 and 4 and report the results in table 6. Column definitions remain unchanged from section 4.2: odd columns are the difference between farm real estate value and the unweighted average sales price and even columns are the difference between value and the acres-weighted average sales price. The specifications include more fixed effects from left to right: columns (1) and (2) include only year fixed effects, (3) and (4) include year and county fixed effects (corresponding to equation 3) and columns (5) and (6) have year,

[3]These results are largely unchanged when median sales price, whether weighted or unweighted, is used instead of average sales price. These results are available in appendix B, table B2.

county, and state-by-year fixed effects (equation 4).[4]

Table 6: Results: Correlates of difference between average sales price and farmland value

	(1)	(2)	(3)	(4)	(5)	(6)
	Difference: Average price per acre					
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
County characteristics						
Population	.00738**	.0031**	-.0798***	-.0346***	-.0699***	-.0315***
	(.0037)	(.00153)	(.0172)	(.0115)	(.0157)	(.0109)
Income per capita	1.06***	.485***	.108	.16	-.0578	.115
	(.129)	(.0947)	(.138)	(.115)	(.187)	(.124)
Cropland acres	-.0172**	-.0101**	.0262*	.00179	.0167	.00169
	(.00743)	(.00494)	(.0155)	(.00726)	(.0175)	(.00914)
Pasture acres	-.0128*	-.00205	.00932	-.00345	.0153	-.0049
	(.00727)	(.00466)	(.0171)	(.00643)	(.0165)	(.00835)
Irrigated acres	.00748	.00109	-.0503	-.012	-.0248	-.00912
	(.00725)	(.00313)	(.0308)	(.0119)	(.031)	(.0124)
Farmland acres	.0118	.00322	-.0329*	-.00138	-.0294	.00115
	(.00716)	(.00444)	(.0181)	(.00628)	(.0183)	(.0084)
Land area (acres)	.000563	-.000299				
	(.000604)	(.000212)				
Weather						
Degree days below 29°C	8.1	5.04	-79.4	-6.2	-22.7	6.42
	(8.74)	(6.26)	(57.7)	(37.7)	(60.3)	(35.4)
Degree days above 29°C	7.9	10.9	553***	275***	188	129
	(14.9)	(9.54)	(145)	(80.6)	(187)	(116)
Precipitation (mm)	-32	-24.9	7.34	-6.66	-99.1	-44.9
	(26.5)	(20.9)	(79.1)	(46.1)	(115)	(63.8)
Annual precipitation (mm)	-.0796**	-.0256	.516	-.187	.524	.00234
	(.033)	(.0216)	(.33)	(.193)	(.322)	(.221)
Growing season precipitation (mm)	.517*	.33	-.385	.318	.00403	.205
	(.291)	(.212)	(.583)	(.461)	(.761)	(.55)
Annual minimum temperature (°C)	29.6***	6.68	-133**	-.414	-85.8	1.79
	(11.4)	(5.68)	(61.1)	(43.6)	(101)	(66.4)
Growing season minimum temperature (°C)	-41**	-12.9	254***	39.4	136	18
	(16.1)	(9.35)	(83.4)	(56.4)	(93.7)	(67.6)
Annual maximum temperature (°C)	.725	-8.08	130*	-42.3	-64.5	-63.8
	(9.35)	(5.69)	(70.3)	(47.5)	(91.4)	(66.8)
Growing season maximum temperature (°C)	-3.01	6.42	-112*	-4.51	44	15.5

[4]Once again, corresponding results using median sales price (weighted and unweighted) are unchanged; these results are available in appendix B, table B3.

	(11.4)	(6.93)	(66.6)	(42.9)	(95.8)	(59.8)
Soil characteristics						
Water capacity	617*	151				
	(322)	(151)				
Percent clay	-12.1	9.48				
	(45.6)	(31.7)				
Minimum permeability	1,208**	476*				
	(491)	(247)				
K-factor of topsoil	8,487**	4,387				
	(4,224)	(2,983)				
Best soil class (%)	-1.54	-1.52				
	(17.5)	(10.7)				
Constant	-21,529**	-19,242***	41,540	60,723	4,130	51,941
	(8,938)	(6,215)	(70,362)	(43,756)	(129,046)	(97,109)
County FE	NO	NO	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
State-Year FE	NO	NO	NO	NO	YES	YES
Observations	4,705	4,705	4,705	4,705	4,705	4,705
Number of counties	2,060	2,060	2,060	2,060	2,060	2,060

Standard errors robust to correlation at the county level in parenthesis
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

As above, we find that there is a significant relationship between population and the difference between agricultural land value and price, in that the difference between the two is significantly smaller in counties with larger populations. One possible explanation is that agricultural land markets are thinner where population is smaller, and so counties with an increasing population also tend to have a more active land market. Absence of a thin market, in turn, causes land values and land transaction prices to converge. Results from the more flexible but still within-county specification shown in column (4) demonstrate the same relationship between population and the difference in the two measures, in addition to a strongly significant and interesting relationship with one measure of changing weather patterns. The difference between average acres-weighted land prices and farm real estate value is significantly higher in counties experiencing an increasing number of degree days above 29 . Prices higher than value imply a potential diminishing return to agriculture in these counties, reflected in the land values but not capitalized into land prices there. This makes sense if land is being sold for non-agricultural purposes, where the impact of weather, especially hot weather that inhibits plant growth, is not nearly as important. Landowners in places experiencing both hotter weather and increasing population may see prices well above their estimated value of their land, providing a further inducement to sell land.

5 Conclusion

As can be expected in a market for a good which is both valuable and highly idiosyncratic, the market for agricultural land is thin and characterized by asymmetric information. It is unsurprising, therefore, that estimates of the inherent value of the land would differ when that inherent value is measured by farmers' estimation of its value, elicited through a survey, and when the value is measured by the price of land from actual market transactions. Although we document the existence of such a divergence, estimated to be close to $2,000 when sales are weighted by acres, we also show that alternative aggregations of the sale price data, such as the median acres-weighted sales price, the average difference shrinks to little more than $1.00, a remarkable convergence considering the heterogeneity of sales. Such a figure also masks considerable hetereogeneity across time and space.

By using the most complete universe of agricultural transactions available to researchers, we are able to effectively decompose this difference by accounting for both spatial and temporal heterogeneity. Potential correlates of this difference include demographic, weather, and agronomic characteristics; our preferred models control not only for time-invariant county characteristics, but also for state-specific time trends, capturing a wide array of political and macroeconomic conditions likely to influence land markets. We find that land value is related to different characteristics than are land prices, implying that farmers evaluating land value in the Census of Agriculture survey capitalize different conditions than do buyers on the land market.

Results from all models show an increasing influence of population growth on land markets, while changing weather patterns, especially increasingly hot weather, are more salient for farmers than for land buyers. This relationship may be inducing farmers in areas more affected by global climate change to sell land. At its most extreme, the sales of land could be for non-agricultural uses, thereby reducing the agricultural land base at a time when climate change has been shown to reduce food security. Therefore, increasing population and increasing temperatures not only increase agricultural production pressure on the demand side, but may also be starting to impact the agricultural asset base on the supply side as well.

References

Anderson, J. E. and R. W. England (2014). *Use-Value Assessment of Rural Land in the United States*. Lincoln Institute of Land Policy.

Banzhaf, H. S. and O. Farooque (2013). Interjurisdictional housing prices and spatial amenities: Which measures of housing prices reflect public goods? *Regional Science and Urban Economics 43*, 635–648.

Bigelow, D., A. Borchers, and T. Hubbs (2016). U.s. farmland ownership, tenure, and transfer. Technical report.

Bigelow, D. P., J. Ifft, and T. Kuethe (2017). The compatibility of farmland sales and opinion survey data. Technical report, Working Paper.

Brorsen, B. W., D. Doye, and K. B. Neal (2015). Agricultural land and the small parcel size premium puzzle. *Land Economics 91*(3), 572–585.

Dickie, M., A. Fisher, and S. Gerking (1987). Market transactions and hypothetical demand data: A comparative study. *Journal of the American Statistical Association 82*(397), 69–75.

Gertel, K. (1995). Farmland values from opinion surveys and sales data: How they differ and why. *Journal of ASFMRA*, 89–100.

Goodman Jr, J. L. and J. B. Ittner (1992). The accuracy of home owners' estimates of house value. *Journal of Housing Economics 2*(4), 339–357.

Grimes, A., A. Aitken, et al. (2008). Water, water somewhere: The value of water in a drought-prone farming region. Technical report, Motu Economic and Public Policy Research Wellington.

Kain, J. F. and J. M. Quigley (1972). Housing market discrimination, home-ownership, and savings behavior. *The American Economic Review 62*(3), 263–277.

Kiel, K. A. and J. E. Zabel (1999). The accuracy of owner-provided house values: The 1978–1991 american housing survey. *Real Estate Economics 27*(2), 263–298.

Kish, L. and J. B. Lansing (1954). Response errors in estimating the value of homes. *Journal of the American Statistical Association 49*(267), 520–538.

List, J. A. and C. A. Gallet (2001). What experimental protocol influence disparities between actual and hypothetical stated values? *Environmental and Resource Economics 20*(3), 241–254.

Ma, S. and S. M. Swinton (2012). Hedonic valuation of farmland using sale prices versus appraised values. *Land Economics 88*(1), 1–15.

Scott Jr, J. T. and D. L. Chicoine (1983). Comparing actual farmland sales with the usda land value index. *Journal of ASFMRA*, 3–7.

Shultz, S. (2006). Differences between agricultural land value surveys and market sales. *Journal of ASFMRA*, 142–149.

USDA-NASS (2016). Land values 2016 summary. *Washington, DC: USDA National Agricultural Statistical Service. http://www.usda. gov/nass/PUBS/TODAYRPT/land0815.pdf*.

6 Appendix A: Summary statistics

Table A1: Summary statistics: Independent variables, by land value: all years

	All counties			High ag land value counties			Low ag land value counties		
	mean	SD	n	mean	SD	n	mean	SD	n
Population	115166.7	354116.2	5178	475659.3***	929198.3	525	32007.3***	89022.1	518
Income per capital	20336.2	5337.7	5178	26456.4***	6545.1	525	17934.5***	4600.7	518
Cropland acres	132959.5	149617.2	5162	98753.2***	148904.1	518	259213.5***	215375.0	515
Pastured acres	105548.4	267370.6	5131	37693.3*	83335.9	507	480960.8***	659626.9	507
Irrigated acres	20987.8	62834.5	4792	26490.0***	96900.1	506	34787.8***	51010.6	482
Farmland acres	254876.7	324588.9	5147	149978.9*	206952.6	515	741076.7***	660242.7	507
Area (acres)	584192.2	882931.9	5174	561375.2***	832871.1	520	1383038	1764006.0	518
Water capacity	8.6	1.9	5103	8.1***	2.1	505	8.6***	2.0	512
Percent clay	24.4	8.5	5103	19.8***	8.4	505	22.0***	7.8	512
Minimum permeability	1.4	1.4	5103	1.9***	1.6	505	1.9***	2.3	512
K-factor of topsoil	0.3	0.1	5103	0.26***	0.1	505	0.3***	0.1	512
Best soil class (%)	60.4	25.1	5103	57.9***	27.4	505	49.3***	30.2	512
Degree days below 29°C	3278.5	637.3	5121	3178.7***	557.0	507	3105.6***	669.8	513
Degree days above 29°C	56.0	56.1	5121	43.2***	59.4	507	80.5***	77.8	513
Precipitation (mm)	546.2	162.7	5121	529.4***	191.1	507	350.6***	140.9	513
Annual precipitation (mm)	992.0	327.2	5180	104338.3	31052.7	526	54839.9***	24355.4	518
Growing season precipitation (mm)	546.6	165.9	5180	53237.2***	19424.3	526	34931.5***	14463.5	518
Annual minimum temperature (°C)	6.1	4.3	5180	6.6	3.5	526	3.5***	4.3	518
Growing season minimum temperature (°C)	11.0	3.8	5180	10.8***	3.0	526	8.9***	4.1	518
Annual maximum temperature (°C)	18.6	4.6	5180	18.4	4.2	526	18.0***	4.5	518
Growing season maximum temperature (°C)	24.2	3.7	5180	23.5***	3.4	526	24.2	3.8	518

[a] ***,**,*: Significantly different from counties with land values between the 10th and 90th percentile at 1%, 5%, and 10%, respectively

7 Appendix B: Results

Table B2: Results: Correlates of median farmland sales price

	(1)	(2)	(3)	(4)	(5)	(6)
	Median price per acre					
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
County characteristics						
Population	.00549**	.00357**	-.0404***	-.0206**	-.0338***	-.0172*
	(.00245)	(.00145)	(.0128)	(.0101)	(.0121)	(.0102)
Income per capita	.754***	.481***	.246**	.263**	.146	.103
	(.106)	(.1)	(.106)	(.134)	(.129)	(.138)
Cropland acres	-.00454	-.00412	.0122	.00679	.00565	.00161
	(.00574)	(.00562)	(.00803)	(.0063)	(.0107)	(.0077)
Pasture acres	.000894	.0022	-.00521	-.00138	-.00229	-.00171
	(.00526)	(.00534)	(.00684)	(.00549)	(.00767)	(.00727)
Irrigated acres	.0107**	.0041	-.038***	-.0121	-.0163	-.00607
	(.00427)	(.00312)	(.0138)	(.00985)	(.0135)	(.0103)
Farmland acres	-.00138	-.00194	-.0121	-.00486	-.00881	-.002
	(.00523)	(.00524)	(.00759)	(.00556)	(.0101)	(.00753)
Land area (acres)	-.0000416	-.000231				
	(.000476)	(.000213)				
Weather						
Degree days below 29°C	-10.4	-1.12	-31.1	9.31	-.0678	20.9
	(7.64)	(6.64)	(36.7)	(37)	(36.1)	(33.3)
Degree days above 29°C	-3.83	-3.86	274***	137**	193*	40.1
	(12.2)	(10.1)	(76)	(61.4)	(112)	(93.3)
Precipitation (mm)	-39.2**	-34.4	32.2	-6.02	-40.4	-42.7
	(19.3)	(22.2)	(47.2)	(41.4)	(68.7)	(57.5)
Annual precipitation (mm)	-.00562	.00653	.295	-.12	.276	-.092
	(.0245)	(.0205)	(.192)	(.167)	(.189)	(.181)
Growing season precipitation (mm)	.425**	.345	-.363	.138	-.104	.259
	(.197)	(.218)	(.416)	(.411)	(.49)	(.463)
Annual minimum temperature (°C)	15.8**	8.44*	-94.3**	-25.2	-44.5	-15.6
	(6.62)	(4.84)	(43.8)	(41.5)	(70.5)	(65.9)
Growing season minimum temperature (°C)	-4.3	-4.87	158***	33.1	70.3	5.97
	(11.5)	(8.89)	(56.9)	(51.2)	(67)	(67.1)
Annual maximum temperature (°C)	-7.68	-11.9**	69.3	-15.1	-2.34	-46.7
	(7.37)	(5.74)	(42.6)	(41.8)	(63.6)	(66)
Growing season maximum temperature (°C)	16.2*	13.1*	-59.3	-18.7	-16.1	8.61
	(8.77)	(7.27)	(44.5)	(36.4)	(61.5)	(47.2)

Soil characteristics						
Water capacity	249	105				
	(192)	(149)				
Percent clay	-19.1	-4.91				
	(33.8)	(32.4)				
Minimum permeability	826***	366				
	(320)	(223)				
K-factor of topsoil	-234	-190				
	(3,228)	(3,013)				
Best soil class (%)	11.3	7.77				
	(11.3)	(10.2)				
Constant	-9,053	-12,255*	-34,817	23,959	-5,488	24,697
	(6,994)	(6,767)	(43,916)	(35,725)	(87,670)	(92,172)
County FE	NO	NO	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
State-Year FE	NO	NO	NO	NO	YES	YES
Observations	4,705	4,705	4,705	4,705	4,705	4,705
Number of counties	2,060	2,060	2,060	2,060	2,060	2,060

Standard errors robust to correlation at the county level in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Table B3: Results: Correlates of difference between median sales price and farmland value

	(1)	(2)	(3)	(4)	(5)	(6)
	Difference: Median price per acre					
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
County characteristics						
Population	.00314	.00127	-.04***	-.0202*	-.0356***	-.019*
	(.00194)	(.00105)	(.0132)	(.0106)	(.0127)	(.0107)
Income per capita	.524***	.224**	.164	.181	.139	.0954
	(.101)	(.0979)	(.108)	(.132)	(.135)	(.135)
Cropland acres	-.00969**	-.00872	.000712	-.00473	-.00315	-.00718
	(.0049)	(.00531)	(.00747)	(.00652)	(.01)	(.00794)
Pasture acres	-.00381	-.00199	-.00992	-.00609	-.00823	-.00764
	(.00456)	(.00518)	(.00648)	(.00576)	(.00774)	(.00743)
Irrigated acres	.00631	-.000771	-.0265*	-.000606	-.0159	-.00564
	(.00416)	(.00275)	(.0139)	(.0104)	(.0141)	(.0116)
Farmland acres	.00433	.00317	-.00174	.00548	.000536	.00735
	(.00436)	(.00501)	(.00701)	(.0057)	(.00953)	(.00765)
Land area (acres)	-.0000695	-.000227				
	(.000423)	(.000214)				
Weather						
Degree days below 29°C	.287	9.1	-25.9	14.5	-6.12	14.8
	(6.77)	(6.59)	(37)	(37.3)	(36.9)	(34.6)
Degree days above 29°C	5.56	4.91	351***	214***	249**	95.9

	(10.1)	(8.6)	(71.5)	(61.3)	(105)	(92.6)
Precipitation (mm)	-25.1	-19.9	34.5	-3.66	-32.3	-34.5
	(18.2)	(21.4)	(46.5)	(41.2)	(67.1)	(56.2)
Annual precipitation (mm)	-.0336	-.0215	.165	-.25	.25	-.118
	(.0224)	(.0194)	(.19)	(.169)	(.19)	(.185)
Growing season precipiation (mm)	.334*	.246	-.217	.284	-.117	.246
	(.184)	(.208)	(.413)	(.416)	(.482)	(.46)
Annual minimum temperature (°C)	10.7*	2.41	-50.8	18.4	-29.6	-.717
	(5.66)	(4.24)	(43.9)	(41.9)	(70.7)	(67.1)
Growing season minimum temperature (°C)	-12.9	-11.8	121**	-3.37	65.3	.918
	(10.2)	(8.54)	(57.4)	(52.5)	(67.2)	(68.3)
Annual maximum temperature (°C)	-4.32	-7.66	40.1	-44.3	-34.4	-78.7
	(6.34)	(5.54)	(41.2)	(41.7)	(61.4)	(65.6)
Growing season maximum temperature (°C)	6.73	2.73	-45.8	-5.16	10.5	35.2
	(7.43)	(7.21)	(43.8)	(36.7)	(60.1)	(47.1)
Soil characteristics						
Water capacity	278	133				
	(184)	(129)				
Percent clay	14.2	25.3				
	(30.8)	(30.6)				
Minimum permeability	729**	269				
	(289)	(184)				
K-factor of topsoil	2,595	2,583				
	(2,892)	(2,854)				
Best soil class (%)	3.68	.64				
	(9.82)	(9.28)				
Constant	-15,624**	-17,428***	-19,593	39,183	-1,827	28,358
	(6,435)	(6,670)	(44,374)	(36,937)	(89,036)	(94,553)
County FE	NO	NO	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
State-Year FE	NO	NO	NO	NO	YES	YES
Observations	4,705	4,705	4,705	4,705	4,705	4,705
Number of counties	2,060	2,060	2,060	2,060	2,060	2,060

Standard errors robust to correlation at the county level in parenthesis
*** p<0.01, ** p<0.05, * p<0.1