Large Scale Institutional Changes: Land Demarcation within the British Empire[1]

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ABSTRACT.

We examine adoption of land demarcation within the British Empire during the 17th through 19th Centuries. We develop a model and test its implications against data from British temperate colonies in North America, Australia, and New Zealand. Three arrangements were implemented—individualized, idiosyncratic metes and bounds; centralized uniform, rectangular; and a centralized, non-uniform demarcation system. The choice among these is examined using demarcation, topographical, and soil quality datasets with qualitative, historical information. We find centralized systems provide coordination benefits, but adoption is less likely when implementation is slow and controlling settlement is costly. Within centralized systems, we find uniform rectangular demarcation lowers transaction costs, but its rigid structure is costly in rugged terrain and alternatives are adopted.

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[I]n the absence of transaction costs, it does not matter what the law is, since people can always negotiate without cost to acquire, subdivide, and combine rights whenever this would increase the value of production. In such a world the institutions which make up the economic system have neither substance nor purpose.

20th Century British Economist Ronald Harry Coase (1989, 14)

I will only repeat the expression of my confident trust that you have sacrificed everything else to the one essential thing--the survey, the survey, the survey.

19th Century British Political Economist Edward Gibbons Wakefield (Wakefield, et al, 1868, 290)

I. INTRODUCTION

Institutions can change in dramatic fashion. For example, after conquest the victor can institute its language, law, currency, economic organizations, and form of government on the vanquished. In so doing it expands its institutional reach.[2] Among these new institutions are those that govern land, perhaps the most fundamental of resources. A conquering regime can decide how property rights to land will be demarcated and assigned. Once implemented, absent another dramatic change, these institutions can persist.

In this paper, we examine the adoption of land demarcation systems within the British Empire in the 17th through 19th centuries with a particular focus on temperate colonies settled by

[2]History is replete with such conquests and expansions – from Ancient Rome two millennia ago, to the British Empire between the 17th and 20th centuries, to the Soviet regime of the 20th century.

British emigrants in North America, Australia, and New Zealand.[3] Within the British Isles, the traditional land demarcation practice is that of metes and bounds, a decentralized process in which individuals define property boundaries with respect to natural features and adjacent parcels without restriction. There is no centralized demarcation arrangement to align borders, provide usable plot shapes, avoid boundary conflicts from overlapping claims, and facilitate infrastructure along borders. Individuals can bargain locally to make such adjustments through parcel trades, but the demarcation system itself does not do this.

Although metes and bounds was firmly entrenched in Britain and throughout the world, the acquisition of vast new territories prompted debate on how to best design and manage land distribution and demarcation in the colonies so as to promote orderly settlement, economic growth to accommodate immigration, as well as to generate higher land values and sales revenues. These issues were debated by leading political economists of the time, including Adam Smith, Jeremy Bentham, John Stuart Mill, Thomas Malthus, David Ricardo, Edward Wakefield, and Robert Torrens (Winch 1965). As an indication of this discussion, the British Colonial Office (Labaree 1967, Vol. 2) and especially Wakefield (1834) called for synchronized, planned settlement and land demarcation in the British colonies.

As we show, centralized demarcation was adopted in parts of the Empire, especially the highly-organized and uniform rectangular system (RS). A key advantage of the RS was that parcel information was standardized and simplified in a way that promoted land markets and provided other advantages that we describe below. Despite these advantages, some regions

[3]In this regard, we follow Acemoglu, Johnson, and Robinson (2001) and Crosby (1986) who also focus on the "Neo-Europes" where settlers tried to replicate European institutions. Primary examples of this include Australia, New Zealand, Canada, and the United States.

within the empire chose to implement mixed systems (MX) that were centrally controlled but allowed flexibility and variety in demarcation arrangements, and other regions followed traditional decentralized metes and bounds (MB).

In this paper, we examine the determinants of these institutions. We develop predictions from an economic model that compares net revenues from the three demarcation systems for a given region and details how these values change with exogenous land characteristics. We provide empirical support for our predictions through both historical and quantitative analysis. We find that centralized demarcation systems provide clear benefits from coordinating demarcation, but their adoption is less likely when implementation is slow and controlling settlement is costly. Within centralized demarcation, we find that uniform RS systems are more likely adopted in large regions with potentially active land markets where network gains are magnified, but less likely in rugged terrain where its rigid uniform structure limits adaptation and increases setup costs.

Our analysis of demarcation institutions is guided by the fundamental insights of Ronald Coase. In his pioneering work Coase (1937, 1960, 1989) was first to develop (or imply) a theory of institutional choice when posting that judges choose the most efficient legal regimes. This work led to discussions of the evolution of legal rules and indeed to the law and economics movement, and later to work on institutions by North (1990), North, Wallis, and Weingast (2009), Acemoglu, Simon, and Robinson (2001, 2002, 2005), and others. Moreover, as the quoted remark above notes Coase (1989) clearly understood that markets themselves are institutions that facilitate trade and indeed "require the establishment of legal rules" for them to function.[4]

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[4]See Coase (1989, 10-14) and Scott (1998, 256, 351) on the role of underlying institutions for

Ironically, many of Coase's most famous examples have to do with land. In "The Problem of Social Cost" Coase used the example of land use conflicts between wheat farmers and cattle ranchers and his examination of English law focused on nuisance (i.e., land use) disputes. In his theory he discussed the importance of the "delimitation of rights" to land (1960, 8). Yet, Coase did not examine in detail how rights to land are actually demarcated, nor did Coase acknowledge that the demarcation of land in his native England is so different from his adopted home in Chicago. But, as Coase would certainly acknowledge, the practicalities of land demarcation are fundamental because they mold land markets and shape land use. Coase, of course, was not alone in overlooking land demarcation. There is little legal or economic scholarship on the factors influencing demarcation, and even major property law treatises (e.g., Dukeminier and Krier 2002, Merrill and Smith 2007) merely describe the dominant American system.[5]

We begin by briefly summarizing land demarcation in the British Empire. In section III we develop a framework for examining the decision to adopt particular demarcation systems. In section IV we examine the implications of our framework by examining the detailed history of

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markets.

[5]Neither of the comprehensive treatises on law and economics by Posner (2002) and Shavell (2007) mentions land demarcation. Demarcation, on the other hand, is examined by economic geographers in describing the use of mapping and cadaster systems. For example, see Scott (1998) and Kain and Baigent (1992). Libecap and Lueck (2011b) and Libecap, Lueck and Lopes (2010) find that there are economically and statistically significant gains in land values from enactment of a systematic, rectangular survey in the United States.

land demarcation in the British colonies and by econometrically examining the determinants of those institutional choices. We summarize our study in section V.

II. LAND DEMARCATION IN THE BRITISH EMPIRE

The British Isles comprise 121,673 square miles. At its peak, the British Empire covered 14.2 million square miles, nearly 25 percent of the world's land area, and the colonial area that we examine involved 10.7 million square miles (see Figure 1).[6] The accumulation of these vast expanses of land beyond the home islands generated the practical problems of how to allocate this land and how it should be demarcated. These decisions were influenced by the institutions that were developing within Britain at the time of expansion and the political economy debates that emerged around colonial policies.

[FIGURE 1 HERE]

A. THE BRITISH ISLES.

By the mid-17th century, land in Britain was becoming more valuable and this led to changes in land institutions from traditional practices that subsequently influenced British colonial policy. For example, the enclosure of scattered and common lands helped to restructure, reshape, and consolidate plots into more useful forms for sheep raising and larger-scale food production. Land that previously had been held and worked in common or in strips was reorganized into plots owned in severalty and in some cases merged into rectangular forms that

[6] By comparison Africa comprises just 20 percent of the earth and Russia, the largest country is about 11 percent of the Earth. The total land area of the Earth is 57,308,738 square miles http://www.enchantedlearning.com/geography/continents/Land.shtml. See also Ferguson (2004, 15).

were recognized as beneficial for production and trading (Turner 1980, Young 1808).[7]Land markets, which historically generally had been local and limited, became more active and broadly based (Darby, 1973, 302-53). To promote trades, Parliament intervened between 1660 and 1830 with roughly 3,500 Estate Acts to free property rights from traditional constraints of inheritance and other communal requirements (Bogart and Richardson 2009, 3; Richardson and Bogart 2008, 7-18).

These changes in land institutions required more accurate measurement and boundary definition and standardization of processes. More precise survey was made possible with new procedures and equipment, particularly the introduction of Gunter's chain in 1620 that spread throughout England and subsequently to the English colonies. Gunter's chain helped to generalize use of a standard statute rod of 16 ½ feet for land measurement by surveyors. Other new equipment and practices included the Theodolite survey, use of telescopes, the solar compass, and triangulation survey emerged over time and influenced the costs and benefits of demarcation.[8]

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[7]The emergence of rectangular fields as a result of some enclosures is noted by Yelling (1977, 120, 123, 131, 138). The enclosure literature is a very large one and we only point to parts of it. For additional discussion of the geography of enclosure, see Kain, Chapman, and Oliver (2004). Scott (1998) 24-49 discusses the expansion of survey and drafting of cadastral maps in the 17th-19th centuries. Allen (1982) finds important redistribution effects of enclosures from farmers to land owners; that open and enclosed fields often were equally efficient; and that the efficiency gains were regionally specific.

[8]Gunter's chain ingeniously linked the measurement of area and perimeter into square parcels using the English system of measurement (i.e., inches, feel, yards, and miles). Richeson (1996,

B. The Temperate British Colonies

Figure 1 shows the colonies in North America, Australia, and New Zealand within the larger British Empire. The addition of these colonies opened vast amounts of new temperate land for British colonists. Abundant land in these regions offered the possibility of transplanting British farms, agricultural practices, crops, and land institutions. The question of how to design and manage colonization became part of British political economy debates in the 17th through 19th centuries, and demarcation of land was a central issue.

A key question was whether land should be allocated in a decentralized, unsystematic manner, with individual land claims and demarcation through traditional English metes and bounds. "Metes" refers to property boundaries defined by the measurement of distances between terminal points, and "bounds" refers to boundary descriptions based on topography. Under metes and bounds demarcation in the colonies occupied parcels were to be surveyed independently after settlement, leading generally to non-uniform, uncoordinated shapes, sizes, and alignment.[9]

An alternative was to allocate and demarcate land in a more organized, systematic manner, with the survey of land parcels prior to distribution and occupation. New territories within the empire provided the opportunity to implement a centralized system. Coordinated demarcation could be within a local area, organized by a particular colonial group or large land

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140-75) discusses the introduction and spread of Gunter's chain as well as other survey innovations. Linklater (2002, 13-20) describes the impact of Gunter's chain on measurement and the opportunity to firm private property rights to land.

[9] See Libecap and Lueck (2011a, 2011b) for a discussion; also see http://en.wikipedia.org/wiki/Metes_and_bounds.

owner, or it might be broader, covering a larger jurisdiction, organized by a government. Two centralized arrangements were considered and implemented in the colonies, the rectangular grid, RS, and a mixed system, MX, that required initial survey before occupancy, but that did not define uniform square parcels.

The use of square grids in smaller areas had a long history in England.[10]Colonial towns often were laid out with square blocks (Thrower, 1966, 9), and Robert Torrens and Edward Gibbon Wakefield, two important 19th century political economists and politicians, called for the strictly planned distribution of all colonial agricultural land and controlled settlement to create productive colonies (Winch 1965, 56-93).[11] One element of Wakefield's Colonial Reform Movement was the survey of land into squares prior to sale and occupation (Winch, 1965, 113-45; Oldham, 1917, 4, 16, 74; Burroughs, 1967, 12-3). Squares offered potential productivity gains as well as clear boundaries and uniform parcels for exchange in land markets.[12] Wakefield

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[10]Rectangular systems had also been used extensively by the Romans and had also been used across Europe in selected areas so the idea had been tested to a degree (Libecap and Lueck, 2011a).

[11]Torrens, originally from Ireland, became Premier of South Australia and later a member of the British Parliament. He is widely known for creating the system of land registration that goes by his name. Wakefield was a leading colonial policy theorist especially for the centralized demarcation of lands in South Australia, New Zealand, and later Canada. He was a Director of the New Zealand Company, co-founder of the Colonial Reform Movement, and a member of the New Zealand Parliament.

[12]Other aspects of the Colonial Reform Movement included constraints on the supply of new lands made available at any point in time and high fixed prices to control internal migration.

argued that allowing individualized claiming and demarcation with uncoordinated metes and bounds would lead to title confusion, a lack of market organization, and economic failure. Accordingly, the interests of individuals to independently claim land could diverge from the broader interests of colonial society, which would be molded by the way in which land was demarcated (Winch 1965, 137).

The potential benefits of more centrally-controlled, planned demarcation were incorporated into circulars issued by the British Colonial Office in the late 17th and 18th centuries:

> *First, that you, our said governor….of our lands for the [northern, southern] district of North America….taking care that such districts so to be surveyed and laid out as aforesaid be divided into such a number of lots (each lot to contain not less than one hundred nor more than one thousand acres) as our survey general shall judge best adapted to the nature and situation of the districts so to be surveyed….That so soon as the said survey shall have been made and returned as aforesaid, you, our said governor or commander in chief of our said province….appoint such time and place for the sale and disposal of the lands contained within the said survey to the best bidder ….*[13]

III. A Framework for Examining Institutional Choice

In this section we examine the decision to adopt a particular land demarcation system

[13] For similar instructions for various other colonies see Labaree (1967, Vol. 2, 537, 540, 541, 586-87).

from the point of view of a colonial authority interested in maximizing revenue from land sales (Labaree 1967, Vol. 2, 536).[14] Although not all colonial officials had this explicit objective, some clearly did, such as the Virginia Company and its shareholders. In all cases, however, colonizing authorities were anxious to promote the economic well-being of their dominions, which is consistent with land revenue maximization, when land was the key asset.

Our analysis is centered on the choice between three types of demarcation found in the British Empire; decentralized metes and bounds (MB), a centralized rectangular system (RS), and a centralized mixed system (MX). Table 1 summarizes the key features of these three land demarcation regimes. For a given region, we denote the expected net revenue for each system as V^{MB}, V^{RS} and V^{MX} to which the colonial authority implements the system with the maximum value. To arrive at testable implications, we analyze authority's decision to adopt a particular system in two steps as illustrated in Figure 2. First, we analyze the choice between centralized and decentralized demarcation with respect to exogenous conditions of the region. The second step focuses within centralized demarcation regimes and analyzes the choice between a standardized RS system and a more flexible MX system.

[TABLE 1, FIGURE 2 HERE]

A. DECENTRALIZED METES AND BOUNDS

We begin with the analysis of the MB demarcation system. Consider a region of size A with n identical claimants indexed $i = 1, \dots n$. Under MB a claimant is free to choose the spatial dimensions of his property including its perimeter (p_i), area (a_i), and location (l_i). For our

[14] In using revenue maximization we ignore redistributive political economy and the details of selling land such as price setting and parcel size.

purposes, the location variable captures a parcel's position and alignment with respect to other parcels in the system. We denote the location structure of the entire region as $L = \{l_1, \ldots l_n\}$.

We assume that claimants choose parcel dimensions in a non-cooperative way to maximize the value of their claim less the costs of demarcation. We denote the instantaneous value function for parcel *i* at time τ is $v_{i\tau}(p_i, a_i, L; q)$ where q is an index of land quality such that $\partial v_{i\tau} / \partial q > 0$. This function represents the value generated from a parcel, net any enforcement and transaction costs in a given period. We also define a one-time demarcation cost function that occurs at time 0 as $c_{i0}(p_i, a_i, L; t)$ where t is a parameter measuring the ruggedness of topography.[15]

Notice that the functions depend on parcel *i*'s perimeter, area, and location *and* on the location of other parcels in the system. The interpretation is that a claimant's uncoordinated location choice can lead to misalignment in parcels, unproductive parcel shapes, gaps in the land, and boundary disputes that generate costs across multiple parties. We will refer to these as location effects that can be internalized in a coordinated, centralized system. Accordingly, we expect individual enforcement costs to fall and total productive value of the land to rise as parcel locations are better synchronized and coordinated with those of the group. Similarly we expect average demarcation costs to fall as more boundaries are shared. As we note below, these are absent or rare in a non-cooperative MB setting.

The claimant's demarcation problem is then to maximize the net value of his claim taking topography, land quality, and the location choices of others as given. Formally claimant *i* solves

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[15]We do not include t in the parcel value function to simplify the analytical model. This simplification does not change the predictions derived from the model, however. We elaborate on the potential implications of the interaction between terrain and productivity at the end of this section.

(1) $\max_{p_i, a_i, l_i} \int_0^T v_{i\tau}(p_i, a_i, L; q) e^{-r\tau} d\tau - c_{i0}(p_i, a_i, L; t)$

Where T is the time horizon and r is a discount rate. We denote the Nash equilibrium solution to this problem as the set (p^*,a^*,L^*) and the equilibrium behavior of person i as (p_i^*,a_i^*,l_i^*).

This solution is defined by two important characteristics -- shape and alignment/location. First, the optimal shape for individual parcels is expected to be square in the case where there are no location conflicts or topographical impediments to demarcation (*flat* land).[16] Rugged topography, however, can significantly influence the costs of demarcation, and thus, we expect rational agents to deviate from squares in these cases, so that with increases in ruggedness, parcel shapes and sizes will be more irregular and varied, mimicking topography (Libecap and Lueck, 2011). Second, the demarcation solution implies uncoordinated location choice. In the absence of coordination, individuals will not account for the effects their choices have on the rest of the group and there exist other location arrangements that achieve a higher total value for the region than the equilibrium. Accordingly, decentralized demarcation will tend to lead to more haphazard alignment, less contiguity, and more boundary conflicts than a centrally planned arrangement or one in which all claimants contract with each other to join a system.

[16]Evidence from the agricultural engineering literature suggests rectilinear farm shapes have considerable production advantages over alternative shapes (Barnes 1935; Lee and Sallee 1974; Amiama, Bueno, and Alvarez 2008).Barnes (1935) and Lee and Sallee (1974) show production advantages in rectangular fields where the farmer works parallel to the longest sides of the field. Squares have the lowest perimeter to area ratio among rectilinear shapes and therefore minimize survey, fencing, and enforcement costs for a given area of land (Johnson 1976, Libecap and Lueck 2011a). Libecap and Lueck (2011b) provide empirical evidence of a preference for square parcels in flat terrain under decentralized MB.

Using the solution to eq. (1) we can calculate the value of land sales under MB. We find i's willingness to pay for a_i^* acres by plugging (p_i^*,a_i^*, L^*) back into the claimant's objective function. Assuming the colonial authority sells land at its net present value, the total revenue received from land sales at time 0 is

(2) $$V^{MB} = \int_0^T V_\tau^* e^{-r\tau} d\tau - c_0$$

where$V_\tau^* = \sum_i^n v_{i\tau} \left(p_i^*, a_i^*, L^*; q\right)$ and $c_0 = \sum_i^n c_{i0} \left(p_i^*, a_i^*, L^*; t\right)$.

B. CENTRALIZED DEMARCATION; RS, MX

Under a centralized demarcation system a colonial authority (land company, colonial charter holder, government) sets the initial demarcation rules for parcels in the system and retains control over the land until demarcation is complete.[17] Prior to sale, the colonial authority incurs the upfront administrative costs of planning, surveying and controlling settlement over the duration of the setup period. We denote this period of setup time as $\tau' > 0$ and the setup cost in each time period as $C_\tau'(A; t)$.We assume that setup costs are increasing in the ruggedness of topography so that $\partial C'_\tau / \partial t > 0$.The objective of the authority is to choose the system parameters that solve

(3) $$\max_{p,a,L} \int_{\tau'}^T \sum_i^n v_{i\tau}(p, a, L; q)\, e^{-r\tau} d\tau - \int_0^{\tau'} C_\tau'(A; t)\, e^{-r\tau}$$

where the first integral represents the present value of revenue generated from the sum of all land sales at τ', and the second integral represents the system setup costs that occur from time 0 to τ'. By maximizing over the sum of all parcel values, centralized demarcation allows for a more complete consideration of location externalities a coordinated alignment and contiguous land-use

[17]Controlling for different ownership regimes in British colonies is difficult because some shifted from one type to another. We examine these issues given the information that we have below.

compared to the decentralized MB outcome. In addition, centralized planning provides consistency in property descriptions that reduces boundary uncertainty and conflict.

The net gains to centralization can be viewed by comparing the relative value of the centralized solution (denoted V') and the MB solution. A colonial authority will centralize demarcation when the present value of revenue, less system costs exceeds the revenue generated under MB, i.e. when V' - V^{MB}> 0. This becomes

(4) $$V' - V^{MB} = \int_{\tau'}^{T} (V_\tau' - V_\tau^*) e^{-r\tau} d\tau - \int_0^{\tau'} (V_\tau^* + C_\tau') e^{-r\tau} d\tau + c_0 > 0.$$

Equation (4) has three terms that illustrate the tradeoffs of centralization. The first integral represents the increased willingness to pay for coordinated alignment, savings on boundary disputes, and other avoided MB costs that accumulate after τ'. The second integral can be thought of as the total cost of setup which includes the forgone MB output that would have occurred during the period of delayed settlement in addition to the centralized system administrative setup. The third term is the avoided individual MB demarcation costs. From (4) comparative statics emerge. The net value of centralized demarcation will increase with the benefits to coordination, decrease with the implementation time τ' and the costs of survey and controlling settlement, increase in the expected time horizon T, and decrease with the discount rate r.

Considering forces likely to change model parameters can illuminate these predictions and tie them to the empirical analysis. The colonial authority is more likely to choose centralized demarcation in regions with: a) larger areas, as the gains from coordination accrue over a larger number of parcels; b) later settlement, as improvements in survey technology lower implementation time; c) less rugged topography t, as ruggedness increases the costs of coordinated survey and control and decreases the speed of implementation. We also expect costs of controlling settlement to become very high when there is an incumbent demarcation system in place or when squatting is prevalent. Expected time-horizons may decrease with external challenges to the governing land authority, but as we explain below, these threats were not significant and time-horizons are effectively constant across our sample.

It is also clear from the model that land quality q is relevant to centralization decisions, but the direction of the impact is contingent on several interacting factors. On one hand, higher q increases the first term of equation (4) by magnifying the value lost from awkward parcel shapes and land gaps that arise under MB. Higher quality land also gives added incentive for individuals to dispute uncertain MB boundaries, which will tend to increase the first term. On the other hand, the second term of equation (4) shows that higher q will increase the opportunity cost of delaying settlement, decreasing the net value of centralization.[18] Without knowing the relative size of these competing pressures for each region, we cannot make clear predictions about the land quality effect. We still control for q in the quantitative analysis using a soil quality proxy, as it is relevant to the model.

DEMARCATION UNDER RS

As we have noted, centralized demarcation often takes on a very specific form in that of the rectangular survey (RS) system. Under the RS system, all parcels are demarcated as identically sized squares and located in a perfectly aligned grid. We denote these spatial dimensions as $(\bar{p}_i, \bar{a}_i, \bar{l}_i)$ for all i where $\bar{p}_i/\sqrt{\bar{a}_i} = 4$ and $\bar{L}$ represents a uniform and contiguous lattice of square parcels. A clear benefit of the $\bar{L}$ structure is that it maximizes the shared

[18]Clearly the time-horizon plays a critical role in which effect dominates. Under sufficiently short time horizons the second effect will dominate and the likelihood of centralization will decrease with q. Under longer time horizons, the first effect increases in relative importance.

benefits that come with alignment and contiguity among the group. Clearly aligned boundaries reduce overlapping claims and the potential for boundary conflicts. In addition, the positioning of identical square parcels on a contiguous grid provides long stretches of straight lines along parcel boundaries where road and related infrastructure investment can occur.

Perhaps most importantly, the RS structure provides network benefits by creating a universal standard for parcel dimensions and addressing throughout the system in a way that is easily communicated.[19] This standardization process is particularly important for facilitating transactions in land markets. Much in the way businesses standardize processes to limit new information acquisition, the standardization of demarcation rules can significantly reduce informational costs involved in land transactions.[20] Spatial dimensions, which are tied to the productive value of the parcel, are particularly important to communicate between buyer and

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[19]We assume the network effects of RS are such that a person's or group's use of the system also benefits others and that it further increases the incentive to participate (Baird, Gertner, and Picker 1994; Farrell and Klemperer 2007).

[20]In general, exchange in land markets requires potential buyers to expend resources acquiring information about various parcels. These informational transaction costs were often exacerbated in frontier land markets. Firstly, colonists and other potential buyers could be great distances from the site in question and it was not uncommon for purchases to be made "sight unseen." Secondly, a large share of the land supply in early markets came from absentee owners who also possessed little knowledge of the site. Lastly, land transactions were risky, and buyers had to be wary of fraudulent claims. As a result of these three reasons, land transfers were often hindered by uncertainty over parcel characteristics Gates (1968).

seller. By fixing boundary dimensions to a uniform standard and arranging parcels in a systematic, identifiable way the RS system eliminates the need for buyers to gather idiosyncratic parcel information, and information can be easily communicated over long distances. Large standardized parcel networks will increase general familiarity with the system and promote greater confidence between buyers and sellers in land markets.

As such, we expect the reduction in transaction costs, conflicts, and related market expansion to increase the price of the land all else equal. However, the extensive uniformity required to provide these additional network benefits essentially rule out adjustments to terrain which can be especially valuable during the survey process. We calculate the present value of the RS system as

$$(5) \qquad V^{RS} = \int_{\tau^{RS}}^{T} \bar{V}_\tau e^{-r\tau} d\tau - \int_0^{\tau^{RS}} C_\tau^{RS}(A; t) e^{-r\tau} d\tau$$

where the first integral is the revenue generated from land sales, the second integral is the cost of setup, and τ^{RS} is implementation time.

DEMARCATION UNDER MX

We refer to a more flexible type of centralized system as a mixed (MX) or hybrid system. Unlike the RS, a MX system does not impose strict requirements for parcel dimensions and alignment, and therefore the details of each mixed system can vary. The MX system allows for adaptation to terrain to find a balance between the benefits of coordinated demarcation and survey costs. Choosing a more flexible arrangement however, forgoes the network benefits that accrue from the standardization of RS parcels. That is, parcels no longer will be uniformly-shaped or sized, but borders can be defined centrally for public benefits (reduced conflict, road construction), and plot addressing can occur locally within the system, with parcel addresses with respect to one another as centrally defined or with respect to some synchronized positioning point. We denote the total value of land under the mixed arrangement at time τ as $\tilde{V}_\tau$ and assume $V_\tau^* < \tilde{V}_\tau < \bar{V}_\tau$ to indicate the intermediate level of network benefits achieved under MX.

We calculate the net benefit of the MX system as

$$(6) \qquad V^{MX} = \int_{\tau^{MX}}^{T} \tilde{V}_\tau e^{-r\tau} d\tau - \int_0^{\tau^{MX}} C_\tau^{MX}(A;t) e^{-r\tau} d\tau$$

This is much like equation (5), but with a different implementation time and setup cost function. For simplicity we assume that $\tau^{RS} = \tau^{MX} = \tau'$. We further assume that $\partial C_\tau^{RS}/\partial t > \partial C_\tau^{MX}/\partial t$ to indicate that MX can lower setup costs by adapting to rugged terrain.[21] Mixed systems are then efficient when there are benefits to providing alignment and coordination relative to MB, but when RS uniformity requirements are too costly to impose (e.g. in rugged terrain). We thus predict that a colonial authority will choose to adopt a uniform RS over a MX system whenever $V^{RS} - V^{MX} > 0$.

$$(7) \qquad V^{RS} - V^{MX} = \int_{\tau'}^{T} (\bar{V}_\tau - \tilde{V}_\tau) e^{-r\tau} d\tau - \int_0^{\tau'} (C_\tau^{RS} - C_\tau^{MX}) e^{-r\tau} d\tau > 0$$

The value comparison between RS and MX is fairly straightforward. The first term reflects the difference in network benefits capitalized into land sale revenues. The second term represents the difference in setup costs. Using equation (7) we can determine that a uniform RS is more likely to be adopted over a flexible MX system with: a) larger region size A, as network benefits accrue with the size of the network n and $A = n\bar{a}_i$; b) less rugged terrain t, as ruggedness increases RS survey costs relative to MX; c) later settlement, as implementation times τ' are reduced by improving survey technology, thus making the relative cost advantages under MX

[21] Flexibility in the MX system may also be expressed through the degree to which demarcation is centralized. In this way the MX system derives its value by economizing on control costs relative to RS. We consider this possibility more explicitly in the empirical analysis.

less important. Further, later settlement dates (within our sample) generally correspond to the escalating development of commercial land markets worldwide which increases the network benefits of RS standardization.[22]

This framework provides the following implications that we can confront using both qualitative and quantitative data on demarcation adoption within the British Empire. First, we predict that a centralized system will be adopted by colonial authorities instead of individualized metes and bounds when areas are large; when the time horizons are long; when the authority has control over migration and settlement; and when terrain is relatively flat. Second, we predict that when a centralized system is chosen, RS will be selected in less rugged terrain and later in colonial settlement.

IV. Empirical Analysis

To test predictions about the choice in land demarcation institutions in the British Empire we employ two methods. First, we examine the history of colonial land demarcation by examining the literature and the contemporary political debates. Second, we assemble a data base at the colonial level which includes information on demarcation institutions and on exogenous land characteristics.

A. Demarcation across the Temperate Colonies

[22]While MB and MX systems differ in important ways, they both can be considered "flexible" demarcation systems. As equation (7) predominantly reflects tradeoffs between uniformity and flexibility we briefly explore whether these predicted relationships hold more generally when MB is included as a flexible demarcation system in the empirical sample.

Our analysis has identified a group of factors we expect to influence the choice of demarcation regime. Two important of these forces--the lack of an incumbent demarcation system and strong British control over the colonial region--did not appreciably vary across the temperate colonies.

By the time Britain was establishing its North American, Australian, and New Zealand colonies in the 17th-19th centuries, it was the premier world power, and this did not change significantly until WWI. Britain was the home of the industrial revolution beginning in the 18th century; it defeated the Dutch and France in North America between 1664 and 1763; and faced no serious competition in Australia or New Zealand. Spain, another potential competitor, was driven from most of its western hemisphere colonies between 1810 and 1825. Accordingly, Britain had secure control over its colonial territories, increasing the expected time path of returns of implementing new institutional forms. In terms of local demarcation practices, indigenous peoples tended to be sparsely populated without formal demarcation of the land at least that was generally adhered to by Britain. The groups were militarily defeated, allowing the Britain to implement British land demarcation institutions across its temperate colonies (Linklater 2002, 24-40).[23]

There were, however, other important colonial characteristics that varied, and we use this information to explain differences in observed land institutions. Table 2 describes the different

[23]In the colonial period, only in New Zealand in the North Island were population numbers sufficiently large that natives had more political and military power requiring accommodation. For discussion, see Hailey (1938, 713). Population estimates for the temperate colonies at the time of settlement are limited. Some sources include Borah (1976, 13-34), Pool (1977), and Vamplew (1987).

institutions found in the temperate colonies, following the classifications described above and organized by system.

[TABLE 2 HERE]

Figures 3 and 4 show examples of varying demarcation practices across the Empire. The discussion of practices across the colonies is ordered according to the type of regime that prevailed in each. Among the variables identified in the framework developed above, historical narratives provide information on the roles of a) Control over land and the population so that survey could precede settlement; b) Time of settlement that indicates access to newer more accurate survey techniques and equipment that lower the costs of centralized demarcation; c)Terrain that influences the costs of survey, setup, and monitoring control over settlement; and d) Land quality that influences agricultural land values, farm size, and population densities, as well as the opportunity cost of delayed settlement under centralized demarcation.

[FIGURES 3 AND 4 HERE]

METES AND BOUNDS DEMARCATION

MB demarcation was used in the Southern American Colonies, the Middle Atlantic Colonies, New South Wales, Tasmania, Queensland, and Western Australia. These were all relatively early colonies, most established in the 17th and early 18th centuries so that settlement and demarcation took place with more primitive, costly survey instruments, making centralized demarcation setup more difficult and protracted. Although there were early plans for more centralized demarcation in Georgia and South Carolina, these failed.[24] There was little control

[24] See Marschner (1960, 22-24, 33-36), Kain and Baigent (1992, 269-76), Price (1995, 97 on free land choice; see also 7, 15-18, 87-205 for discussion of the southern colonies), Thrower (1966, 10), Johnson (1957, 22), Kinda (2001, 143), Mitchell (1983).

over the internal migration of land claimants in the southern American colonies, and rugged terrain reduced the attractiveness of the area for agriculture. As colonial immigrants moved into the interior, land areas were indiscriminately selected, settled, and then surveyed in a haphazard manner using metes and bounds. As a result there was little consistency in parcel shapes, sizes, or alignment, and boundaries were vague and often disputed. Swamps and irregular terrain also made more systematic survey costly(Linklater 2002, 32-40).

In the Middle Atlantic colonies, William Penn, who was granted the territory of Pennsylvania in 1681, also had envisioned centralized land distribution with contiguous tiers of townships of 5,000 acres square with rectangular plots, surveyed prior to settlement, moving west from the Delaware River. But this also generally did not occur in Pennsylvania or elsewhere in New Jersey, New York, and Delaware where there was only loose colonial control over the occupation of land in rugged terrain, and parcels were haphazardly defined prior to survey (Marschner 1960, 2734, 35; Price 1995, 212).

Limited control, rough terrain and variable soil quality also led to MB in the early Australia colonies of New South Wales (1770), Tasmania (1803), Queensland (a part of New South Wales until 1859), and Western Australia (1826). New South Wales and Tasmania began as penal colonies for Britain and not initially as locations for emigration to new land. As a result, there was little constraint on internal migration and land claims. Although instructions to colonial governors called for British institutions to be implemented for planned, centralized allocation and survey of land into small farms under RS, these instructions could not be enforced. As a result, claiming and demarcation was much more *ad hoc* under individualized metes and bounds.

In the interior of New South Wales, rough terrain increased the costs of systematic demarcation strategies and semi aridity increased the need for claimants to disperse, reducing potential network gains for centralizing demarcation in a given region(Jeans 1966, 125-7; Jeans 1967, 243-54; Kain and Baigent 1992, 307-10). Efforts to implement Wakefield's plans for centralized survey and distribution via RS in 1821 failed (Winch 1965, 94-108; Jeans 1966, 119-23).[25]Queensland and Tasmania (or Van Diemen's Land) were initially administered as part of New South Wales but had little planning in settlement prior to them becoming separate territories in the mid-19th century (Kain and Baigent 1992, 307; Jones 1989, 41). The same terrain problems and lack of control over land claiming led to the dominance of MB in both Queensland (Jeans, 1966, 122-23; Kain and Baigent,1992, 307) and Tasmania (Jones 1989, 75).[26]As in New South Wales, the most arable land was occupied by individuals and then surveyed under decentralized MB. Although not adjacent to New South Wales, Western Australia faced similar problems of controlling settlement prior to survey, coupled with very dry terrain and mixed soil quality that did not blend with a small, systematic land distribution policy.[27]

DEMARCATION IN A RECTANGULAR SYSTEM

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[25] Similar arguments are found in Jeans (1975).

[26] Also through personal communication with Brownwyn Meikle, a post graduate student at the University of Tasmania who is studying early land policies, January 2010. See also McKay (1962) for discussion of Tasmanian survey and land demarcation. .

[27]Jeans (1975, 3-5) discusses the general problem in Australia of limited good farm land and dry conditions that favored pastoral pursuits, rather than farming. For problems in Queensland and Western Australia with squatting and "free homesteading, see Williams (1975, 94).See Kain and Baigent (1992, 307, 309) for reference to unregulated distribution of land in huge parcels in West Australia (Swan River colony).

Rectangular systems were used to demarcate land in the (US) Federal Public Lands, the Canadian Dominion Lands, Ontario, New Brunswick, South Australia, and Victoria. There regions have characteristics distinct from those in which MB was established. They were settled relatively later, generally in the late 18th and early to mid19th centuries; are characterized by large land areas, flat terrain, and fertile soil; by more effective control over internal migration; and by improvements in survey technology. Our analysis implies that these factors would facilitate survey prior to settlement into RS.

The advantages of the broad, uniform rectilinear demarcation of land were recognized in the U.S. at the end of the colonial period during Congressional debates over the Land Ordinance of May 20, 1785 that ultimately resulted in the Public Lands Survey System, PLSS.[28]The law gave government authority over demarcation and settlement as a condition of granting individual titles. Congress rejected metes and bounds and instead called for survey before occupation with properties to be marked in squares, aligned with each other.[29] The land was surveyed into 6 by 6

[28] Ford (1910, reprinted 1976, 27, 55), Linklater (2002, 116, 117), Pattison (1957, 87). http://www.nationalatlas.gov/articles/boundaries/a_plss.html. A survey technique that used in the 19th century was triangulation http://en.wikipedia.org/wiki/Triangulation. Triangulation involves measurement of the angles of a series of triangles to fix property location and boundaries. If done in an organized manner, parcels could be demarcated with respect to one another.

[29]It seems likely that American colonial, and later government, leaders were influenced by British intellectual discussions of land demarcation. These individuals traveled to England and elsewhere in Europe and studied conditions there. We, however, have not located direct links between Congressional arguments and the statements of British political economists on demarcation.

mile townships (480 chains per side) and subdivided into 36 sections of one square mile each before sale and settlement (Linklater 2002, 68-72; White 1983, 9).[30]

The PLSS was inaugurated for the comparatively flat and rich soils of the Midwest and gradually extended across the Great Plains. The rectangular survey was adopted because of its ability to promote "…an orderly settlement of new lands," prevent the scattered and uneven claiming of only the best lands "…leaving vacant and uncultivated, in such irregularity, small and incommodious parcells that it is thought scarcely worth any one's While….," reduce land boundary conflicts and "prevent innumerable frauds and enable us to save millions", and importantly raise land values and revenue "…these Lands will provide 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."[31]

In Ontario, beginning in 1763, the flat and fertile land along the Great Lakes and St. Lawrence River also was demarcated in a grid with 6-mile square townships a standard, although there was variation in township and subdivision size across the province. Near lakes, narrow, rectangular long lots also were used (Kain and Baigent 1992, 298-303; Taylor 1945, 90-92; Thomson 1966, 237-43). Similar demarcation was practiced in the south and east of the St. Lawrence in Quebec, called the "Eastern Townships" and the colony of New Brunswick (1784) (Kain and Baigent 1992, 298; Taylor 1945, 89; Thomson 1966, 99, 224-5; Schott 1980). The

[30] As described by Pattison (1957, 49-51), the rectangular survey used Gunter's chain with 10 square chains to the acre; a mile divided into 80 chains; and a square mile in to 640 acres; White (1983).

[31]Ford (1910, 15) in describing a letter from Governor Sharp of Maryland to Lard Baltimore in 1754. See also Kain and Baigent (1992, 289-92) and Cazier (1976).

Dominion Land Survey (DLS), which began in1871, was implemented in the Prairie Provinces of Canada to parallel the PLSS in the U.S. with land surveyed into 6-mile square townships that were aligned and addressed along lines of latitude and longitude (Kain and Baigent 1992, 303; McKercher 1986, 21; Taylor 1975, 11; MacGregor, 1981).

In Victoria, Australia (separated from New South Wales in 1851) RS was used as the agricultural frontier moved northwest beyond Port Philip (Melbourne) in the 1850s.The main cadastral unit for surveying and mapping properties was the parish that varied in size between 15 and 33 square miles. Some parish borders were aligned rectilinearly toward magnetic north, similar to PLSS in the U.S. In the Melbourne-Colac-Geelong triangle to the west of Melbourne, parishes were divided into sections of 640 acres and subdivisions of 80 and 40 acres (Kain and Baigent 1992, 311-13; Powell 1970, 51-68; 1975, 35).

South Australia (1834) was the definitive planned colony. Colonization was organized after 1835 by the South Australian Land Company. Land was surveyed into rectangular grids following Wakefield's philosophy (Winch 1965, 97-110; Burroughs 1967, 179; Oldham 1917, 4, 10, 14; Wakefield 1834, 3-19). Wakefield wanted "…to prevent 'a few good judges of their own interests' from buying up all the available profitable, waste lands" and avoid the "injurious" dispersion of settlement where "each settler became the proprietor of a small section of land; under such conditions society was impossible…." (Oldham 1917, 14-15; Wakefield 1834, 87-89). [32] A land registry system designed by Robert Torrens to facilitate the clear assignment of land rights and active land markets was adopted and represented a break from use of English common law deeds of transfer (Kain and Baigent 1992, 313-17; Burroughs 1967, 179; South Australia Department of Lands 1986, 8, 38; Powell, 1972).

[32] Wakefield admired the U.S. federal lands policy (1834, 99-103).

MIXED DEMARCATION SYSTEMS

In New England, Nova Scotia, Quebec, and New Zealand mixed demarcation systems were established. Mixed systems come in various forms, but follow the general rules predicted by the framework. In contrast to MB, MX systems exhibited greater control over settlement and demarcation and survey occurred prior occupation, but they also lacked the uniformity of RS. These colonies also generally had rough terrain that raised survey costs of uniform demarcation and limited the use of RS. In terms of timing all, but New Zealand (largely settled in the 19th century), were early colonies dating from the 17th century.[33]Quebec was colonized beginning in 1608 by France and French land demarcation was incorporated by the British. All mixed systems were flexible in the demarcation patterns they implemented, but the earlier systems were also flexible in the extent of centralization they imposed. This timing suggests the use of primitive survey technology in earlier settlements, which all things equal, would increase the costs of extensive centralized systems such as the RS. On the other hand, most of these colonies were communal settlements with strong ties to the center of the settlement, which effectively lowered the cost of controlling settlement relative to the MB observations (Price 1995). The result was a mixed demarcation system that varied across the colonies.

In New England land was demarcated into (generally) square townships of 6 to 10 miles and internally divided into town lots and agricultural plots, including common fields. Proprietors distributed land to the township inhabitants. Within the township, properties were not of equal size or uniform shape, but based on social standing, wealth, and family size. Settlement was

[33]New England included Massachusetts (1620, Plymouth, 1628, Massachusetts Bay Colony), Maine (1622), New Hampshire (1623), Rhode Island (1636), and Connecticut (1633). Nova Scotia was (1621), while New Zealand settlement largely occurred in the 19thcentury after 1838.

communal, often organized around religious groups from an existing community in England (Marschner 1960, 24, 25; Egleston 1886, 21-22, 41-45; Price 1995, 13-14, 28-29; Kinda 2001, 142). As settlers moved into the interior, they petitioned colonial governments for land grants that were distributed as new “towns” or townships (Kain and Baigent 1992, 285-86; Egleston 1886, 15). Lands were to be occupied collectively to build a “compact state of freeholders” and were to be surveyed and marked within 12 months of the township grant. There was limited independent squatting on land (Egleston 1886, 15-18; Price 1995, 28-35.) Township locations were not coordinated and could be scattered. This organized pattern of survey and demarcation tended to weaken as migration moved further into the more rugged New England interior (Price 1995, 34-35).

Nova Scotia (1621) land demarcation patterns were similar to those in New England with local townships. In some cases townships were large, of 100,000 acres given to a collective group. Individual shares within the township could be up to 500 acres. The external township lines were surveyed prior to the grant and the township community was responsible for subdivision (Kinda (2001, 142), Thomson (1966, 118-120).

Quebec was made part of the British Empire in 1763 after the treaty of Paris. The French crown granted land to seigneurs who subdivided their grants into individual plots of 60-100 acres in long narrow lots that fronted the St. Lawrence River. The seigneurs then recruited colonists to occupy and rent their lands. In this way, the land was surveyed and demarcated prior to settlement in a manner similar to townships in New England (Harris and Guelke 1977, 135-53; Kain and Baigent1992, 276-98, 303; Thomson 1966, 38, 76-77).

Demarcation in New Zealand was affected by the control over settlement provided both by Wakefield’s philosophies implemented by the New Zealand Land Company organized in

1838 (Winch 1965, 111-13) and by improvements in surveying with triangulation that appeared by the 19th century. Triangulation techniques accelerated the implementation of large-scale surveys and made centralized demarcation more feasible. Indeed, the initial plan was to use a rectangular system. Six (and later 10) provinces were established in New Zealand and each adopted a separate, but similar land demarcation system: Wellington, Nelson, Taranaki, Otago, Canterbury, and Hawke's Bay (Scott 1998, 51; Kain and Baigent 1992, 318, 319).[34] The New Zealand Company's initial RS system worked to some degree in Canterbury, which was relatively flat, but ran afoul of rough terrain and other natural features that raised the costs of demarcating into square sections elsewhere. An alternative centralized survey system as MX with variable parcel sizes, shapes, and alignment was adopted. However, as opposed to MB, the centralized system provided systematic location, addresses, and well defined boundaries. It was first used in Otago and spread throughout all of New Zealand by 1876 (Kain and Baigent 1992, 320-24).

The historical data are consistent with the framework in Section III. To more precisely examine the effects of the variables described in the framework, we now turn to econometric analysis of the adoption of a particular regime.

B. ECONOMETRIC ANALYSIS USING DATA ON LAND CHARACTERISTICS

The historical data are consistent with the framework in Section III. To more precisely examine the effects of the variables described in the framework, we now turn to econometric analysis of the adoption of a particular regime.

DATA AND DESCRIPTIVE STATISTICS

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[34]They were combined into a single colony in 1876. Through 1870 most agricultural settlement took place on the South Island (Greasley and Oxley 2009, 326).

With the use of Geographic Information System (GIS) data, we compile a dataset of land characteristics at the colonial level for each area listed in Table 2. Observations are centered at the initial point of British settlement within the colony and include all land area within a 50 mile radius. By overlaying publicly available spatial data we calculate variables for terrain ruggedness, soil quality, area governed and year of settlement. Terrain ruggedness is a measure of average surface slope in a region and is derived from 90m digital elevation models (DEMs) generated by the Shuttle Radar Topography Mission (SRTM). Soil quality represents an average of soil quality scores assigned at a 1km resolution. The score ranges from 1 to 7 with 1 indicating soil unsuitable for agriculture and 7 indicating unconstrained soil. Soil quality data was taken from the Global Agro-Ecological Zones (GAEZ) dataset. Area governed represents the land area within the boundaries of the observation measured in units of 1,000 km^2. More complete descriptions of how the variables were constructed can be found in the Data Appendix.

Table 3 provides descriptive statistics for the variables in our analysis by demarcation type. On average, RS is observed over large regions with relatively flat terrain and above average soil quality, which is consistent with the historical analysis presented above. In addition, the reported means for settlement year suggest an increasing level of order and uniformity in demarcation practices over time.

[TABLE 3 HERE]

DETERMINANTS OF ADOPTION: OLS ESTIMATES

To understand the relative importance of the variables in Table 3, we estimate the decision to adopt a centralized demarcation system by ordinary least squares (OLS) from the following linear regression model:[35]

[35]OLS regression is chosen over maximum likelihood because of its preferable small sample

(8) $Y_i = \mu + \alpha T_i + \beta S_i + \delta A_i + \theta D_i + \varepsilon_i$

Where Y_i is a binary outcome variable in which a 1 indicates a centralized RS or MX system (10 observations) in colony i and a 0 indicates decentralized MB (13 observations).[36] In (8) T_i is the terrain ruggedness in colony i, S_i is soil quality (both within the 50-mile radius of the initial settlement point), A_i is the area governed (size of colony or region in 10,000 km^2), D_i is the date of initial settlement in years, α, β, δ and θ are regression coefficients, μ is a constant, and ε_i is a random error term. OLS estimates are reported in Table 4. Given the linear model, we can loosely interpret the dependent variables as response probabilities and the coefficients as marginal effects.[37]

[TABLE 4 HERE]

The most salient result that comes out of Table 4 is the clear shift toward centralized demarcation over time. Our main interpretation of this effect is that the progressive development of survey technology over time lowered the costs and increased the speed of implementing a systematic survey that preceded settlement. To get a general idea of the magnitude of the effect of settlement date, the results imply that adoption of centralized demarcation in a temperate frontier setting is 40% more likely over a century within the time-frame of our sample. The

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properties.

[36]As the model distinguishes between centralized and decentralized systems, we exclude New England and Canadian MX observations in which centralization was only partial.

[37]A probit analysis generates qualitatively similar results. The estimated marginal effects are: Terrain Ruggedness .046; Soil Quality .055; Area Governed .00017; Year of Settlement .0064**. Heteroskedasticity-consistent standard errors were used in the significance tests (***p<.01, ** p < 0.05, * p < 0.1).

estimated coefficient on terrain ruggedness is negative as predicted, but is not statistically different from zero. As seen in the historical analysis, additional confounding factors such as accounting for political control may be affecting setup costs and adding noise to the results. Similarly, the estimated coefficient on area governed is positive as predicted, but not statistically significant. In addition to issues of confounding control costs, these results may indicate that some public benefits to centralized demarcation, particularly in MX regimes, occur over a relatively small range. Lastly, the insignificant coefficient on the soil quality variable is not surprising, as the direction of the land quality effect was ambiguous in the theory. We can interpret the positive sign of the coefficient as an indication that on average, the future potential of more valuable land justified the upfront cost of a centralized system.

We next analyze the decision to adopt a uniform demarcation system over a more flexible one by estimating

(9) $$U_i = \mu + \alpha T_i + \gamma A_i + \theta D_i + \varepsilon_i$$

where U_i is a binary outcome variable in which a 1 indicates a uniform RS system. All other variables in (9) are the same as those used to estimate (8), except that soil quality is not included. The first specification uses the entire sample and looks at the general tension between uniformity and flexibility. The second specification restricts the analysis to only RS and MX observations, ones in which an identifiable level of control has been established, to more precisely test the predictions from equation (7). OLS estimates of equation (9) are reported in Table 5.

[TABLE 5 HERE]

The estimates reported in Table 5 are generally consistent with our predictions and historical analysis. The estimated coefficient on area governed is highly significant and supports the prediction that gains from uniform demarcation increase with the size of the network. Both coefficient estimates suggest that that an increase in 2 million square kilometers (about 250 million acres), approximately one standard deviation, should increase the likelihood of adopting uniform demarcation by 9%. The estimated coefficients on terrain ruggedness are negative and significant in both regressions, also indicating the important impact of topography and the increased survey costs of uniform demarcation in rugged terrain.

We also find a positive and significant effect for the year of initial settlement in both samples. The results suggest about a 20% increase in the likelihood of RS adoption over one century. This is consistent with our predictions for two reasons. First, improvements in survey technology increase the speed of implementation of extensive and uniform demarcation systems and reduce the total cost of setup relative to alternatives. Second, as land markets evolved and expanded over time, there was a greater role for parcel standardization in lowering transaction costs.

V. Conclusion

A half century has passed since Ronald Coase taught economists the importance of the fundamental institutions that underlie markets. He pointed out the link between property rights and transaction costs; how legal and other factors determine them; and how these in turn shape economic outcomes. These insights have influenced subsequent work of economists working on transaction costs, property rights, economic organization, and development.[38] Ironically, the

[38]The list is far too large to do justice to the literatures. Besides those noted earlier, one would certainly include the work of Barzel (1982); Demsetz (1988, 1997); Williamson (1975, 1985), and others on the theory of the firm.

institutions of land – one of Coase's original examples – have been neglected in the expansion of institutional economics.

In this paper we have examined the economic history of land demarcation in the expansive British Empire, using the insights of Ronald Coase. We have developed an economic framework for examining the decision to adopt a particular system of demarcation of rights to land. Using that framework we have analyzed the variation in institutions across the temperate British Empire, ranging from the systematic rectangular survey to an organized hybrid, to unsystematic metes and bounds. This variation occurred despite efforts by leading British political economists and colonial politicians, such as Edward Gibbons Wakefield, as well as the British Colonial Office to implement a planned and controlled rectangular survey for the demarcation of land.

We have found that a simple framework that outlines the costs and benefits of implementing the demarcation systems can explain the different institutions that are observed. Once in place, these institutions persist, indicating a strong institutional path dependence that can influence transaction costs, the extent of land markets, and the nature of resource use. The agricultural land institutions that we have examined in the U.S., Canada, Australia, and New Zealand that were put into place between the 17th and 19thcenturies, remain in force today. In this regard, institutions of land are durable, much as are other institutions, such as language and law.

This persistence of demarcation regimes indicates the costs of institutional change once land has been allocated and parcels developed. Individuals can consolidate or subdivide their properties as necessary through land markets, but restructuring demarcation requires coordination among adjacent land owners in readjusting boundaries, parcel shapes and sizes, fencing, and past capital investments. The costs of valuing and reallocating existing plots and investments are likely to be significant and holdup is a possibility. Further, the network benefits of a centralized regime are public goods that are not necessarily captured by individuals unless they are very large land owners. Most of the gains require large areas and a stable sovereign to capture long term benefits. A centralized regime would not be worth the new set up costs for individual property owners. Finally, as we argue changes in technology can dramatically alter the cost of implementing demarcation systems. Although, technology lowered the costs of centralization between the 17th and 19th centuries, more recent advances in GPS, GIS, and other geographic technologies may serve to make MB and MX parcels more comprehensible, lowering the advantages of the RS.

APPENDIX: VARIABLES AND DATA SOURCES

OBSERVATIONS: Observations are centered at the initial point of British settlement and include all land area within a 50 mile radius. For the US Public Land Survey we use the 'Point of Beginning' located in present day East Liverpool, Ohio at the coordinates 40°38′32.61″N 80°31′9.76″W. For the Dominion Land Survey of Canada we use the center of Winnipeg as the initial point. Coordinates for initial settlements were obtained from http://facstaff.unca.edu/mcmcclur/GoogleMaps/Projections/GoogleCoords.html.

TERRAIN RUGGEDNESS: Measures average surface slope for the region (see Libecap Lueck 2009). The measure is derived from 90m digital elevation models (DEMs) downloaded from http://srtm.csi.cgiar.org. The DEMs are generated from NASA's Shuttle Radar Topography Mission (SRTM) and further processed by the International Centre for Tropical Agriculture (CIAT) to fill voids in the dataset. We exclude water bodies in our measure of terrain ruggedness. This was done by removing areas in the DEM which overlap data from the SRTM Water Body Database (SWBD). SWBD data was obtained online from http://dds.cr.usgs.gov/srtm/version2_1/SWBD.

SOIL QUALITY: Based on a seven-point score measuring constraints on soil fertility from the Global Agro-Ecological Zones (GAEZ) dataset downloaded at 30 arc second resolution from http://www.iiasa.ac.at/Research/LUC/GAEZ. We reverse the order of the GAEZ ranking to reflect quality of the soil rather than constraints. A score of 1 indicates soil unsuitable for agriculture. Scores 2-6 indicate soil suitable for agriculture but with constrained productivity and severity of constraints decreasing with score. A score of 7 indicates unconstrained soil. The final measure is an average over the area of the observation.

YEAR OF SETTLEMENT: Initial year of settlement was obtained from http://www.britishempire.co.uk/timeline/colonies.htm. The earliest year listed for each colony is used for the analysis with the exception of New Zealand and Victoria, 1840 and 1851 respectively, in which we use the year they separated from New South Wales. Initial years for the PLSS and DLS are 1785 and 1871 respectively.

AREA GOVERNED: Measured as the land area of the territory in 1,000 km^2. Current boundaries of Ontario and Quebec were used to determine area for Upper and Lower Canada respectively. Area under the Dominion Land Survey was calculated as the collective area of the provinces Manitoba, Saskatchewan, and Alberta. Area under the U.S. Public Land Survey System was calculated as the collective area of all U.S. states not included in our sample with the exceptions of Hawaii, Texas, Louisiana, New Mexico, California, Alaska, Kentucky, West Virginia, Tennessee and Vermont. Area for New Zealand territories were adapted from the map in Kain and Baigent (1984, 319, Figure 8.30).Area for all other observations use current boundaries.

REFERENCES

Acemoglu, Daron, Simon Johnson, and James A. Robinson. 2001. "The Colonial Origins of Comparative Development: An Empirical Investigation," The American Economic Review, 91 (5): 1369–1401.

Acemoglu, Daron, Simon Johnson, James A. Robinson. 2002, "Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution," *The Quarterly Journal of Economics*, 117 (4): 1231-1294

Acemoglu, Daron, Simon Johnson, James A. Robinson. 2005. "The Rise of Europe: Atlantic Trade, Institutional Change, and Economic Growth," *The American Economic Review*, 95 (3): 546-579.

Allen, Robert C. 1982. "The Efficiency and Distributional Consequences of Eighteenth Century Enclosures," *The Economic Journal* 92 (December): 937-53.

Barnes, Carlton P. 1935. "Economies of the Long Lot Farm", *Geographical Review*, 25 (April): 298-301.

Barzel, Yoram. 1982. "Measurement Costs and the Organization of Markets," *Journal of Law and Economics* 25(1): 27-48.

Bogart, Dan and Gary Richardson. 2009. "Making Property Productive: Reorganizing Rights to Real and Equitable Estates in Britain, 1660-1830," *European Review of Economic History,* 13: 3-30.

Borah, Woodrow W. 1976. "The Historical Demography of Aboriginal and Colonial America: An Attempt at Perspective." in *The Native Population of the Americas in 1492*. William M. Denevan, ed. Madison: University of Wisconsin Press. 13-34.

Burroughs, Peter. 1967. *Britain and Australia, 1831-1855: A Study in Imperial Relations and Crown Lands Administration.* Oxford: Clarendon Press.

Coase, Ronald H. 1937. "The Nature of the Firm" *Economica*, 4 (16) 386-405.

Coase, Ronald H. 1960. "The Problem of Social Cost" *Journal of Law and Economics,* 3:1-44.

Coase, Ronald H. 1988. *The Firm, the Market and the Law.* Chicago: The University of Chicago Press.

Crazier, Lola. 1976. *Surveys and Surveyors of the Public Domain, 1785-1975*. Washington D.C.: Government Printing Office.

Crosby, Alfred. 1986. *Ecological Imperialism: The Biological Expansion of Europe 900-1900*. New York: Cambridge University Press.

Darby, H.C. Ed. 1973. *A New Historical Geography of England*. Cambridge: Cambridge University Press.

Demsetz, Harold. 1988. "The Theory of the firm Revisited," *Journal of Law, Economics and Organization* 4(1): 141-61.

Demsetz, Harold. 1997. "The Firm in Economic Theory: A Quiet Revolution." *American Economic Review* 87(2): 426-29.

Dixit, Avinash. 2003. "Trade Expansion and Contract Enforcement," *Journal of Political Economy* 111:1293-1317.

Dukeminier, Jesse and James E. Krier. 2002. *Property* 5th ed. New York: Aspen Law and Business.

Egleston, Melville. 1886. *The Land System of the New England Colonies*. Baltimore: N. Murray, Publication Agent for Johns Hopkins University.

Ferguson, Niall. 2004. *Colossus: The Price of America's Empire.* New York: The Penguin Press.

Ford, Amelia Clewly. 1910. Reprinted 1976. *Colonial Precedents of Our National Land System as it Existed in 1800*. Madison: Bulletin of the University of Wisconsin. No. 352. History Series, Vol. 2. No. 2. Reprinted. Philadelphia: Porcupine Press.

Gates, Paul W. 1968. *History of Public Land Law Development*, Washington D.C.: GPO.

Greasley, David and Les Oxley. 2009. "The Pastoral Boom, the Rural Land Market, and Long Swings in New Zealand Economic Growth, 1873-1939." *Economic History Review*, 62 (2), 324-49.

Johnson, Hildegard Binder. 1957. "Rational and Ecological Aspects of the Quarter Section." *Geographical Review* 47: 330-48.

Jones, Alan. 1989. *Backsight: A History of Surveying in Colonial Tasmania*. Hobart: Institution of Surveyors, Australia Inc, Tasmanian Division.

Hailey, Lord. 1938. *An African Survey: A Study of Problems Arising in Africa South of the Sahara.* London: Oxford University Press.

Harris, R. Cole and Leonard Guelke. 1977. "Land and Society in Early Canada and South Africa." *Journal of Historical Geography*, 3(2): 135-53

Jeans, D.N. 1966. "The Breakdown of Australia's First Rectangular Grid Survey."*Australian Geographical Studies*, IV: 119-28.

Jeans, D.N. 1967. "Territorial Divisions and the Locations of Towns in New South Wales, 1826-1842."*Australian Geographer*. 19: 243-255.

Jeans, D. N. 1975. "The Impress of Central Authority upon the landscape: South-Eastern Australia 1788-1850." *Australian Space Australian Time*, J.M. Powell and M. Williams, ed. Melbourne, Oxford University Press.7-12.

Kain, Roger J. P. and Elizabeth Baigent.1992. *The Cadastral Map in the Service of the State: A History of Property Mapping*. Chicago: University of Chicago Press.

Kain, Roger J., John Chapman, and Richard R. Oliver. 2004. *The Enclosure Maps of England and Wales 1595-1918 : A Cartographic Analysis and Electronic Catalogue*. New York: Cambridge University Press.

Kinda, Akihiro. 2001. "The Concept of 'Townships' in Britain and the British Colonies in the Seventeenth and Eighteenth Centuries." *Journal of Historical Geography* 27(2): 137-52.

Labaree, Leonard Woods. Ed. 1967. *Royal Instructions to British Colonial Governors, 1670-1776*, Vol. II. New York: Octagon Books, Inc.

Lee, D. R., and G. T. Sallee. 1974. "Theoretical Patterns of Farm Shape and Central Place Location," *Journal of Regional Science*, 14:3 423–30.

Libecap, Gary D. and Dean Lueck. 2011a. "Land Demarcation Systems." In Research Handbook on the Economics of Property Law, Research Handbooks in Law and Economics, edited by Kenneth Ayotte and Henry E. Smith, Northampton, MA: Elgar, 257–95.

Libecap, Gary D. and Dean Lueck. 2011b. "Land Demarcation and the Role of Coordinating Property Institutions," *Journal of Political Economy*, 119 (3) June: 426-467.

Libecap, Gary D., Dean Lueck, and Adrian Lopes, 2009. "The Effect of Land Demarcation Systems on Agriculture in 19th Century California." Manuscript University of Arizona.

Linklater, Andro. 2002. *Measuring America: How the United States was Shaped by the Greatest Land Sale in History*. London: Harper Collins

Marschner, Francis J. 1960. *Boundaries and Records in the Territory of Early Settlement from Canada to Florida: With Historical Notes on the Cadaster and its Potential Value in the Area*. Washington D.C.: Agricultural Research Service, USDA.

MacGregor, James. 1981. *Vision of an Ordered Land: The Story of the Dominion Land Survey*. Western Producer Prairie Books. Saskatoon, Saskatchewan.

McKay, Anne. ed.1962. *Journals of the Land Commissioners for Van Diemen's Land*, 1826-28. Hobart: University of Tasmania in conjunction with the Tasmanian Historical Research Association.

McManis, Douglas R. 1975. *Colonial New England: a historical geography*. New York: Oxford University Press.

Merrill, Thomas and Henry Smith. 2007. *Property: Principles and Policies*. New York: Foundation Press.

Mitchell, Robert D. 1983. "American Origins and Regional Institutions: The Seventeenth Century Chesapeake." *Annals of the Association of American Geographers* 73 (2): 404-20.

North, Douglass C. 1990. *Institutions, Institutional Change and Economic Performance*. New York: Cambridge University Press.

North, Douglass C, John Joseph Wallis, and Barry R. Weingast. 2009. *Violence and Social Orders: A Conceptual Framework for Interpreting Recorded Human History*. New York: Cambridge University Press.

Oldham, Wilfrid. 1917. *The Land Policy of South Australia from 1830 to 1842*. Adelaide: G. Hassell& Son.

Price, Edward T. Price. 1995. *Dividing the Land: Early American Beginnings of Our Private Property Mosaic*. Chicago: University of Chicago Press.

Pattison, William D. 1957. *Beginnings of the American Rectangular Land Survey System, 1784-1800*, Department of Geography Research Paper No. 50, University of Chicago.

Pool, D. Ian. 1977. *The Maori Population of New Zealand 1769-1971*. Auckland: University of Auckland Bindery.

Posner, Richard A. 2002. *Economic Analysis of the Law,* 6th ed. Boston: Little, Brown.

Powell, J.M. 1970. "The Victorian Survey System, 1837-1860." *New Zealand Geographer*. 26(1): 50-69.

Powell, J.M. 1972. "The Records of the New Zealand Lands and Survey Department." *New Zealand Geographer*, 28: 72–77.

Powell, J.M. 1975. "Conservation and Resource Management in Australia 1788-1860." In *Australian Space Australian Time*, Edited By J.M. Powell and M. Williams. Melbourne, Oxford University Press, 18-60 1975

Reps, John W. 1965.*The Making of Urban America*. Princeton: Princeton University Press.

Richardson, Gary and Dan Bogart. 2008. "Institutional Adaptability and Economic Development: The Property Rights Revolution in Britain, 1700 to 1830." Cambridge, MA: NBER working paper 13757.

Richeson, A.W. 1966. *English Land Measuring to 1800: Instruments and Practices*. Cambridge: MIT Press.

Schott, Carl. 1936. *Landnahme und Kolonisation in Canada, am beispielSiidontarios*(Kiel 1936), 83-101, translated, 1980, by Andrew Burghardt; maps redrawn by Margaret Chan. McMaster University, *Canadian Geographer*, 25 (1), 1981, 77-93.

Scott, James C. 1998. *Seeing Like a State: How Certain Schemes to Improve the Human Condition have Failed*. New Haven: Yale University Press.

Shavell, Steven. 2004. *Foundations of Economic Analysis of Law.* Cambridge: Harvard University Press.

South Australia, Department of Lands. 1986. *The Measure of the Land*, Adelaide.

Taylor, Griffith. 1945. "Towns and Townships in Southern Ontario." *Economic Geography*. 21 (2): 88-96.

Taylor, W. A. 1975. "Crown Lands: A History of Survey Systems." *Registries and Titles Department*. Victoria, B.C.: Ministry of Sustainable Resource Management.

Thomson, Don W. 1966. *Men and Meridians: The History of Surveying and Mapping in Canada*. Volume I: Prior to 1867. Ottawa: Queen's Printer.

Thrower, Norman J. W. 1966.*Original Survey and Land Subdivision: A Comparative Study of the Form and Effect of Contrasting Cadastral Surveys*. Association of American Geographers. Chicago: Rand McNally and Co.

Torrens, Robert. 1821. *An Essay on the Production of Wealth.* London: Longman, Hurst, Rees, Orme, and Brown.

Turner, Michael E. 1980. *English Parliamentary Enclosure: Its Historical Geography and Economic History*. Hamden, Connecticut: Dawson.

Vamplew, Wray. ed. 1987.*Australian Historical Statistics*. Sydney: Fairfax, Syme, and Weldon.

Wakefield, Edward Gibbon. 1834. *The British Province of South Australia or a Description of the County, Illustrated by Charts and Views with an Account of the Principles, Objects, Plan and Prospects of the Colony*. London: William Clowes.

Wakefield, E.G., Wakefield, E. J., Godley, J. R. 1868. *The Founders of Canterbury: Being Letters from the late Edward Gibbon Wakefield to the late John Robert Godley, and to Other Well-Known Helpers in the Foundation of the Settlement of Canterbury in New Zealand*. Christchurch, New Zealand: Stevens & Co.

White, C. Albert. 1983. *A History of the Rectangular Survey System*. Washington D.C.: Government Printing Office.

Winch, Donald. 1965. *Classical Political Economy and Colonies*. Cambridge: Harvard University Press.

Williams, M. 1975. "More and Smaller is Better: Australian Rural Settlement 1788-1914." In *Australian Space Australian Time*, Edited By J.M. Powell and M. Williams. Melbourne, Oxford University Press. 1975, 61-103.

Williamson, Oliver E. 1975. *Markets and Hierarchies, Analysis and Antitrust Implications: A Study in the Economics of Internal Organization*. New York: Free Press.

Williamson, Oliver E. 1985. *The Economic Institutions of Capitalism: Firms, Markets and Relational Contracts*. New York: Free Press.

Yelling, James. 1977. *Common Field and Enclosure in England, 1450-1850*. Hamden, Connecticut: Archon Books.

Young, Arthur. 1808. *General Report on Enclosures*. Drawn Up by Order of the Board of Agriculture, London: B. McMillan

TABLE 1: THREE LAND DEMARCATION REGIMES

Characteristic	Rectangular Survey	Mixed	Metes and Bounds
Controlled entry	Yes	Yes	No
Prior survey	Yes	Yes	No
Plot shape	Rectilinear	Varies	Idiosyncratic
Plot alignment	Yes (often N-S)	Varies	No
Fully contiguous	Yes (within region)	Varies	No

TABLE 2: LAND DEMARCATION SYSTEMS IN THE BRITISH EMPIRE

Jurisdiction	Demarcation System
U.S. Federal Lands	RS
Canadian Dominion Lands	RS
South Australia	RS
Ontario, Canada	RS
Victoria, Australia	RS
New Zealand: Otago	MX
New Zealand: Nelson	MX
New Zealand: Wellington	MX
New Zealand: Canterbury	MX
New Zealand: Hawkes Bay	MX
New Zealand: Taranaki	MX
Connecticut	MX
Rhode Island	MX
Massachusetts	MX
Maine	MX
New Hampshire	MX
Nova Scotia	MX
New Brunswick	MX
Quebec	MX
Georgia	MB

South Carolina	MB
North Carolina	MB
Virginia*	MB
Maryland	MB
Delaware	MB
Pennsylvania	MB
New Jersey	MB
New York	MB
New South Wales	MB
Tasmania	MB
Queensland	MB
West Australia	MB

Sources: See text.

* includes what is now Kentucky and West Virginia.

TABLE 3: SUMMARY STATISTICS BY DEMARCATION TYPE

System Type	Terrain Ruggedness	Soil Quality	Area Governed (10,000 km^2)	Year of Settlement
MB (13)	1.61	3.01	45.7	1707
	(1.39)	(0.74)	(78.7)	(75)
MX (14)	2.36	3.34	13.7	1746
	(1.33)	(.97)	(35.4)	(99)
RS (5)	1.09	4.32	283.2	1827
	(0.65)	(1.63)	(373.9)	(37)
Total (32)	1.85	3.39	68.8	1743

Notes: Means for each system type are reported with standard deviations below in parentheses.

TABLE 4: DETERMINANTS OF CENTRALIZATION (OLS REGRESSION ESTIMATES)

Dependent Variable	Terrain Ruggedness	Soil Quality	Area Governed	Year of Settlement	R^2	F Stat
MB = 0; RS, MX = 1	-0.0477	0.0816	0.00007	0.0041***	.50	18.9
(23 Obs)	[0.0618]	[0.105]	[0.0004]	[0.0011]		

Notes: Coefficient estimates are reported for an OLS regression on a [0,1] binary outcome variable where a value of 1 indicates centralized demarcation. Centralized demarcation includes RS and fully centralized MX, but excludes MX systems in New England and Canada where centralization was only partial. Heteroskedasticity-consistent standard errors are in brackets (***p<.01, ** p < 0.05, * p < 0.1).

TABLE 5: DETERMINANTS OF UNIFORMITY (OLS REGRESSION ESTIMATES)

Dependent Variable	Terrain Ruggedness	Area Governed	Year of Settlement	R^2	F Stat
<u>Full Sample</u>					
MB, MX = 0; RS = 1	-0.117***	0.00085***	0.0019**	.46	21.3
(32 Obs)	[0.0417]	[0.00017]	[0.0007]		
<u>Restricted Sample</u>					
MX = 0; RS = 1	-0.173**	0.00089***	0.0022***	.57	44.3
(19 Obs)	[0.065]	[0.00017]	[0.0007]		

Notes: Coefficient estimates are reported for OLS regressions on a [0,1] binary outcome variable where a value of 1 indicates a uniform RS demarcation system. The first sample utilizes all observations in the dataset and compares the flexible systems of MB and MX with the uniform RS. The second sample restricts the analysis to only MX and RS systems where an identifiable level of control has been established. Heteroskedasticity-consistent standard errors are in brackets (***p<.01, ** p < 0.05, * p < 0.1).

FIGURE 1: THE BRITISH EMPIRE AND TEMPERATE COLONIES

Source: The figure is modified from the figure provided in

http://meta.wikimedia.org/wiki/File:British_Empire_evolution.gif

FIGURE 2: DECISION TREE FOR COLONIAL DEMARCATION CHOICES

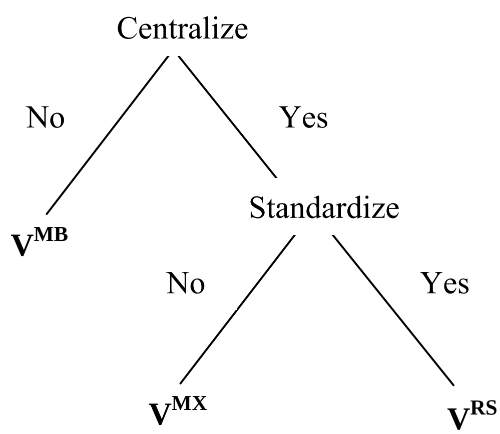
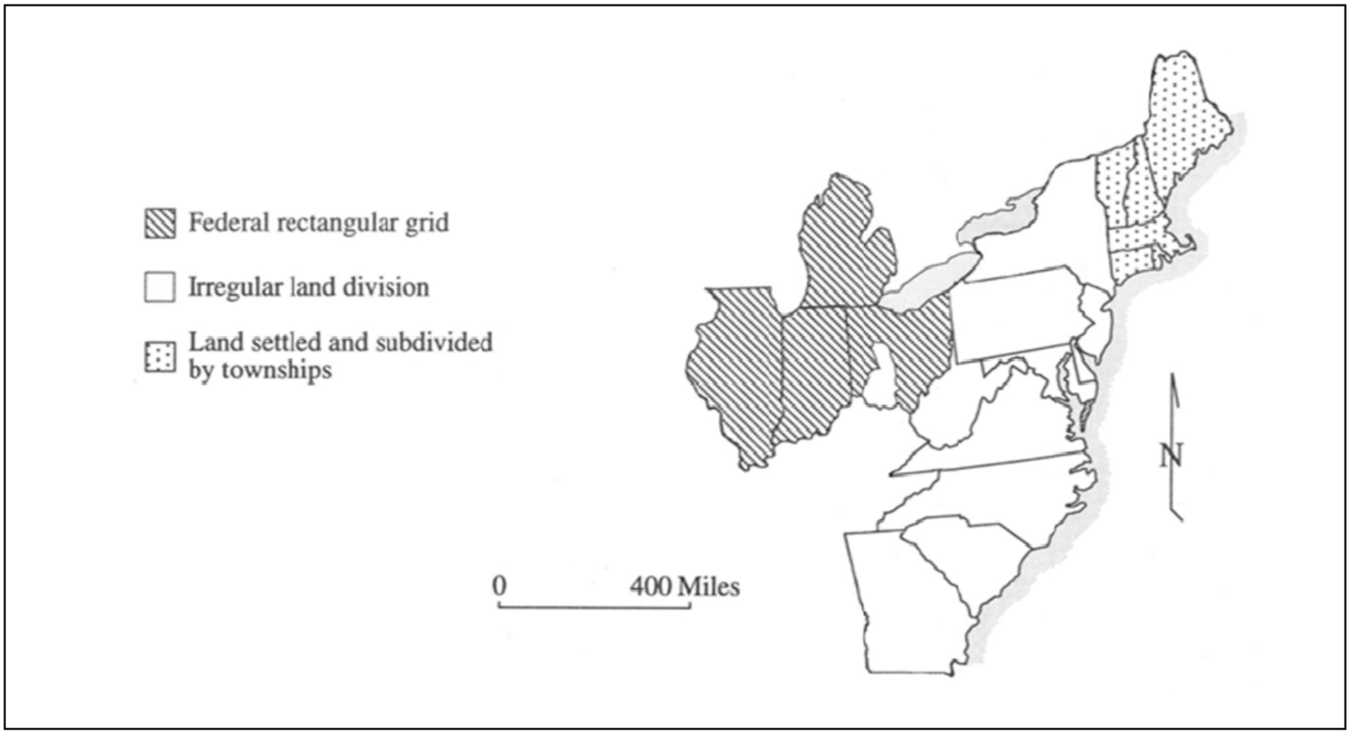
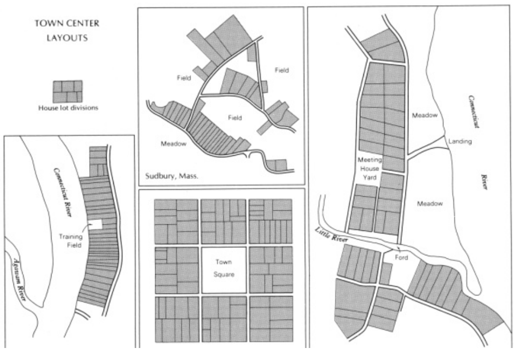


FIGURE 3: EARLY U.S. DEMARCATION SYSTEMS

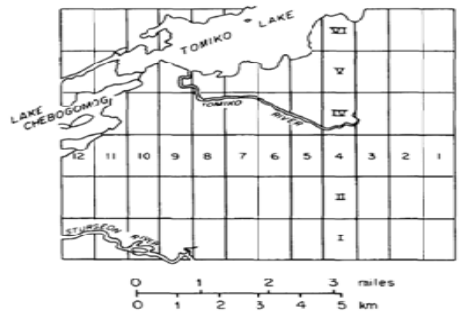


Source: Adapted from Price (1995, 8). Price's Federal rectangular grid corresponds to our RS; Townships to our Mixed Demarcation; and Irregular to our MB classification.

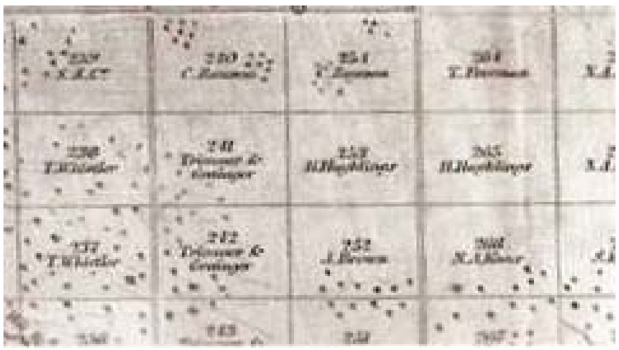
FIGURE 4: LAND DEMARCATION PRACTICES IN THE BRITISH COLONIES

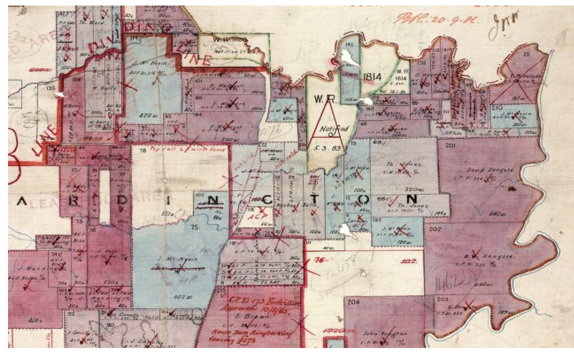


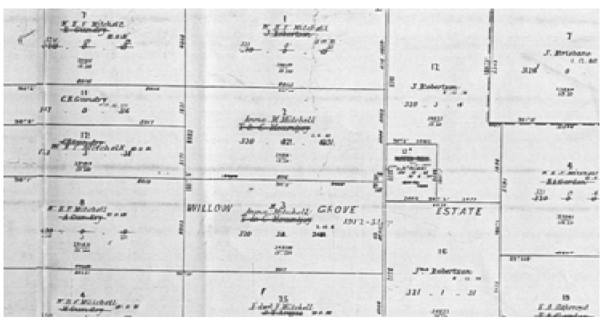
Mixed Demarcation, New England Townships

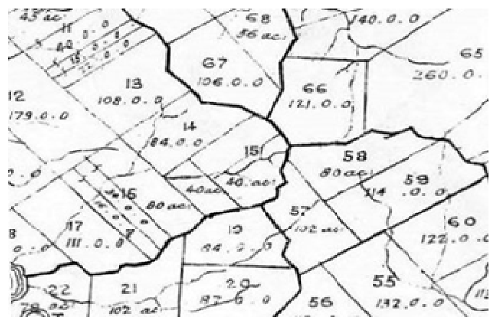


RS Demarcation, Ontario, Canada


RS Demarcation, South Australia


MB Demarcation, New South Wales,


RS Demarcation Victoria,
Australia


Mixed Demarcation, New Zealand

Sources: New England: McManis (1975, 56); Ontario: Schott (1936, reprinted, 1981, 84); South Australia: Kain (1992, 315); New South Wales: http://parishmaps.lands.nsw.gov.au/mrsid/show_map.pl?client=pmap&image=PMapEast02/1007

5001.sid&mapval1=CARDINGTON&mapval2=560&maptype=PL; Victoria: http://www.honeycombe-archive.com/thegreatwork/10maps/html/map04.html; New Zealand: http://sites.google.com/a/aotea.org/don-armitage/_/rsrc/1233729039315/Home/great-barrier-island-history/maps---charts-of-great-barrier-island/1880%20map%20gbi2.jpg

References: