THE RECTANGULAR SURVEY VERSUS METES AND BOUNDS: SYSTEMATIC AND UNSYSTEMATIC LAND DEMARCATION

GARY D. LIBECAP AND DEAN LUECK

Abstract. We examine the economic effects of an important institutional innovation, the systematic demarcation of property boundaries relative to indiscriminate land claiming and bounding. The former results in a uniform grid of rectangular surveys (RS), whereas the latter results in haphazard localized bounding of properties, referred to as metes and bounds (MB). Metes and bounds are used throughout the world. In the U.S. they are found in the original 13 states, Kentucky, and Tennessee, as well as in the Spanish and Mexican land grants in the Southwest. The rectangular survey outlines boundaries in terms of a centrally-controlled grid of square plots. In the US, widespread use was implemented by the Northwest Land Ordinance of 1785, which divided federal government frontier lands into square mile 'sections' that were further divided into smaller uniform allotments for individual claiming or purchase. We develop an economic framework for examining land demarcation systems, focusing on a comparative analysis of the rectangular survey and metes and bounds. We begin by considering how a decentralized system of land claiming would generate patterns of land holdings that would be unsystematic and depend on natural topography and the characteristics of the claimant population. We then consider how a centralized system generates different ownership patterns and incentives for land use, land markets, investment, and border disputes. The rectangular survey is likely to lead to more market transactions, fewer border disputes, greater investment, higher land values, and more infrastructure investment than metes and bounds. In our initial analysis, we compare two adjacent parts of central Ohio which used the metes and bounds system (the Virginia Military District) and the rectangular survey which was used in the rest of the state. Our primary data include U.S. census manuscripts, court opinions, and various state reports on infrastructure, legal disputes, and productivity. The results indicate that in Ohio the rectangular survey led to fewer legal disputes over land title and land boundaries and led to more transactions in land compared to the metes and bounds system. Our data also suggest that the metes and bounds region of Ohio saw less net economic growth over the history of Ohio because of the comparative limitations of the metes and bounds system.

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Libecap: University of California, Santa Barbara, glibecap@bren.ucsb.edu. Lueck: University of Arizona, lueck@email.arizona.edu. Research support was provided by National Science Foundation through grant #34-3416-00-0-79-340. Support was also provided by the Cardon Endowment for Agricultural and Resource Economics at the University of Arizona. We also acknowledge the research assistance of Trevor O'Grady, Adrian Lopes, and Sarah McDonald and the support of the staff at the Ohio State Library. Helpful comments were provided by Benito Arruńada.

"The beauty of the land survey…was that it made buying simple, whether by squatter, settler or speculator. The system gave every parcel of virgin ground a unique identity, beginning with the township. Within the township, the thirty-six sections were numbered in an idiosyncratic fashion established by the 1796 Act, beginning with section 1 in the north-east corner, and continuing first westward then eastward, back and forth,….And long before the United States Postal Service ever dreamed of zip codes, every one of these quarter-quarter sections had its own address, as in ¼ South-West, ¼ Section North-West, Section 8, Township 22 North, Range 4 West, Fifth Principal Meridian." Linklater (2002, 180-81).

I. INTRODUCTION

The demarcation of rights to land is likely one of the earliest activities undertaken by human societies. Primitive societies demarcated and defended territories to hunting and gathering sites in order to limit open access exploitation (Bailey 1992). Early agricultural societies demarcated rights to much smaller plots of land for farming (Ellickson 1993). In modern societies rights are demarcated for residential and commercial use in dense urban areas, for farmland in highly mechanized large-scale fields, for huge landscapes allocated primarily as wildlife refuges or wilderness parks, and for such related resources as minerals and water. Yet, despite the somewhat obvious point that a system of demarcating rights to land will be important in determining the use of that land, the literature in economics and in law is completely absent.

In this paper we examine the impact of two different – decentralized or unsystematic and centralized or systematic— demarcations of property boundaries: metes and bounds (MB) and the rectangular survey (RS). Under the metes and bounds system, land claimants define property boundaries in order to capture valuable land and to minimize the individual costs of definition and enforcement. Individual surveys are not required to occur before settlement and they are not governed by a standardized method of measurement or parcel shape. Property is demarcated by natural features of the land (e.g., trees, streams, rocks) and relatively permanent human structures (e.g., walls, bridges). Under a centralized and systematic land survey regime a large area is governed by a common system of plot shapes, sizes and boundary descriptions. In the United State's case we study the based plots are one-mile square and all aligned with north-south and east-west borders. In addition all the land is surveyed before any land allocation.

We argue that the rectangular survey tends to lower the costs of land development and exchange through its measurement, enforcement, and incentive effects as compared to using metes and bounds to define land ownership boundaries. The latter are necessarily vague and imprecise ("four paces from the most northerly rock pile…"), temporary (trees disappear, stream beds change, so that boundary markers had to be periodically investigated to insure that they were still visible), idiosyncratic (different terms used locally), and for all of these reasons, subject to dispute and conflict. The idiosyncratic nature of measurement limits the size of the land market because remote purchasers have little knowledge of local land features and have to rely on localized interpretation of their meaning for property boundaries. Infrastructure development, such as for roads, may be more costly because of the inexact nature and multitude of land boundaries that must be crossed. Further, where incongruent individual plots collide, there are gaps of unclaimed land that remains essentially open-access. As these land gaps ultimately became valued they were inevitably subject to competing and wasteful claims by the adjacent parties.

The centralized rectangular survey defines land ownership in a manner that reduces the costs of measurement, enforcement, and exchange. By bearing upfront costs of systematic survey prior to occupancy the marginal costs of demarcating and establishing boundaries is low compared to metes and bounds. Individual plots are aligned north –south, boundaries are clear, precise, and uniformly positioned and the system of description is uniform across the country. The centralized system itself is public good (much like a library catalog system) so that the market for land is expanded dramatically. By contrast a decentralized system remains idiosyncratic and requires local information for market participants.

A glimpse of the potential impacts of the two systems can be seen in Figure 1(from Thrower 1966) which shows aerial photographs and schematic drawings of the rectangular survey (left side) and metes and bounds (right side). The land governed by the rectangular survey shows a uniform system of plots and roads, while the metes and bounds system shows a seemingly random array of plots and fewer roads.

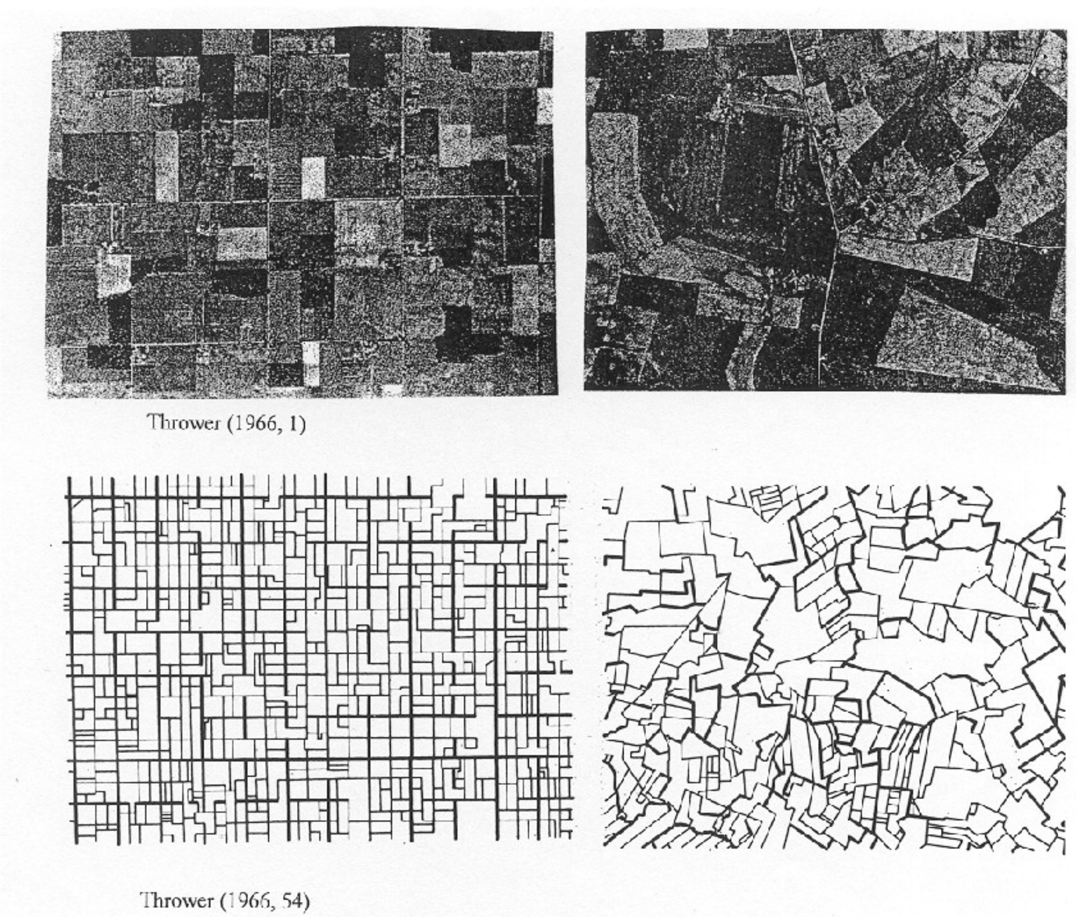

Figure 1: Comparison of Rectangular Survey with Metes and Bounds

The demarcation of property rights is connected to a growing literature on the nature of property rights in contributing to different patterns of economic growth across countries.[1] Much of this literature has focused on the investment effects of differences in legal title to land (e.g., Besley 1995, 1998) but the empirical findings have often been limited by endogeneity in the data and small differences in the title systems under study. Nevertheless, there is compelling evidence for the importance of property rights on economic incentives as evidenced in the cases of natural resource use (Libecap and Smith, 2002; Bohn and Deacon 2000), American Indian reservation agriculture (Anderson and Lueck, 1992), and urban residential land development (Miceli et al. 2002). The key empirical design issue is to define a setting for which fundamental property systems are exogenous to the agents in the data. Our empirical analysis which focuses on Ohio takes advantage of such a natural experiment

We begin in section II with a brief history of the land survey systems, focusing on the developments in the United States. In section III we develop an economic framework for analyzing the effects of the rectangular survey on land use, land market, property disputes and public land-based infrastructure. Section IV is an empirical analysis of the implications of our model. Here we focus on central Ohio, where an area of metes and bounds land demarcation (the Virginia Military District) is surrounded by land demarcated by the rectangular survey. These two land systems had been adjacent for roughly two centuries and hence, provide a natural experiment for examining the comparative effects of the two methods of land demarcation. The paper concludes in section V with a discussion of the finds and implications for economic development.

[1] See (e.g., Glaeser, La Porta, Lopez-De-Silanes, and Shleifer, 2004; Deininger (2003); La Porta, Lopez-De-Silanes, Shleifer, and Vishney, 2002; Acemoglu, Johnson, and Robinson, 2001; Bohn and Deacon 2000; Jean-Philippe Platteau, 2000; Keefer and Knack, 1995; Barro, 1991; North, 1990; de Soto, 1989; and Scully, 1988).

II. A Brief History of Land Survey Systems

Throughout human history land demarcation has been dominated by indiscriminate or unsystematic systems such as metes and bounds (Gates 1968, Linklater 2002, McEntyre 1978, Thrower 1966). Indeed the early settlement of the U.S. defined property rights to land in terms of metes and bounds (MB) as had been the practice in Britain, France, Spain, and elsewhere (Brown 1995, Estopinal 1993, Gates 1968, Linklater 2002, Marschner 1960, Thrower 1966, Price, 1995, Linklater, 2002).[2] While these systems vary and tend to be highly local in details, they share a method of defining land boundaries in terms of natural features of the land and even some relatively permanent human structures (e.g., bridge, wall). This dominance of metes and bounds suggest that there are substantive costs of establishing either systematic demarcation regimes or rectangular regimes or both.

Though metes and bounds has dominated history people have occasionally used more systematic demarcation methods.[3] These methods have tended to be rectangular, much like the modern US system, and can be found around the world. The most famous is perhaps the Roman system known as centuriation. This system was established in the second century BC and used a square unit called the *centuria quadrata* with a side of 710 meters (Bradford, 1957). This had a hundred square *heredia* or 132 acres which was allotted to a *curia* or 100 families (Johnson, 1976). At the center of the centuria a north-south axis intersects an east-west line and thus making four quarters. Unliked the modern US system, however, centurialism was not designed for continuous stretches, but rather started again at new cross-points and thus varied somewhat with natural land

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[2] The term 'metes and bounds' is primarily an English term though we use it to describe an decentralized, topography-based demarcation system. Geographers (e.g., Thrower 1966) use the term 'indiscriminant' survey.

[3] It is possible that a centralized land demarcation system could use nonlinear boundaries but we are unaware of any such system. The 19th century soldier and explorer John Wesley Powell (cite), however, proposed a land demarcation system based on river drainages. He also, however, called for large, rectangular homesteads in the semi-arid West that were larger than those designed for the eastern US.

features. Today, traces of centuriation have been found in northern Italy, Braga in Portugal, Chester in England, Tarragona and Merida in Spain, Cologne and Trier in Germany (Stanislawski, 1946) , and Carthage in Tunisia. Other rectangular systems were present in ancient India and in the Indus Valley Civilization in what is now Pakistan. Neither of these were as extensive as the Roman system. Table 1 summarizes features of the major historical and contemporary rectangular systems.

Table 1: Comparison of rectangular survey systems in the world

Place	Period	Shape	Dimensions	Alignment
Greece	479 BC - c.146 BC	Rectangle	Not uniform	Unknown
Rome	170 BC – Fall of the Roman Empire c. 500 AD	Square	0.44 miles x 0.44 miles	North – South
Ancient India	Inconclusively placed at several centuries before Christ	Rectangle	0.72 - 0.87 miles x 0.94 - 1.09 miles	North - South
Indus Valley Civilization	3300 – 1700 BC	Squares and rectangles	-	North – South
Netherlands	11th century	Square	Not uniform	Not uniform
Mexico	1523-1656	Rectangle	Central square: 0.113 miles x 0.075 miles	-
Long lot farms in Quebec	1620	Elongated rectangles	1 mile x 0.1 miles	Aligned according to rivers
New England colonies	17th century	Square	6 mile x 6 mile townships	
Philadelphia	1681	Rectangle	0.123 miles x 0.075 miles for a city block	Boundaries on north and south sides for area fronting the Delaware River
USA	1785	Square	1 mile x 1 mile section	North – South
Canada	1871	Square	1 mile x 1 mile	North – South
Australia	1821 New South Wales	Square	Not uniform	

Sources: Barnes (1935); Bradford (1957); Dilke (1985); Dutt (1925); Jeans (1966); Johnson (1976); Kain and Baigent (1992); Marshall (1931); Nelson (1963); Stanislawski (1946) and Wainright (1956)

In the United States metes and bounds is found in the thirteen original states as well as in Hawaii, Kentucky, Maine, Tennessee, parts of Texas, Vermont, and West Virginia. Further, metes and bounds were used where Spanish and Mexican land grants were prevalent—Texas, New Mexico, California. Consider a property description (of the perimeter) under the metes and bounds in the Virginia Military District of Ohio:[4]

> "Beginning at two sugar trees and a Buckeye, upper corner to Philip Slaughter's survey, No. 588, running with his line N. 66 degs. W. 290 poles, to a lynn sugar tree and ash, in the line of said Slaughter's survey."

Metes and bounds in the United States essentially ended with the enacted of the-Land Ordinance of 1785.[5] The 1785 law required that the federal public domain be surveyed prior to settlement and that it follow a rectangular system as described below. Land sales were to be the primary source of revenue for the federal government, and the government bore the upfront costs of survey prior to allocation in order to provide for a uniform grid of property boundaries that were standard regardless of location and terrain.[6] The rectangular survey applied to most of the U.S. west and north of the Ohio River and west of the Mississippi north of Texas as indicated in Figures 2. Canada adopted the rectangular survey (called the Dominion Land Survey) for the western Prairie Provinces in 1871, and it was introduced into parts of Australia and New Zealand (Powell 1970, Williams 1974).

The U.S. rectangular survey system uses a surveyed grid of meridians, baselines, townships and ranges to describe land (Brown 1995, Estopinal 1993, Pattison 1957, Thrower 1966, White 1983, Linklater, 2002).[7] The survey begins with the establishment of an Initial Point with a precise latitude and longitude. Next, a Principle Meridian (a true north-south line) and a Baseline (an east-

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[4] Cited in *Wyckoff v Stephenson*. 14 Ohio 13.
[5] Cite statute --
[6] Ultimately, though, homesteading and related first possession polices were used to settled much of the western federal lands governed by the rectangular survey. See Allen (1991) for an analysis of the choice between land sales and first possession policies.
[7] Now often called the Public Land Survey System or PLSS; see http://www.nationalatlas.gov/plssm.html.

west line perpendicular to the meridian) are run through the Initial Point. On each side of the Principal Meridian, land is divided into square (six miles by six miles) units called townships. A tier of townships running north and south is called a “range.” Each township is divided into 36 sections; each section is one mile square and contains 640 acres. These sections are numbered 1 to 36 beginning in the northeast corner of the Township.[8] Each section can be subdivided into halves and quarters (or aliquot parts). Each quarter section of 160 acres is identified by a compass direction (NE, SE, SW, NW). Each township is identified by its relation to the Principal Meridian and Baseline.[9] In this manner, each property is positioned relative to others in a standardized way.

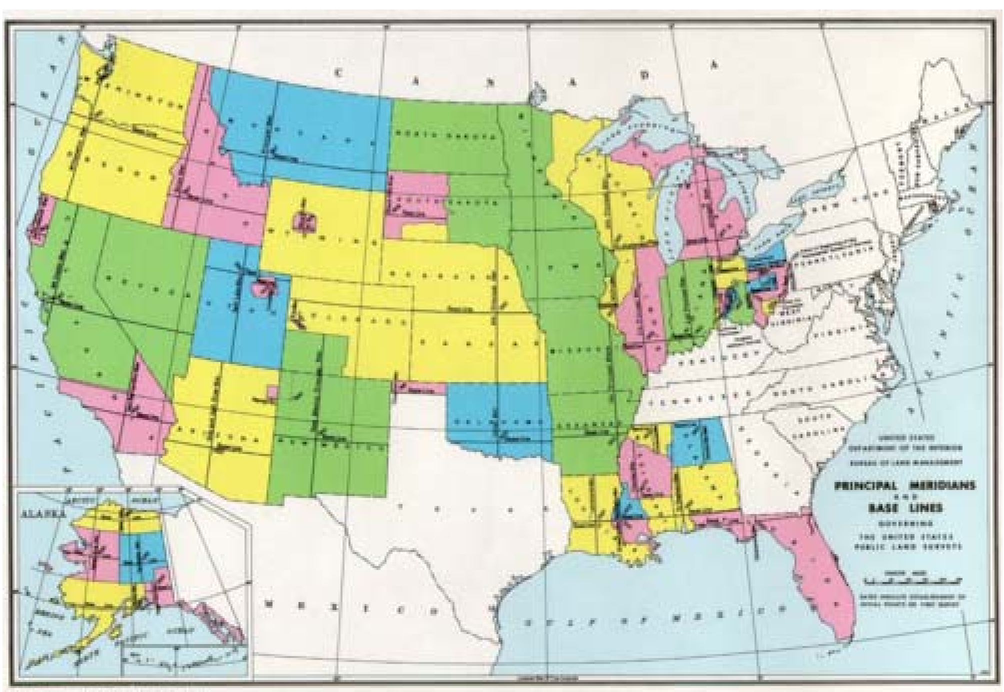

Figure 2: The Rectangular Survey System in the United States

[8] Some of the earliest surveys in the rectangular system had slightly different numbering systems but by the mid 1800s this system was in place (see Thrower 1966). Canada’s system uses a slightly different numbering system but has 36 sections in a township (see Table 1).
9 For example, the seventh township north of the baseline, third west of the Principal Meridian would be T7N, R3W, 6TH Principal Meridian.

There are 34 sets of Principal Meridians/Baselines—31 in the continental United States and 3 in Alaska, all shown in Figure 2. Figure 3 shows the details of the rectangular system.

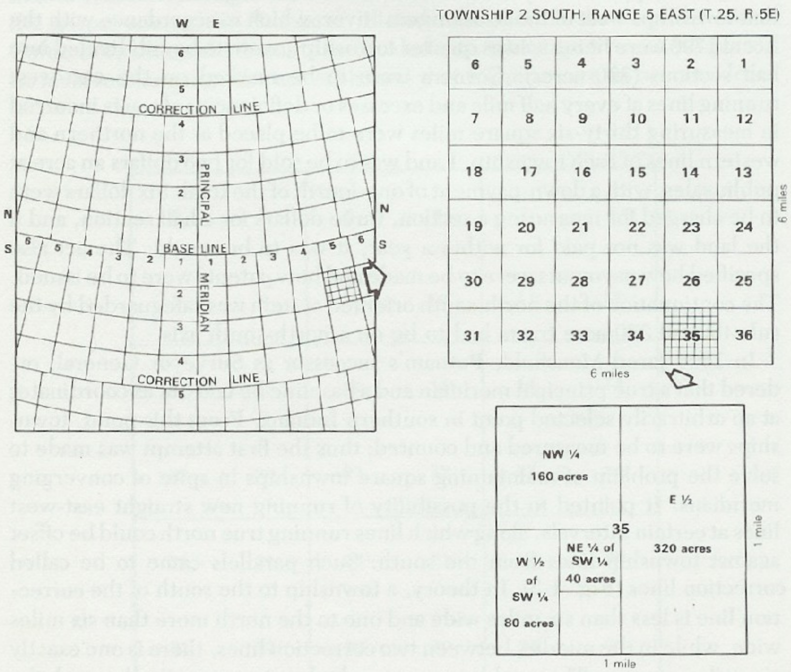

Figure 4-3. The U.S. Rectangular Survey System. After 1796, each township was numbered with reference to a baseline and principal meridian and subdivided into 36 sections, always numbered as shown. Tracts sold by the government decreased in size between 1796 and 1832 from 640 to 40 acres.

Figure 3: The Structure of the Rectangular Survey System

In the fall of 1785, what is now called the Public Land Survey System began with the first survey in eastern Ohio on the Pennsylvania border at what is now called the *Point of Beginning* (Linklater, 2002,71). The first townships to be surveyed are now known as the "Seven Ranges" (a north-south tier of townships) in eastern Ohio. Ohio was surveyed in several major subdivisions, each with its own range and base descriptions. Proceeding westward, the system was made more uniform by establishing one major north-south line (principal meridian) and one east-west (base) line that control descriptions for an entire state. County lines frequently follow the survey, so there are many counties in the western two-thirds of the US are highly linear and often rectangular.[10]

Beyond the original colonies which used metes and bounds, there are five major exceptions to the application of this system. Louisiana recognized early French and Spanish descriptions, particularly in the southern part of the state. Texas is distinct because it was not carved out of federal land and thus has its own system, partly based on Spanish land grants (with internal metes and bounds surveys) and used several different rectangular surveys as well as some metes and bounds. There are no meridians or baselines because these rectangular surveys were not part of the federal system. California is similar to Texas in that the southern part of the state is based on Spanish land grants, called *ranchos*; there is, however, an overlay of the rectangular survey.[11]
Hawaii adopted a system based on the native system in place at the time of annexation. Maine uses a variant of the rectangular system in unsettled parts of the state. And finally, in central Ohio there is a pie-shaped section of land governed by metes and bounds called the Virginia Military District. This area is subject of the empirical analysis in Section IV.

III. Economic Analysis of Land Demarcation Systems

In this section we develop an economic framework for examining land demarcation systems, focusing on a comparative analysis of the rectangular survey and metes and bounds. We begin by considering how a decentralized system of land claiming would generate patterns of land holdings that would be unsystematic and depend on natural topography and the characteristics of the claimant population. We then consider how a centralized system generates different ownership patterns and

[10] Individual properties tend not to overlap county boundaries in order to designate administrative jurisdiction and taxing authority See (xxxx) on political jurisdictions and borders.
[11] *Thomas Guides*, the canonical map books of Southern California, include both *rancho* and RS or Public Land Survey System (PLSS) designations.

incentives for land use, land markets, investment, and border disputes. In this analysis we focus on the particular features of the American rectangular system.

Land Demarcation in a Decentralized System: Metes and Bounds

A useful way to start is to examine a case in which non-cooperative agents claim and enforce separate plots in order to maximize the value of their land net of demarcation and enforcement costs. Consider a large tract of land available to a large group of potential claimants, where the external boundary is enforced collectively or otherwise so that only internal and shared borders are considered by individual decision makers. Within the external borders there is no coordination or contracting among claimants.[12] It is true, however, that even with metes and bounds there are legal and social rules (e.g., custom, norms) enforcing the right to claim and define rights to land using geographic and topographic landmarks. So even here there is not complete decentralization but an institutional framework that support non-cooperative claiming as has been the case under most metes and bounds systems.[13]

In this setting each potential claimant chooses the amount of acres to claim and the amount of border to enforce in order to maximize the profits net of enforcement costs.[14] Formally each claimant will solve

$$(1) \qquad \max_{a_i, p_i} V_i - y_i(a_i, p_i, t_i) - c_i(a_i, n_i, p_i, t_i)$$

where a_i is the area claimed (e.g., acres), p_i is the plot perimeter (e.g., miles), n_i is the number of neighbors on the plot border, t_i is a indicator of the land's topographical features or land quality, $y_i(a_i,p_i,t_i)$ is the total value function that depends on the acres claimed and the perimeter, $c_i(a_i,p_i,n_i,t_i)$

[12] We ignore the optimal time to claim under first possession rules which are associated with an open access resource (Lueck 1995). Similarly we assume that a claimant obtains something akin to fee simple (perpetual) ownership of the parcel and not just a one-time claim to a flow of output from the land asset.

[13] In England and the United States, for example, the common law courts developed doctrine on claiming and border demarcation.

[14] To start we lump all demarcation and enforcement costs together though in practice there are likely to be distinctions such as costs of surveying, costs of maintaining fences for livestock, costs of observing intruders, and so on.

is a border demarcation and enforcement cost function that also depends on *a* and *p*. The noncooperative Nash equilibrium solution to this problem is the optimal size (*a*) and perimeter (*p*) pair -- (a_i^*, p_i^*) -- which implies a plot shape.

Consider the simple case in which all claimants have the same productivity $(v_i = v_j, i \neq j)$ and the same enforcement costs $(c_i = c_j, i \neq j)$. In this case the problem for each party is to simply minimize the border demarcation and enforcement costs, constrained by the productivity of the land. If the land is perfectly flat these costs might simply be $c = kpa$ where *k* is a parameter, so the question is what shape and by implication what perimeter will minimize these costs for a give area?[15] Alternatively the question is what shape generates the largest area (and thus the lower enforcement costs per area) for a given perimeter. Put this way, the question is the ancient and famous *isoperimetric problem*.[16]

The answer is that a circle will maximize the area for a given perimeter and thus if enforcement costs depend on the perimeter or the perimeter relative to area we should see circular plots as a Nash equilibrium. Panel A of Figure 4 shows such a pattern of land ownership for a 5 mile by 5 mile tract of land. Consider a circular plot with a 4 mile perimeter. The area will be $4/\pi = 1.27$ square miles.[17] A square parcel with a 4 mile perimeter will have an area of just 1 square mile. Panel B of Figure 4 shows the same 5 mile by 5 mile landscape with square parcels as a comparison with the circular plots.

As the discussion of circles and squares suggests, however, the enforcement cost function is likely to be more complex than simply minimizing the perimeter for a given area. First, circular

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[15] Later we consider how *c* might depend on distance from a central location, on discontinuities in the perimeter, and on costs of patrolling or building on the perimeter because of topographical variation.
[16] See Dunham (1994) for history and analysis and http://en.wikipedia.org/wiki/Isoperimetry for an overview of the problem.
[17] The formula for the area of a circle is $A = \pi r^2$ and the perimeter is $P = 2\pi r$ where *r* is the radius.

plots of land are simply not observed refuting the implication.[18] Second, as Figure 4 shows circular plots leave large areas of unclaimed land.[19] In fact the unclaimed corners in circular pattern amount to about 22% of the total tract.[20] These unclaimed open access areas would not only dissipate rents derived from the land but might create locales where intruders can threaten the border of the circular plot thus adding to the costs of demarcation and enforcement. They may also lead to disputes if the land later became valuable.

Given these problems with a circular landscape, we narrow the set of equilibrium parcels to regular polygons.[21] Regular polygons maximize the area enclosed by a given perimeter (Dunham 1994) and have the potential to eliminate open access waste between parcels within a given tract.[22] In fact, there are only three regular polygons – triangles, squares, and hexagons – that will create patterns, with a common vertex, that have no interstices (space) between the parcels.[23] As suggested above a land ownership pattern comprised of contiguous regular polyhedrons would eliminate the unclaimed parcels so the equilibrium pattern will either be triangles, squares or hexagons, all of which are shown in the remaining panels of Figure 4.

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[18] Circular towns, forts and villages, however are observed (e.g., Carcassonne in southern France) suggesting that a circle may indeed be optimal for the external border of a society. Circles also minimize the distance to the border from the center of the parcel.

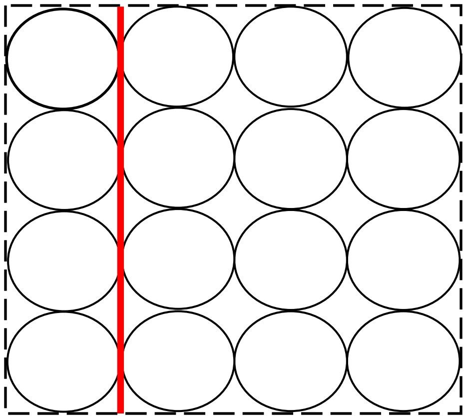
[19] This is readily apparent when flying over the western US and observing circular irrigated fields within the rectangular system – the corners are dry and uncultivated (but of course not unclaimed).

[20] For a circle with a diameter of 1 mile the area is 0.785 square miles, or 21.5% less that a 1 mile square section. If you count the corners as 4 separate plots then the total perimeter of the circular plot and the corner plots is 7.142 miles compared to just 4 miles for a single square. This total is from adding the perimeter of the circle (3.142 miles) to that of the square.

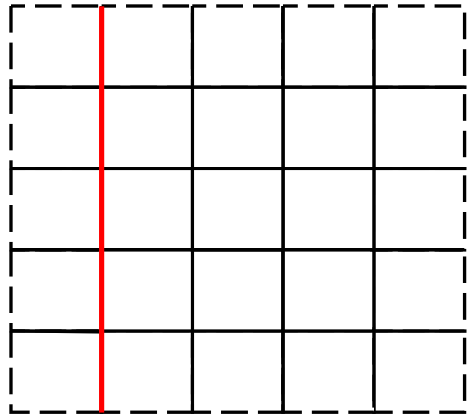
[21] A polygon is a closed figure made from line segments joined together such that each line segment intersects exactly two others. A regular polygon is a polygon with all sides the same length and all angles the the same. The sum of the angles of a polygon with *n* sides, where *n* is 3 or more, is 180(*n* - 2) degrees.

[22] For example, a square (a regular polygon) has the smallest perimeter to area ratio of all 4-sided polygons (i.e., rectangles).

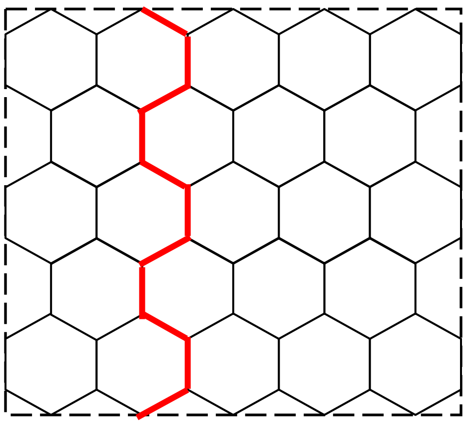
[23] Dunham (1994, pp. 108-111) discusses the proof of this proposition and notes that the Greek scholar Pappus sought to explain the hexagon shape of bee's honeycombs in terms of maximizing the area (volume actually) for honey storage.



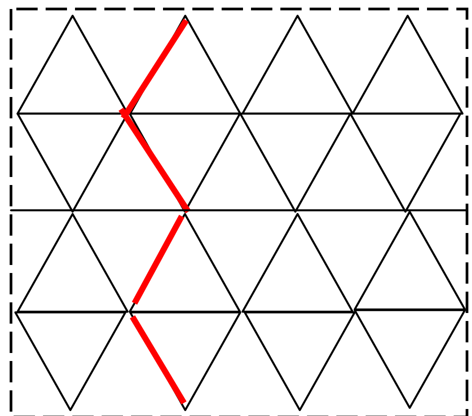
A. Circles (16 plots)



B. Squares (25 plots)



C. Hexagons (20 plots)



D. Triangular (32 plots)

Parcel shape	*Area (A)*	*Perimeter (P)*	*P/A ratio*	*Plots in tract*	*North-south distance**
Squares	1.00 sq miles	4 miles	4.000	25	5 miles
Circles	1.27 sq miles	4 miles	3.142	16	5 miles
Hexagons	1.15 sq miles	4 miles	3.464	20	6.7 miles
Triangles	0.77 sq miles	4 miles	5.196	32	5.76 miles

* Shown by red line.

Figure 4: Possible Parcel Configurations

The choice between triangles, squares and hexagons can be examined by further analysis of enforcement costs. The perimeter to area ratio (*p/a*) generates the following ranking from highest to lowest: hexagons, squares, triangles. The summary table in Figure 4 shows the specific ratios. The number of shared borders will likely effect enforcement costs but it is not clear how, so we cannot rank the three possible shapes.[24] Another factor is that survey and fencing costs should be lower with fewer angles and longer straight boundary stretches. This clearly favors squares over triangles and hexagons. A similar point is that a system of squares has the shortest distance across a tract for roads that follow property boundaries (see Figure 4 for the details). This leads us to our first prediction.[25]

> **Prediction 1**: With homogeneous (flat) land and homogeneous parties (in both productivity and enforcement ability) then a decentralized metes and bounds system will yield a land ownership pattern of identical square parcels.

This is a case when where a decentralized metes and bounds system could generate patterns of land holdings that looked like the modern rectangular survey system.

Even with homogeneous terrain (i.e., flat, uniform) and homogeneous claimants, however, there is no reason to expect these patterns of squares to be aligned in any particular direction without some sort of convention or other coordinating device.[26] Individual rectangular claims or clusters of claims could meet other competing claims at odd angles. A north-south or other similar alignment then requires either a social convention or centralized direction. Panel A of Figure 5 shows a case in which two sections of land with square plots might have different alignments. Gaps between these claims and overlapping claims might also result from imprecision in location recording and communication.

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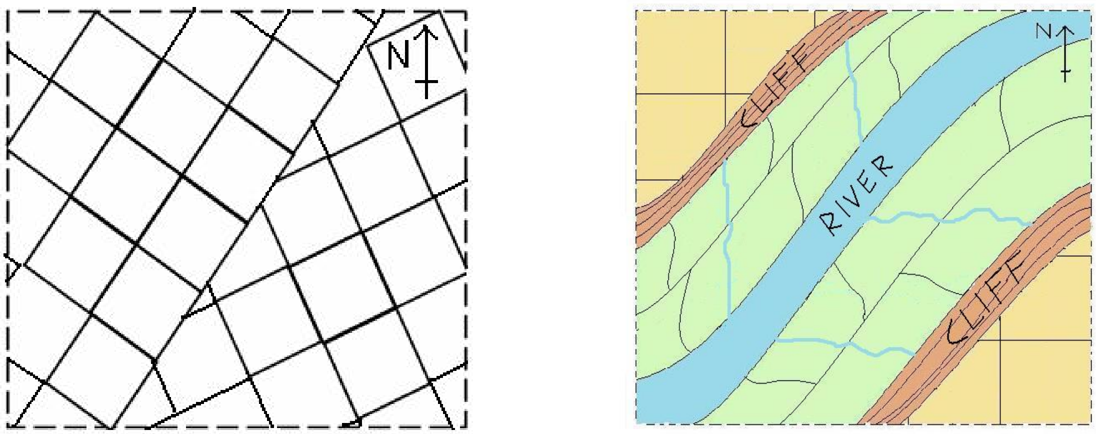
24 Will more neighbors mean economies of enforcement or more potential intruders?

25 If demarcation and enforcement costs are now $c = c(p/a, n)$ where $c'(n) > 0$, then a plausible Nash equilibrium in land claiming could be patterns of square parcels on a flat landscape.

26 Sugden (1990) develops a theory of conventions (e.g., which side of the road to drive on) based on repeated game theory.



A. Squares with different alignments B. Parcels with non-planar topography

Figure 5: Square parcels with different alignment

Adding heterogeneous terrain and heterogeneous claimants (either in land use or in costs of demarcation and enforcement) could yield a pattern of land ownership that would appear almost random to an outside observer. If demarcation and enforcement costs depend on terrain (because of surveying or fencing or road building costs), we would expect borders to roughly follow the topography.[27] To take an extreme example, suppose a deep canyon cut through a fertile valley. The cost (and benefits) of demarcating and enforcing a border across the canyon may be so excessive that the canyon edge becomes the optimal boundary. Panel B of Figure 5 shows such a case where extreme topography makes linear boundaries too costly. The canyon itself might remain as unclaimed open access land. [28] Thus we have a second prediction

[27] Even if costs depend linearly on perimeter, a non-planar topography will increase these costs and alter shapes and sizes. For example, consider a plot with a triangular 'valley' – 1 mile wide with a 90 angle in the bottom. Using the Pythagorean theorem this adds 0.41 miles (41%) more to the perimeter. Each side of the valley is 0.707 miles long for a total of 1.414 miles compared to 1.0 mile across the plain.

28 Dahlman (1980) describes the English open field system has having large acreage in 'wastes' – essentially unclaimed open access land.

Prediction 2: With heterogeneous land and parties (in both productivity and enforcement ability) then a decentralized metes and bounds system will yield a land ownership pattern of parcels whose borders mimic the topography and vary in size.

We thus expect the non-cooperative Nash equilibrium to yield a pattern of land ownership sizes and shapes that depends on the character of the land (topography, vegetation, and so on) and of the potential claimants (farming productivity, violence and monitoring productivity, and so on). Indeed, the observed pattern of metes and bounds parcels is consistent with a non-cooperative claiming equilibrium with heterogeneous land and claimants. Adding land heterogeneity (e.g., river, broken terrain) changes the cost function $c(kp,n)$ and leads to non-linear claims as well as unclaimed areas -- the so-called 'gaps and gores' described by so many historians of land.

Land Demarcation with Centralized System: The Rectangular Survey

The rectangular survey (RS) is a centralized land demarcation system with three distinctive features. First, it all land is demarcated in a system of squares (sections and township). Second, all of the squares are aligned true north, so that all borders are at a specific longitude and latitude. Third, the location of each section is part of a coordinated and systematic national system of location that does not vary by region.

In addition to these geographical and information features of the RS, the land was surveyed prior to individualized ownership and use. The RS is a regime in which claiming cannot be undertaken prior to a survey and can only be made in square blocks. Not until the land is surveyed and the plots are demarcated can individual claims be made – in the U.S. this has been through purchase and through various types of first possession (i.e., homesteading) mechanisms.[29]

Because the RS is a federal system there were substantial costs of designing the details of the system (e.g., size of squares) and implementing the survey (e.g., determining initial points and

[29] There were of course squatters on un-surveyed federal land that were dealt with through various preemption laws (cite).

conducting the surveys). The size of these costs has been substantial but no effort is made to examine or estimate them in this study. Importantly these costs were not borne by the individual land claimants unlike land claims made under metes and bounds.

The effects of the rectangular survey have been discussed by historians and geographers but there has been no literature on how the rectangular survey might effect incentives and thus affect such outcomes as land value, boundary disputes, land transactions, and land-based public infrastructure. The rectangular system creates linear and geographic-based borders that are fixed and thus impervious to changes in the land and verifiable using standard surveying techniques. This is a distinct difference compared to the impermanent and locally described borders in metes and bounds. The rectangular system creates a public good information structure that expands the market (Linklater 2002). This leads to three related predictions.

> **Prediction 3A**: There will be more land transactions under the rectangular survey than under metes and bounds.
>
> **Prediction 3B**: There will be higher (per acre) land values under the rectangular survey than under metes and bounds.
>
> **Prediction 3C**: There will be less variance in the size and shape of parcels under the rectangular survey will have a greater variance in size and shape.

The impact of expanding the market and lowering transaction costs should make it cheaper for land parcels to be reorganized as market conditions change. This should be observed as a greater number of transactions such as mortgages and conveyances per unit if land. This should also increase the value of land on a per unit basis and should also lead to more uniformity in the size and shape of parcels in a region. For example, in a competitive market with access to a common technology, farms within homogeneous regions should be roughly the same size and shape.[30] Since the RS lowers the cost of transactions it will be more likely to see the result than if the original

[30] Even though the original plots are square consolidation under RS might lead to unusual shapes, though likely still linear since the plots can be subdivided into quarter sections and so on.

demarcation were under metes and bounds. Because surveys are standardized and aligned under the RS, there are no unclaimed gaps in property claims. With this and the fixity of the boundary lines this implies another following prediction.

> **Prediction 4**: There will be fewer legal disputes (and litigation) over boundaries and titles under the rectangular survey than under metes and bounds.

The clarity and linearity of the rectangular system is also expected to have an impact on public infrastructure such as roads and other systems that require long right-of-way stretches. Identification of property lines is likely to be cheaper, contiguous linear borders should lower the cost of assembling such rights of way even if eminent domain is required. This imples another prediction.

> **Prediction 5**: There will be more roads per unit of land under the rectangular system than under metes and bounds.

To this point we have stressed the benefits of the rectangular system over metes and bounds and we have ignored the upfront costs of establishing such a centralized and systematic regime. Yet the rectangular system also has costs. In cases of rugged or extreme terrain forcing a square grid on the landscape can lead to extremely costs surveys, fence lines, and roads. Under a metes and bounds system property boundaries would tend to avoid such extreme topography thus reducing such costs. Indeed in some of the most remote and rugged parts of the western United States the most obvious components of the rectangular survey simply disappear from the landscape. For example, roads do not follow section lines but rather natural contours and in some cases only simple fences mark the property boundaries. Fields too, often lose their rectangular shape in rugged terrain. In addition, where the land use requires relatively large parcels (e.g., forests, national parks) the rectangular survey system may also lead to overinvestment in land demarcation.[31]

IV. Empirical Analysis

In this section we test the predictions of the model against a variety of data taken primarily from 19th century Ohio where historical events created a landscape in which metes and bounds is adjacent to the rectangular survey. We begin by describing the land demarcation systems in central Ohio where both the rectangular survey was used as well as the metes and bounds in a region know as the Virginia Military District. Next we examine the demarcation of land under metes and bounds in the Virginia Military District in order to test predictions 1 and 2 which posit a relationship between topography and parcel demarcation. The next section use detailed data on original land parcels and 19th century farms to estimate the effects of land demarcation systems on the land market (prediction 3). We then examine legal disputes over property title and boundaries in the Ohio courts (prediction 4), public roads (prediction 5), and finally examine the modern effects in Ohio and the Virginia Military District.

A. Ohio and the Virginia Military District.

The Virginia Military District (VMD) is an approximately 4.2 million acre area of land in south central Ohio that was created out of an agreement whereby Virginia ceded her claims to federal land northwest of the Ohio River in 1783. The VMD lies between the Scioto and Little Miami Rivers and north of the Ohio River. Eight of Ohio's 88 counties lie wholly within the VMD and 14 other counties are partially within it. Figure 6 shows the location of the VMD within the state of Ohio. Virginia was granted this area to provide military bounty land grants to pay her

[31] Note that the borders of such national parks as the Grand Canyon and Yellowstone have linear borders even in some of the most rugged terrain.

Revolutionary War veterans. The land in the VMD was demarcated using metes and bounds under Virginia law.

Because the VMD was demarcated under metes and bounds and the rest of Ohio was part of the original rectangular survey the south central region of Ohio is a case where the land demarcation systems are exogenous for the purposes of our study. The cession of the VMD to Virginia too place before the Land Ordinance of 1785 and thus before the rectangular survey began in Ohio. Moreover, the territory comprising Ohio was ceded to the United States in the Treaty of Paris in 1783 and in 1787 become the Northwest Territory. Ohio was virtually unsettled before 1800 but grew extremely fast thereafter and became a state in 1803.[32]

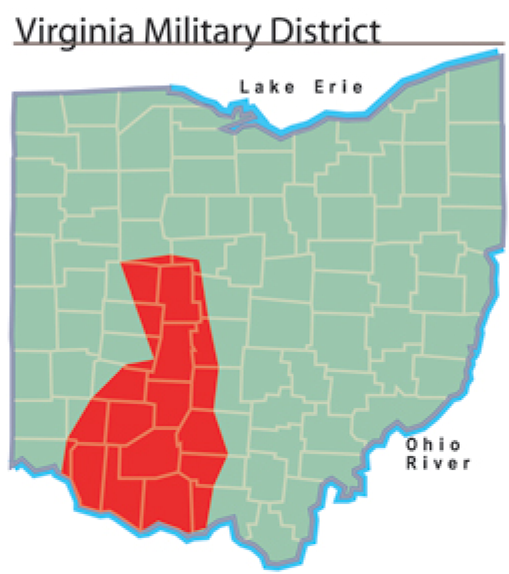


Figure 6 – The Virginia Military District

To gain ownership of a plot of land in the Virginia Military District entailed a process whereby individuals with military land warrants could enter the district, select property for claiming,

[32] It had a population of just 45,000 in 1800 but over 230,000 by 1810.

survey to document their claims, and then file their claims along with thir warrants.[33] The first step in claiming VMD land was to obtain a valid warrant by presenting a certificate of rank and service from his commanding officer to a court of law and then a warrant would be obtained from the Virginia Land Office in Richmond. The warrant was the legal document that entitled the bearer to make a location and survey of lands within the VMD. With a warrant in hand, the claimant[34] would proceed to locate his claim. The location would include a description of the land claimed. The subsequent survey was required to follow the description in the entry, so the entry would have to include the natural markers used to establish the boundaries of the claim. The claimant (or entry man) would then hire a surveyor who would conduct the survey to measure the boundaries of the claim, prepare a plat map, and calculate the actual size of the claim, which should conform to both the warrant and the entry. The survey would, similar to the entry, be filed with the proper land office and could be filed with the county recorder, but was not required to be. The cases indicate a common practice of locating and surveying claims based on the boundaries of already existing claims. This made the surveying process much easier, but also had the potential to create enormous later problems if one of the early surveys, on which many subsequent surveys were based, turned out to be incorrect. The final step in the process was to obtain a patent covering the claim that would transfer fee title to the land from the federal government to the claimant.

B. The Size and Shape of Parcels in the Virginia Military District

The model of land demarcation predicts that under metes and bound the demarcation of parcels will depend on the topography of the land. In relatively flat terrain we predict squares and in

[33] The sources for this description are Thrower (1966) and the Illinois Historical Survey website which has a page on the VMD (found at http://www.library.uiuc.edu/ihx/land.html) as part of their collection of the papers of Richard Clough Anderson, who was one of the principal surveyors of Virginia military bounty lands in Kentucky and Ohio from the 1780s to the 1820s.
[34] This could be the war veteran himself or his heir or assign if he had either sold the warrant or devised it upon his death, and was probably physically located on the ground by someone designated to locate the claim on behalf of the warrant holder – typically termed an entry-man) Most warrants were sold.

relatively rugged terrain we predict that the parcels will follow ridges, rivers and other significant natural features that influence the costs of demarcation and the value of the land. We test these predictions by examining the relationship between the topography of the land and the size and shape of the original parcels in the VMD. To start we discuss the topographical features of the VMD and then examine the details of the original parcels.

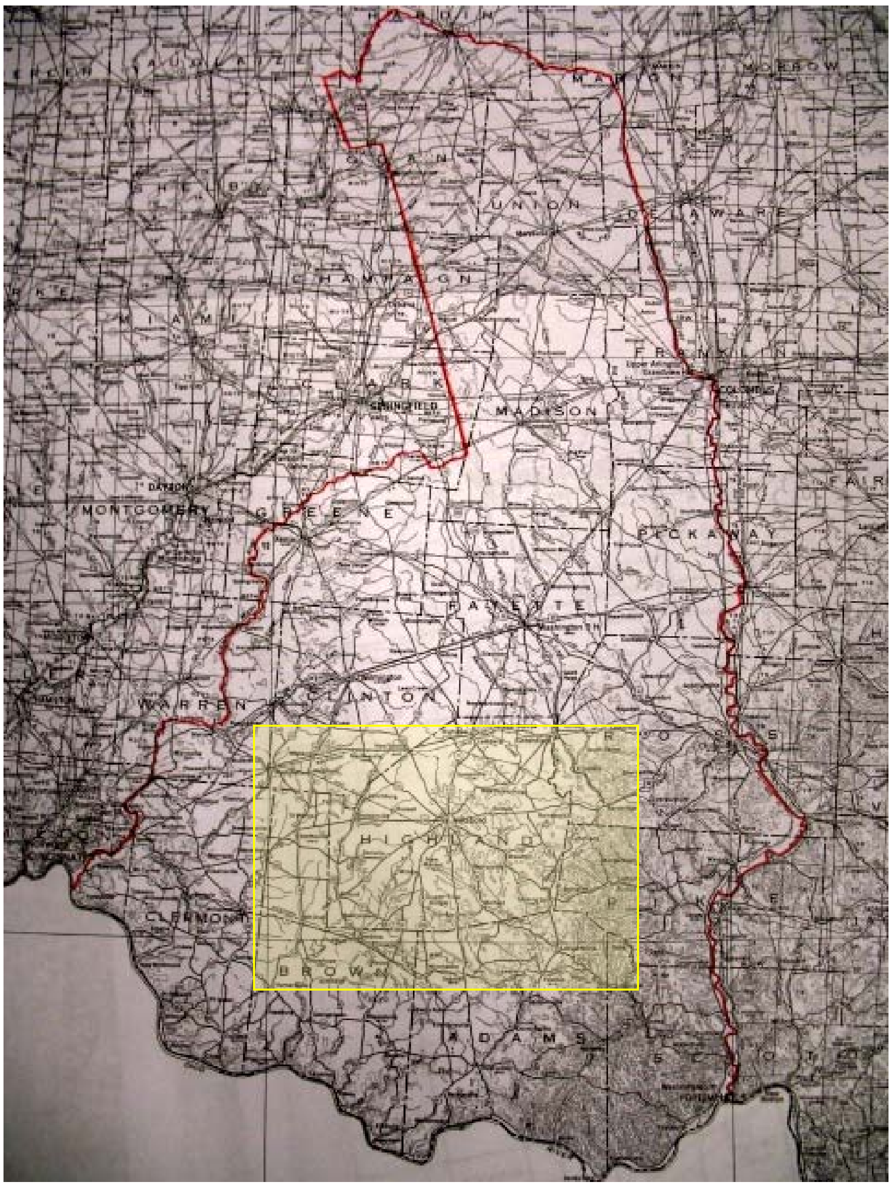


Figure 7. VMD with Highlighted Area of Focus

Topography of the Virginia Military District. Glacial recession shaped much of Ohio's topography. The glaciated portion of the state is relatively smooth and flat while the un-glaciated part is rougher and more distinct. The Virginia Military District contains an intersection of these two distinct types of Ohio landscape with the western counties lying mostly in the glacial lands and the eastern counties in the un-glaciated lands. The western counties in the glacial land are in the central plains, which have a fertile limestone topsoil overlying soft rock. The glacial boundary is marked by the Allegheny Escarpment in which the land changes from the flatter land in the west to higher, steeper land in the east. The eastern VMD counties of Adams, Pike, Scioto, Ross are found in the Allegheny Escarpment and have rugged hills and valleys with bedrock of shale and sandstone. The northern VMD counties of Champaign, Logan, and Union counties lie within an upland area known as the Bellefontaine Outlier, which has some of the highest land in the state. Figure 7 also highlights a rectangular region around the city of Hillsboro in Highland County which we examine below.

Parcel Variation within the Virginia Military District. Within the Virginia Military District there is a high degree of variation of parcel shape, size. By visually examining a parcel (Sherman 1922) map of the highlighted area in Figure 7 we can distinguish a general trend of larger, square-shaped parcels in the western portion of the VMD and smaller, more irregular parcels in the eastern portion of the VMD. This is consistent with the prediction of our land demarcation model.

The western counties that make up the VMD tend to have parcels which are much larger in size and are regular polygons, typically squares or rectangles. Because often military veterans who claimed land within the district did not settle but immediately sold their title to land speculators in the area, there is some evidence of organized surveys (likely by a land speculator) that generate a large tract with adjacent parcels aligned in the same direction. Figure 8 shows both the topography and original parcels from the central VMD.

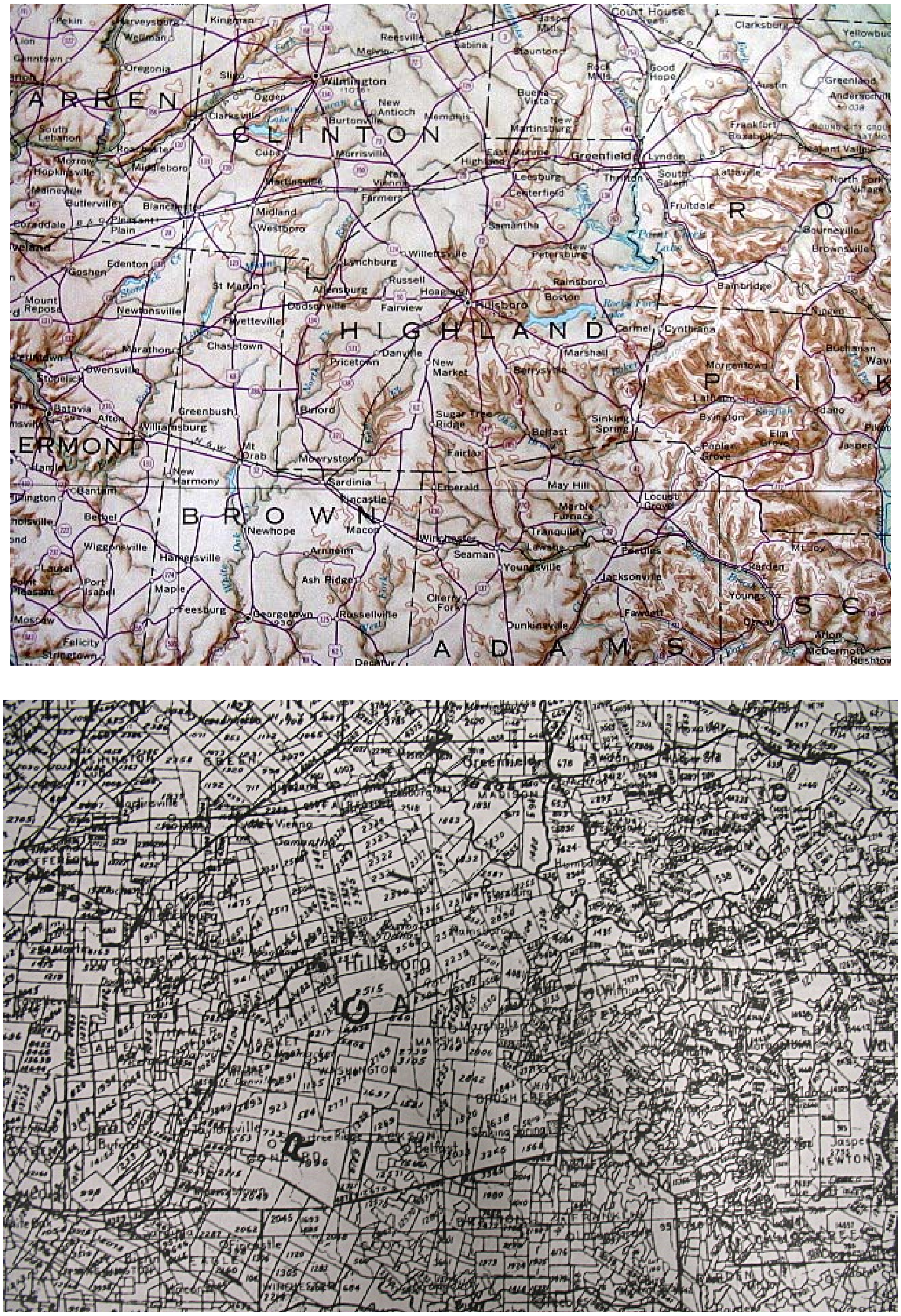
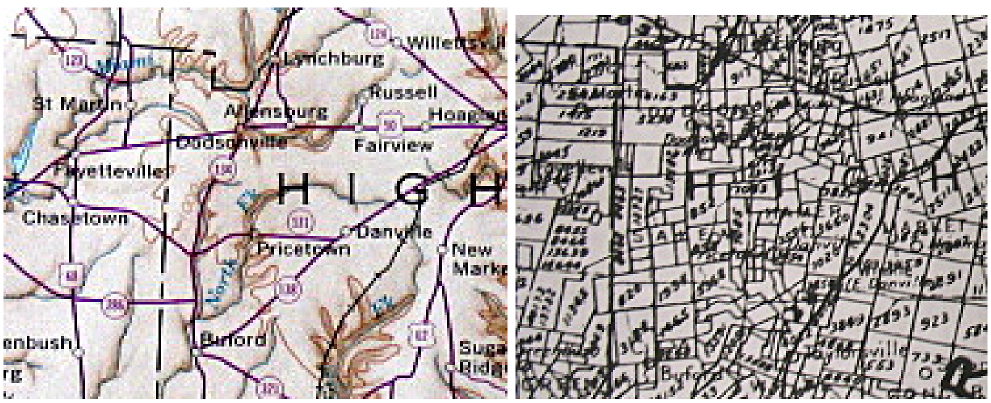
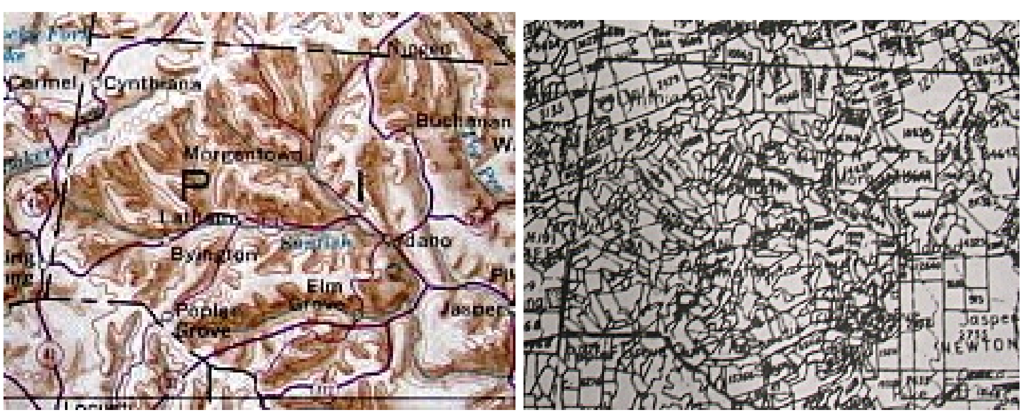


Figure 8: Topography and Parcels of the Central VMD where Glacial Plains meet Escarpment

The analysis can be further illustrated by examining smaller locales as in Figure 9. Panel A shows a section of flat land in Highland and Clermont. It is clear that the parcels are rectangular and even square as predicted. Again, the pattern also shows evidence of coordinated surveying, where there are tract aligned in the same directions, but not typically north-south as in the rectangular survey. In case where different sections of coordinated parcels abut one another, the result is triangular sections, some of which were unclaimed originally.



Panel A -- Parcel boundaries in flat topography (Highland and Clermont counties)



Panel B -- Parcel boundaries in rugged topography (Pike County)

Figure 9: Correlation between topography and original VMD parcel demarcation

Panel B shows a similarly sized area in Pike County (eastern VMD) where the terrain is more rugged Here the parcels tend to have much more variation in parcel shape, with the boundaries often following natural land features such as rivers and valleys. Additionally, there is greater variation in parcel size, with many very small parcels and a few extremely large parcels. There is no evidence of a coordinate parcel boundary alignment as seen in Panel A. Overall the Figures 8 and 9 show a remarkable matching between parcel boundaries and the topography of the land.

In order to quantify the variation in parcel shape, size, and alignment, we have begun to digitally analyze the parcels using some basic measures. We have gathered data at the parcel level for the following variables: area, perimeter, perimeter-area ratio, number of sides, and angle deviations.[35] The perimeter area ratio variable is a useful measure for determining how efficiently a boundary is used to define a specific area requirement. Normally the square root of area is used to ensure that the numerator and denominator are both measured in the same units (Longley et al. 2005). The perimeter-area ratio takes a value of four for a square (our reference shape), thus the closer the value to four, the more square the parcel. Additionally, the number of sides helps us to determine how regular the shape and how the parcel varies from a square.[36]

For this preliminary analysis we have used eight counties (four western VMD and four eastern VMD) to illustrate some of the parcel differences.37 Table 2 shows the mean values for various measures of size and shape in the two regions. As shown, the parcels in the western VMD (flatter topography) are larger, as predicted, and with a relatively smaller variance. Parcel in the western VMD are also have fewer sides and a perimeter-area ratio closer to that of a square. The lower part of the table shows the t-value for a difference in means test – in all cases we reject the hypothesis that the two regions have the same means for the shape variables. Overall, these data suggest a quantifiable difference in parcels in different regions of the Virginia Military District and

[35] These measures are likely linked to the costs of demarcation and are ways to quantify the size and shape of parcels.
36 For highly organic shapes, the computer program (ArcMap) converts the "squiggly" lines into many smooth sides, thus the higher the number of sides, the more organic (naturally linked to topography) the parcel shape.
37 These data come from Sherman (1922) and McDonald et al. (2006).

that difference is correlated with topographical difference in the regions. Future analysis will use regression techniques to estimate the determinants of parcel shape and size using individual parcel data.

Table 2: Comparison of Parcels in the Western and Eastern VMD

County	Number of Observations	Area (acres)	Perimeter-Area Ratio	Number of Sides	Alignment
Western VMD Counties (flat topography)					
Brown	200	1240.52 (750.11)	5.01 (3.23)	5.70 (2.34)	21.13 (20.15)
Clermont	188	1298.16 (918.12)	5.01 (2.29)	5.64 (1.98)	26.64 (19.75)
Clinton	241	1087.61 (893.98)	4.37 (.93)	4.82 (1.53)	33.83 (22.31)
Greene	196	902.86 (655.15)	4.54 (.88)	5.27 (2.12)	25.63 (20.87)
Eastern VMD Counties (rugged topography)					
Adams	1,135	304.74 (520.02)	5.16 (2.68)	7.49 (3.70)	27.22 (23.04)
Pike	595	279.31 (462.79)	5.25 (1.16)	8.22 (3.90)	30.46 (25.01)
Ross	521	544.92 (672.95)	5.10 (1.17)	7.85 (3.53)	32.00 (23.54)
Scioto	418	332.19 (626.96)	5.75 (4.03)	7.79 (3.16)	31.24 (24.26)
Difference of Means Test					
Western Counties	825	1128.77 (826.89)	4.71 (2.05)	5.32 (2.03)	27.16 (21.38)
Eastern Counties	2,669	350.26 (567.26)	5.26 (2.49)	7.77 (3.65)	29.51 (23.85)
t-value		25.27***	6.37***	24.5***	2.67**

Alignment of Rectangular Parcels in the VMD

Our theoretical discussion of land demarcation under metes and bounds noted that there was no reason to expect a particular directional alignment of parcels even when the land was flat and squares were chosen. In particular, there is no reason to expect that the parcels will be aligned north-south as I the rectangular survey. Indeed the evidence from the western VMD shows that alignment of square (or nearly square) tracts varied and often led to conflicting tracts as suggested in panel A of figure 8. On average the parcels in these counties are aligned at 36 degrees or a northeast-southwest alignment.[38]

C. The Market for Land

Our model of land demarcation under the rectangular survey predicted more transactions, higher land values and less variance in parcel size and shape than for land demarcated under metes and bounds. In this section we test these predictions by using both historical accounts of land markets and detailed data on farms and land transactions from the 19th century.

Historical Accounts. There is considerable historical evidence that Jefferson and others in the US government pushed for the establishment of the rectangular survey because they expected a positive impact on land markets and were frustrated by the metes and bounds system. In discussing the origins of the Northwest Ordinance, Linklater (2002, 68-70) describes how Jefferson was head of a committee of the Continental Congress organized to choose the best way to survey and sell land. The pervasive Virginia method allowed claimants to choose their property, survey by metes and bounds, and then purchase it. This was ruled out by the committed, which instead called for survey before occupation with properties to be marked in squares, aligned with each other, "so that no land would be left vacant." Under this approach the U.S. could sell land to raise money and would have the system "decimalized." Hamilton stressed the importance of land sales for the U.S. Treasury (Linklater, 2002, 116, 117) and supported Jefferson: "The public lands should continue to be surveyed and laid out as a grid before they were sold." This recommendation became incorporated in the Land Ordinance of May 20, 1785 for disposing lands in the western territory.

A major way in which the grid raised land values was to expand the market. As noted by Linklater (2002, 80), the advantages were clear as demonstrated by the first patent issued at the New York City Land Office, March 4, 1788. In that patent, John Martin paid $640 for a square mile

[38] North-south is 0 degrees (or 180) and east-west is 90 degrees (or 270).

section in NW territory (Belmont County, Ohio), Lot 20 Township 7, Range 4. Although it was in the frontier, "once it had been surveyed and entered on the grid, it could be picked out from every other square mile of territory, and be bought from an office three hundred miles away on the coast."

In discussing the colonial survey system where metes and bounds dominated, Price (1995, 12-13) stated that there was no standard approach to land demarcation in the colonies—in some cases there were large land grants, others haphazard local claiming, generally individuals "wanted freedom to pick out the choicest land …". Individual claimants drove the process—no pre survey, except in parts of New England where there was some more systematic effort to survey and allocate, but even there individual choice of parcels dominated. Similarly, Linklater (2002, 37) notes that where there was open entry claiming by unorganized claimants on the frontier, MB dominated with survey following claiming.

By contrast, Price (1995, 232-6) points out that although metes and bounds were common in New York state, in northwestern New York, large tracts of land were purchased from the Iroquois and other large military tracts were divided by land developers into townships to be surveyed and sold. A rectangular grid was used dividing the lands into 100 square lots of 600 acres each for soldiers. These subdivisions, such as Cooper's tract, were subdivided before sale and settlement.

Statistical and Econometric Evidence. The historical accounts are consistent with our predictions about land markets but we not examine statistical data on farms and land markets for more precise tests. In the analysis presented below we rely on Ohio state reports and federal census data.[39] To start we first present a comparison of un-weighted mean values for counties within and

[39] Brown, Clarence J. *Annual Report of the Secretary of State to the Governor and General Assembly of the State of Ohio for the Year Ending June 30, 1928*, Springfield, Ohio: The Kelly-Springfield Publishing Company, State Printers, 1928; *Annual Report of the Commissioner of Statistics to the General Assembly of Ohio for the Year 1857*, Columbus, Ohio: Richard Nevins, State Printer, 1858; *Second Annual Report of the Commissioner of Statistics, to the General Assembly of Ohio*: For the Fiscal Year 1858. Columbus, Ohio: Richard Nevins, State Printer. 1859; *Third Annual Report for the Commission of Statistics for 1860,* Columbus, Ohio, Richard Nevins; *Proceedings of the Several State Boards of Equalization, Assembled Under the Laws of Ohio, Previous to, and Inclusive of, the Year 1853*. Columbus, Ohio:

adjacent to the Virginia Military District in 1850 and 2000 in Table 3. The VMD counties are paired with adjacent RS counties in order to control for land quality and location. Table A1 in the appendix indicates the breakdown of the counties used for this comparison.

Table 3. Land Values under Metes and Bonds and the Rectangular Survey

1850				2000			
Counties outside VMD		**VMD counties**		**Counties outside VMD**		**VMD counties**	
Name	**$/acre**	**Name**	**$/acre**	**Name**	**$/acre**	**Name**	**$/acre**
Shelby	14	Union	12	Shelby	2742	Union	2563
Hancock	12	Union	12	Hancock	2424	Union	2563
Knox	19	Union	12	Knox	2878	Union	2563
Miami	25	Madison	14	Miami	3275	Madison	3099
Licking	12	Madison	14	Licking	3517	Madison	3099
Fairfield	22	Madison	14	Fairfield	3324	Madison	3099
Montgomery	30	Fayette	17	Montgomery	3876	Fayette	2423
Vinton	9	Clinton	22	Vinton	2064	Clinton	2900
Butler	38	Highland	19	Butler	4111	Highland	2452
Vinton	9	Highland	19	Vinton	2064	Highland	2452
Mean	$19.00		$15.50		$3,027.50		$2,721.30

Source: Barnard, Charles H. and John Jones. *Farm Real Estate Values in the United States by Counties, 1850-1982*. USDA Economic Research Service. Statistical Bulletin Number 751. 2002 Census of Agriculture. Table 1: County Summary Highlights. Available at www.nass.usda.gov/census/census02/volume1/index2.htm.

The data in the table show that in the majority of cases the lands governed by the rectangular survey are more valuable in both 1850 and 2000. The effects of the MB system appear to persist. While this evidence is not conclusive since we use no control variables, it nevertheless is suggestive of the positive effects of the rectangular survey. The counties compared are small and homogeneous. Additional data from comparisons of land in other Ohio counties under the RS system with adjacent metes and bounds counties in Kentucky, Pennsylvania, and West Virginia show similar suggestive results.

Franklin Printing Company. 1854; "County Level Reports for 1850." *Eleventh Annual Report of the Commissioner of Statistics for 1868*, Columbus, Ohio, L.D. Myers and Bro. State Printer; Annual Report of the Secretary of State for 1870, Columbus, Ohio, Columbus Printing company; *Annual Reports of the Secretary of State for1871, 1874-5, 1876, 1875-6,* Columbus, Ohio: Nevins and Myers; Geospatial & Statistical Data Center. http://fisher.lib.virginia.edu/collections/stats/histcensus/php/county.php. June 2006.

Our model predicted that lower costs of land transactions under the rectangular survey would lead to less variance in farm sizes than under metes and bounds. The data in Table 4 show a comparison of farm size distributions by reporting the ratio of the largest to smallest farm size and the ratio of extreme farm sizes--the number of farms over 5,000 acres to the number under 20 acres in VMD counties, counties partially in the VMD and hence, with both RS and MB, and counties adjacent, but outside the VMD. As shown, farm size differences are much greater in the VMD counties.

Table 4. Mean Values for Distribution of Farm Sizes

Ratio: largest acreage held/average acreage held			Ratio: number of farms over 5,000 acres/number of farms under 20 acres		
Regime (# of counties)	Mean	St Dev	Regime (# of counties)	Mean	St Dev
MB (4)	44.73	23.681	MB (8)	0.5552	0.9292
Mixed (12)	46.489	35.048	Mixed (14)	0.0451	0.06
RS (11)	19.38	11.431	RS (17)	0.0451	0.06

To further examine the effects of land demarcation systems on land markets we use Ohio county data from 1860 to estimate the impact of the rectangular survey. We use the number of mortgages and conveyances as our measures of land market activity and estimate the following empirical model.[40]

(2) $$y_i = \mathbf{X}_i \quad _i + RS_i\theta_i + \upsilon_i$$

where i indexes the county variables, y_i is the number of mortgages or conveyances in absolute terms as well as per acre and per 1,000 people in county i, $\boldsymbol{X}_i$ is a row vector of exogenous variables including a constant, demographic variables, economic and land use variables, county size and topography, $\boldsymbol{\beta}_t$ is a column vector of unknown coefficients, RS_i is the percent of rectangular survey

[40] Tables A-2 and A-3 in the appendix provide summary statistics for these data.

in a county, θ_i is an unknown coefficient, and υ_i is a plot specific error term.[41] The results are provided in Table 5

Table 5. Estimates of the Determinants of Land Transactions
(Dependent variables are various measures of county land transactions)

INDEPENDENT VARIABLES	(1) mortgages	(2) mortgages per acre	(3) mortgages per 1,000	(4) conveyances	(5) conveyances per acres	Conveyances per 1,000
CONSTANT	-16.545 (0.17)	0.305 (0.85)	30.213 (4.20)**	-82.577 (0.90)	-0.223 (0.74)	7.866 (4.16)**
POPULATION	6.71 (4.94)**	0.024 (4.65)**	-------	5.323 (4.21)**	0.020 (4.82)**	-------
FARMS	0.167 (0.00)	0.00012 (0.78)	0.0019 (0.86)	0.122 (2.35)**	1.01E-03 (0.80)	0.0015 (1.50)*
TOTAL FARM ACREAGE	2.35E-04 (0.45)	--------	7.13E-06 0.33)	-3.19E-04 (0.65)	_____	3.72E-07 (0.04)
FARM VALUE PER ACRE	0.00002 (0.45)	0.032 (3.39)**	-0.177 (2.20)**	1.917 (0.84)	0.1212 (1.54)*	0.0015 (0.04)
% RECTANGULAR SURVEY	51.30 (0.81)	0.373 (1.55)*	1.21 (0.43)	52.67 (0.89)	0.311 (1.55)*	1.924 (1.53)*
TOPOGRAPHY	-10.687 (3.24)**	-0.039 (3.39)**	-0.66 (4.83)**	-6.534 (2.16)**	-0.0266 (2.69)**	-0.285 (4.64)**
Adjusted R^2	.724	.6593	.1949	20.28	22.75	6.58
F-Statistic	39.10	34.68	5.21	.571	0.556	0.243
Observations	88	88	88	88	88	88

Notes: Absolute values of t-statistics in parentheses. *Significant at the 10% level for a one-tailed t-test. **Significant at the 5% level for a one-tailed test. ***Significant at the 1% level for a one-tailed t-test.

As can be seen from estimates in Table 5, controlling for other factors, there are more mortgages per acre, more land conveyances per acre, and per 1,000 people in RS counties relative to MB counties. A one percent increase in the share of rectangular survey lands in a county, results in a 0.4, 0.3, and 1.9 percent increase in the number of mortgages per acre, conveyances per acre and conveyances per 1,000 people. In addition variables such as population, farm value and topography all are statistically significant determinants of land transactions.

[41] Future analysis will include township level data on the specific character if the MB parcels in order to control for VMD claiming under MB.

D. Legal Disputes

Another prediction of our model was that there should be more legal disputes over title and property boundaries under the metes and bounds system than under the rectangular survey. To test this prediction we have examined historical accounts and also examined the case law in the Ohio courts during the 19th century. We first discuss the historical accounts.

Historical Accounts. The major scholar of Ohio lands, William Peters (1930, 30) argued that there were more land boundary and title disputes in the VMD than in the rest of Ohio combined. The gaps and irregular surveys that were inherent in MB would contribute to boundary disputes. Marschner (1960) notes that where 'uncertain boundaries' affected land investment and use and value and tax implementation (p.1); that land claim disputes where borders were not well defined required special courts to resolve (p.39); and that fractionation of ownership raised costs of parcel consolidation (p.57). Marschner also finds that claim disputes were so common that in many states (e.g., Kentucky, North Carolina) the total amount of land claimed sometimes exceeded the total acreage in the state by as much as ten percent. Pattison (1960, p. 231) notes that there were higher litigation costs associated with the metes and bounds system.

By using "perishable" landmarks such as trees, stones, and waterways, metes and bounds allowed for settlers to pick and chose the "best" land, adjusting the landmarks as necessary, leaving gaps of unclaimed land. It also allowed for multiple claims, including entering, withdrawing, and reentering the same land.[42] Because of an inability of military warrant holders to successfully claim and obtain clear patents to land, Congress was repeatedly involved in VMD issues: "In 1855, one congressman estimated that Congress had passed some forty-four acts dealing with the affairs of the

[42] http://www.library.uiuc.edu/ihx/rcanderson.htm, Richard Clough Anderson Papers, University of Illinois Library.

Virginia Military District because, despite its origin as a state project, it soon became part of national public lands administration."[43]

There appears to have been a large amount of litigation early on caused by overlapping entries and surveys. This is cited as the reason for the VMD Act of 1807 that provided protection to entries and surveys, which were not yet patented, from attempts to make entries and surveys that overlapped. The other main body of statutes concerning VMD lands was the series of acts between 1804 and 1850 (which included the 1807 act) that set time limits for locating, surveying, and patenting warrants – with each successive act extending the time available.

Price (1995, 21, 89, 145) describes how the MB allowed individuals to claim what they wanted where qualities varied—"But a boundary good for one selection was not necessarily good for the next tract, and the selections of earlier settlers might leave large areas of undesirable land in awkward shapes for later comers." (21). Gaps in claimed land resulted due to the strange shapes of individual claims and rejected areas. In discussing the Virginia Military District, Peters (1930, 30, 135) points to many gaps and overlapping claims. He says that by 1852 all military warrants had been used in VMD for land claiming, but still 76,735 acres of land were unclaimed—vacant lands.

Analysis of Ohio Courts. To examine the claim of excessive land boundary disputes in metes and bounds counties, we searched compendiums of Ohio court cases in the 19th century and then turned to Westlaw and Lexus/Nexus for case reports.[44] We focused on all ejectment cases in the

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[43] Taken from James W. Oberly, *Sixty Million Acre* as quoted in the Richard Clough Anderson papers, University of Illinois Library, http://www.library.uiuc.edu/ihx/rcanderson.htm.

[44] *Page's Ohio Digest: A Digest of All Reported Decisions of the Courts of Ohio from the Earliest Period to Date*, John L. Mason Editor in Chief, Volume One, Part One, Abandonment to Assault and Battery; Part Two, Assignments to Charities, Volume Four, Deeds to Equity, Volume Eight, Subrogation to Youthful Employee, Cincinnati: The W.H. Anderson Company, 1914; *A Digest of All Reported Decisions of the Courts of Ohio from the Earliest Period to Date*, Lifetime Edition, edited by William Herbert Page, Volume 10, Parties to Receipts, Volume Twelve, Part One, Taxation to Venditioni Exponas, Cincinnati: W.H. Anderson Company, 1936. *Ohio Jurisprudence: A Complete Statement of the Law and Practice of the State of Ohio with Forms*, Editor in Chief: Willis A. Estrich, Consulting Editor William M. McKinney, Managing Editor, George S. Gulick, Volume 1 (1928), Historical Introduction to Adverse Possession; Volume 5, Bail to Boundaries (1929), Volume 15 (1931), Easements to Encumbrance, Volume 32 (1934); Pledges to

19th century. Ejectment suits are particularly relevant in a situation of imprecise or conflicting property boundaries when surveys are haphazard and indistinct as is the case with metes and bounds. Ejectment is an action to recover a possessory property interest in land. In order to bring an ejectment action, one party claims that someone else is in control of his or her land. Ejectment includes the actions of quiet title and eviction. Ejectment cases are often referred to as "an action to recover possession." Once an ejectment action is brought, the plaintiff needs to state exactly *why* the land claimed is his.[45]

Table 6 shows a preliminary search of Ohio Supreme Court cases involving boundary disputes in the 19th century. The cases are divided according to whether or not the county of the dispute was in the VMD or not and hence governed by metes and bounds. As is apparent in the data shown in Table 6, metes and bounds counties had more property disputes than all other counties in the state combined. Boundary conflicts could have long-term economic consequences. They could linger for long periods of time with uncertain title. For example, in *Fitzpatrick's Heirs v. James Forsythe* (1879) 6 Ohio Dec.Reprint 682 from Logan County in the VMD, the district court ruled that properties held in adverse possession for twenty-one years could be presumed to be a grant from the original parties who held a patent. In *Morrison v. Balkins*, the Court of Common Pleas, Hardin County in the VMD, in 1880 ruled on an effort to quiet title to some 120,000 acres of unpatented lands, occupied for twenty-one years by parties who cannot trace title to the original holder. The properties had been entered in 1822, so that at least for almost 60 years there was no clear title.

Public Schools, Volume 39 (1935), Taxpayers' Actions to Trial, Rochester, New York: The Lawyers Co-operative Publishing Company.

[45] Within ejectment subcategories were: Survey Issues, Boundary Issues, Adverse Possession, and Validity of Deeds/Patents. These are described in more detail in the Appendix.

Table 6. Number of Legal Cases involving Property Boundary Conflicts

VMD Counties (MB)	Non VMD (RS)	Non VMD (RS)	Non VMD (RS)
Adams 3	Allen (adjacent)	Ashland	Muskingum
Brown 5	Auglaize (adjacent)	Ashtabula	Noble 1
Clermont 2	Butler (adjacent) 2	Athens 2	Ottawa 1
Clinton 2	Crawford (adjacent) 2	Belmont	Paulding
Fayette 2	Fairfield (adjacent) 1	Carroll	Perry
Highland 2	Hancock (adjacent)	Columbiana	Portage 1
Madison 5	Hocking (adjacent)	Coshocton	Preble
Union 2	Jackson (adjacent)	Cuyahoga	Putnam
Champaign (part) 1	Knox (adjacent) 1	Darke 2	Richland 1
Clark (part) 1	Lawrence (adjacent) 1	Defiance	Sandusky
Delaware (part) 1	Licking (adjacent) 2	Erie 2	Sceneca
Franklin (part) 4	Miami (adjacent) 1	Fulton	Stark 1
Greene (part) 1	Montgomery (adjacent) 1	Gallia	Summit 1
Hardin (part) 5	Morrow (adjacent) 1	Geauga	Trumbull 1
Hamilton (part) 6	Shelby (adjacent)	Guernsey 2	Tuscarawas 1
Logan (part) 3	Vinton (adjacent) 1	Harrison	Van Wert 1
Marion (part)	Wyandotte (adjacent)	Henry	Washington
Pickaway (part) 5		Holmes	Wayne
Pike (part) 2		Huron 2	Williams 1
Ross (part) 7		Jefferson	Wood
Scioto (part) 2		Lake	
Warren (part)		Lorain	
		Lucas 2	
		Mahoning	
		Medina	
		Meigs	
		Mercer	
		Monroe	
		Morgan	
Total 61	Total 13		Total 22

Note: 8 "other" in VMD.

In another case, *Kerr and Others v. Mack* 1 Ohio 161, Ohio Lexis, December 1823, the Ohio Supreme Court ruled on a case in Adams County in the VMD regarding conflicting surveys and claims that began in 1792 and continued through 1807. The survey of the plaintiff was vague and uncertain so that Kerr, the defendant, alleged he "did not know where it was intended to lie." The disputes simmered for over 20 years.

The preliminary analysis of Ohio court case on property disputes suggest that metes and bounds lands have a disproportionate amount of the disputes in 19th century Ohio but further work is necessary before conclusions can be drawn. Some caveats are also in order. First, we are only able to examine cases that reach the Supreme Court which certainly biases the sample in ways that are not obvious. Second, more detailed reading of these case summarizes in Table 8 indicates that many of the disputes have to do more with the patenting process in the VMD than the metes and bounds system per se.

E. Public Infrastructure: Roads.

We also predicted that public infrastructure such as road will be more well developed under a rectangular system than under metes and bounds. Indeed, scholars of land demarcation have noted this. Notably , in his detailed study Thrower (1966, p.86) stated that: “perhaps the most obvious difference between the systematic and the unsystematic surveys is the nature of the road network developed under these contrasting types of land subdivision.” In his analysis of Ohio counties (88-97, 123) he found that the road density higher was higher in counties with RS than with MB, even when population density was higher in the latter.

Table 7: RS vs MB: Difference of Means of Roads in the VMD Region, 1870

Variable	Number of Roads		Number of Roads/Acre		Length of Roads		Length of Roads/Acre	
	MB	RS	MB	RS	MB	RS	MB	RS
Number of Counties	8	28	8	28	8	28	8	28
Mean (St. Dev)	12.38 (6.65)	8.82 (12.77)	4.43 (2.63)	217.97 (1137.9)	127 (53.90)	72.21 (81.99)	45.52 (22.24)	2174.1 (11380)
t-value	1.05		0.53		2.23**		0.52	

We assemble county level data on roads in Ohio from 1870 to further examine this prediction. The data in Table 7 show mean values of roads and road miles in metes and bounds (MB) and rectangular survey counties (RS) within the greater VMD area comprising 36 of Ohio’s 88 counties. The mean values are larger for both roads and road miles in the MB counties but once these variables are normalized by the size of the county we find more roads and more miles in RS counties as we expect, though the differences are not statistically significant. Future work will estimate the relationship between roads mileage and control for county specific variables.[46]

F. The VMD versus the rest of Ohio

With regard to the Virginia Military District, there is evidence suggesting the broader impact on the economy. Table 8 and Figure 10 show the pattern of population growth in the VMD relative to the rest of Ohio. The VMD was settled early and rapidly in Ohio. The first capital of Ohio was Chillicothe (in Ross County) and lay in the VMD just on the west bank of the Scioto River. In general, however, the VMD has lost ground as Ohio grew.

Table 8. Comparison of Virginia Military District with the rest of Ohio*

	Population					
Year	**VMD**			**Non-VMD**		
	Total	**Mean**	**% of State**	**Total**	**Mean**	**% of State**
1810	53,744	5,374	13.88	177,016	6,808	76.71
1830	197,398	10,967	12.31	740,505	13,464	78.95
1850	274,867	18,324	9.72	1,705,462	23,687	86.12
1880	393,748	26,250	7.15	2,804,314	38,415	87.69
1900	404,035	26,936	6.02	3,753,510	51,418	90.28
1920	411,748	27,450	7.15	5,347,646	73,255	92.85
1950	478,487	31,899	6.02	7,468,140	102,303	93.98
1980	748,711	49,914	6.93	10,051,939	137,698	93.07
2000	970,658	64,711	8.54	10,393,743	142,380	91.46

* This county level comparison uses a VMD group that contains counties which have more than 50% of land in the VMD.

Moreover, the VMD has lower levels of urbanization than the rest of the state, with no major cities, even though the terrain and land quality do not vary importantly between the VMD and other nearby Ohio counties. Notably the cities of Cincinnati and Columbus lie just outside the VMD and grew on land governed by the rectangular survey.[47]

[46] We might expect MB to do better than RS for watercourse transportation since the parcels should mimic the landscape closely.
[47] Columbus actually lies in both the VMD and outside it (in Franklin County), but the overwhelming portion of the city is on the east side of the Scioto River where the rectangular survey governs.

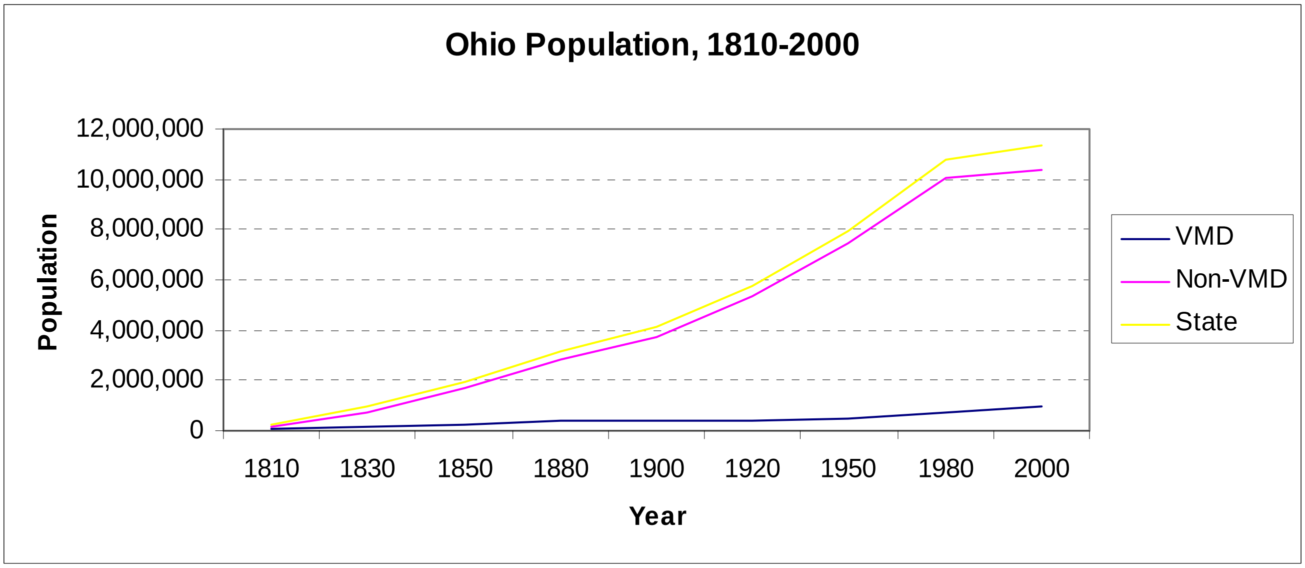

Figure 10 Ohio Population Over Time

V. SUMMARY AND CONCLUSION

This paper is the first economic study of the two dominant types of land demarcation systems – metes and bounds and the rectangular survey. We have developed a model of land demarcation to examine the use and effects of these two systems and tested a variety of hypothesis against data from Ohio where the two systems coexist as a result of exogenous political and economics forces. We have two preliminary findings. First, we find that the characteristics of parcels in the metes bounds regimes of the Virginia Military District are strongly correlated with the topography of the land which is predicted by our model. We also find that in relatively flat topography where metes and bounds yields rectangular parcels these parcels are not uniformly aligned as they would be in the rectangular survey. Second, we find that in the Virginia Military District there was less land market activity, generally lower land values, fewer roads, and more property disputes.

We caution that our results are preliminary and that future work will use farm and plot level data from 1850 and 1860 to estimate the effects of land demarcation system on a variety of land market and land dispute variables. In this work we will be able to control for land quality, topography, the details of the original parcels (under both systems). Still our early findings are suggestive of the importance of land demarcation in influencing the use of land and perhaps ultimately in economic growth more generally. Linklater (2002, 238-41), for example, comments on the subtle importance of uniform, systematic land survey in describing Stephen Austin's decision to adopt the RS in those parts of Texas not governed by Spanish and Mexican land grants. Seeing confusion over land boundaries in Kentucky and Tennessee where many of Austin's followers had originated, he selected the RS: "The advantages inherent in the square-based federal land survey gave the state's economy a vigor its neighbours lacked." Indeed, as suggestive of the effects of the survey on land markets, in those parts of the U.S. where rectangular survey dominated, the capital gains from land sale were the largest source of wealth creation (Ferrie1994, Galenson and Pope 1989).

We note that even though we find evidence that the rectangular system has some clear benefits over metes and bounds, we have no estimate of the costs of the RS system to indicate what the net effect might be. Furthermore, it is not clear how much we can extend our findings from the United States to less developed countries where metes and bounds dominate. And even within the United States, our focus on Ohio, with its relatively mild and flat terrain, may cause us to overlook issues that arise in the Rocky Mountains or the desert southwest.

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Table A1: Ohio Counties by Land Survey Regime

Metes and Bounds	Mixed	Rectangular Survey		
Adams	Champaign	Allen (VMD)	Coshocton	Muskingum
Brown	Clark	Auglaize (VMD)	Cuyahoga	Noble
Clermont	Delaware	Butler (VMD)	Darke	Ottawa
Clinton	Franklin	Crawford (VMD)	Defiance	Paulding
Fayette	Greene	Fairfield (VMD)	Erie	Perry
Highland	Hardin	Hancock (VMD)	Fulton	Portage
Madison	Hamilton	Hocking (VMD)	Gallia	Preble
Union	Logan	Jackson (VMD)	Geauga	Putnam
	Marion	Knox (VMD)	Guernsey	Richland
	Pickaway	Lawrence (VMD)	Harrison	Sandusky
	Pike	Licking (VMD)	Henry	Sceneca
	Ross	Miami (VMD)	Holmes	Stark
	Scioto	Montgomery (VMD)	Huron	Summit
	Warren	Morrow (VMD)	Jefferson	Trumbull
		Shelby (VMD)	Lake	Tuscarawas
		Vinton (VMD)	Lorain	Van Wert
		Wyandotte (VMD)	Lucas	Washington
		Ashland	Mahoning	Wayne
		Ashtabula	Medina	Williams
		Athens	Meigs	Wood
		Belmont	Mercer	
		Carroll	Monroe	
		Columbiana	Morgan	

VMD indicates those rectangular survey counties included in the VMD region.

Table A-2
1860 County Data -- Variable Definitions and Summary Statistics

Variable Name	Definition	Mean	Standard Deviation	Minimum	Maximum
Dependent Variables					
NUMBER OF MORTGAGES	Number of farm mortgages recorded in the county	638.68	333.67	0.00	2,280.00
NUMBER OF MORTGAGES PER 100,000 ACRES		2.19	1.21	0.00	8.75
NUMBER OF MORTGAGES PER 1,000 PEOPLE		25.77	8.58	0.00	52.74
NUMBER OF CONVEYANCES	Number of conveyances of property recorded in county	278.07	248.99	0.00	1,892.50
NUMBER OF CONVEYANCES PER 100,000 ACRES		0.95	0.88	0.00	6.45
NUMBER OF CONVEYANCES PER 1,000 PEOPLE		10.30	3.98	0.00	24.25
CRIMES AGAINST PROPERTY	Number of crimes against property cited in each county (includes a variety of offenses, such as trespassing, illegal acquisition of property)	9.80	16.80	0.00	133.67
CRIMES PER 100,000 ACRES		3.51	6.49	0.00	51.27
CRIMES PER 1,000 PEOPLE		0.32	0.28	0.00	1.51
LAND DISTRIBUTION	The largest acreage held by a single owner divided by the average acreage held by an owner	36.63	43.52	0.00	304.35
Demographic Variables					
POPULATION	County population divided by 1,000	26.59	23.00	4.95	216.41
POPULATION CHANGE	Percent change in population from the previous decade (1850-1860)	26.96	37.88	-22.62	180.01
Economic and Land use Variables					
FARMS	Total number of farms in the county	1,970.22	644.04	404.00	3,520.00
TOTAL FARM ACREAGE	Total land in farms, including both unimproved and improved farmland				
FARM VALUE PER ACRE	Total value of farms divided by total farmland in county	31.74	12.82	12.67	98.47
EQUIPMENT VALUE	Total value of farm implements and machinery	198,168.55	92,216.46	17,005.00	427,963.00
LIVESTOCK VALUE	Total value of all livestock (horses, cattle, sheep, goats,	913,463.85	371,421.79	100,447.00	1,820,577.00

	oxen)				
ORCHARD VALUE	Total value of all orchard products	21,923.97	15,136.24	948.00	68,184.00
GARDEN VALUE	Total value of all market garden products	10,312.65	49,388.88	25.00	459,196.00
SLAUGHTER VALUE	Total value of all slaughter animals	167,340.28	162,990.18	23,974.00	1,523,568.00
Land Regime Variable					
PERCENT RECTANGULAR SURVEY	The percent of land in the county in which the rectangular survey system is used*	0.837657	0.3221347	0	1
Control Variable					
TOPOGRAPHY	Scale of land topography (1-21, 1=flat plains, 21=high mountains)	8.02	7.01	1.00	19.00

Table A-3
1870 County Variable Definitions and Summary Statistics

Variable Name	Definition	Mean	Standard Deviation	Minimum	Maximum
Dependent Variables					
NUMBER OF ROADS	Number of turnpike and plank roads per county	11.90	13.80	1.00	58.00
NUMBER OF ROADS PER 100,000 ACRES		4.09	5.11	0.22	22.68
NUMBER OF ROADS PER 1,000 PEOPLE		0.42	0.50	0.03	2.17
LENGTH OF ROADS	Length (miles) of turnpike and plank roads per county	97.46	85.16	3.00	325.00
LENGTH OF ROADS PER 100,000 ACRES		33.07	30.28	1.16	127.07
LENGTH OF ROADS PER 1,000 ACRES		3.47	3.29	0.16	12.81
CRIMES AGAINST PROPERTY	Number of crimes against property cited in each county (includes a variety of offenses, such as trespassing, illegal acquisition of property)	22.30	23.88	1.00	178.50
CRIMES PER 100,000 ACRES		7.79	9.17	0.40	68.47
CRIMES PER 1,000 PEOPLE		0.71	0.35	0.06	1.95
Demographic Variables					
POPULATION	County population divided by 1,000	30.29	29.05	8.54	260.37
POPULATION CHANGE	Percent change in population from the previous decade (1860-1870)	14.01	19.73	-11.71	90.48
PERCENT ILLITERATE	Percent of the population over age 10 that cannot read	3.60	2.24	0.32	12.49
Economic and Land use Variables					
FARMS	Total number of farms in the county	Later			
TOTAL FARM ACREAGE	Total land in farms, including both unimproved and improved farmland				
FARM VALUE PER ACRE	Total value of farms divided by total farmland in county				
EQUIPMENT VALUE	Total value of farm implements and machinery				
ORCHARD VALUE	Total value of all orchard products				
GARDEN VALUE	Total value of all market garden products				
SLAUGHTER VALUE	Total value of all slaughter				

	animals	
Land Regime Variable		
PERCENT RECTANGULAR SURVEY	The percent of land in the county in which the rectangular survey system is used*	
Control Variables		
TOTAL ACRES	Total acres of land in county	
TOPOGRAPHY	Scale of land topography (1-21, 1=flat plains, 21=high mountains)	
MANUFACTURING SITES PER ACRE	Number of manufacturing establishments in the county per 1,000 county acres	Later

Description of Legal Issues in Ohio Court Analysis

Survey Validity Issues:

These cases involve a dispute where two different surveys claim the same land. *E.g., McArthur v. Phoebus*, 2 Ohio 415 (1826). In these, the general question is which survey was valid and which was invalid. This should be differentiated from cases where two parties claim the same land because the survey, or several competing surveys, does not clearly delineate a line between the properties. These cases generally hinge on whether the survey was correctly recorded or implemented. In general, these cases are more common in VMD areas, but do exist in RS areas of Ohio, but the issues are far easier to resolve in the latter, generally hinging on resolving a clear surveying error, rather than conflicting land claims. *See Hamil v. Carr*, 21 O.S. 258 (Ohio 1871).

Boundary Issues:

This is a broader area of conflict, and basically encompasses when there is a dispute about where a boundary line actually stands. The majority of relevant cases fall in this area. These generally occur because the survey, or multiple surveys, do not make it legally clear where the boundary line stands. These cases also frequently occur when a deed does not make clear part of a plat it is granting.

Both these disputes occur in VMD and non-VMD areas, although the former are generally far more complex, hinge on far less clear legal principles, and as we show below occur with greater frequency than in RS areas.

Adverse Possession:

Ohio follows standard hornbook law on adverse possession, with the time being defined by statute, 21 years, and case law defining the elements. The generally required five elements of actual, continuous, open and notorious, hostile and exclusive possession exist. The Ohio Supreme Court, in *Yetzer v. Thoman*, 17 O.S. 130 (Ohio 1866), adopted the Connecticut Doctrine in regards to adverse possession. This doctrine essentially states that one can adversely possess land regardless of whether one knew that one did not actually have good title. Previous to this, courts presumably selectively required either the Maine Doctrine (requiring knowledge that you did not in fact have good title) or Good Faith (a requirement of a belief that you had good title to the land you were in fact adversely possessing), or did not inquire at all. The adoption of the Connecticut Doctrine allows for cases where two parties incorrectly believed they owned the same land. Ohio uses the related claim of "Acquiescence." If two parties knowingly agree to a different boundary line, when the correct boundary line is known by the parties, for the statutory period (21 years), then the party who loses land under the change cannot return the boundary to its correct position after this period through legal action. *See Bobo v. Richmond*, 25 O.S. 115 (Ohio 1874).[48]

Validity of Deeds/Patents:

These cases occur frequently and all hinge on whether a deed or patent was valid. While these are actually two fairly different legal issues, they generally depend on the same type of questions, namely was the deed/patent correctly recorded under the relevant statute and does the deed/patent correctly describe the land it grants. If not, the deed/patent is generally invalid. For the most part, these cases do not involve any boundary disputes, except in the cases where the validity of a patent is used as a collateral attack on cases of overlapping surveys. It is worth noting, however, that patent validity seems to be an issue mostly in VMD cases, largely due to the complexity of the statutes involved in the land grants.

The case, Ohio (Pt 1) 206 *Porter v Robb* from Clermont County illustrates some of the boundary problems found in the VMD. It is a case where a party mistakenly surveyed his entry and patented it, leading to conflict over the original survey. Notice the description of the land boundary: warrant No 77 used to claim land, "beginning two hundred poles on a right line, below the mouth of a creek, emptying into the Ohio, by computation ten miles above the mouth of the Little Miami, and nearly opposite a creek of equal size, running in on the oppose side, running thence up the meanders of the Ohio four hundred poles on a direct line; thence including the mouth of the creek…" The case shows how entries were filed with respect to earlier, adjacent ones, so if they were off, then all would be off. Many patents then are made at risk. The case also describes the process of using a warrant to make an entry, then surveying, and then patenting.

The problem of a chain of entries and surveys also appears in *Huston v McArthur*, 7 O (Pt 2) 54. An adjustment factor was included with each entry, and this caused conflict as the amount of the land claimed by various parties overlapped. The court claimed that to through out the adjustment factor in the VMD "…at this late period …would be fraught with much evil. It is insisted that it has ever been the custom in making surveys, to extend the lines five percent beyond the length called for, and that this custom has been so long and so uniformly persevered…" Court goes on to say, however, "That the locators in the district have been in the constant habit of appropriating by entry and survey more lands than their warrants called for,…"

[48] It should be noted that both Adverse Possession and Acquiescence are a defense to ejectment and generally may not be brought as initial actions by a plaintiff who wishes to claim the land.