Research Handbook on the Economics of Property Law

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13 Land demarcation systems

*Gary D. Libecap and Dean Lueck**

I. INTRODUCTION

Land demarcation systems are ancient human artifacts and are fundamental to property law, use, and markets. In this chapter we develop an economic framework for examining systems of land demarcation and examine the economic history of demarcation in the United States and elsewhere. Land demarcation is one of the earliest actions of organized human groups. Territories to hunting and gathering sites have been marked and defended among the most primitive peoples (Bailey 1992). The earliest agricultural societies defined rights to 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 utilization and value, the literatures in economics and in law have not addressed these issues in any depth.

In this chapter we examine the economic structure and function of land demarcation systems. We direct attention to the two systems that have dominated land demarcation: metes and bounds (MB) and the rectangular system (RS). Under 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 local, natural features of the land (trees, streams, rocks) and relatively permanent human structures (walls, bridges, monuments). Moreover, properties can be comprised of multiple small parcels, leaving unclaimed tracts as open gaps. Further, where incongruent individual plots collide, there also can be gaps of unclaimed land that remain essentially open-access. As these lands ultimately become valued they are inevitably subject to competing and wasteful claims by the adjacent parties.

By contrast under RS, demarcation of individual plots is governed by a common system of plot shapes, sizes, and boundary descriptions. Further, properties are not fractured, but cover all land claimed within a single parcel. As we argue in this chapter, the rectangular survey tends to lower the costs of land development and exchange through its measurement, enforcement, and incentive effects as compared to using metes and bounds to demarcate land ownership boundaries. The latter are necessarily vague and imprecise ('four paces from the most northerly rock pile . . .'), temporary (trees disappear, stream beds change, so that boundary markers had to be periodically investigated to insure that they were still visible), idiosyncratic (different terms used locally), and for all of these reasons, subject to dispute and conflict. The idiosyncratic nature of measurement limits the size of the land market because remote purchasers have little knowledge of local land features and have to rely on localized interpretation of their meaning for property boundaries. Infrastructure development, such as for roads, may be more costly because of the inexact nature and multitude of land boundaries that must be crossed, raising coordination costs.

A centralized rectangular system defines land ownership in a manner that reduces the costs of measurement, enforcement, and exchange. By bearing upfront costs of systematic survey prior to occupancy the marginal costs of demarcating and establishing boundaries are lower compared to metes and bounds. Individual plots are aligned north–south, boundaries are clear, precise, and uniformly positioned, and the system of description is uniform across the region covered.

While the demarcation of land is fundamental to a system of property law it is largely unexplored by property law scholars and instead simply, or implicitly, taken for granted. Indeed Dukeminier and Krier (2002: 675–679) do not mention the distinction between the two systems but only describe the rectangular system. Merrill and Smith (2007) and Thompson and Goldstein (2006) similarly describe the rectangular system. Neither of the comprehensive treatises on law and economics by Posner (2002) and Shavell (2007) mentions land demarcation.[1]

This chapter begins with a survey of land demarcation systems used around the world, with a focus on the US, including rectangular and metes and bounds systems, but also other less common practices. In section III we outline an economic framework for analyzing the demarcation of land generally as well as under both metes and bounds and the rectangular systems. In Section IV we explore some empirical implications of our model in metes and bounds, in the US rectangular system, and in rectangular systems in urban areas and foreign countries. The chapter concludes with a discussion of the findings, implications for property law, and areas for further study.

II. A BRIEF SURVEY OF LAND DEMARCATION SYSTEMS

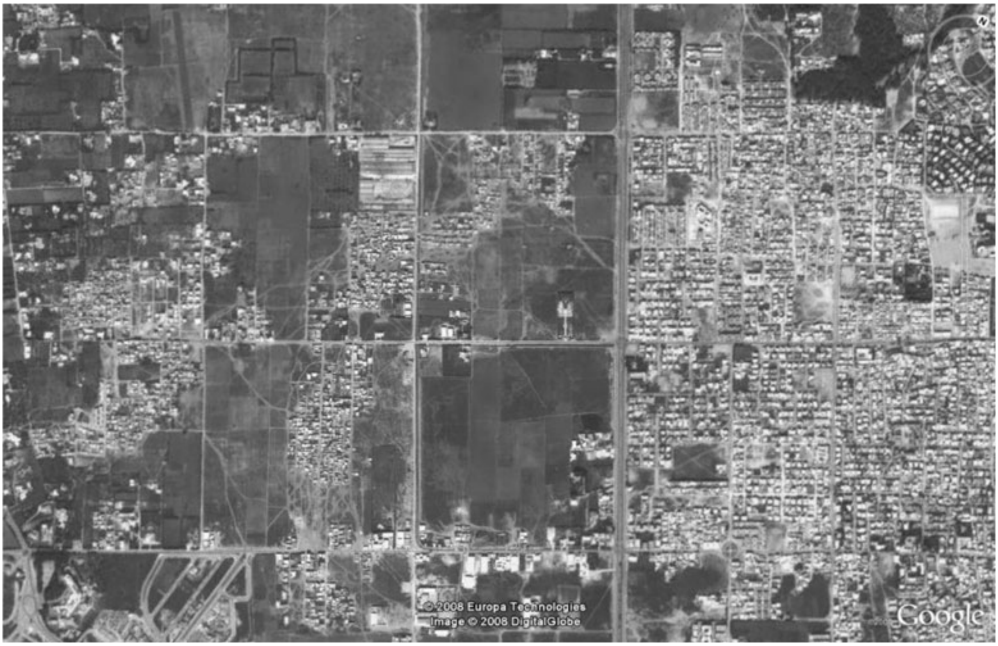
Throughout the world and through history, land demarcation has been dominated by indiscriminate or unsystematic systems such as metes and bounds (Brown 1995; Estopinal 1998; Gates 1968; Linklater 2002; Marschner 1960; McEntyre 1978; Price 1995; Thrower 1966).[2] While these systems vary and tend to be highly local in details, they share a method of defining land boundaries in terms of natural features of the land and even some human structures. The dominance of metes and bounds systems indicate that there are substantive costs of establishing organized rectangular systems. Metes and bounds systems are effective and likely efficient when land is not traded regularly in land markets involving buyers remote from the site, and where agriculture is small-scale, not requiring larger, well-defined fields for cultivation or for pasture for livestock. Metes and bounds allows individuals to mold their land holdings around local contours to lower measurement and bounding costs of individual plots and to include only the best land in areas where land is heterogeneous in quality.

In cases where land and agricultural commodity market are more developed, however, metes and bounds is less satisfactory, as we discuss in more detail below. As described by Barzel (1982), markets require standardized measurement of items traded so that sellers and buyers know what is being exchanged and can agree to a market-clearing price. The greater the precision and transparency of measurement, the lower the transaction costs of exchange and the greater reach of markets. Measurement, however, is costly, and hence the accuracy of property rights definition and bounding depends in part on the value of the asset to be traded (Demsetz 1967). Higher valued assets merit more investment in measurement and demarcation to protect them from other claimants and to promote market trading by generating information about the asset. Market transactions, in turn, raise asset values by facilitating its reallocation to those who value it more highly than current owners.

For these reasons, metes and bounds limits market trades because outsiders have little knowledge of local conditions and topography to determine the exact location and nature of parcels to be traded. Moreover irregularly-shaped, scattered small plots may limit cultivation and pasturing practices that allow for economies of scale and use of mechanized capital equipment, as well as raise overall fencing and bounding costs relative to more consolidated, regularly-shaped parcels.

Although MB has dominated in history, people have occasionally used more systematic demarcation methods. [3] These have tended to be rectangular, much like the modern US system, and can be found in many parts of the world. In the ancient world the most famous of these was 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; Dilke 1971). 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 an axis intersected at a right angle making four quarters. Unlike the US practice, however, centurialism was not designed for continuous stretches, but rather was reinitiated at each new cross-point and thus varied somewhat with natural land features. In addition centuria were not always aligned on a north-south axis but rather were aligned for topographical reasons (e.g., water drainage). Today, traces of centuriation (in the form of rectangular plots and field) have been found in northern Italy, Braga in Portugal, Chester in England, Tarragona and Merida in Spain, Cologne and Trier in Germany, and Carthage in Tunisia (Stanislawski 1946). Other RS were present in ancient India and the Indus Valley.

Based on the theoretical framework and cases discussed in this chapter, we are able to draw some conclusions about when a rectangular system will be chosen over the more common metes and bounds system. First, RS is more likely when some party or organization is in a position to capture the overall gains of the 'grid', such as a government or urban/rural land developer. Second, RS is more likely when the land has high potential market value under the grid, such as urban/suburban properties. Third, RS is more likely when the upfront costs of the RS are relatively low. This situation can occur when the land is relatively flat; when the land is not already demarcated as MB;[4] when the land is occupied and demarcated as MB, but current occupants have no political standing (e.g., after an invasion and capture); or when infrastructure such as roads have not been established. Figure 13.1 shows an early example of rectangular property demarcation under Roman law. Table 13.1 summarizes features of the major historical and contemporary rectangular systems.



Note: Latitude and Longitude: 36°N 10°E.

Source: Google Earth.

Figure 13.1 Roman rectangular demarcation in present-day Carthage, Tunisia

A. Land Demarcation in the United States

As indicated in Figure 13.2, the United States uses both metes and bounds and rectangular systems. Metes and bounds generally is dominant in the original 13 states as well as Hawaii, Kentucky, Maine, Tennessee, Vermont, and West Virginia. Further, metes and bounds were used where Spanish and Mexican land grants were prevalent in parts of Texas, New Mexico, Arizona, and California. The rest of the US, as well as parts of Canada, Australia, New Zealand, and South Africa, is covered by RS (Powell 1970; Williams 1974).

Metes and bounds

The use of metes and bounds was brought to North America from practices in Europe (Price 1995: 11). Land availability was the most important lure in the decision to migrate and immigrants needed a familiar means of marking their land claims in the new land: '[i]mmigrant colonists gazing at a wilderness envisioned its taming and imagined new markets bounding the edges of their own fields and meadows. The men who could measure the metes and bounds of those fields held the key to transforming a worthless, uncultivated territory into individual farms' (quoted in Kain and Baigent 1992: 265). The idiosyncratic and localized nature of MB demarcation is illustrated in the following quote:

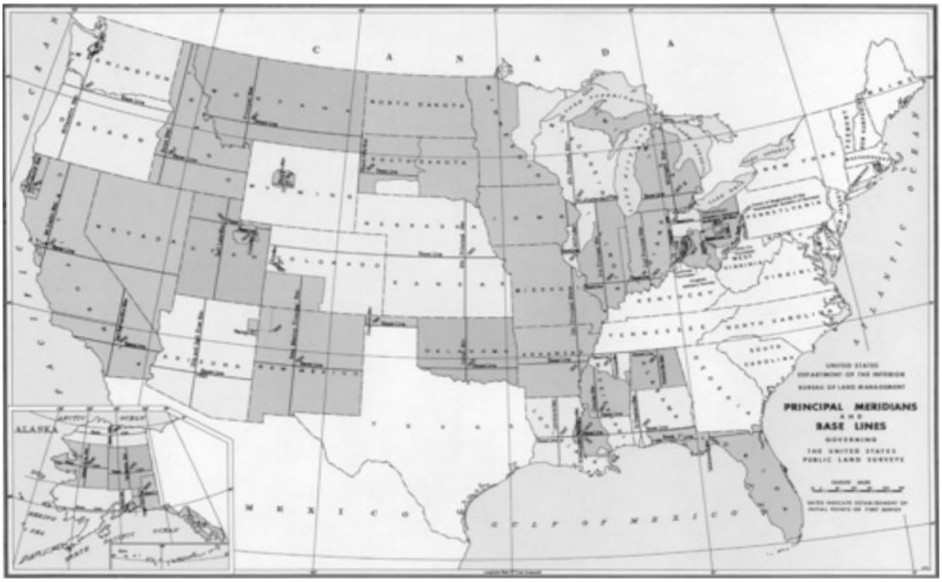
Table 13.1 Rectangular demarcation systems around the world

Location (authority)	Date	Parcel Shape	Dimensions	Alignment
Greece	479 BC–c.146 BC	Rectangle	Not uniform	Unknown
Ancient 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 (federal government)	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 (1971, 1985); Dutt (1925); Jeans (1966); Johnson (1976); Kain and Baigent (1992); Marshall (1931); Nelson (1963); Stanislawski (1946); and Wainright (1956).

> Beginning at a white oak in the fork of four mile run called the long branch & running No 88° Wt three hundred thirty eight poles to the Line of Capt. Pearson, then with the line of Person No 34° Et One hundred Eighty-eight poles to a Gum on the So Wt side of the run corner to persons red oak & chestnut land, then down the run & binding therewith So 54° Et Two hundred & ninety poles to the beginning, Containing One hundred Sixty six Acres, [Stetson (1935: 90)]

As described above, MB systems were characterized as 'unsystematic' or 'indiscriminant' because the land was not surveyed prior to occupation and because the surveys were not governed by a standardized method of measurement or shape. Metes and bounds was especially common in frontier regions of the southeastern US where land quality varied, where native opposition to settlement was more muted than in the North,



Source: Bureau of Land Management website: www.nationalatlas.gov/articles/boundaries/a_plss.html.

Figure 13.2 Land demarcation systems in the US and the location of principal meridians and baselines under the rectangular survey

allowing for sporadic, dispersed holdings, and where the climate accommodated small-scale, subsistence agricultural production in the interior. Indeed, the two major land demarcation systems in the British North American colonies were the New England system with townships as discussed below and the Virginia system of metes and bounds. Both initially used the same survey technologies (Gunter's chain) and defined holdings in acres (Kain and Baigent 1992: 268).

Figure 13.3 shows Gunter's chain which was developed in 17th century England, and was an indispensable tool for all surveyors in the colonial US because it provided for the standardized measurement land for survey (Linklater 2002: 5). One chain equaled four rods (16 ½ feet, 22 yards, 66 feet or 1/80th of a mile). Each chain equals 100 links with each link 7.92 inches and 1 square link is 1/100,000 of an acre.[5] As settlement increased over time and as land values rose, there was a need to update survey instructions and practices, leading to the publication of numerous surveying textbooks in the mid 18th century, such as John Carter's *Young Surveyor's Instructor: or, An Introduction to the Art of Surveying* and Robert Gibson's *Treatise of Practical Surveying* (Kain and Baigent 1992: 268).

In the southern colonies, most land was distributed to individual settlers via headrights, whereby individuals could receive warrants for 500 or more acres of land. Under MB, migrants could move inland; pick and chose their parcels; and stake their claims individually, with little coordination with their neighbors. Once the periphery of their land holdings was marked on trees and rocks, claimants would file their warrants and land claims at local government land offices and have the boundaries surveyed. Once

Source: www.tngenweb.org/tnland/terms.htm, accessed on January 29, 2010.

Figure 13.3 Edmund Gunter's chain

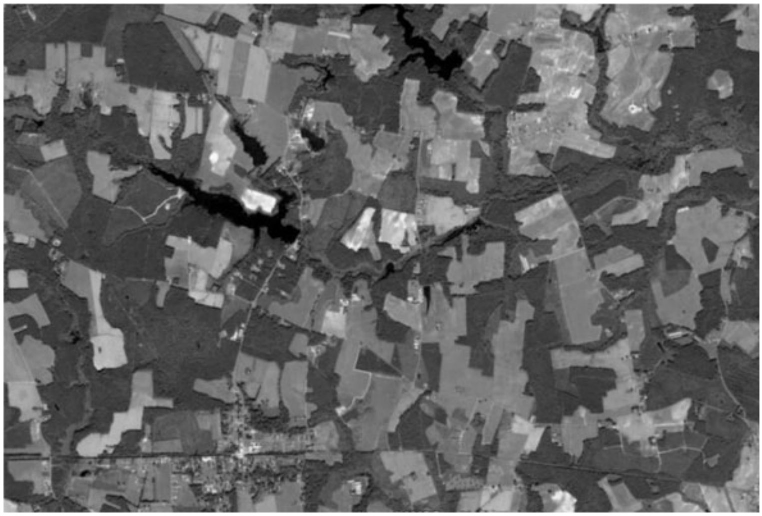
surveyed, title could be granted (Linklater 2002: 37; Kain and Baigent 1992: 273). Figure 13.4 shows the pattern of land parcels that developed in Virginia where metes and bounds were used.

Other systematic land demarcation systems

On very productive alluvial land along rivers, where land values were high, particularly in Virginia, Louisiana, Texas, and along the Ohio River long lots were used rather than metes and bounds. Long lots involved more systematically surveying plots of land with axes perpendicular to the river. Long lots were long rectangles of generally definite shapes and boundaries. They facilitated river access for transport and cultivation of the land, and reduced the potential for disputes. Long lot practices were recognized in both Spanish and French land grants (Kain and Baigent 1992: 279). Figure 13.5 shows a map of long lot demarcation in southern Louisiana where the French long lot system was established.

More systematic demarcations of property boundaries also were found in parts of the northern colonies. In the New England colonies of Massachusetts Bay, Rhode Island, coastal New Hampshire and Maine, as well as the Connecticut Valley, the frontier was more constrained by hostile natives, climate and topography than in the South. Accordingly, coastal and valley land values were somewhat higher and the need for coordinated settlement greater. We address these issues in more detail below.

Under the New England system, townships, generally of 6 square miles, were granted



Note: Latitude and Longitude: 36°N 76°W.

Source: Google Earth.

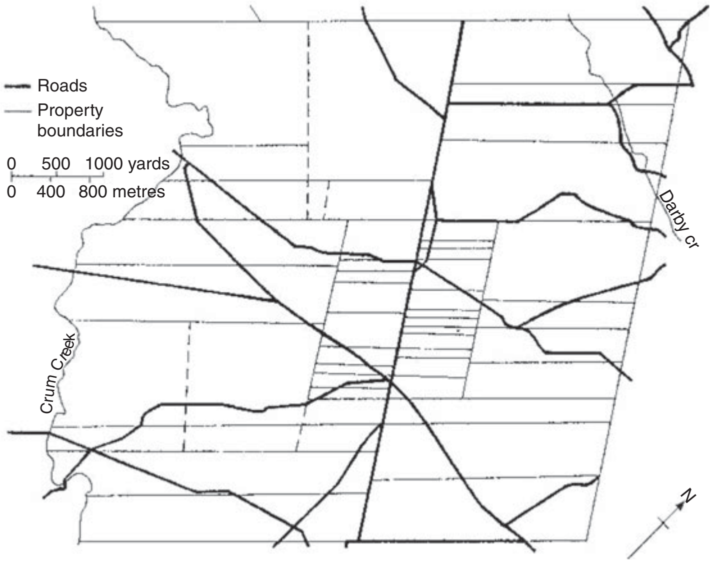
Figure 13.4 Land parcels under metes and bounds in Walters, Virginia

Note: Latitude and Longitude: 31°N 92°W.

Source: Kain and Baigent (1992: 280) and Google Earth.

Figure 13.5 Long Lot Demarcation in Cheneyville, Louisiana

to groups of settlers for occupancy after survey. The internal parcels were not always uniform in shape or size, but were less irregular than found under the Virginia system (Kain and Baigent 1992: 285–6; Price 1995: 27–85). They encouraged denser development and followed the English open-field village model (Price 1995: 32, 44–7, 54, 58). Outside of these settled towns, however, lands in New England were demarcated under metes and bounds (Price 1995: 82).



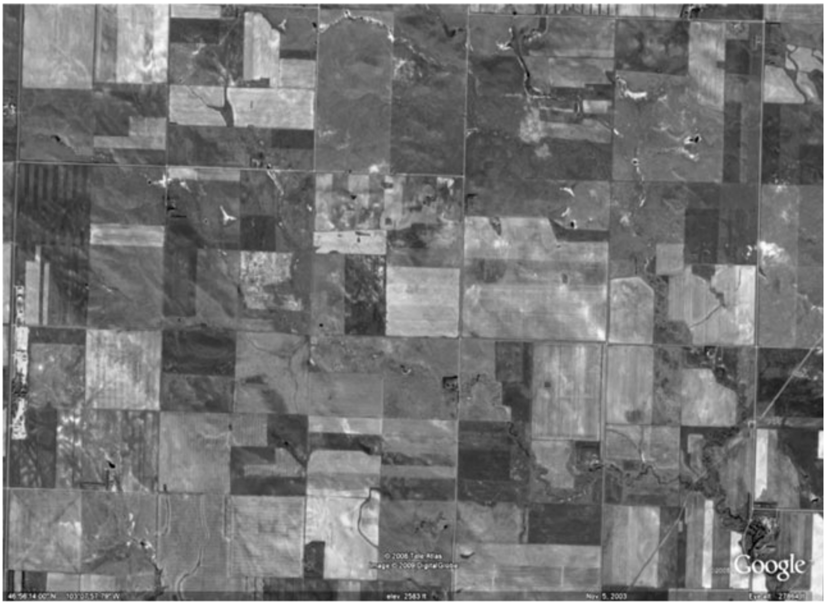
Source: Kain and Baigent (1992: 286) and Google Earth.

Figure 13.6 Demarcation under the William Penn Land Grant

Somewhat similar practices were followed in eastern Pennsylvania by William Penn: 'We do settle in the way of Township or Villages each of which contains 5,000 acres, in square and at least Ten Families . . .' (Kain and Baigent 1992: 287; Price 1995: 259–61). Although metes and bounds were common in New York state, in northwestern New York, rectangular systems were also used by land developers. These developers purchased large tracts of land from the Iroquois, and also secured other large military tracts, and then, divided these large properties into townships and surveyed them before sale. For example, in subdivisions, such as Cooper's tract, a rectangular grid was used dividing the land into 100 square lots of up to 600 acres each and then marketed to settlers (Price 1995: 232–6). In Ohio, the Ohio Company of Associates secured 1,000,000 acres of land divided into townships 6 miles square from the federal government in 1787 and followed the same procedures as the government in surveying and selling the property as a grid (Linklater 2002: 81). Figure 13.6 shows land demarcation in eastern Pennsylvania in the late 17th century. While the borders are linear they are not aligned north–south, nor are the parcels the same size and shape.

A. The rectangular survey in the United States

The geographical extent of metes and bounds in the United States was halted by the enactment of the Land Ordinance of 1785. The 1785 law required that the federal public domain be surveyed prior to settlement and that it follow a rectangular system. Land sales were 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.



Note: Latitude and Longitude: 47°N 104°W.

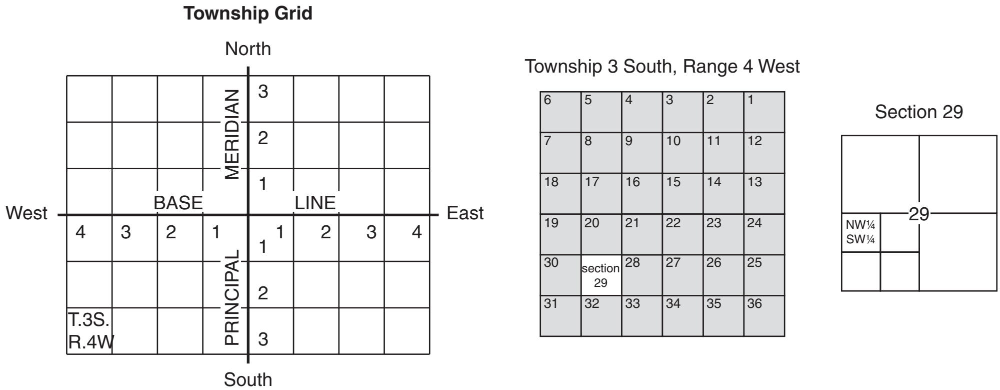
Source: Google Earth.

Figure 13.7 Land demarcation in the US under the federal land survey in Belfield, North Dakota

The rectangular survey, as the RS was called in the US, west and north of the Ohio River and west of the Mississippi north of Texas as indicated in Figure 13.2. This rectangular survey system uses a surveyed grid of meridians, baselines, townships and ranges to describe land (Brown 1995; Dukeminier and Krier 2002; Ellickson 1993; Estopinal 1998; Hubbard 2009; Pattison 1957b; Thrower 1966; White 1983).[6] Figure 13.7 illustrates the regularity provided by this RS.

The survey began with the establishment of an Initial Point with a definite latitude and longitude. Next, a Principal Meridian (a true north–south line) and a Baseline (an east–west line perpendicular to the meridian) were run through the Initial Point. On each side of the Principal Meridian, land was divided into square (6 miles by 6 miles) units called townships. A tier of townships running north and south was called a 'range.' Each township was divided into 36 sections; each section was one mile square and contained 640 acres and 160 square rods. These sections were numbered 1 to 36 beginning in the northeast corner of the township and ending in the southeast corner.

Each section can be subdivided into halves and quarters (or aliquot parts). Each quarter section of 160 acres was identified by a compass direction (NE, SE, SW, NW). Each township is identified by its relation to the Principal Meridian and Baseline. For example, the seventh township north of the baseline, third west of the Principal Meridian would be T7N, R3W, 6th Principal Meridian. There are 37 sets of Principal Meridians/ Baselines – 34 in the continental United States and 3 in Alaska. Figure 13.2 shows the



Source: Merrill and Smith (2007).

Figure 13.8 Details of US rectangular demarcation system

Principal Meridians and Baselines for the lower 48 states. Figure 13.8 shows the details of the rectangular system.

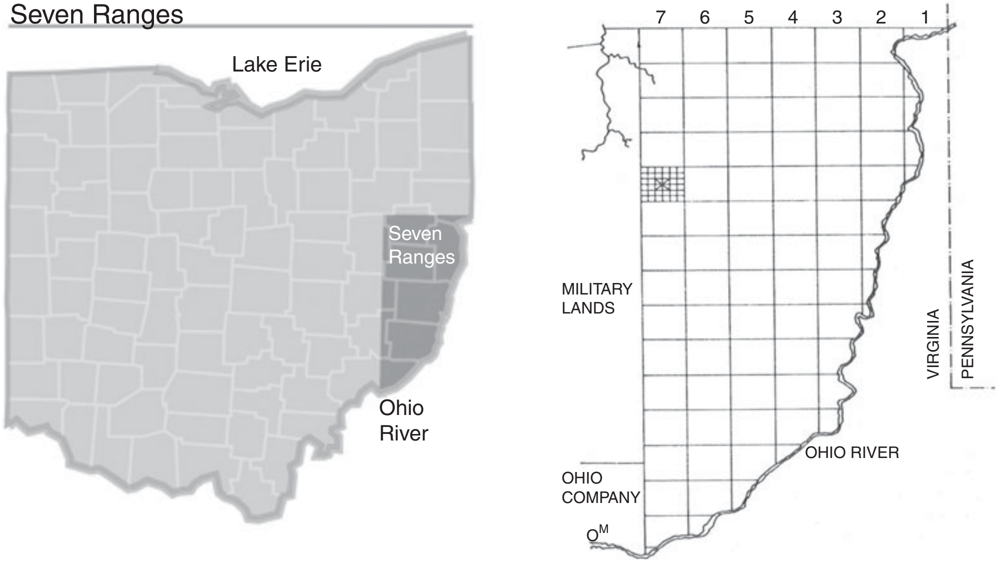
In the fall of 1785, the survey for this system began in Ohio on the border with Pennsylvania at what is now called the *Point of Beginning* (Linklater 2002: 71). The first townships to be surveyed are known as the 'Seven Ranges' (a north–south tier of townships) in eastern Ohio. Ohio was surveyed in several major subdivisions, each with its own range and base descriptions. Figure 13.9 shows the initial federal survey at the *Point of Beginning*.

The early surveying, particularly in Ohio, was performed with more speed than care, with the result that many of the oldest townships and sections vary considerably from their specified shape (square) and area (640 acres). Proceeding westward, accuracy became more of a consideration than rapid sale, and the system was simplified 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, explaining why there are many rectangular counties in the western two-thirds of the nation (Stein 2008). There are no federal meridians or baselines in Texas because there were no federal lands in Texas. Instead, Texas has its own system of land demarcation that is similar to, but not part of, the US rectangular system.[7]

Under the federal rectangular survey, the land was surveyed before any settlement, by first marking out corners at the interval of every mile along the boundaries of the townships usually with monuments or notches on trees to establish the grid (Pattison 1957a: 159, 164). Initially, all surveys were to be done by surveyors hired by the Geographer of the United States (White 1983: 14).

Rectangular systems in Canada and Australia

In the modern era several other countries have also adopted rectangular systems, primarily countries once part of the British Empire where immigration took place to secure land and where land markets developed as an essential part of the new economy.[8] As early as 1783 there was some rectangular demarcation in Canada. 6x6



Sources: Morris (1994); and www.ohiohistorycentral.org/image.php?img=634 (accessed on October 17, 2008).

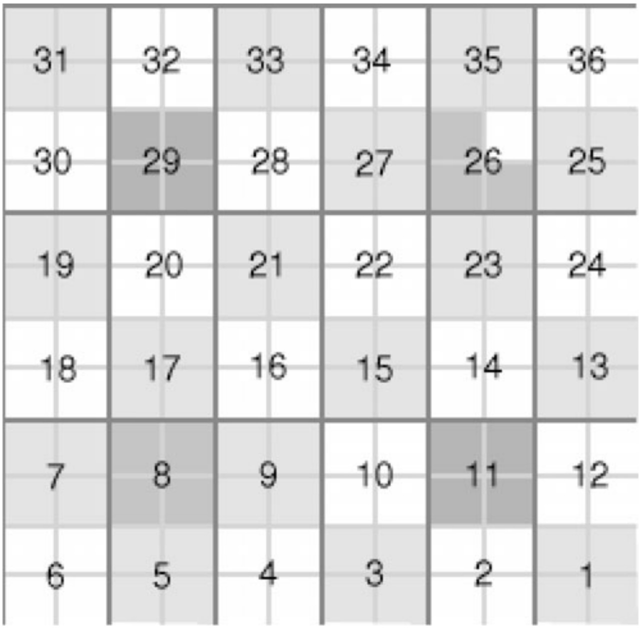
Figure 13.9 Map of Ohio showing the Seven Ranges and the Point of Beginning

mile townships were laid out in Ontario (Kain and Baigent 1992: 298). The township was the settlement unit adopted for the area along the upper St. Lawrence River. After 1784, the township dimensions were increased to 9x12 square miles. Unlike in the US the Canadian surveys experimented with different dimensions and internal subdivisions until the 1860s.

In 1869 the system of land survey mandated 9-mile square townships and 600 acre sections in ranges running east and west of the Winnipeg Meridian. In 1871 the Dominion Land Survey was established and the dimensions were reset at 6x6 mile townships to conform to the US on the southern border with the state of Minnesota and the Dakota Territory (Kain and Baigent 1992: 303). Canada was competing with the US for settlers to the prairies and likely sought to have similar demarcation practices.

The Dominion Survery began on July 10, 1871 and divided the land into one square mile sections.[9] As in the US system, there were Meridians running north–south and Base Lines running east–west. The only difference was that the section numbering system started with Section 1 in the southeast corner of the township rather than the northeast corner as shown in Figure 13.10.

In Australia a rectangular system was established in the state of New South Wales (Kain and Baigent 1992) in 1821. At that time Governor Brisbane set out to survey land following the American system identically with 6x6 mile townships. Later, however, Governor Darling came from London with a new set of instructions. These townships were abandoned and there were introduced 40 mile-square counties, 10 mile-square hundreds and 25 square-mile parishes to facilitate the creation of contiguous and close settlements (Kain and Baigent 1992: 309). These competing policies did not use a common



Source: http://en.wikipedia.org/wiki/Dominion_Land_Survey.

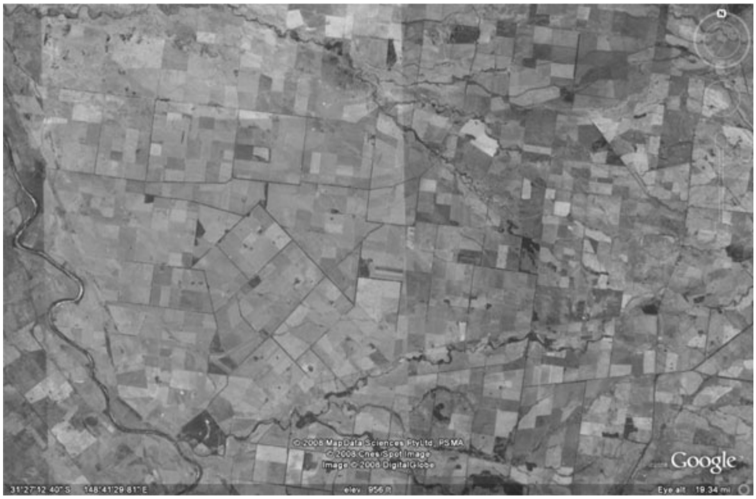
Figure 13.10 Section numbering system according to the Canadian Dominion Land Survey

baseline and meridian to reference the coordinates, and hence what became of it was a series of regional grids with confounding alignments as seen in Figure 13.11.

Urban land demarcation patterns

In western North America where the rectangular demarcation has been established on a continental scale there are many cities, such as Chicago, San Francisco, Phoenix, Denver, and Calgary, with grid systems. These were all settled to be commercial centers and land markets were active. There are, in addition, examples of rectangular demarcation in cities surrounded by metes and bounds demarcation. These include New York City, Barcelona, Philadelphia, Brasila, and elsewhere.[10] Such urban rectangular systems have been established by local governments and by private developers, typically with the intention to increase commercial activity.

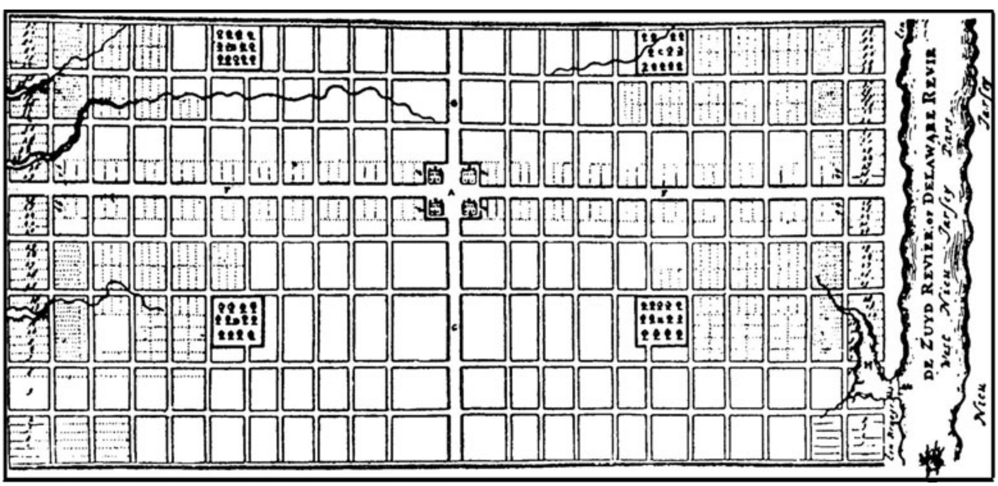
Philadelphia. In 1682 William Penn, who held the royal charter to Pennsylvania, drew up a plan for the new settlement of Philadelphia, which was to be the market center of the new colony. He instructed three commissioners to lay out a city 2 miles long and 1 mile wide stretching across a peninsula between the Delaware and Schuylkill Rivers. There were to be two main cross streets, each 100 feet wide, 8 east–west streets and 20 north–south minor streets that were each to be 50 feet wide. The main central square was 10 acres and 4 minor squares were 8 acres each (Morris 1994: 339). Figure 13.12 shows the layout of his plan.



Note: Latitude and Longitude: 32°S 147°E.

Source: Google Earth.

Figure 13.11 Rectangular demarcation in New South Wales, Australia



Source: Morris (1994).

Figure 13.12 William Penn's plan for Philadelphia

New York City. Unlike Philadelphia, New York started without a plan and was settled under metes and bounds for roughly 150 years. By the late 18th century the city was spreading northward in a tangle of independently laid-out grids by developers who were converting meadows and marshland into urban real estate (Morris 1994; and Kostof

Note: Latitude and Longitude: 40°N 73°W.

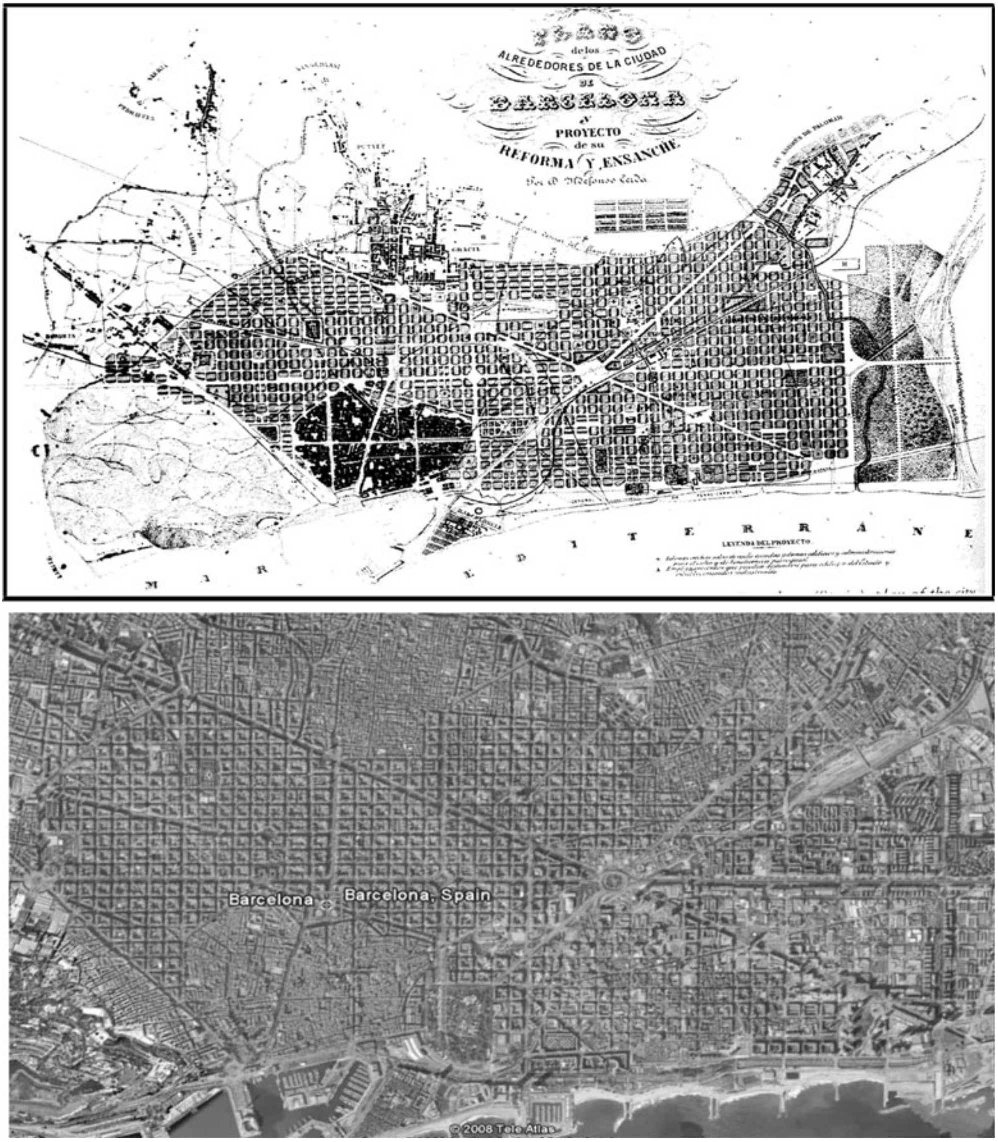
Source: Google Earth.

Figure 13.13 Rectangular demarcation in Lower Manhattan, New York City

1991: 343). In 1807 the city was authorized by New York state to appoint commissioners to plan the undeveloped parts of Manhattan Island, north of Washington Square. The Commissioners' plan of 1811 imposed a uniform grid on the rest of Manhattan. Twelve 100-foot-wide north–south avenues and 155 east–west streets 60 feet wide were established between the Hudson and East Rivers. Figure 13.13 shows a satellite picture of the grid in Lower Manhattan today.

Barcelona. The city of Barcelona in northeastern Spain developed over time in a seemingly haphazard manner typical of cities governed by metes and bounds demarcation (Kostof 1991: 152). In 1860 a government surveyor Ildefonso Cerda y Suner was given government authority to demolish old and obsolete fortifications of the city and create a general plan for future commercial growth. Ildefonso Cerda began to spread a grid across 10 square miles of flat land. According to his plan, streets were to have an equal width of 66 feet each and square blocks would have cut-off corners to match this width. Figure 13.14 shows Cerda's plan and a satellite picture of modern Barcelona. The plan depicts the irregular pattern of the medieval city core (dark area at the lower left) as being sliced by the grid of boulevards.

Chandigarh, India. India is a country dominated by metes and bounds demarcation, and its cities are notoriously confusing and congested. Chandigarh, the capital city of the northern state of Punjab, however, is unique within this larger system (Kostof 1991).[11] In 1951, shortly after Indian independence from Great Britain, the government assigned French architect Le Corbusier to design the city. Le Corbusier created a well-ordered matrix that comprised a regular grid of fast traffic roads that defined a neighborhood unit or 'sector'. The sectors measured 0.5 miles by 0.75 miles on a NW–SE alignment. Each block was bisected by one major market street, forming a linear shopping system.



Note: * Latitude and Longitude: 41°N 2°E.

Source: Kostof (1991); and Google Earth.

Figure 13.14 Cerda's plan for Barcelona, Spain and satellite picture of the city*

The civic center was at the intersection of the two major axes just like a forum in a Roman grid system.

The governmental complex was designed on a module of rectangles measuring 800 meters by 400 meters. The residential pattern was characterized by a loose grid pattern of primary roads that defined super-blocks. There were also provisions made for green belts, sites for schools and sports facilities. Figure 13.15 shows the plan and a modern satellite photograph.

III. AN ECONOMIC FRAMEWORK FOR UNDERSTANDING LAND DEMARCATION

In this section we develop an economic framework for understanding the functions and impacts of land demarcation systems. We focus on rectangular and metes and bounds systems but also consider land demarcation as an economic choice more generally. 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 a centralized and coordinated land demarcation system that governs a large region. In this analysis we focus on the particular features of the American rectangular system.

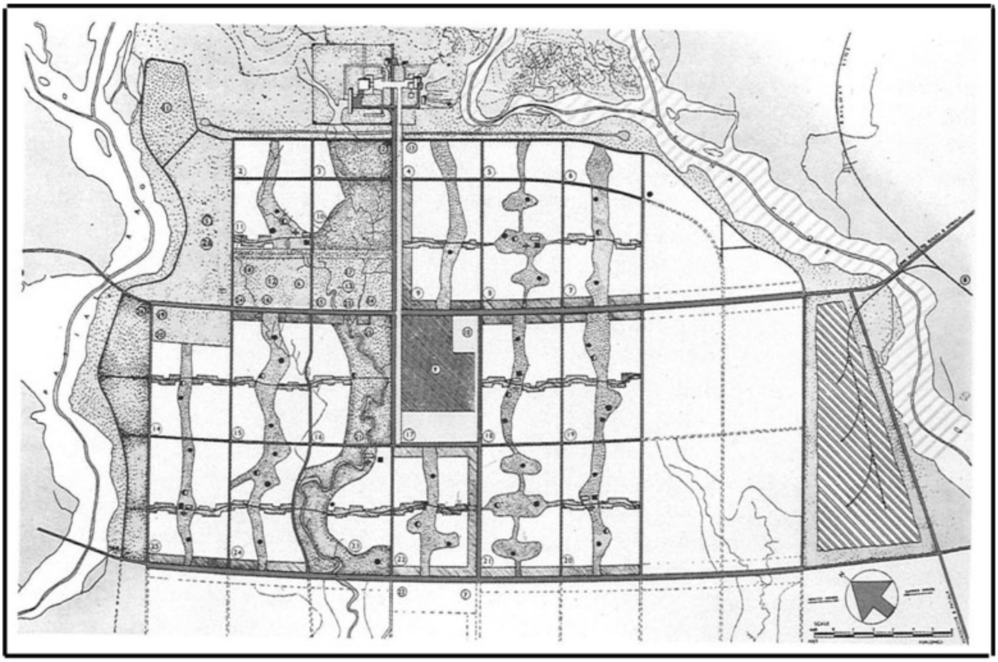
A. Land Demarcation in a Decentralized System

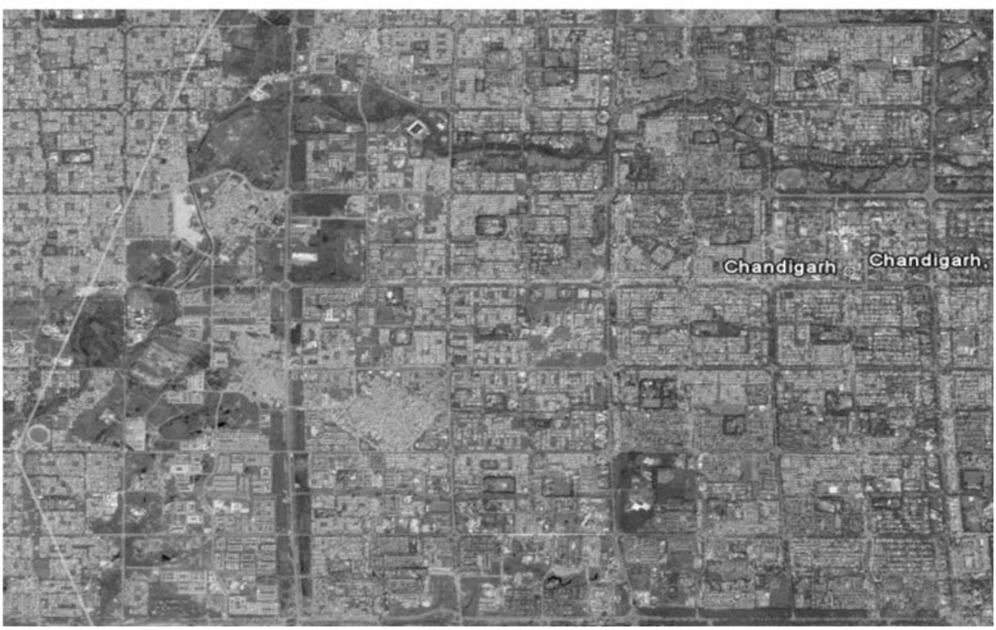
Consider a large tract of land available to a large group of potential claimants, where the external boundary is enforced collectively or otherwise, so that only internal and shared borders are considered by individual decision makers. Within the external borders, there is no coordination or contracting among claimants.[12] In the simple case where all claimants have the same productivity and the same enforcement costs, the problem for each party might be to simply minimize the border demarcation and enforcement costs, constrained by the productivity of the land. Alternatively the question is what shape generates the largest area (and thus the lower enforcement costs per area) for a given perimeter – this is the ancient and famous *isoperimetric problem*.[13]

The answer to the isoperimetric 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. Figure 13.16 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. A square parcel with a 4 mile perimeter will have an area of just 1 square mile. Figure 13.16 also shows the same 5 mile by 5 mile landscape with hexagons and triangles.

However, the enforcement cost function is likely to be more complex than simply minimizing the perimeter for a given area. Further, as Figure 13.16 shows circular plots leave large areas of unclaimed land. In fact the unclaimed corners in the circular pattern amount to about 22 percent of the total tract.[14] 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 or if the circular claims overlapped rather than were perfectly adjacent as in Figure 13.16.

Given these problems with a circular landscape, we narrow the set of plausible equilibrium parcel shapes to regular polygons. Regular polygons maximize the area enclosed by a given perimeter (Dunham 1994) and have the potential to eliminate open access

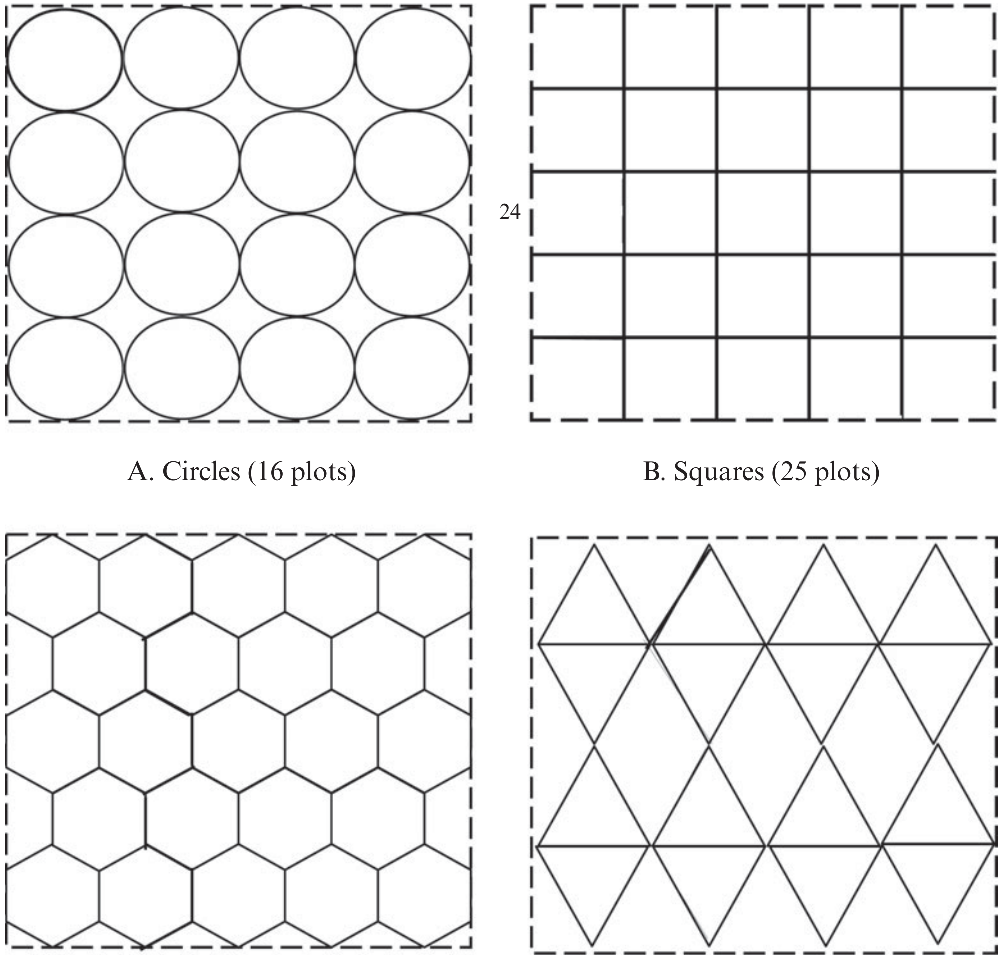




Note: Latitude and Longitude: 30°N 76°E.

Source: Kostof (1991); and Google Earth.

Figure 13.15 Chandigarh, India: Le Corbusier's plan for and current satellite view

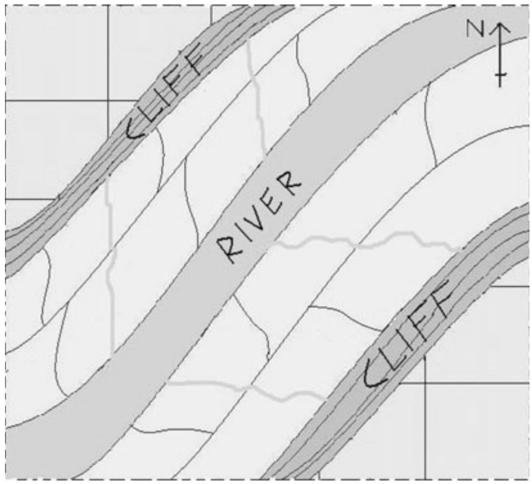


Source: Authors' calculations; also in Libecap and Lueck (2009).

Figure 13.16 Possible parcel configurations

waste between parcels within a given tract. In fact, there are only three regular polygons – triangles, squares, and hexagons – that will allow patterns, with a common vertex, that have no interstices (space) between the parcels.

The choice among triangles, squares, and hexagons can be examined by further analysis of enforcement costs and the economic value of alternative shapes. The perimeter to area ratio (*p*/*a*) generates the following ranking from lowest to highest: hexagons, squares, triangles. The number of shared borders may affect enforcement costs. 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. In addition square parcels are likely to have more efficient shapes for productive uses such as agricultural fields and urban buildings compared to triangles and hexagons.



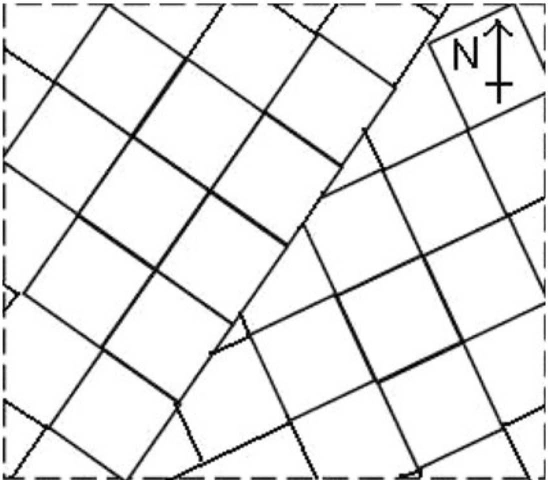
Source: Authors' creation.

Figure 13.17 Decentralized claiming in non-planar topography

This discussion implies that 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. Under these conditions a decentralized MB system could lead to individual square plots like a RS system.

Adding heterogeneous terrain and heterogeneous claimants (either in land use value 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 surveying or fencing or road building costs), we would expect borders to roughly follow the topography. 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 13.17 shows such a case where rugged topography makes linear boundaries too costly so that boundaries are square only on the flat plateau but are irregular in the canyon itself. The canyon itself might remain as unclaimed open access land. Thus we also expect that 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.

We thus expect a pattern of parcel sizes and shapes that depends on the character of the land (topography, vegetation, soil) and of the potential claimants (farming productivity, violence and monitoring productivity, and so on). Adding land heterogeneity (river, broken terrain) leads to non-linear claims as well as unclaimed areas – the so-called 'gaps and gores' described by many historians of MB land systems. This illustrates a tradeoff between the two systems. With RS plots of land are created as squares, irrespective of the quality and features of the land. With MB, however, plots are separated into attractive and unattractive plots. RS then avoids the problem of later conflict over these areas,



Source: Authors' creation.

Figure 13.18 Colliding rectangular demarcation systems with decentralized alignment

while RS requires that even currently unvalued areas be claimed and enforced within a larger plot. We examine these implications in Section IV below.

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 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 results in similarly aligned properties and avoids the gaps of unclaimed land that arise when unsynchronized demarcation systems collide.

Consider adjacent areas settled under metes and bounds. Even with homogeneous terrain (flat, uniform) and homogeneous claimants, there is no reason to expect these patterns of squares to be aligned in the same direction as nearby claims without some sort of convention or other coordinating device. Without such coordination, individual rectangular claims or clusters of claims could collide with other such claims at odd angles, thus creating a series of slivered triangular parcels which are expected to be less valuable. A north–south or other uniform alignment then requires either a social convention or centralized direction.

Figure 13.18 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. Finally, a coordinated survey of heterogeneous land prior to allocation fixes individual land claim borders and avoids the incentives of claimants to initially 'float' boundaries to cover the most productive land. Such opportunistic border adjustments could result in long-term border and ownership disputes among adjacent properties.

C. Land Demarcation in a Rectangular System

Many possible centralized land demarcation systems can be imagined and some historical rectangular systems were noted above. The American RS is a particular type of centralized land demarcation system. 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 (size of squares), implementing the survey (determining initial points and conducting the surveys), and controlling access until the survey was completed. Generally, because of these costs, only agents who expected to internalize gains of an RS would adopt such a system. Their returns would accrue through the revenues of land sales to claimants who did not have to bear individual survey costs and who benefitted from the other advantages of the rectangular survey. This implies that large land holders, such as sovereign government, rural land and suburban developers or other organizations where entry could be controlled, would adopt a rectangular survey.

The effects of the American rectangular survey have been discussed by historians and geographers but there is no literature on how the rectangular survey might affect 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). Expanding the market and lowering transaction costs should make it cheaper for land parcels to be reorganized as market conditions change. This should be observed as a greater number of transactions such as mortgages and conveyances per unit of 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. This discussion implies that there will be certeris paribus: 1) more land transactions under the rectangular survey than under metes and bounds; 2) less variance in the size and shape of parcels under RS than MB; and 3) higher (per acre) land values under the rectangular survey than under metes and bounds.

The clarity and linearity of the rectangular system are also expected to have an impact on public infrastructure such as roads and other systems that require long right-of-way stretches. Identification of property lines is likely to be cheaper and contiguous linear borders should lower the cost of assembling such rights of way even if eminent domain is required. This implies that there will be more roads per unit of land under the rectangular system than under metes and bounds. Because surveys are standardized and aligned under the RS, there are no unclaimed gaps or gores in property claims. RS also brings coordinated survey and fixed boundaries. These factors imply there will be fewer legal disputes (and litigation) over boundaries and titles under the rectangular survey than under metes and bounds. These implications are tested in Libecap and Lueck (2009), and generally there is strong empirical support for the hypotheses.

Modern Geographic Information Systems (GIS) could potentially allow for the more precise positioning and demarcation of land thus reducing some of the costs of metes and bounds. But, as we discuss below, the coordinating function of a large scale rectangular survey remains an important advantage in avoiding conflicting or overlapping boundaries, in providing usable and recognizable parcel shapes and sizes, in reducing the amount of initially unclaimed gaps of land unmarked and costly to place into production, and in providing a clear set of addresses for all parcels, regardless of location and terrain.

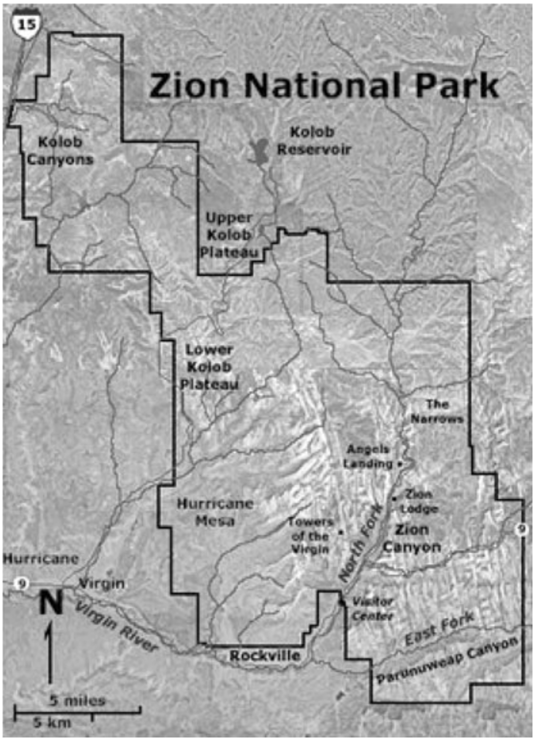
To this point we have stressed the benefits of the rectangular system over metes and bounds but we have ignored the costs of establishing such a centralized and systematic regime. In cases of rugged or extreme terrain forcing a square grid on the landscape can lead to extremely costly surveys, fence 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, in rugged terrain in the US, even using the RS, 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 (forests, national parks) the rectangular survey system might lead to overinvestment in land demarcation. Note that the borders of such US National Parks as the Grand Canyon, Mount Rainier, and Yellowstone have linear borders even in some of the most rugged terrain. Yellowstone and Mount Rainier are virtually squares, while others comprise combinations of linear and geographic borders. Figure 13.19 shows Zion National Park which is extremely rugged terrain (in southwest Utah), yet its border is almost completely comprised of linear segments.

IV. ECONOMIC IMPLICATIONS AND ECONOMIC HISTORY

The framework we developed above generates a wide range of implications for both the choice of land demarcation systems and the effects of those systems. In this section we examine some of the economic history of land demarcation systems in light of these implications. We divide this analysis into four sections. First, we examine land demarcation under metes and bounds. Second, we examine the determinants of the adoption of rectangular demarcation in the United States and some of the effects of this system. Third, we examine rectangular demarcation systems in urban areas and in areas outside the United States. Fourth, we examine the rather unique system of circular land demarcation in Cuba that illuminates many issues discussed above.

While we use a variety of data sources in this section a significant portion of our findings are from south central Ohio, where the Virginia Military District, a region of 4.2 million acres and 22 counties totally or partially within it, was governed by metes and



Sources: www.utah.com/maps/zion/index.htm.

Figure 13.19 Border of Zion Canyon National Park, Utah

bounds, while the federal rectangular survey governed the remaining 22 million acres and 66 counties in the state.[15] These two land 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.

A. Demarcation under Metes and Bounds

Under metes and bounds demarcation individuals choose and shape parcels more or less unconstrained by explicit links to other existing or potential landowners. A number of choices can be examined including the size and shape of the parcels, the alignment of the parcels, and the disputes over borders. All of these are examined below and compared ultimately with these choices under rectangular demarcation.

Size and shape of parcels

In Section III we hypothesized that 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. Conversely, we hypothesized that with heterogeneous land and parties a decentralized metes and

A Parcel boundaries in flat topography (Highland and Clermont countries)

B Parcel boundaries in rugged topography (Pike County)

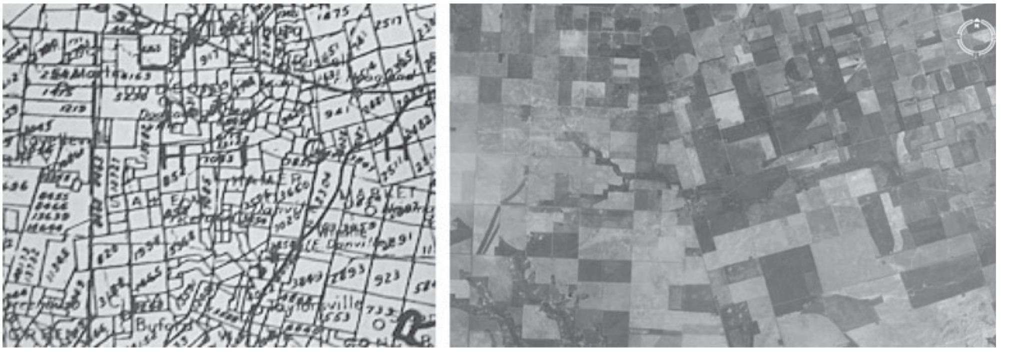
Source: Libecap and Lueck (2009).

Figure 13.20 Topographic and demarcation correlation under metes and bounds

bounds system will yield a land ownership pattern of parcels whose borders mimic the topography and vary in size with no particular alignment.

We can examine these implications through visual inspection of topography and parcel size and shape within the central Virginia Military District of Ohio where metes and bounds was used to demarcate property. Figure 13.20, 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 Virginia Military District there were large sections of land that had been assembled by speculators who purchased warrants from veterans. The pattern shows evidence of organized grid-like surveying of small blocks of land, where groups of tracts are aligned in the same directions, but not typically north–south as in the rectangular system.[16] In the case where different grids abut one another, the results are triangular parcels, some of which were unclaimed originally.

Panel B shows a similarly sized area in Pike County (eastern Virginia Military District) 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.



A Virginia Military District B Crowell

Note: Latitude and Longitude: 33°N 99°W.

Source: Libecap and Lueck (2009); and Google Earth.

Figure 13.21 Colliding Tracts of Rectangular Parcels in the Virginia Military District (Highland and Clermont counties) and Crowell, Texas

Alignment of parcels

As the analysis above shows, when the land is flat we expect and find that parcels under metes and bounds tend to be rectangles and even squares. But, as we argued in Section III, without a central coordinating system it is likely that sets of square parcels will not be aligned because their original alignment will be focused on nearby settlements or transportation routes. Thus we expect to find collisions between chunks of squares and the attendant slivers of triangular parcels that result. Figure 13.21 (Panel A) again shows this in the Virginia Military District in Clermont and Highland counties, where these patterns of colliding grids are evident. A similar outcome is seen in Texas (Figure 13.21 Panel B) where there were several distinct rectangular systems.

Boundary conflicts under metes and bounds

In his examination of Ohio lands, William Peters (1930: 26, 30, 135) concluded that there was more litigation due to overlapping entries, uncertainty of location, unreliable local property markers, and confusion of ownership in the 19th century in the Virginia Military District under metes and bounds than in the rest of Ohio combined. Seeing confusion over land boundaries in Kentucky and Tennessee, Stephen Austin had Texas adopt rectangular grid surveys where possible and thereby avoided the litigation associated with metes and bounds in other southern states. As noted by Linklater (2002: 241): 'The advantages inherent in the square-based federal land survey gave the state's economy a vigor its neighbours lacked.'

The same flexibility that allowed for open entry in land claiming also encouraged boundary disputes and fraud. As Linklater (2002: 165) described: 'A metes and bounds survey did not just produce shapes that only the best surveyors could measure, it created a maze of bureaucratic form-filling that invited fraud and wholesale corruption.' Competing claimants burned blazed trees that marked parcel boundaries or moved monuments so that claims often exceeded the amounts stipulated in their warrants and no longer fitted the property description filed at the land office. The irregular shapes of land holdings made it difficult to clearly define boundaries and properties often overlapped. In eastern Georgia, where the maximum land grant was 1,000 acres, more than 100 individuals put in multiple headright claims for in total more than 100,000 acres. Georgia's area in 1796 covered 8,717,960 acres, but, as Kain and Baigent (1992: 275) report, land claims within the state exceeded 29,000,000 acres, more than three times the total land area within the state's borders.

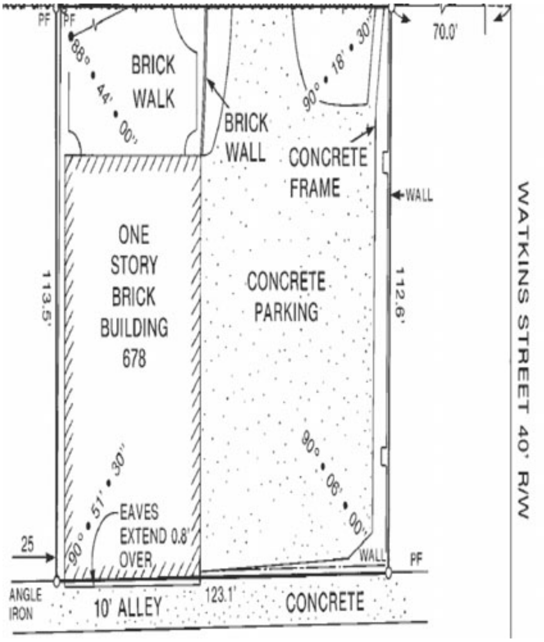
Under metes and bounds settlers had incentives to leave boundaries vague and flexible for at least two reasons. One was that in a wilderness it was costly to locate precise boundaries during the initial land claim, and hence difficult for the surveyor who followed to find those boundary markers. Second and more important, given the lack of information about the location of the most desirable lands at the time of the initial land entry, claimants did not want to be bound to absolute markers. Rather, they wanted the original boundaries left sufficiently indistinct so that they could be moved during the survey to encompass more valuable areas that had been missed. Indeed, a major reason for fragmenting holdings under MB was to secure only the best lands. These practices made boundaries much more costly to survey and mark.

Metes and bounds also encouraged property conflict because irregularities in one property's boundaries affected the perimeters of all neighboring properties. Lacking an overall framework for positioning and demarcating property boundaries under metes and mounds, each successive land claim typically was designated or 'chained' with respect to existing adjoining property descriptions, their surveys, and monuments. Consider, for example, a parcel description from one Ohio case: '[s]urveyed for Thomas Perkins, assignee 1,866 2/3 acres of land, on a military warrant, No 3,442, and part of 3,530, on the waters of Three Mile and Eagle creek, beginning at two lynns, a sugar tree and white oak, southwest corner of Humphrey Brooks' survey, 1,690; thence south 30 degrees west 227 poles to a white walnut, hackberry and buckeye, southwest corner of Benjamin Beasley's survey' (*Nash v. Atherton* (10 Ohio 163, 165 (1840)). Whenever the adjacent property corners could not be verified; when that property's survey was found to be faulty (covering too much land or land that did not fit the property description at the land office); or if the surveys overlapped, then the boundaries and titles for all of the affected, chained properties could be clouded and potentially be declared invalid by the courts because they did not conform to one another or legal descriptions.[17]

Land values in the southern frontier typically were lower than in the North, as discussed below. This situation encouraged careless survey: '[w]hen land was thought of as limitless, there was little incentive to accuracy' (Kain and Baigent 1992: 271). For these reasons, metes and bound areas, especially in the US Southeast – interior Virginia, Tennessee, Kentucky, Alabama, Mississippi, and Georgia – were characterized by land conflicts: '[i]n effect the metes and bounds system was skewed in favour of those with deep enough pockets to hire lawyers and land jobbers, and to keep sweet an army of state officials' (Linklater 2002: 166). These overlapping and confused boundaries also encouraged title disputes (Kain and Baigent 1992: 274–75).

Complexity of the metes and bounds system

Another cost of the metes and bounds system is that it is a very local system using local language and local surveys as reference points. This has two costs. First, descriptions are



'Beginning at an iron pin found on the south side of 10th Street 70 feet west of the center line of Watkins Street as measured along the south side of 10th street; thence south and forming an interior angle of 90°18'30" from 10 Street 112.6 feet to a 3 inch steel fence post on the north side of an alley; thence, west along the north side of said alley and forming an interior angle of 90°06' from the preceding call 123.1 feet to a 3 inch steel fence post; thence north and forming an interior angle of 90°51'30" from the preceding call 113.5 feet to a 3 inch steel fence post on the south side of 10th Street; thence east along the south side of 10t Street and forming an interior angle of 88°44' from the preceding call 125 feet to the point of beginning.'

Source: Hinkel (2003).

Figure 13.22 Plot description under metes and bounds, Fulton County, Georgia

simply complicated and thus costly to use and convey. Second, it is difficult for someone outside the local market to understand the nature of the property and thus to interact in the market. Local systems like metes are bounds act as barriers to entry into the land market.

As noted earlier, new technology, such as Geographic Information Systems (GIS), may mitigate some of the costs associated with metes and bounds. With GIS, individual property boundaries, demarcated by local terrain and geographic characteristics, can be determined more precisely without knowledge of narrow idiosyncratic factors. Even with this technology, the absence of a centralizing coordinating mechanism provided by the rectangular survey remains. Under metes and bounds overlapping or colliding boundaries are still possible; complex property descriptions persist; oddly shaped parcels remain; and the opportunistic bounding of the best lands leaves gaps of less desirable lands unmarked and difficult to place into effective production.

To illustrate the cumbersome nature of property description and definition under metes and bounds consider the description of a square plot of land. In the rectangular system a square plot would simply be noted, for example, as Section 12, in a certain township related to a particular principal meridian. As described above this is typically a one line address. Under metes and bounds even a simple square parcel cannot be described simply. Figure 13.22 illustrates this complexity of property demarcation under metes and bounds measurement with a lot description – of a nearly square parcel no less – in Fulton County, Georgia.[18]

B. Demarcation under the US Rectangular System

The history of the adoption and use of rectangular demarcation in the United States allows us to examine many of the implications of our economic framework. In particular we examine the forces that led to the adoption of the rectangular system and its effects on land markets, land use and land disputes.

Adoption of the American rectangular system

We argue that the RS provides a public good in terms of systematic location of properties, coordinated survey, and reduced title conflict. We also note that there are considerable initial costs associated with employing an initial rectangular survey prior to entry. These arguments 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.

The discussion of the history of the Federal Land Law of 1785 and the motivating incentive to raise revenue through the use of systematic demarcation outlined in Section III is consistent with this implication. Moreover, the use of centralized land demarcation in New England townships, the William Penn land grant in Pennsylvania, and for land company holdings in colonial New York likely reflects the ability of the parties to capture the benefits of coordinated land demarcation and settlement. Finally, these benefits are also reflected in the adoption of grids in commercial urban subdivisions, where the value of land was relatively high compared to political urban settings where other demarcation practices were used.

Between 1781 and 1802, the Federal Government acquired 267,730,560 acres of land in cessions from the states. Ultimately, with the Louisiana Purchase, annexation of Texas, acquisition of Oregon and Mexican lands, the public domain included 1,309,591,680 acres, a huge estate (Hibbard 1965: 31). Lacking other sources of revenue in the late 18th and early 19th centuries the Federal Government sought a land demarcation system that would maximize land value, while encouraging orderly, dense settlement.

The Virginia metes and bounds and the New England township system were the dominant and available competing models. Southern representatives to the Continental Congress generally supported metes and bound demarcation, but key southerners including Jefferson, Washington, and William Grayson,[19] along with northern representatives, supported the New England plan. In debating the legislation, Thomas Jefferson and others in the Continental Congress pushed for the establishment of the rectangular survey because they were frustrated with the metes and bounds system and expected a positive impact on land values that would raise federal revenues from land sales.[20] 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,' to prevent overlapping claims, and to simplify registering deeds.[21] Under this approach the US could sell land to raise money and would have the system 'decimalized.'[22] Squares also reduced survey costs because only two sides of each township and smaller parcel had to be surveyed.[23]

Alexander Hamilton stressed the importance of land sales for the US Treasury and supported Jefferson: '[t]he public lands should continue to be surveyed and laid out as a grid before they were sold.' The importance of revenue in the selection of the RS is indicated in the *Letters of the Members of the Continental Congre*ss. For example, Arthur Lee wrote to Joseph Reed on April 5, 1784: 'General Clarke, Wolcot, Green, Butler, and Mr. Higgenson are appointed to negotiate a treaty and purchase from the Indians their claims, which will secure the settlements in that Country, and enable us to satisfy the demands of the Army, and sink the public debt by the sale of the Lands. A consummation devoutly to be wished' (Burnett 1934: 485). Additionally, the New Hampshire Delegates wrote May 5, 1784: 'We flatter ourselves these Lands will prove a considerable resource for sinking the national debt, and, if rightly conducted, liten the burthens of our fellow-citizens on account of Taxes as well as give relief to the creditors of the United States.' (Burnett, 1934: 513).

Demarcation prior to settlement was also seen as a means of generating information about the value of federal lands before sale: '[i]t was pointed out that congressional surveys would disclose a great deal of valuable information concerning the western lands.'[24] Jefferson's committee also argued that survey before sale was necessary to prevent overlapping claims and to simplify registring and deeds. A rectangular system would prevent gaps and gores, making the buyer take the good land with the bad. Every man's land was to share a boundary with his neighbor's. The existence and costs of thousands of boundary disputes in the courts made the proposed rectangular system and prior survey sound attractive, even to the Southern delegates (White 1983: 9). For all of these reasons, Jefferson's recommendation became incorporated in the Land Ordinance of May 20, 1785 for disposing lands in the western territory.[25]

The gains from coordination

The coordinating influence of the federal land survey is dramatically different from what was found under metes and bounds. Instead of irregular, localized plots defined by topography and natural monuments, each property under the RS was anchored by the federal survey to a location within a specific section, township and range, such as a 80-acre tract in '. . . the west half of section 13, T[ownship] 3, R[ange] 4, east of M.D' or a 40-acre tract at 'R[ange] 4, T[ownship] 3, S[ection] 13, p. N. . .' (*Treon's Lessee v. Emerick* 6 O 391, 392) or '¼ South-West, ¼ Section North–West, Section 8 Township 22 North, Range 4 West, Fifth Principal Meridian' (Linklater 2002: 181).

Because MB demarcation defines property borders relative to neighboring properties, it is common for boundary disputes to arise and have effects even on non-adjacent properties. This cannot happen under RS because demarcation does not rely on the demarcation of other properties. Instead, the RS provided a uniform structure that coordinated the location of all parcel boundaries with respect to township and range lines that were tied to latitude and longitude coordinates. Accordingly, a property could be located precisely without resort to the knowledge of local, idiosyncratic land characteristics, trees, rocks, and other monuments. Further, all lands within the specified parcel were included, regardless of quality. It was not possible to gerrymander the claim under the rectangular system could be done under metes and bounds. As a result there were fewer gaps of unclaimed, open terrain as were common in metes and bounds. All of this likely reduced individual survey costs under the rectangular system; made boundaries and titles more definite than under metes and bounds; and removed sources of boundary and title disputes.[26]

The advantages of the RS grid were demonstrated as early as 1788 when the first patent to Ohio lands was issued at the New York City land office to John Martin who paid $640 for a square mile section: Lot 20 Township 7, Range 4. It was in the frontier but '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' (Linklater 2002: 84). This simple statement illustrates how the RS creates information that greatly expands and simplifies the market for land.

In 1787, the Northwest Land Ordinance was passed reaffirming the use of the RS called for in 1785. The rectangular survey provided for a systematic, simple, uniform method of allocating land on the frontier in a manner that could generate income for the government and at the same time meet the demand for land coming from immigrants to North America. New base lines and meridians were selected as settlement moved west.[27] These new points of origin became important starting points for surveying in new territories as the country grew and new areas were settled. The first Principal Meridian was a mile from the Ohio–Indiana border and the second Principal Meridian was placed in southern Indiana (Linklater 2002: 176–7), and they moved across the continent as indicated in Figure 13.1.

Linklater (2002: 181) describes the benefit of this regular survey system: '[t]he beauty of the land survey as refined by Jared Mansfield 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. . .'.

C. Land Markets

Because of historical accident, there is a portion of central Ohio in which the RS and MB regimes are adjacent. In short, the state of Virginia was granted ownership of 4 million acres of Ohio as compensation for its Revolutionary War veterans and settled this land using MB. This area was named the Virginia Military District (VMD). Simultaneously, the RS was implemented in the rest of the state and in the countries surrounding the VMD.[28]

Libecap and Lueck (2009) study this natural experiment in land demarcation and examine the effects of MB and RS on land disputes, values and markets, using a wide range of data from the area surrounding the Virginia Military District.

Property disputes

As Libecap and Lueck (2009) find, the Ohio courts repeatedly noted the difficulty of titles in the Virginia Military District. A typical comment was found in an 1840 property dispute from Brown County in *Nash v. Atherton* (10 O 163, 167): 'This case involves principles which are important, and upon its correct decision must depend in some measure the security of titles within the Virginia military district, which at the best, have been heretofore considered as somewhat precarious, and have been, and still continue to be, subject to much litigation.'[29]

Indistinct property boundaries resulted in competing land claims. To designate property for titling under metes and bounds and to inform subsequent locators so that they could make their own claims with respect to the property's boundaries, Ohio law required that borders be defined clearly with corner monuments, which could be natural or artificial; the direction or courses be described precisely; and the distances involved measured accurately. Unfortunately few properties met these requirements and many titles were voided. But when one property's boundaries and title were questioned, all adjacent boundaries and titles were clouded because original land entries were made with respect to one another.

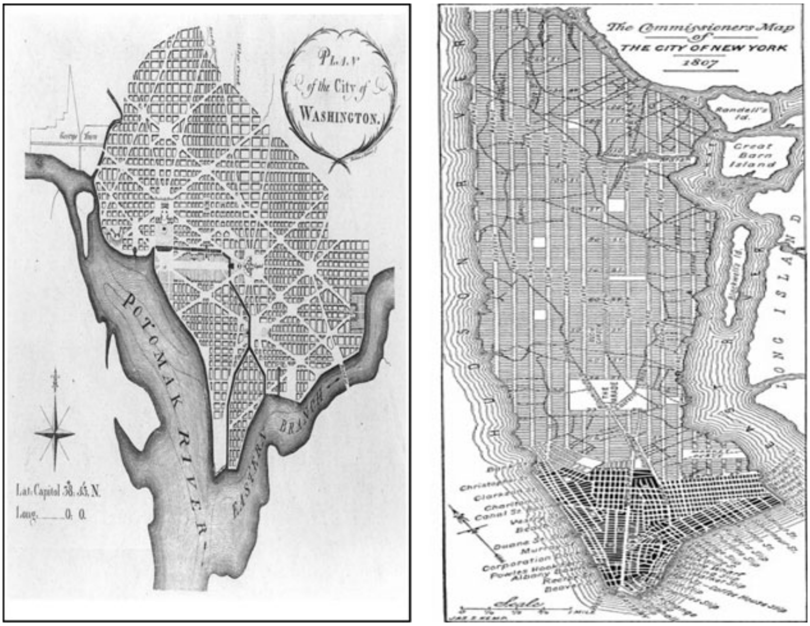
Mistakes by one surveyor or opportunism by a claimant either by over claiming beyond the amount of land authorized in the land warrant or by subsequently floating boundaries to include the best lands had a contagious effect on nearby parcels when the original property was challenged in court. Because of these linkages, the court called for definite boundaries, rejecting the common practice of adding an adjustment factor to each survey line: '[w]here a chain of entries of land in the Virginia military district are made dependent upon each other, each calling for a line of a specified distance and the next commencing at the termination of that distance, the actual location of each must be ascertained by measuring the number of poles called for in the entry. An extension of these distances is not allowable upon an alleged custom of extending at a distance of five percent.'[30]

Market transactions, land values, and infrastructure investment

Libecap and Lueck (2009) use Ohio county data from 1860 of the number of mortgages and conveyances as measures of land market activity and find that controlling for population, number of farms, farm acreage, land value, and land topography, there were significantly more mortgages per acre, land conveyances, land conveyances per acre, and per capita in RS counties relative to MB counties. When the dependent variables are evaluated at their means, counties within the RS system had 50 percent more conveyances compared to adjacent MB counties.

Using data from the 1850 and 1860 agricultural and population census manuscripts for matched parcels taken from C.E. Sherman's (1925) map of original Ohio parcels, Libecap and Lueck estimate average land value per acre by townships, controlling for a variety of natural and demographic factors, they find that the pre-acre property values were substantially higher under the RS system relative to those under MB.[31] Contributing to these surprisingly large effects of land demarcation is the finding that there were fewer roads and railroads, all else equal, in the MB regions, relative to RS areas.

Earlier, scholars of land demarcation have noted this possibility. In his detailed study of the RS and MB in parts of four counties in northwestern Ohio in 1955 Thrower (1966: 86, 88–97, 123) 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' with greater road density in the RS areas.



Source: Morris (1994).

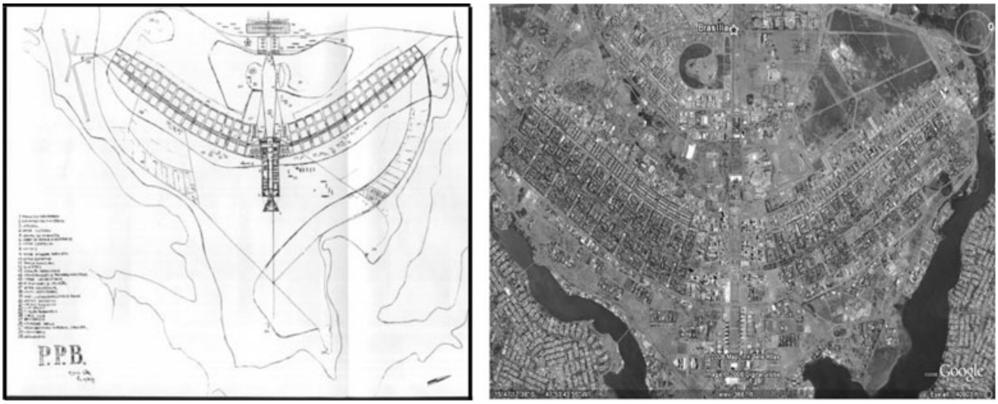
Figure 13.23 Land demarcation in Washington, DC and New York City

D. Demarcation in Urban Areas

Throughout human history most cities have developed piecemeal under metes and bounds or similar indiscriminate land demarcation systems. As noted above, however, there are notable cases in which rectangular systems were adopted by cities operating within a larger metes and bounds system. The impacts of these systems on economic growth and urban land markets are hard to assess, but in this section we briefly summarize both the choice to adopt rectangular systems and the effects of these systems. We start by examining two relatively modern national capitals – Brasilia and Washington, DC. Next we examine some major cities where rectangular systems were chosen.

National capitals

Washington, DC. President George Washington was authorized by the Residence Act of 1790 to select a 10 mile square site for the US capital on the Potomac River and appoint a committee of three surveyors to set up the city by the year 1800 (Morris 1994: 351). Washington, DC was designed to be a political, rather than commercial, center and had its major streets laid out as spokes radiating from circles (Morris 1994: 351). The distinct differences between DC and NYC are shown in Figure 13.23 that shows the initial plat map for Washington, DC as well as Manhattan as of 1802.[32]



Source: www.infobrasilia.com.br/pilot_plan.htm and www.aboutbrasilia.com/facts/history.html.

Figure 13.24 Brasilia – Costa's cross design and satellite picture

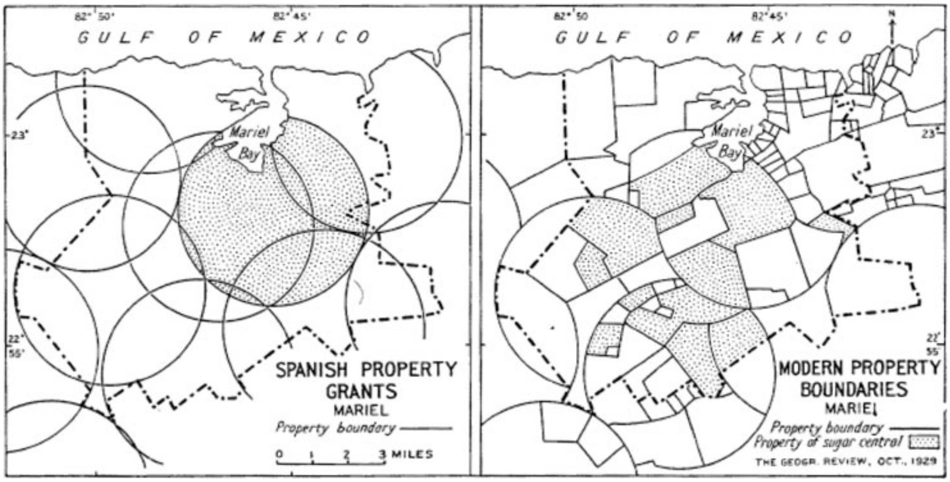
Brasilia. Ever since the 18th century the Portuguese King, the Brazilian Emperors and the Brazilian Presidents of the Republic were interested in moving the capital to an interior area, thereby minimizing exposure to maritime raids.[33] In 1823, J.B. de Andrade e Silva, a leader in Brazilian Independence, proposed this move and suggested the name of Brasília. An area of 14,400 square kilometers was reserved for the capital, and over 100 years later, in 1956–1957 a public contest was announced accepting designs for the new capital that would be remote from the commercial centers of Rio de Janeiro and Sao Paulo. Lúcio Costa won the competition with his innovative design known as the *Plano Piloto* (Pilot Plan). The plan resulted in a rather unusual grid as seen in Figure 13.24. Costa designed a portion of Brasilia in 1957 on the basis of a cross, with two axes crossing at right-angles. He adapted this cross to the local topography of the city. One of the axes was curved in such a way as to fit into an equilateral triangle that would limit the urbanized area.[34] The emphasis of the plan was on design befitting a capital and not to promote land market transactions.

Cities with rectangular systems

There are no systematic studies available to definitively answer how much economic activity was stimulated by the adoption of rectangular systems in places like Barcelona, New York and Philadelphia, but there is some historical evidence to suggest it was important for commercial development. For New York City, the grid appears to have facilitated its expansion as the country's major commercial center with active land markets. The process of filling empty spaces in the grid continued over time and reached 42nd Street by 1850, and the entire island of Manhattan was covered by 1890.[35]

E. The Cuban Circular System

Earlier we argued that circles were unlikely to be used because of the high cost of bounding, division, wasted space, and overlapping claims. The Cuban experience seems to



Source: Platt (1929).

Figure 13.25 Circular royal grants and subsequent subdivision of plots

support these notions. During the 16th century, land grants were made by the King of Spain for stock-raising in circular corrals (Platt 1929: 604). These were 1 league (3.45 miles) in radius from a given center, thus having an area of 37 square miles. Land was cheap and there were few settlers. The initial selection of a center was important and boundaries were not as areas distant from ranch centers were not valuable, and thus not likely to be contested or requiring active enforcement.

As the population grew, however, boundaries became more important and reassembling the lands into sugar plantations became desirable. The circular grants were difficult to survey, resulting in legal battles over title. Sugar cultivation could occur on smaller plots, but the division of circles was costly, contributing to uneconomically small residual plots and waste as indicated in Figure 13.25.

IV. SUMMARY AND CONCLUSION

The demarcation of land is an ancient human practice likely beginning with large-scale fluid hunting territories established by hunter-gather groups. This chapter has examined the economic structure of land demarcation systems. We focused on two major practices, metes and bounds and rectangular systems primarily as they have been used in the US. We explain the nature of metes and bounds and the rectangular systems in the US and the legislative history and motivation for its adoption of RS in the Land Law of 1785. We also explain how RS has been adopted in parts of Canada and Australia and cities in other parts of the world.

Given this background, we explored the causes and consequences of these two dominant systems. We postulated that a decentralized system of land claiming would generate patterns of land holdings that would be uncoordinated and depend on natural topography and the characteristics of the claimant population. We then showed how a centralized, rectangular system are expected to generate different ownership patterns and incentives for land use, land markets, investment, and border disputes. We discussed some empirical findings from a comparative analysis of MB and RS in Ohio, other parts of the US, Canada, and Australia, as well as urban areas in a variety of locations. We find that RS is adopted when land values are potentially high and those values can be captured by a land developer (private or government). We also find evidence that RS increases land values by promoting land markets, reducing land boundary disputes, and stimulating investment in infrastructure. For these reasons, more attention should be placed on these fundamental institutions and their roles in influencing property rights to land and the transactions costs of exchange.

It is difficult to separate the shape and the standard location (i.e., system) effects of a rectangular system. Yet, we find even under metes and bounds squares predominate in areas that are flat, but there is no overall coordinating mechanism, so that where tracts of parcels collide there will be oddly formed shaped parcels. This effect is avoided in a large rectangular system where parcels do not collide nor overlap and where squares are generally imposed regardless of topography. Accordingly, uniform productive shapes and standard, identifiable locations are the benefits of a rectangular system as a *coordinating* institution. For these reasons we believe that a centralized land demarcation system is a fundamentally important and overlooked institutional innovation for promoting production and markets for land.

NOTES

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1. There is, however, a practical literature in real estate law that is well aware of the difference in land demarcation systems. See, for example, Eldridge, *Evidence and Procedures for Boundary Location* (1962).
2. The term 'metes and bounds' is primarily an English term though we use it to describe a decentralized, topography-based demarcation system. Geographers, such as Thrower (1966) use the term 'indiscriminant' survey.
3. It is possible that a centralized land demarcation system could use nonlinear boundaries but we are unaware of any such system. The 19th century soldier and explorer John Wesley Powell (1878), 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.
4. In that case, resurvey and RS marking may pose uncertain redistribution and hence be resisted by current occupants;
5. The history of the development of the chain is detailed in Linklater (2002).
6. It is now called the Public Land Survey System or PLSS; see www.nationalatlas.gov/plssm.html.
7. Below we discuss the rather unique case of Texas.
8. Libecap, Lucek and O'Grady (2010) examine the factors leading to the adoption of the rectangular survey in parts of the British Empire.
9. http://en.wikipedia.org/wiki/Dominion_Land_Survey.
10. Note some other cities with substantial grids.
11. See also http://whc.unesco.org/en/tentativelists/5082/.
12. For more detailed development, see Libecap and Lueck (2009).
13. See Dunham (1994) for history and analysis and http://en.wikipedia.org/wiki/Isoperimetry for an overview of the problem.

14. In fact, it is possible to pack circular plots together by having each parcel touch six others in what is called 'hexagonal packing'.
15. Libecap and Lueck (2009) give a detailed discussion and analysis of the Virginia Military District.
16. Libecap and Lueck (2009) find further statistical support for this correlation between topography and parcel size and shape.
17. Libecap and Lueck (2009) examine land disputes under RS and MB in Ohio more systematically and find more boundary and title conflicts under MB.
18. This is taken from Hinkel (2003: 88). This parcel is not perfectly square but the closest we were able to discover.
19. Grayson was a delegate from Virginia and member of the committee to draft a land ordinance.
20. Ford (1910: 55); Treat (1910: 16); Pattison (1957a: 87), Webster (1791: 493–95); White (1983: 9).
21. Linklater (2002: 68–70); White (1983: 9).
22. Linklater (2002: 68–70).
23. Burnett (1934: 563).
24. Taylor (1922: 12).
25. Linklater (2002: 116, 117), Gates (1968: 59–67), Treat (1910: 24).
26. If a parcel did not become private property it remained owned by the Federal government. In many cases, such unclaimed or unsold land became part of the national parks or national forests.
27. Indeed, forces such as mineral discoveries and white–Indian relations dramatically influenced the pattern of settlement and the demand for land.
28. Libecap and Lueck (2009) discuss this history in detail.
29. See also Porter v Robb, 7 Ohio (Pt. 1) 206, 210–211 (1835): 'To relieve would shake more than half the titles between the Scioto and Little Miami rivers. . ..;' and Lessee of Cadwallader Wallace v Richard Seymour and H. Rennick, 7 Ohio 156, 158 (1836): '. . .a variety of questions are presented of more than ordinary difficulty, in consequence of the nature of the titles in the Virginia military district. . .'.
30. Andrew Huston v Duncan McArthur, 7 Ohio (Pt. 2) 54, 55 (1835).
31. Libecap, Lopes and Lueck (2009) find even larger positive effects from RS in a study of 19th century agriculture in California.
32. www.library.cornell.edu/Reps/DOCS/nyc1811plan.jpg http://en.wikipedia.org/wiki/Image:L%27Enfant_plan.jpg.
33. See www.infobrasilia.com.br/pilot_plan.htm and http://www.aboutbrasilia.com/facts/history.html accessed on October, 13, 2008).
34. Super-blocks were assigned numbers and residential buildings were given letters and apartments with numbers. Therefore a typical address would read for instance: N-S3-L, apt. 201.
35. See Atack and Margo (1996) for discussion of the development of NYC land markets.

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