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THE DEMARCATION OF LAND: PATTERNS AND ECONOMIC EFFECTS

GARY D. LIBECAP AND DEAN LUECK

Abstract. We examine the pattern of property rights demarcation in centralized and indiscriminate land survey systems and their economic effects. 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). MB 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 RS outlines boundaries in terms of a centrally-controlled grid of square plots. Widespread use followed the Northwest Land Ordinance of 1785 that 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 RS and MB. 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 conflicts, greater property investment, higher land values, and more infrastructure than metes and bounds. Our empirical analysis focuses on a 22-county area of Ohio where MB is used relative to the remaining 66 counties that emply RS. Our data include parcel maps, U.S. census manuscripts, court opinions, and state reports on infrastructure, legal disputes, and productivity. The results indicate that topography influences parcel shape and size under a MB system; that parcel shapes are aligned under the RS; and that the RS is associated with higher land values, more roads, more land transactions, and fewer legal disputes than MB, all else equal. It may also be that the comparative limitations of MB contributed to the observed relative decline of that area relative to the rest of Ohio.

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"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 land is likely one of the earliest activities undertaken by human societies. Primitive societies marked and defended territories to hunting and gathering sites in order to limit open access exploitation (Bailey 1992). Early agricultural societies defined rights to much smaller plots of land for farming (Ellickson 1993). In modern societies rights are designated for residential and commercial use in dense urban areas, for farmland in highly mechanized large-scale fields, for 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 its use and value land, the literatures in economics and in law have not addressed these issues. We now turn to such an analysis.

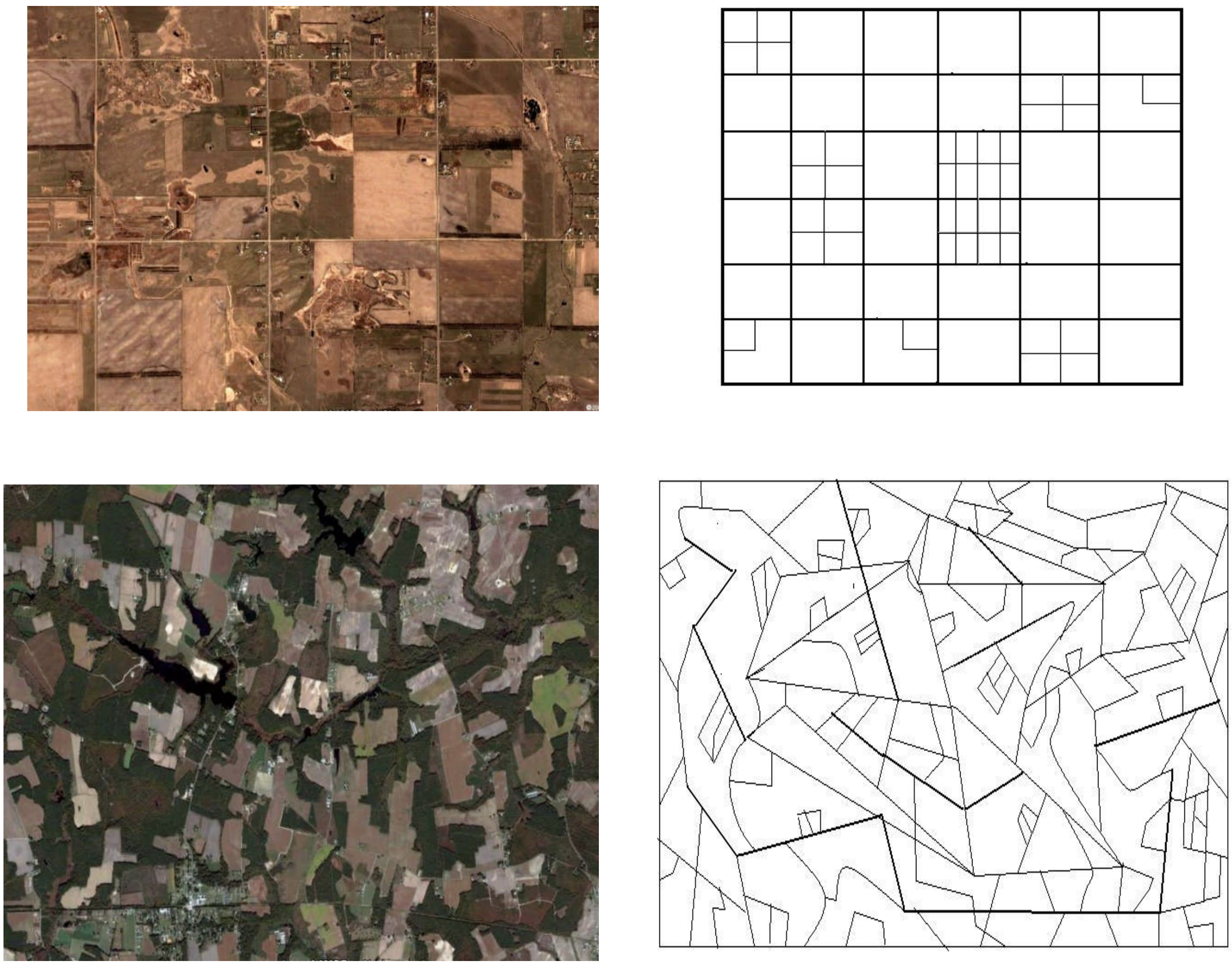
In this paper we examine the impact of two different – indiscriminate (or decentralized and unsystematic) and centralized (i.e., systematic) — demarcations of property boundaries: metes and bounds (MB) and the rectangular survey (RS). Under the indiscriminate MB land claimants define property boundaries in order to capture valuable land and to minimize the individual costs of definition and enforcement. Individual surveys do not 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, markers). 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 many cases, the RS is likely to lower the costs of land development and exchange through its measurement, enforcement, and incentive effects as compared to using MB to define land ownership boundaries, even though there are initial costs associated with the RS. MB boundaries 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 negotiated and crossed. Further, where incongruent individual plots collide, there are gaps of unclaimed land that remain essentially open-access. As these land gaps ultimately became valued they are inevitably subject to competing and wasteful claims by the adjacent parties.

The centralized RS, however, involves initial upfront costs of delaying occupancy (or ejecting incumbent occupants) and surveying land in a uniform manner. We term these as coordination costs because once the RS is complete, it coordinates subsequent land allocation in a manner that provides economic benefits by reducing the marginal costs of property rights measurement, enforcement, and exchange. Accordingly, the centralized system is a public good (much like a library catalog system), and capturing those gains provides incentives for use of RS where possible. Although MB avoids these coordination costs, the subsequent marginal costs of individual claiming, enforcing and trading property rights are likely to be higher than under RS.

A glimpse of the potential impacts of the two systems can be seen in Figure 1which shows aerial photographs and schematic drawings of the rectangular survey and metes and bounds.[1] 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 (Mitchell, South Dakota) with Metes and Bounds (Walters, Virginia)



The demarcation of property rights is connected to a growing literature on the nature of property

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[1] Thrower (1966) shows similar photographs and related schematic drawings.

rights in contributing to different patterns of economic growth across countries.[2] 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 setting focused on 19th century Ohio satisfies this requirement.

We begin in section II with a brief history of the land demarcation 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 systems have 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.

II. A BRIEF HISTORY OF LAND SURVEY SYSTEMS

Throughout human history land demarcation has been dominated by indiscriminate or unsystematic systems such as MB (Brown 1995, Estopinal 1993, Gates 1968, Linklater 2002,

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[2] 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).

Marschner 1960, McEntyre 1978, Price 1995, Thrower 1966).[3] 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). The dominance of MB suggests that there are substantive coordination costs of establishing RS regimes.

Although MB has dominated history, people have occasionally used more systematic demarcation methods. [4] These 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. Unlike the US practice, however, centurialism was not designed for continuous stretches, but rather started again at new cross-points and thus varied somewhat with natural land 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 RS were present in ancient India and the Indus Valley. Table 1 summarizes features of the major historical and contemporary rectangular systems.

> In the United States MB is found in the 13 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. 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 MB surveys) and partially on different rectangular surveys with no meridians or baselines. California is similar to Texas in that many parts

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[3] 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.

[4] 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.

of the state (particularly the south and central coastal regions) are based on Spanish land grants, called *ranchos*; there is, however, an overlay of the rectangular survey.[5] New Mexico and Arizona also have a mix of RS and MB due to the existence of Spanish and Mexican land grants. 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 as noted above, in central Ohio there is a pie-shaped section of land governed by metes and bounds called the Virginia Military District. Consider a property description (of the perimeter) in the Virginia Military District of Ohio:[6] “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.”

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)

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[5] *Thomas Guides*, the canonical map books of Southern California, include both *rancho* and RS or Public Land Survey System (PLSS) designations.
[6] Cited in *Wyckoff v Stephenson*. 14 Ohio 13.

MB in the United States essentially ended with the enactment of the-Land Ordinance of 1785.[7] The 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.[8] The RS 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 Figure 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. RS 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).[9] 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-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.[10] 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

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[7] Cite statute --

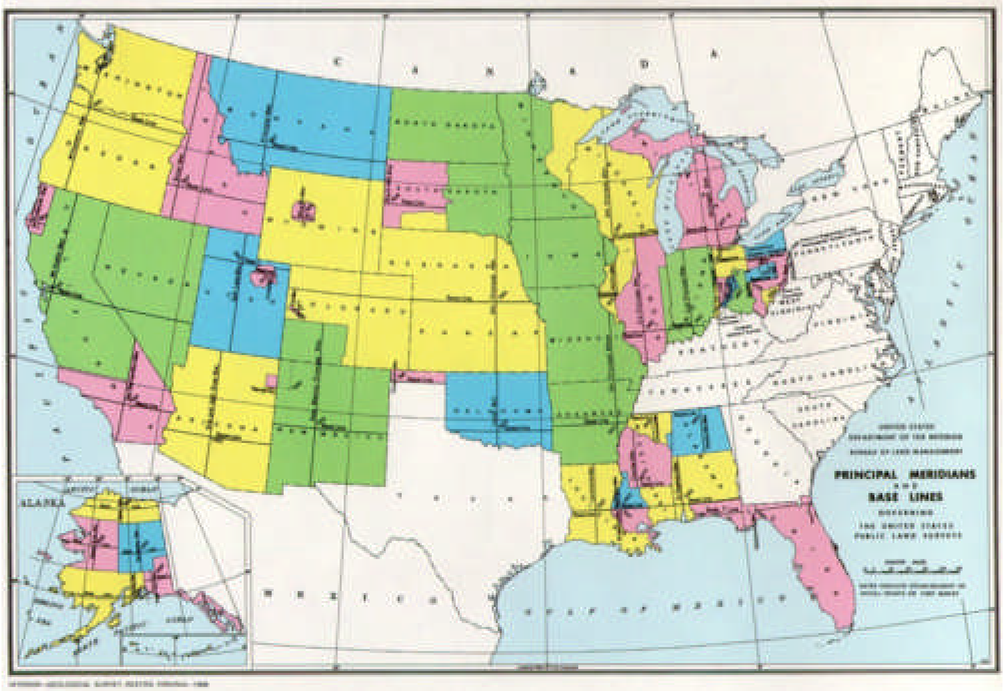
[8] Ultimately, though, homesteading and related first possession polices were used to settled much of the western federal lands governed by the rectangular survey. See Allen (1991) for an analysis of the choice between land sales and first possession policies.

[9] This system is officially known as the Public Land Survey System or PLSS; http://www.nationalatlas.gov/plssm.html.

[10] 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).

township is identified by its relation to the Principal Meridian and Baseline.[11] In this manner, each property is positioned relative to others in a standardized way.

Figure 2
The Rectangular Survey System in the United States



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.

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[11] For example, the seventh township north of the baseline and third township west of the i^{TH} Principal Meridian would be T7N, R3W, i^{TH} Principal Meridian.

Figure 3
The Structure of the Rectangular Survey System

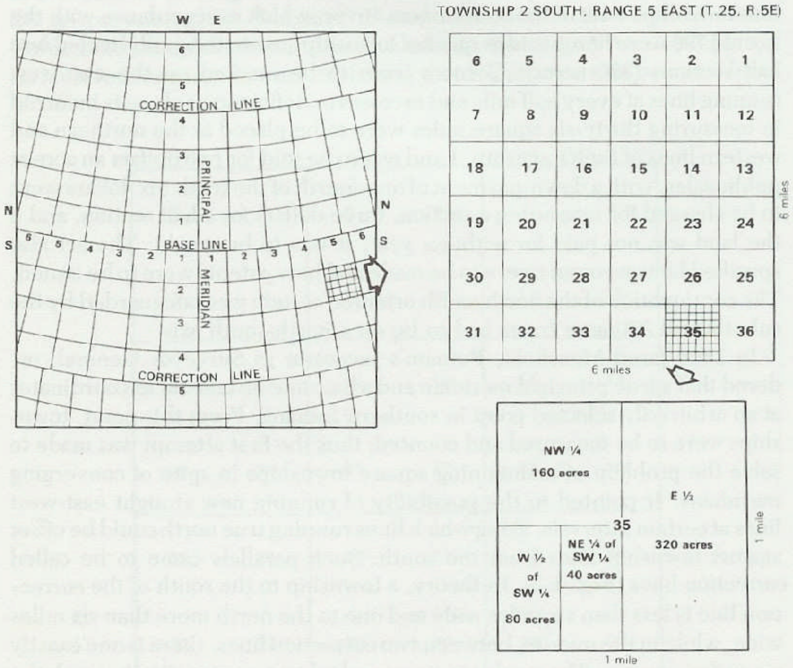

Figure 4-3. The U.S. Rectangular Survey System. After 1796, each township was numbered with reference to a baseline and principal meridian and subdivided into 36 sections, always numbered as shown. Tracts sold by the government decreased in size between 1796 and 1832 from 640 to 40 acres.

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 across the federal domain, 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 that are highly linear and often rectangular.[12]

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[12] Individual properties tend not to overlap county boundaries in order to designate administrative jurisdiction and taxing authority See (xxxx) on political jurisdictions and borders.

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 the potential gains from centralized and coordinated land demarcation system that governs are large region. In particular we examine how the rectangular survey generates different ownership patterns and incentives for land use, land markets, investment, and border disputes. In this analysis we focus on the particular features of the American rectangular system.

A. Individual 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.[13]

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[13] 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. Also, it is likely that even with MB 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 MB systems. In England and the United States, for example, the common law courts developed doctrine on claiming and border demarcation.

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) $$\max_{a_i, p_i} V_i - y_i(a_i, p_i, t_i) - c_i(a_i, n_{i,} p_i, t_i)$$

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, perimeter, and land characteristics; $c_i(a_i,p_{i,}n_i,t_i)$ 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]

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[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. We also assume that the claims are made simultaneously rather than sequentially.

[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.

The answer to this problem is that a circle will maximize the area for a given perimeter, providing the lowest perimeter to area ratio. 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 plots of land are rarely 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

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[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.

[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.

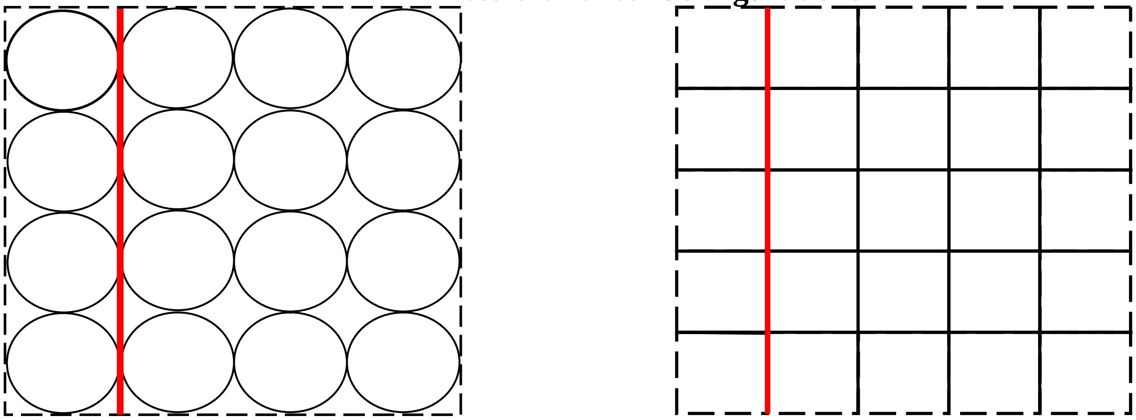
[19] This is readily apparent when flying over the western US and observing circular irrigated fields within the rectangular system – the corners are dry and uncultivated (but of course not unclaimed).

[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 same. The sum of the angles of a polygon with n sides, where n is 3 or more, is $180(n - 2)$ degrees. A triangle comprises 180 degrees, a square 360 degrees, and so on.

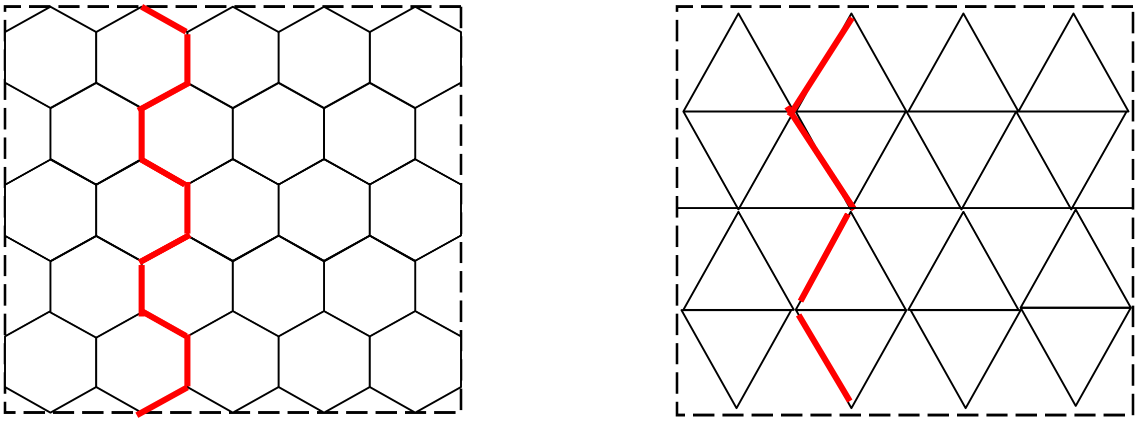
1994) and have the potential to eliminate open access waste between parcels within a given tract.[22] In fact, there are only three regular polygons – triangles, squares, and hexagons – that will create patterns, with a common vertex, that have no interstices (space) between the parcels.[23] As suggested 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.

Figure 4
Possible Parcel Configurations



A. Circles (16 plots)

B. Squares (25 plots)



C. Hexagons (20 plots)

D. Triangular (32 plots)

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[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.

Parcel shape	*Area (A)*	*Perimeter (P)*	*P/A ratio*	*Plots in tract*	*N-S & E-W distance*[*]
Squares	1.00 sq miles	4 miles	4.000	25	10 miles
Circles	1.27 sq miles	4 miles	3.142	16	10 miles
Hexagons	1.15 sq miles	4 miles	3.464	20	13.4 miles
Triangles	0.77 sq miles	4 miles	5.196	32	10.76 miles**

* North-south shown as red line. ** Of course the triangular system can be aligned north-south as well.

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) a decentralized metes and bounds system will yield a land ownership pattern of identical square parcels.**

This is a case where a decentralized MB system could lead to individual square plots like a RS system. .

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 aerial observer. If demarcation and enforcement costs depend on terrain (because of

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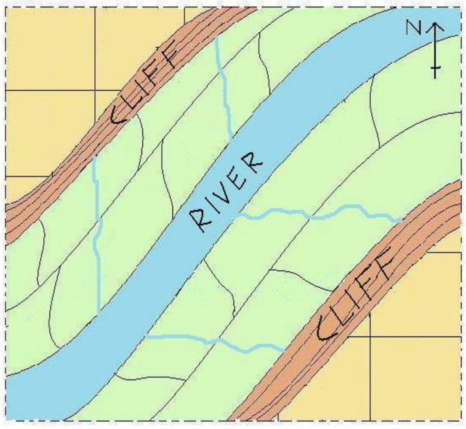
[24] Will more neighbors mean economies of enforcement or more potential intruders?

[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.

surveying or fencing or road building costs), we would expect borders to roughly follow the topography.[26] To take an extreme example, suppose a deep canyon cut through a fertile plateau. 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. Figure 5 shows such a case where rugged topography makes linear boundaries too costly. The canyon itself might remain as unclaimed open access land.[27] Thus we have a second prediction

> **Prediction 2: With heterogeneous land and parties (in both productivity and enforcement ability) a decentralized metes and bounds system will yield a land ownership pattern of parcels whose borders mimic the topography and vary in size with no particular alignment.**

Figure 5
Decentralized Claiming in Non-planar Topography



We thus expect the non-cooperative Nash equilibrium to yield a pattern of parcel sizes and shapes that depends on the character of the land (*e.g.,* topography, vegetation, soil and of the potential claimants (farming productivity, violence and monitoring productivity, and so on). Adding land heterogeneity (e.g., river, broken terrain) changes the cost function *c(kp,n)* and leads to non-linear

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[26] 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 ($a^2+b^2=c^2$) 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.
27 Dahlman (1980) describes the English open field system has having large acreage in ‘wastes’ – essentially unclaimed open access land – which were not valuable for cultivation or pasture..

claims as well as unclaimed areas -- the so-called ‘gaps and gores’ described by many historians of MB land systems.

B. Coordination and Collective Action in a Land Demarcation System

The previous analysis shows how land rights would be privately demarcated in an indiscriminate system with individual claiming and enforcement. It is readily apparent, however, that there are potential gains from a centralized system. First, there can be enforcement cost savings from coordinating on common borders. Second, and more generally, a common system provides information about the location of individual parcels and is thus a public good and will have greater net value if spread over a larger region. Third, coordination of survey results in similarly aligned properties and avoids the gaps of unclaimed land that arise when unsynchronized surveys collide.

Consider adjacent areas settled under metes and bounds. 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.[28] 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.

Figure 6 shows a case in which two sections of homogeneous flat land with square plots might have different alignments. Gaps between these claims and overlapping claims might also result from imprecision in location recording and no communication or coordination among the parties.

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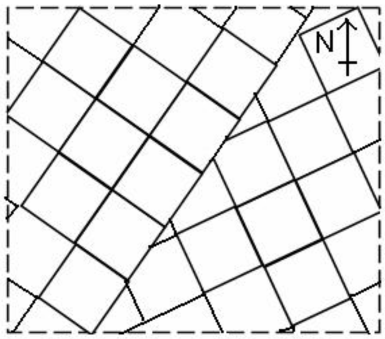
[28] Sugden (1990) develops a theory of conventions (e.g., which side of the road to drive on) based on repeated game theory.

Figure 6
Decentralized Claiming with Decentralized Alignment



Finally, coordinated survey of heterogeneous land prior to allocation fixes individual land claim borders and avoids the incentives of claimants to “float” boundaries to cover the most productive land. Such opportunistic border adjustments could result in long-term border and ownership disputes among adjacent properties.[29]

C. Land Demarcation with Centralized System: The Rectangular Survey

Many possible centralized land demarcation systems can be imagined and some historical rectangular systems were noted above. The American rectangular survey (RS) is a particular type of centralized land demarcation system with three distinctive features. First, 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 individual 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

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[29] Clay and Wright (2005) describe the process of moving or floating claims to mineral land during the early California gold rush when the location of ore was uncertain. Mineral claims were uncoordinated under MB.

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[30].

Land claims under MB required individual surveys without the aggregate coordination benefits described above. Nevertheless, there were likely substantial upfront costs of providing coordinated surveys through designing the details (e.g., size of squares), implementing the survey (e.g., determining initial points and conducting the surveys), and controlling access until the survey was completed. Generally, because of these costs, only property owners who expected to internalize gains of the RS would adopt such a system. Their returns would accrue through the revenues of land sales to claimants who did not have bear individual survey costs and who benefitted from the other advantages of the rectangular survey. This discussion leads to another prediction:

> **Prediction 3. Large land holders, such as the Federal Government, rural land and suburban developers or other organizations where entry can be controlled, will adopt a rectangular survey.**

The effects of the rectangular survey have been discussed by historians and geographers but there is 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). The impact of expanding the market and lowering transaction costs should make it

---

[32] There were of course squatters on un-surveyed federal land that were dealt with through various preemption laws. Squatting, however, was not a general characteristic of the U.S. frontier by the mid 19th century. In contrast, on the Brazilian frontier, squatting is predominant, Lee Alston, Gary Libecap, and Bernardo Mueller, 1998. “Property Rights and Land Conflict: A Comparison of Settlement of the U.S. Western and Brazilian Amazon Frontiers,” in *Latin America and the World Economy since 1800*, John H. Coatsworth and Alan M. Taylor, Cambridge: Harvard University Press.

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.[31] Since the RS lowers the cost of transactions it will be more likely to see the result than if the original demarcation were under metes and bounds. This discussion leads to three related predictions.

> **Prediction 4A: There will be more land transactions under the rectangular survey than under metes and bounds.**
>
> **Prediction 4B: There will be less variance in the size and shape of parcels under RS than MB.**
>
> **Prediction 4C: There will be higher (per acre) land values 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 transportation 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.[32] This implies another prediction.

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

---

[31] 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.

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

Because surveys are standardized and aligned under the RS, there are no unclaimed gaps in property claims. RS also brings coordinated survey and fixed boundaries. These factors imply another prediction.

> **Prediction 6: There will be fewer legal disputes (and litigation) over boundaries and titles under the rectangular survey than under metes and bounds**.

We now turn to an empirical analysis, first of the size, shape, and alignment of land claims under unsystematic MB and second to the economic contribution of the RS.

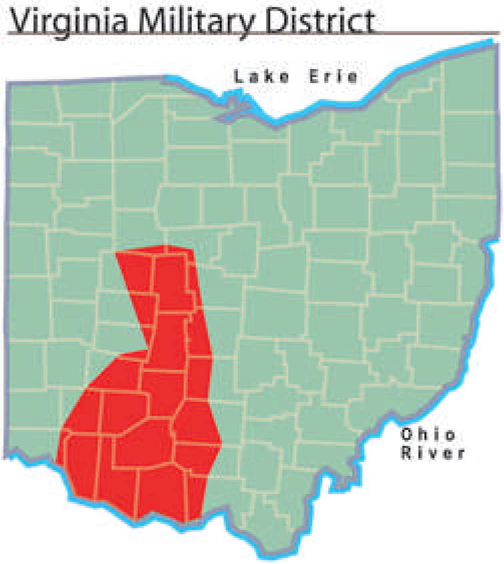
IV. EMPIRICAL ANALYSIS

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 Ohio where both the rectangular survey was used as well as the metes and bounds in the Virginia Military District. Next we examine the demarcation of land under MB in the Virginia Military District in order to test predictions 1 and 2 which posit a relationship between topography and parcel demarcation. We follow with qualitative discussion of the incentive to provide RS (prediction 3) and then provide parcel level observations for Ohio as well as evidence from state reports to estimate the effects of land demarcation systems on the land market and road construction (predictions 4a-c and 5). We then examine legal disputes over property title and boundaries in the Ohio courts (prediction 6.).

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 granted to Virginia to provide military bounty land grants to pay Revolutionary War veterans. The land in the VMD was demarcated using metes and bounds under Virginia law. The area was ceded to the Federal Government in 1783 and became part of Ohio. Ohio was virtually unsettled before 1800 but grew extremely fast thereafter and became a state in 1803.[33] 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. Because the VMD was demarcated under MB while the rest of Ohio was part of the original federal RS, the land demarcation systems are exogenous for the purposes of our study.[34] Figure 7 shows the location of the VMD within the state.

Figure 7
The Virginia Military District



To gain ownership of a plot of land in the VMD, individuals with military land warrants could enter the district, select property for claiming, survey to document their claims, and then file their claims along with their warrants.[35] The first step required obtaining a valid warrant by

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[33] It had a population of just 45,000 in 1800 but over 230,000 by 1810.
[34] 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.
[35] 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.

presenting a certificate of rank and service to a court of law, and if approved, 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 or entry and survey of lands within the VMD. Second, once granted a warrant, the claimant[36] proceeded to locate a claim (the entry). The location included a description of the land with natural boundary markers, which was filed with the local land office, and then followed by a survey. Third, the surveyor measured the boundaries of the claim, prepared a plat map, and calculated the actual size of the claim, which was to 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. 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.

Although surveys were to designate the claim's perimeter, two practices potentially created subsequent sources of conflict over property rights. One was the incentive of individuals faced with heterogeneous land to leave boundaries sufficiently vague or flexible that they could be moved to encompass more valuable areas that had been missed in the initial entry. The other was a common practice of locating and surveying claims based on the boundaries of already existing claims. This lowered the costs of surveying, but if one of the earlier surveys was incorrect or moved, then title to all the affected properties could be clouded. We explore this issue below.

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

The model of land demarcation predicts that under MB the demarcation of parcels will depend on the topography of the land. In relatively flat terrain we predict squares and in relatively rugged terrain we predict that the parcels will follow local features (ridges, rivers) that influence the costs of demarcation and the value of the land. We test these predictions by examining the

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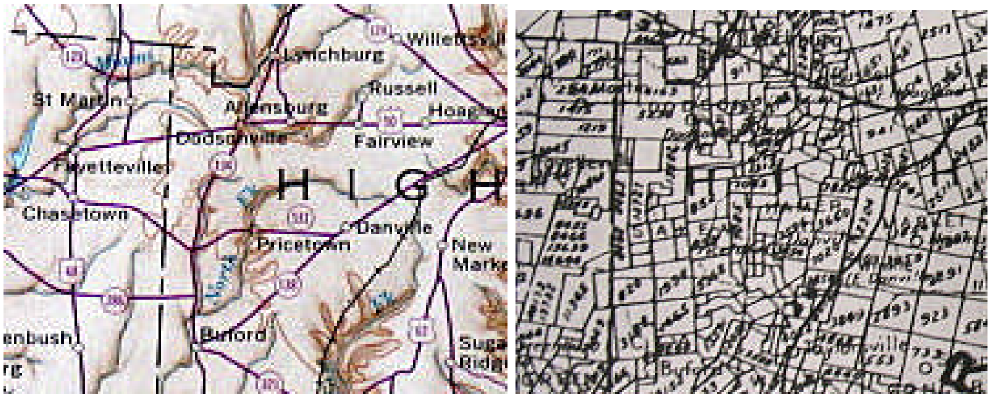
[36] This could be the war veteran himself or his heir or assign if he had either sold the warrant or devised it upon his death, and was probably physically located on the ground by someone designated to locate the claim on behalf of the warrant holder – typically termed an entry-man) Most warrants were sold.

relationship between the topography of the land and the size and shape of the original parcels in the VMD.

We begin the analysis with visual inspection of topography and parcel size and shape within the central VMD. Figure 8, Panel A shows a section of flat land in Highland and Clermont counties. It is clear that the parcels are rectangular and even square as predicted. In the VMD there were large sections of land that had been assembled by speculators who purchased warrants from veterans. The pattern here shows evidence of coordinated surveying, where groups of tracts are aligned in the same directions, but not typically north-south as in the RS. This pattern is consistent with Prediction 3 regarding the incentives to provide systematic survey. Because we do not have original ownership information, we cannot directly test the prediction for the VMD, but we can do so elsewhere and return to this issue again. In case where different sections of coordinated parcels abut one another, the result is triangular sections, some of which were unclaimed originally.

Figure 8
Visual correlation between topography and original VMD parcel demarcation



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

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

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 coordinated parcel boundary alignment as seen in Panel A.

In order to quantify the variation in parcel shape, size, and alignment, we have digitally analyzed all parcels in Ohio in 1853, calculating area, perimeter, perimeter-area ratio, number of sides, angle deviations, and alignment.[37] We also have calculated topography and soil quality by parcel. The perimeter area ratio variable is a useful measure for determining how efficiently a boundary is used to define a specific area requirement. The 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.[38] To measure topography we use measures of surface slope. Values of surface slope are

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[37] The data come from maps in Sherman (1922) as digitized by McDonald et al. (2006).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). These measures are likely linked to the costs of demarcation and are ways to quantify the size and shape of parcels.

38 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.

derived from a digital elevation grid in which each cell (approximately 30 meters^2) represents an elevation value and the slope is calculated as the change in elevation between cells.

Parcel Shape in VMD.

We predicted that under MB, where there was no overall coordination of surveys, topography would play a key role in the shape and size of a parcel because the cost of survey by individual claimants would be critically affected by the terrain. Our model predicts that parcel shape will tend to conform to more organic patterns of the natural topography and deviate farther from a square as the land becomes less flat, resulting in larger perimeter-area ratios and numbers of sides. We test predictions 1 and 2 by regressing township averages of various measures of parcel shape--perimeter-area ratio and the number of parcel sides on topography (average township slope). Only townships with more than half their area within the VMD were used in the analysis (n = 194). The results are presented in Table 2.

Table 2
Topography and Parcel Shape

INDEPENDENT VARIABLES	(1) Average Perimeter-Area Ratio of Parcels	(2) Average Number of Parcel Sides
AVERAGE SLOPE	0.0618***	0.246***
	[9.232]	[9.383]
CONSTANT	4.474***	5.309***
	[167.5]	[50.77]
Observations	193	193
R^2	0.309	0.316
F-Statistic	85.23	88.04

Notes: Values of t-statistics in brackets (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

As shown in both regressions, average township slope has a significantly positive effect on the average perimeter to area ratio of a parcel and the number of sides of a parcel. An increase of one standard deviation in average slope corresponds to about a one-half standard deviation increase in the expected perimeter-area ratio and the expected number of sides.[39] These results suggest that property boundaries increasingly conform to topography as the slope becomes more imposing, leading to more irregular boundaries, a higher perimeter-area ratio and more sides under uncoordinated land claiming and surveying within the VMD.

Alignment of Parcels in the VMD and Ohio.

Our theoretical discussion of land demarcation under MB 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, we would not expect that the parcels will be aligned north-south as in the federal RS. To test this prediction, we regress the standard deviation of parcels' alignment within a township (where alignment was measured as the angle of orientation of the longest side of the parcel, measured in degrees) for all Ohio parcels against the percent of a township in the VMD and topography. We anticipate that parcels under a decentralized metes and bounds system to have larger variation in parcel alignment and that steeper topography will increase demarcation costs and obstruct systematic alignment.

Table 3
Parcel Alignment

Independent Variables	Standard Deviation of Parcel Alignment
AVERAGE SLOPE	0.0873***
	[4.563]
% AREA IN VMD	9.694***
	[49.98]
CONSTANT	0.793***
	[7.963]
Observations	1353
R-squared	0.649
F-Statistic	1249

---

[39] A one SD shift in slope results in a .2 increase in perimeter-area ratio (4% increase from the mean value) and a .7 increase in number of parcel sides (12% increase from the mean value).

Notes: Values of t-statistics in brackets (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

The coefficient on average slope is positive and significant as expected and supports the prediction that steeper topography poses obstacles to uniform alignment. In addition, location within the VMD has a strong effect on its coefficient and is highly significant. In fact, the results indicate that a township within the VMD would have 10 times the amount of variation in parcel alignment than a township outside the VMD, when evaluated at the mean value of the dependent variable.[40] This is further testament to the high-level of land organization instituted by the U.S. rectangular survey.

C. Provision of the Public Good of the Rectangular Survey.

We argued above that the RS provides a number of public goods in terms of systematic location of properties, coordinated survey, and reduced title conflict. We also noted that there were costs associated with employing an initial rectangular survey prior to entry. These notions suggest that the RS would be used only when these benefits could be internalized to offset the costs of systematic survey. Governments, large land grantees or land speculators who planned to subsequently subdivide and sell, as well as suburban real estate developers are examples of cases where the RS would be used. These owners would capture the resulting higher land values.

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 that would raise federal revenues from land sales and were frustrated by the metes and bounds system. In discussing the origins of the Northwest Ordinance, Linklater (2002, 68-70)

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[40] The comparison between being in the VMD and out is determined by inserting the mean value for average slope into the model and see how the dependent variable changes by going from the VMD:
DV(outsideVMD) = Constant + B1(mean average slope) + B2(VMD = 0)
DV(insideVMD) = Constant + B1(mean average slope) + B2(VMD = 1)
DV(inside) / DV(outside) = increase in variation

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 committee, 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.

[also evidence of survey by large land speculators, evidence of urban property patterns.]

D. 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.

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 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.

The historical accounts are consistent with our predictions about land markets but we now examine statistical data on farms and land markets for more precise tests. In the analysis presented below we rely on Ohio state reports, federal census data, as well as parcel level data.[41]

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[41] 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: 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.

Township Level Estimates of Variation in Parcel Size VMD and Ohio.

In the following regressions, the standard deviation of parcel acreage in all Ohio townships is used as the dependent variable (n = 1361). We expect that parcels under a decentralized metes and bounds system to have larger variation in parcel size compared to rectangular survey. If the RS promoted market sales, then transactions should have been more common to consolidate properties. We control for topography that would have also affected variation in parcel size in a township.

Table 4
Deviation in Parcel Size by Township

Independent Variables	Standard Deviation of Parcel Size
AVERAGE SLOPE	5.222***
	[3.562]
% AREA IN VMD	534.6***
	[35.99]
CONSTANT	83.97***
	[11.01]
Observations	1353
R-squared	0.490
F-Statistic	647.8

Notes: Values of t-statistics in brackets (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

As shown the VMD variable has a substantial effect in the model. A township within the VMD has 6 times the amount of variation in parcel size compared to townships under the rectangular survey. This is an indication of the effectiveness of the rectangular survey in determining the size of a parcel and in promoting market transactions so that there was less variance in parcel size. Steeper average slopes also have a significant positive effect at the 1% level, suggesting that terrain affected parcel size.

Parcel Land Values in Matched Townships, VMD Townships and Adjacent Townships.

To further analyze the effect of land demarcation systems on land values we examined the value of land in adjacent townships along the border of the VMD. By examining townships along the VMD border we can control for many economic, demographic, and landscape variables. Figure 9 shows the township pairs used in this test. Data limitations prevent us from using all adjacent township pairs at this time. The results of the pair-wise comparison of mean township land values are reported in Table 5 and indicate that – as predicted – the value of land outside the VMD, using the rectangular survey, has higher values than similar land governed by metes and bounds demarcation.

Figure 9
Paired Townships along the border of the Virginia Military District

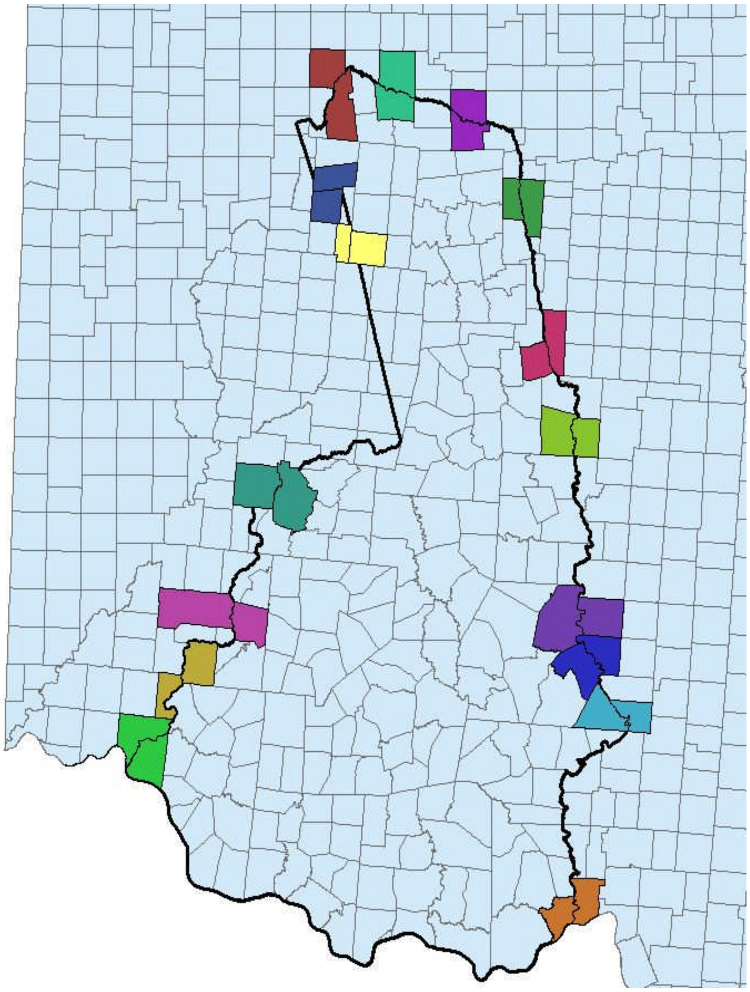

Table 5
Pair-wise comparison of mean Township Land Values

	Non-VMD	***VMD***
Mean	40.24	35.35
Variance	302.87	215.23
Observations	27	27
Pearson Correlation	0.62	
Hypothesized Mean Difference	0	
Df	26	
T Stat	1.80	
P(T<=t) one-tail	0.04	
t Critical one-tail	1.71	

Land Value Estimates at the Township Level for VMD and Ohio

In Table 6 we report estimates of land value per acre across Ohio townships where we have collected farm value data from the 1850 and 1860 censuses. All values are in constant \$1860, but we add a dummy variable for 1860 to reflect for overall growth in land values between the census years. We report estimates for land value as a function of topography, transportation density, 1860, and location within the VMD.[42] Because, as we show below, road density and railroad access may be correlated with the percent area within the VMD, we report the land value regressions with and without density. Land value is the township average of farm value per acre from matched farms dataset from the 1850 and 1860 census manuscripts. Average slope is as before, road density represents the miles of roads within a township divided by the square root of the land area.[43]

In order to capture other means of transportation that affect land value, proximity to railroads and waterways was included in the model. To calculate access to railroads, a raster grid was created within ArcMap 9.2. Raster cells were assigned values that decreased linearly with increasing distances from railroad lines, and the average value of the cells within a township was used to determine access to railroads. The same process was used to calculate the proximity to major transportation waterways.[44] The variables for market distance and Cincinnati distance represent the distance in miles from the center of a township to the nearest county seat and to the city of Cincinnati, respectively.[45]

Table 6
Average Total Farm Value/Acre
DV: Average Census Farm Value/Acre by Township

INDEPENDENT VARIABLES	(1)	(2)	(3)	(4)	(5)
			Value Per Acre		
% AREA IN VMD	-11.38***	-12.26***	-14.33***	-15.74***	--
	[-3.58]	[-3.91]	[-4.58]	[-5.15]	--
1860	17.67***	17.51***	17.43***	17.20***	17.68***
	[8.33]	[8.26]	[8.14]	[8.03]	[8.27]
ROAD DENSITY	0.712	--	0.966**	--	1.026**
	[1.49]	--	[2.02]	--	[2.17]
RAILROAD ACCESS	86.90***	91.22***	--	--	104.9***
	[3.99]	[4.23]	--	--	[4.92]

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[42] Soil quality, which would impact land value, is highly correlated with average slope (-.70).
[43] 1860 Dummy – A value of one indicates that the farm value data came from the 1860 Agricultural Census. A value of zero indicates that the farm value data came from the 1850 Agricultural Census
[44] Waterways include the Ohio River and the Ohio canal system as drawn the 1868 Walling Atlas.
[45] Cincinnati is included as a separate variable because its population in the mid 19th century is larger than any other population center near the study area by an order of magnitude.

RIVER PROXIMITY	3.262***	3.611***	2.735**	3.180***	5.163***
	[2.97]	[3.36]	[2.48]	[2.94]	[5.32]
MARKET DISTANCE	-0.870***	-0.863***	-1.429***	-1.458***	-0.764**
	[-2.66]	[-2.64]	[-4.80]	[-4.89]	[-2.33]
CINCINNATI DISTANCE	-0.364***	-0.383***	-0.380***	-0.407***	-0.279***
	[-9.14]	[-10.13]	[-9.49]	[-10.77]	[-8.69]
AVERAGE SLOPE	-0.451	-0.565	-0.852**	-1.037***	-0.383
	[-1.21]	[-1.55]	[-2.35]	[-2.95]	[-1.02]
CONSTANT	57.13***	63.37***	71.37***	80.97***	38.87***
	[7.03]	[9.09]	[9.69]	[14.34]	[6.11]
Adjusted R^2	0.307	0.306	0.294	0.291	0.297
F-Statistic	44.01	49.9	47.1	54.05	47.74
Observations	776	776	776	776	776

Notes: Values of t-statistics in brackets (*** p<0.01, ** p<0.05, * p<0.1).

The expected change in land value from location within the VMD is substantially negative and highly significant in the four models the variable appears in. This is consistent with the prediction that the rectangular survey better enhances land value compared to metes and bounds. In the models where road density and/or railroad access variables are removed for potential collinearity, the effect and significance of the VMD variable becomes even stronger. Evaluating the full land value model, where the estimate for the VMD coefficient is the most conservative, we expect a 32% increase in land value per acre, when assessed at its mean, for townships governed by the rectangular survey compared to townships solely using a system of metes and bounds.

County Estimates of Land Transactions, VMD and Ohio

To further examine the effects of land demarcation systems on land markets we use Ohio county data from 1860 of the number of mortgages and conveyances as our measures of land market activity and estimate the following empirical model.[46]

$$\text{(2)} \qquad \mathrm{y_i} = \mathbf{X}_\mathrm{i}\boldsymbol{\beta}_\mathrm{i} + RS_i\theta_i + \upsilon_i$$

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

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 in a county, θ_i is an unknown coefficient, and υ_i is a plot specific error term.[47] The results are provided in Table 7.

Table 7
Estimates of the Determinants of Land Transactions
DV: 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 acre	(6) conveyances per 1,000
POPULATION	7.45***	0.027***	--	5.67***	0.022***	--
	[5.156]	[4.864]	--	[4.198]	[4.908]	--
FARMS	0.160***	0.000015	0.0019	0.116**	0.000027	0.0014
	[2.791]	[0.0985]	[0.883]	[2.176]	[0.223]	[1.328]
TOTAL FARM ACREAGE	0.000029	--	-0.0000068	-0.00045	--	-0.0000053
	[0.0570]	--	[-0.334]	[-0.927]	--	[-0.559]
FARM VALUE PER ACRE	3.488	0.0305***	-0.179**	1.749	0.0117	0.0112
	[1.365]	[3.031]	[-2.323]	[0.733]	[1.405]	[0.310]
% AREA IN VMD	-38.29	-0.428*	-1.49	-52.8	-0.376*	-2.423*
	[-0.584]	[-1.734]	[-0.537]	[-0.862]	[-1.841]	[-1.872]
AVERAGE SLOPE	-12.38***	-0.042***	-0.814***	-6.825*	-0.0271**	-0.304***
	[-3.230]	[-2.848]	[-5.558]	[-1.907]	[-2.226]	[-4.452]
CONSTANT	88.58	0.802**	34.35***	-4.182	0.16	10.71***
	[1.064]	[2.419]	[10.62]	[-0.0538]	[0.585]	[7.093]
Adjusted R^2	0.723	0.651	0.248	0.566	0.549	0.239
F-Statistic	38.81	33.48	6.75	19.88	22.15	6.45
Observations	88	88	88	88	88	88

Notes: Values of t-statistics in brackets (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

As can be seen from estimates in Table 7, controlling for other factors, there are significantly more mortgages per acre, land conveyances per acre and per 1,000 people in counties outside the VMD relative to counties within the VMD. When compared to a county with only metes and bounds demarcation, the results imply that we expect rectangular surveyed counties to have 20%

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

more mortgages per acre, 40% more conveyances per acre, and 24% more conveyances per 1,000 people.

E. Public Infrastructure: Roads and Railroads.

We also predicted that public infrastructure such as roads and railroads 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.

Road Density and Metes and Bounds: VMD and Ohio

In Table 8 we report estimates of road density across Ohio townships as a function of location within the VMD with control variables on topography and proximity to various travel destinations. It is undoubtedly more costly to build roads through steep topography so we expect a negative relationship between average slope and road density. We also expect higher demand for travel to areas such as cities, markets, trading posts, rivers, and other means of long-term transportation, and therefore anticipate higher road densities near these areas.

Table 8
Road Density
DV Length of roads in a township divided by the square root of the land area.

INDEPENDENT	(1)	(2)	(3)	(4)
VARIABLES		Road Density		
% AREA IN VMD	-1.354***		-1.591***	
	[-4.28]		[-5.14]	
RAILROAD ACCESS	6.660***	8.995***		
	[3.02]	[4.13]		
RIVER PROXIMITY	0.508***	0.765***	0.478***	0.786***
	[4.66]	[8.24]	[4.36]	[8.33]
MARKET DISTANCE	0.0169	0.0295	-0.026	-0.0292

	[0.5]	[0.87]	[-0.85]	[-0.92]
CINCINNATI DISTANCE	-0.0282***	-0.0187***	-0.0299***	-0.0187***
	[-7.25]	[-5.74]	[-7.68]	[-5.63]
AVERAGE SLOPE	-0.181***	-0.175***	-0.217***	-0.224***
	[-4.91]	[-4.65]	[-6.16]	[-6.21]
CONSTANT	8.833***	6.912***	10.10***	8.252***
	[12.53]	[12.47]	[17.66]	[18.04]
Adjusted R-squared	0.335	0.308	0.322	0.282
F-Statistic	37.56	39.81	42.45	43.88
Observations	437	437	437	437

Notes: Values of t-statistics in brackets (*** p<0.01, ** p<0.05, * p<0.1).

As predicted, the model shows a strong negative relationship between road density and the metes and bounds land of the VMD. The full regression model implies that road density is expected to 20% be higher, starting from its mean value, in areas under the rectangular survey compared to metes and bounds. Additionally, in the two models where the VMD variable is not included, the Adjusted R^2 value is lower than in the two models that do. This further suggests that the choice of demarcation systems has substantial power in explaining variation in the density of road infrastructure in Ohio.

Railroad Density and Metes and Bounds: VMD and Ohio

The same rationale used for the road density relationship can be used for analyzing the effect of the RS on railroad density. In Table 9 we report estimates of railroad density models that follow the same structure as the road density models reported in Table 8. Railroad density is a measure of the length of railroad track running through a township divided by the square root of its area. This variable is different from the railroad variable used in previous models which was used to measure proximity and access to railroads.

Table 9
Railroad Density
DV: Length of railroad tracks in a township divided by the square root of the land area.

INDEPENDENT	(1)	(2)	(3)	(4)

VARIABLES	Railroad Density			
% AREA IN VMD	-0.148**		-0.166***	
	[-2.427]		[-2.805]	
ROAD DENSITY	0.0114	0.0168*		
	[1.238]	[1.866]		
RIVER PROXIMITY	-0.0380*	-0.0136	-0.0325	-0.000377
	[-1.776]	[-0.714]	[-1.553]	[-0.0213]
MARKET DISTANCE	-0.0278***	-0.0279***	-0.0281***	-0.0284***
	[-4.743]	[-4.740]	[-4.795]	[-4.813]
CINCINNATI DISTANCE	-0.00114	0.000000254	-0.00148**	-0.000312
	[-1.443]	[0.000397]	[-1.996]	[-0.503]
AVERAGE SLOPE	-0.0134*	-0.0129*	-0.0159**	-0.0167**
	[-1.913]	[-1.836]	[-2.361]	[-2.467]
CONSTANT	0.721***	0.505***	0.836***	0.643***
	[5.026]	[4.464]	[7.648]	[7.508]
Adjusted R-squared	0.079	0.069	0.078	0.063
F-statistic	7.243	7.429	8.374	8.368
Observations	437	437	437	437

Notes: Values of t-statistics in brackets (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

The adjusted R^2 values are low, suggesting that the survey system had less of an impact on the construction of railroads than for local roads. This may be due to the fact that more capital intensive railroads were influenced by broader variables. Nevertheless, the VMD variable is significant in the expected direction when it is included in the model. In conjunction with the road density model, these results are consistent with the hypothesis that the linear continuity of the rectangular survey is more conducive for creating public infrastructure that requires long right-of-way stretches.

F. 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.[48] 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 Virginia Military District because, despite its origin as a state project, it soon became part of national public lands administration."[49]

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

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

[49] 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.

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.[50]

The majority of the cases in the 19th century involved disputes over validity of title (see Table 10 below). There were still boundary disputes occurring in the courts during this time, but they were often mere pretenses to challenge a title or to add to adjoining lands held by one of the speculators. Because of the nature of the claiming process it was natural for duplicate or overlapping claims to be made – there was no requirement that a claim be registered with the county in which it was located,

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

only with the local land office – therefore, notice of an existing claim would be difficult to obtain. Additionally, it was not uncommon for a survey registered with the local land office to have calls that were insufficiently precise to permit a subsequent claimant to know exactly where the claim was located. Hutchinson and Rubenstein both noted a common practice by the surveyors in the territory in which they would record claims to the best land early on, but not sufficiently describe the land claimed so that others could clearly locate it. This had the effect of preempting later claims to the land, under the laws protecting faulty claims (i.e. the VMD Act of 1807), by both preventing others from finding the location and filing overlapping claims and defeating those later claims with superior equitable title, assuming the surveyor could prove the validity of his claim (which depended on the records kept in the principal surveyor's office).[51]

Table 10
Property Disputes, VMD and Rest of Ohio

VMD			Non-VMD		
10	59	17	23	16	5
Boundary Dispute?	Validity of Entry/ Patent?	Validity of Survey?	Boundary Dispute?	Validity of Entry/ Patent?	Validity of Survey?
86			44		

As the data in Table show, many of the VMD cases classified as dealing with the validity of a survey were also included as cases dealing with the validity of an entry or patent – because challenging the survey typically involved challenging the ultimate right of possession the party had. For similar reasons there is considerable overlap among cases disputing a boundary with cases disputing the original survey – the claims are often inextricably intertwined. Looking at percentages of each type of dispute shows that 81% of the VMD cases involved a challenge to the validity of the

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[51] Asa Lee Rubenstein,, _Richard Clough Anderson, Nathaniel Massie, and the Impact of Government on Western Land Speculation and Settlement, 1774-1830_, University of Illinois, dissertation, 1986, p. 240; William Thomas Hutchinson,, _The Bounty Lands of the American Revolution in Ohio_, University of Chicago, dissertation, 1927. p. 117.
.

entry or patent, while only 14% of the VMD cases involved a dispute over property boundaries. Finally, 24% of the VMD cases involved a dispute over the validity of a survey.

The non-VMD cases show some overlap between boundary dispute and validity of survey cases. The boundary dispute cases in non-VMD areas seem to be more typical adverse possession cases – they generally involve a dispute between adjacent landowners of a small strip of land located along their common property boundary. The validity of title cases in non-VMD areas generally involve failure to comply with some procedural requirement involved in obtaining a patent or filing with county recorders or land offices. Percentage-wise the non-VMD cases break out as 45% involving a boundary dispute, 31% concerning validity of title, and 10% with validity of survey issues.

Property 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.

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.

G. 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 11 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 11
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.[52]

Figure 12
Ohio Population Over Time – VMD and Statewide

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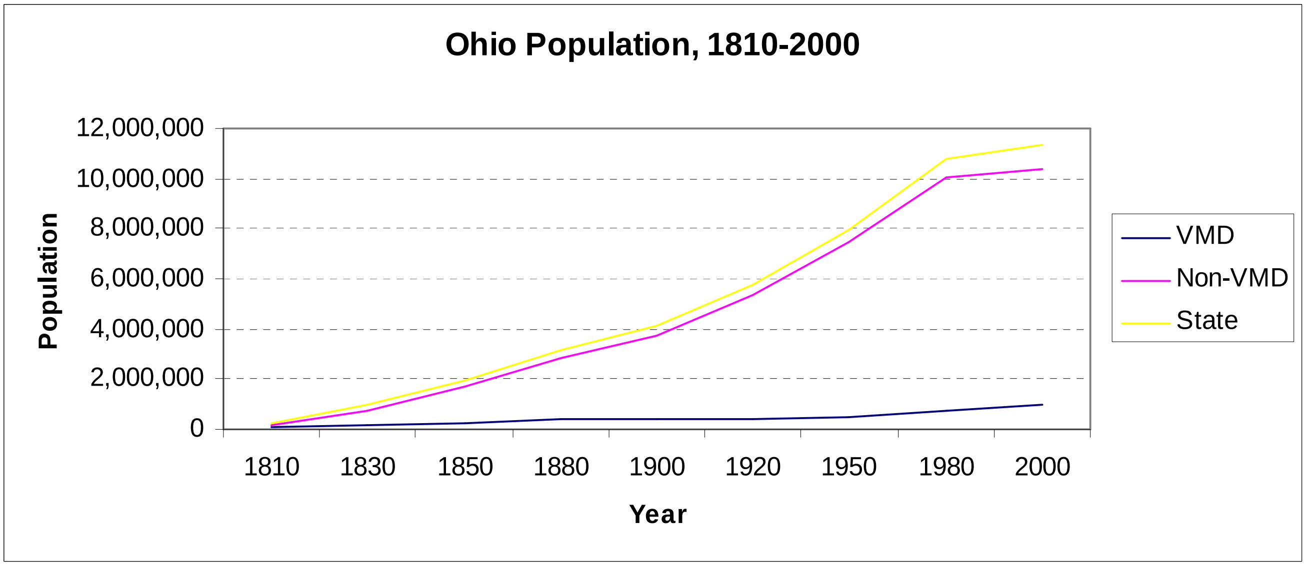
[52] Columbus actually lies in both the VMD and outside it (in Franklin County), but the overwhelming portion of the city is on the east side of the Scioto River where the rectangular survey governs.



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 the following 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.

Our 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, oxen)	913,463.85	371,421.79	100,447.00	1,820,577.00
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).[53]

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,…"

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[53] 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.

Description of Parcel Data

We obtained the geospatial dataset *Ohio Original Land Subdivisions* (McDonald et al, Ohio Division of Geological Survey, Columbus, OH, 2002) as a set of geographic information system (GIS) files from the Ohio Department of Natural Resources. These data include a map that represents the only known digital compilation of the original land subdivisions in Ohio, styled after Sherman's (1922) map of original land subdivisions. The digital dataset can be used with geographic information systems (GIS) software, which has critical information on the geometry of parcels in MB and RS systems throughout Ohio, and obtain information on the precise spatial relationships of parcels, townships, and counties to relevant control variables such as topography and proximity to transportation. We use ArcGIS 9, a GIS software package to calculate shape values for each parcel, including the *p/a* ratio, the number of sides, and the alignment angle. The dataset contains over 73,000 parcels. The perimeter area ratio (*p/a* from our model) is an important measure of parcel shape and will be key in our analysis. This ratio is typically measured by $(p/\sqrt{a})$ to ensure that the numerator and denominator are both measured in the same units (Longley et al. 2005). Values for area and perimeter are being collected for each parcel using ArcMap Version 9.2. To measure topography we downloaded digital elevation models (DEMs) from the 1 Arc Second National Elevation Dataset (NED) (*Data available from U.S. Geological Survey, EROS Data Center, Sioux Falls, SD*) that span the state of Ohio. These DEMs are raster grids in which each cell (approximately 30 meters^2) is assigned an elevation value. While topography can be evaluated qualitatively, a DEM allows for precise, systematic, and quantitative measures of topography. We will use the standard deviation of elevation to reflect the topography of an area. The Spatial Analyst in ArcMap will be used to calculate the standard deviation of elevation on the county, township, and parcel levels.