Journal of Institutional Economics (2021), **17**, 764–780
doi:10.1017/S1744137421000266

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

De jure property rights and state capacity: evidence from land specification in the Boer Republics

Kara Dimitruk[1]*, Sophia Du Plessis[1] and Stan Du Plessis[2]

[1]Department of Economics & LEAP, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa and [2]Department of Economics, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
*Corresponding author. Email: karadimitruk@gmail.com

(Received 14 December 2019; revised 2 April 2021; accepted 2 April 2021)

Abstract

We examine the development of *de jure* property rights to land by assessing how accurately governments recorded borders of property. We use surveys of farm parcels from two historical states, the Republic of the Orange Free State (OFS) and the South African Republic (ZAR), which are in modern-day South Africa, and employ a descriptive analysis to infer how accurately maps represent parcels of property. We argue that differences in state administrative capacity explains differences in map accuracy and therefore the provision of *de jure* property rights to land. We find that maps of farms in the ZAR, which had lower administrative capacity, tend to be less accurate than maps of farms in the OFS. Comparisons with military maps compiled under a different administration provide evidence that the costs incurred from previous administrations can limit future attempts to accurately record property. The analysis shows how state administrative capacity can facilitate (or hinder) the provision of property rights to land.

Key words: Africa; frontier economics; land demarcation; property rights; state capacity

1. Introduction

The ability of states to carry out policies or provide services, such as 'collect taxes, enforce law and order and provide public goods' – their 'capacity' – is seen as crucial for economic development. The legal capacity to enforce rule of law and provide property rights is a key component of state capacity because it complements market activity (Besley and Persson, 2011; Johnson and Koyama, 2017: 2).[1] Providing property rights includes demarcating and re-defining rights, operating deeds registries, and arbitrating conflicts. These issues are usually studied from an institutional perspective (Besley and Ghatak, 2010; Coase, 1960; de Soto, 2000; Lamoreaux, 2011; Libecap *et al.*, 2011; Libecap and Lueck, 2011; North, 1990; Yoo and Steckel, 2016).

The ability of states to coordinate property rights provision is therefore central to our knowledge of the connection between state capacity and economic development. We study the provision of *de jure* property rights to land in two historical states in southern Africa, the Orange Free State (OFS) and the South African Republic (ZAR), primarily during the latter half of the 19th century. Known as the Boer Republics, both states implemented a metes and bounds (MB) land demarcation system where government officials recorded boundaries of farm parcels after European settlement (Braun, 2015; Christopher, 1970: 96; Giliomee, 1981; Liebenberg, 1973). Both states sought to improve their demarcation and recording systems, known as 'inspections', because they became an unreliable method to accurately record information in maps and deeds. The inaccurate information hampered each state's ability to collect taxes and led to conflicts amongst claimants.

[1]We discuss the other key component, fiscal capacity – the ability of states to raise taxes – further below.

We hypothesize that the different administrative capacities of the two states to implement and reform the inspection system influenced the quality of information of farm parcel boundaries in maps and thus the provision of *de jure* rights to European settlers. Accurate farm boundaries in maps reflect the government's ability to provide useful title deeds, maintain records that facilitate the transfer of ownership, and provide the public service of cartography. We use parcel shape in historical maps as a measure of map accuracy. We argue that the extent to which farm parcels are represented as squares[2] captures inaccurate specification of farm boundaries and therefore poorer quality *de jure* rights. A key issue is that square parcels are optimal in relatively flat areas in an MB system (Libecap and Lueck, 2011; Libecap *et al*., 2011).

A model of the government's choice to survey farms after settlement by *de facto* claims in an MB system shows in a simple way how greater administrative capacity can lower the costs of survey and improve map accuracy. Because we measure outcomes from specific historical maps, we then include a review of the administrations and incentives of map compilers as the proximate factors influencing the accuracy of maps. The different administrations in the OFS and ZAR shaped the incentives of map creators because the administrations had different resources, standards of surveying and enforcement, training and expertise, and resistance to mapping by farmers. There were also other 'macro' factors at play, such as the relative political stability and wealth of the ZAR and the OFS.[3]

To conduct a quantitative analysis and test the hypothesis that administrative capacity influenced the accuracy of farm parcels in maps, we collect information on farm boundaries. We digitize two sets of historical maps of farm boundaries. The first set was constructed by officials in the OFS and the ZAR at the end of the 19th century (OFS in 1886 and ZAR in 1892). The second set was constructed by the British military during the Anglo-Boer War (OFS in 1901 and ZAR in 1900). We also collect shapefiles of current (2019) properties provided by the South African government. We expect parcels of the ZAR to be less accurate (more square) than the OFS because it had lower administrative capacity. We also expect the 1900 military maps and 2019 shapefiles to be more accurate than the 19th-century maps because the administrations creating the later maps had better capacity.

Using OLS, where our outcome of interest is farm parcel shape (relative squareness) and including parcel-level measures of ruggedness, our findings broadly lend support to these hypotheses. We find that parcels in maps of the ZAR, which had less administrative capacity, tend to be more square compared to farms in the OFS. Within the ZAR, areas where map-makers had incentives to map the least accurately also have the most square farms on average. Last, compared to the maps created in 1886 and 1892, parcels tend to be less square in the 1900 British military maps (though imprecisely estimated) and 2019 property deeds. Areas in the ZAR show the largest 'improvement': farms are significantly less square in the 2019 shapefiles compared to the 1892 and the 1900 maps. The lack of a large statistical difference between the 19th-century maps and 1900 military maps suggests that the costs of previous administrations can limit future attempts to provide property rights (in terms of collecting information) even if the administration has resources, the officials have incentives, and officials have the training and expertise to accurately map property.

State capacity is usually thought of as consisting of fiscal capacity and legal capacity. Much research, which is primarily macro-historical owing to the concept's original use in comparative economic and political development, studies the determinants of a state's fiscal capacity (i.e. ability to collect taxes) and its relationship to economic development (e.g. Besley and Persson, 2011; Cingolani, 2013; Dincecco and Prado, 2012; Johnson and Koyama, 2017; Williams, 2021).[4] In contrast, this paper contributes to our understanding of the development of legal capacity. Most work on legal capacity tends to be cross-country

[2]In the analysis, we technically calculate correlation with a rectangle and do not impose that parcels have four equidistant sides. For simplicity and consistency with previous work on land demarcation, we use the term 'square' until the analysis section.

[3]As recognized in the theoretical literature, state capacity is a multidimensional problem: states with weak capacity have high poverty rates and internal conflicts while developed states are high income, resolve conflict peacefully, and have bureaucracies that function (Besley and Persson, 2011).

[4]Most of the research on state capacity in African economic history is on fiscal capacity (e.g. Cogneau *et al*., 2020; Gardner, 2012; Gwaindepi and Siebrits, 2020).

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

and often relies on indices of security of property rights, such as investor protection or property rights protection (e.g. Besley and Persson, 2009, 2011).[5] We provide more micro-level evidence on how the administrative structure was important for map accuracy, which helped coordinate other property rights services like deeds.[6] Last, our measure of map accuracy is novel in the literature on property rights cited above and specifically the literature on land demarcation (Libecap and Lueck, 2011; Libecap *et al.*, 2011). Our measure of 'accurate' information in maps complements recent work on the ability and resources of states to capture and process information in the production of aggregate statistics, which is particularly important for African states today (Brambor *et al.*, 2020; Jerven, 2013). South Africa's surveying administrations have adapted over time to adopt international standards and new technologies of surveying, even though it is currently considered a 'weak state' along other dimensions.[7]

Next, we provide background on the Boer Republics and their land demarcation systems. Section 3 overviews a model of the government's decision to survey. Section 4 reviews how the administrative structure and personnel incentives influenced the accuracy of maps created by OFS and ZAR officials in the 19th century, maps created by the British military in 1900, and the 2019 shapefiles provided by the South African government. Section 5 discusses the digitization of the maps, construction of measures of parcel accuracy, and our regression approach. Section 6 reports results. Section 7 concludes.

2. Historical background

Figure 1 shows the two Boer, which means farmer, Republics, the Republic of the OFS and ZAR (or Transvaal), relative to other territories and colonies in 19th-century southern Africa. At the frontier of southern Africa, substantial migration by settlements of European, largely Dutch, descent from the British Cape Colony led to more dense population settlement in these areas in the 1830s and 1840s (Muller, 1993).[8] The expansion of the British Cape Colony into the interior from the 1830s to the 1850s also helped consolidate the Boer Republics into official states that sought self-governance and independence from British colonial influence.[9]

Their creation went with the appropriation of the land of and resistance from indigenous populations as well as the creation of so-called native locations (Braun, 2008, 2015; Colson, 1971; Keegan, 1987). We focus on the provision of *de jure* property rights for white settlers in largely Venda and Pedi lands (Braun, 2005, 2008).[10] Both republics transferred a significant amount of land to private Europeans during the 19th and 20th centuries (shown in Figure 1).

2.1 Land alienation and demarcation in the Boer Republics

The OFS and the ZAR provided *de jure* property rights to land to satisfy basic objectives: 'the settlement of Europeans upon land, the raising of revenue, provision of security, raising agricultural and

[5]See Cingolani (2013) for a survey of the measures used in the literature.

[6]Williams (2021) discusses the limits of the concept of 'bureaucratic capacity' for studying a single reform, bureaucratic organization, or policy implementation, particularly in development practice. We use 'administrative structure' when discussing the specific organizations, resources, and rules leading to the creation of maps. We think administrative capacity is appropriate when comparing administrations in a more macro-historical way. State 'administrative capacity' is usually studied with fiscal capacity (e.g. Hup, 2020; Johnson and Koyama, 2014).

[7]See Williams (2021).

[8]Frontiers are important settings to study the provision of property rights. See Alston *et al.* (2012) and Libecap and Lueck (2011) for the United States, Alston *et al.* (2012) and Dye and La Croix (2013) for Australia, Alston *et al.* (2012) for Brazil, Dye and La Croix (2013) for Argentina, and Dye and La Croix (2021) for the Dutch Cape Colony.

[9]The ZAR was formally recognized as an independent republic with the Sand River Convention in 1852. The government sought to remain outside British influence. The OFS was created at the Orange River Convention in 1854, but remained closely aligned with the British colonial government at the Cape.

[10]For dispossession and the creation of native locations, see Braun (2008, 2015). Braun's work also provides a helpful summary of the literature on dispossession and its particular significance for understanding *apartheid* policies and debates about land reform in South Africa. See also Ntsebeza and Hall (2007).

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

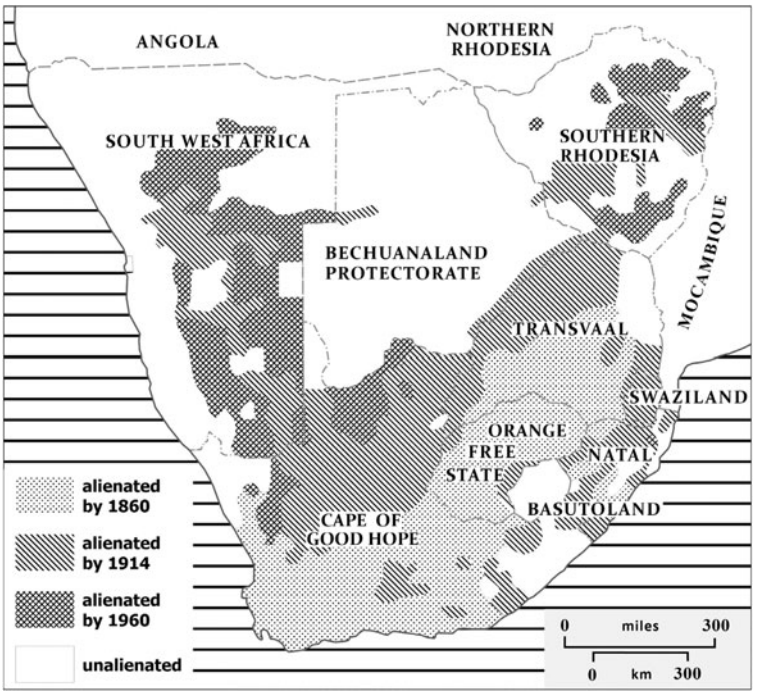

Figure 1. Main states in southern Africa and land alienation, 1860–1960. Source: Christopher (1983).

pastoral production' (Christopher, 1983: 374). Revenues came through land sales, leases, and taxes. The ZAR also used land to back its currency notes in the 1860s and it continued to be used for the settlement of state debts until the 1890s (Christopher, 1983: 375).

Both states had liberal land grant policies and a demarcation system that was based on the Cape-Dutch model, which was a type of MB system. Officials recorded parcel boundaries after European settlement (Christopher, 1970: 96; Giliomee, 1981).[11] Farms were generally granted in standardized areas with sides of one-hour ride via horseback. This was estimated to give owners about 3,750 morgen or 3,200 hectares (approximately 12.5 square miles) of land (Christopher, 1970, 1983). The 'idea' of a square farm had been accepted in southern Africa (Christopher, 1970: 96), but a square farm was not guaranteed: farms were measured by horse-riding and horses could ride at different paces, the authorities did not have to enforce farm parcels to be a certain shape, and, as will be discussed further below, square parcels are not economically efficient in rugged areas (Libecap and Lueck, 2011; Libecap *et al.*, 2011).

The states used an 'inspection system' to demarcate property boundaries. Generally, a settler submitted a claim to a local official (such as a field cornet or magistrate). A commission of local officials and landowners (3 in total) then inspected the land. The result of the inspection was a description of the parcel and sketch maps of the property. The description and sketches were then included in government records. The government conferred title after payment for inspection. In the ZAR, there was a three-month period where neighboring landowners could contest the claim. In the OFS, an advertisement for the claim was placed in the *Bloemfontein Gazette* six weeks before the inspection. After the inspection, the commission submitted a copy of the report with a diagram of the claim to the government secretary. If there

[11] A rectangular system surveyed land before settlement: 'each parcel is predefined as part of a standardized system of identical squares within a large grid' (Libecap and Lueck, 2011: 427–428). The process of settlement and demarcation in the Boers was similar to that of 'selection before survey' in Victoria and New South Wales (Alston *et al.*, 2012).

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

was no opposition three months after publication, the state president signed the land title and the settler could collect a copy of the title from the magistrate (Braun, 2008: 239–240; Liebenberg, 1973).

The MB-inspection system may have held initial cost advantages for the governments because land had been settled before the creation of the Republics. Conducting a survey before allowing further occupation would have required the governments to forego revenues from land sales and delay pastoral and agricultural production (Libecap *et al.*, 2011). The inspection systems, however, became increasingly insufficient for reliable information on the extent and value of land for reasons discussed in section 4. Continual conflicts between settlers also led to additional expenses from surveys and re-surveys (Braun, 2015: 208; Liebenberg, 1997: 133).

Both the OFS and ZAR sought to improve the quality of information in maps by improving the administration of the inspection system. Building on the historical narrative, we hypothesize that differential improvements in the administration in the OFS and the ZAR mediated the inspections and therefore the accuracy of farm parcel boundaries recorded in maps.

3. State capacity and provision of *de jure* property rights

3.1 Model

To understand how state capacity can influence the specification of farm parcels in maps, we analyze a model of a government's decision to survey property and provide *de jure* rights when *de facto* rights have been established in an MB system.[12] In our context, the governments already possessed some information about the location of farm parcels, so 'survey' can be interpreted as 'resurvey or reinspect'. The model is fully described in the online Appendix. Here we present and interpret the main condition relating when a government will decide to survey land and how it relates to state administrative capacity and map accuracy.

A government will survey land at time τ when the present value of revenue under survey less the costs of surveying (V^{s}) is greater than the revenue of maintaining an MB system ($V^{\mathrm{MB}'}$): $V^{\mathrm{s}} - V^{\mathrm{MB}'} > 0$. This condition yields

$$V^{\mathrm{S}} - V^{\mathrm{MB}'} = \int_{\tau'}^{T} (V'_{\tau} - V^{*}_{\tau}) e^{-\mathrm{r}\tau} d\tau - \int_{0}^{\tau'} C'_{\tau}(A; B, t) e^{-\mathrm{r}\tau} d\tau > 0.$$

The first term is the increased benefits (in terms of revenue) of surveyed land, accurate records and information, and savings on boundary disputes that would have occurred after time τ' if an MB system continued. The second term is the costs of implementing a survey, which is a function of the area A to be settled, the state's administrative capacity B, and the ruggedness of the terrain t. Governments looking to replace a land demarcation system face a cost of constructing an accurate survey that depends on their capacity (B).

If there is a larger area A or a more rugged terrain t, the costs of survey will increase ($(\partial C'_{\tau}/\partial A) > 0$, $(\partial C'_{\tau}/\partial t) > 0$). If a government has greater capacity to carry out surveys B, the costs of surveying land are less than the costs in states with less capacity ($(\partial C'_{\tau}/\partial B) < 0$). The model treats 'state capacity' as exogenous. Economic theories of state capacity show that political leaders or governments can choose to invest in state capacity (e.g. Besley and Persson, 2009, 2011). The OFS and ZAR sought to invest in their administrative capacities to improve inspections and the informativeness of maps (discussed in the next section).

There are two important points about the model and how it relates to the empirical analysis. First, we think of the administrative structure and incentives of map compilers to accurately record parcel boundaries as central components of capacity B when comparing two different states. The

[12]This is an extension of a model in Libecap *et al.* (2011).

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

administrative incentives depended on the governments' standards and the standards' enforcement, surveyors' expertise and training, resources or mapping technologies available, and the willingness of farmers to have their property accurately measured. For simplicity, we assume the individual demarcation costs incurred by *de facto* claimants are zero because they are sunk (see the online Appendix). Their sunk costs, however, may influence officials' incentives to accurately survey. For example, farmers who invested in agricultural production may be more likely to resist mapping if they may lose land as a result of more accurate surveys of their property. Facing this opposition, officials may have been more likely to quickly and haphazardly conduct inspections.

State administrative capacity was also likely a result of macro influences, such as political stability and wealth, that shaped the organizational incentives of map compilers during the 19th century.[13] In the model above, greater political instability could decrease the time horizon T and increase the government's incentives to keep the existing MB system without an accurate survey. Greater wealth could allow a government to invest in the survey department's resources to map, enforce standards of measurement, or employ trained surveyors.

Second, the model predicts if governments will choose to 'survey or not'. Our empirical analysis proposes to use a measure of the 'accuracy of surveys' as the main outcome as opposed to if a survey was conducted or not. In a simple way, the difference between V^{S} and $V^{MB'}$ can be thought of as a measure of how accurately farms will be mapped (the smaller the difference, the less accurate). We use the shape of farms, specifically a farm's relative squareness, as our outcome of interest.

A key alternative hypothesis is that farms are more square because, as discussed in the online Appendix and established in the literature, it is economically efficient to have square farms in areas that are relatively flat under an MB system (Libecap *et al.*, 2011; Libecap and Lueck, 2011). The model also shows that more rugged terrain increases the costs of mapping, which would lead to poorer quality maps (i.e. more square parcels). The historical narrative suggests that the terrain and distance from capitals (governments' administrative centers) influenced officials' incentives to accurately record parcels (Braun, 2015). We include measures of ruggedness at the farm level in the analysis. The sign of the coefficient will be informative about which effect dominates.

4. State capacity and map accuracy

We use maps of farm parcels compiled in the 19th century under the OFS and ZAR (OFS in 1886; ZAR in 1892), by the British military (OFS in 1901; ZAR in 1900), and shapefiles provided by the current South African government (2019) to create measures of accuracy of farm parcel specification. In this section, we overview how different administrative capacities influenced the construction of each source.

4.1 Nineteenth-century maps: 1886 survey of farms in the OFS and Troye's 1892 Map of the Transvaal

The first maps were created by government officials from the OFS and ZAR in the 19th century. The ZAR map is *Troye's 1892 Map of the Transvaal*, published by Wurster Randegger & Co., of Winterthur, Switzerland (hereafter referred to as *Troye's 1892* map). Troye worked in the Office of the Surveyor General in Pretoria. The map is considered a 'compilation map' because he compiled it using property diagrams and cadasters in local survey departments and in the Office of the Surveyor General. The information available to him accumulated over 60 years of inspection reports, disputes, and re-inspections. Diagrams were sketches that were often without mathematical data, such as angle and side measurements (Braun, 2008: 240–260, 2015, Chapter 5). Troye's goal to "show all the landed properties in the Republic […] was utterly impossible to complete […] owing to a lack of sufficient reliable information" (qtd. in Liebenberg, 1973: 170).

[13]And are thus correlated with B. See Besley and Persson (2011).

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

The diagrams were the work of untrained inspectors who abused the inspection system. Inspections were generally without meaningful accountability or standards even though the government (*Volksraad*) sought to implement national standards and improve inspection commissions from 1864 to 1899. There was no existing system for training surveyors in European methods and instrumentation, which were necessary to conduct accurate maps.[14] Inspectors had incentives to misreport property and there was little enforcement of standards.[15] There is evidence of officials inspecting blocks of hundreds of parcels (or plots, *plaatsen*) at a single time (Braun 2015: 201, 202).[16] Last, some farmers in the ZAR were resistant to mapmakers and more accurate surveys, which likely decreased inspectors' incentives to provide accurate information (Carruthers, 2003: 959, 965; Pelzer, 1950: 56, 172).[17] While accurate maps could help resolve conflicting claims, some farmers could significantly lose. Braun (2015) notes that proper surveys could entail additional taxes, diminish the value of farms by making property smaller or excluding valuable ground, or dispossess an owner entirely without compensation (p. 212). Reforms were incrementally taken throughout the period, depending on the ZAR's finances. When new standards were implemented, enforcement was weak. Though the administration did not incur large fixed costs to initially survey the land, the poor quality of maps and inspections compounded and significantly increased the costs of correcting initial inspection reports.[18]

In contrast to the compilation map of farm parcels in the ZAR, the OFS map we use is an original 'plan of survey' of the border area between the OFS and Basutoland (now Lesotho). Government surveyors and commissioners delineated and surveyed the new border area in the division of Ladybrand.[19] The survey appears to have been conducted by government officials in 1886 to accompany the commission report sent to the OFS government. Surveyors likely had an incentive to map the area as accurately as possible because the survey was of an important area of the OFS (the new border). The 1886 survey was conducted after improvements in standards for surveying in the OFS (discussed next). It contains information set out in the new standards, such as coordinates, scale, location of land beacons, and the direction for true north.

Unqualified surveyors initially sat on commissions that inspected farms in the OFS in the 1850s. Diagrams attached to land commission reports were as primitive as inspections conducted in the ZAR. The legislature made early efforts to improve the accuracy of recording (Liebenberg, 1973: 135–137). Though a Surveyor General was only appointed in 1876, chairmen of land commissions and surveyors were warned to take greater care and make diagrams more accurate. They were also instructed to not only note the size (area) of the farm, but also the scale and the direction (northern point). Ordinance 1 of 1863 dictated that the Title Deeds Office should not accept diagrams if the lengths of the borders and the corners were not marked. In 1868, a standard measurement unit

[14]According to Braun (2015), nearly 'every land surveyor admitted to practice in the ZAR through the South African War [in 1899] was an import, most often from the British Cape or Natal Colonies' (pp. 208–209).

[15]For example, there is evidence of inspectors engaging in speculation and using their information at auctions of debtors' freehold farms (Braun, 2015: 201). Part of the law also allowed inspectors to guess at boundary marker placement, distance, and area (Braun, 2015: 210). Officials also rarely had compasses for basic corrections (Braun, 2008: 244).

[16]See pages 202–203 for details on how inaccuracies compounded themselves in the block system. Inspection commissions likely 'rode around a large area and divided [areas] by reckoning without actually carrying out the individual inspections' (Braun, 2015: 203–204).

[17]A famous British explorer, Thomas Baines, was detained in 1850 and only released after he agreed not to make maps and sketches of areas in the ZAR.

[18]See Braun (2015: 206–211). The *Volksraad* suspended the issue of new title and inspections in 1871 until they could determine whether the inspection law had been followed in existing diagrams. By 1877, the *Volksraad* abandoned correction efforts until a general survey law could be implemented. Initial inspection reports of the Zoutpansberg district were so confusing that a special commission of the Surveyor-General and three trained land surveyors was created in 1875. It was charged with sorting out the facts and concluded that 'the earlier inspection was so cursory as to have effectively not happened' (Braun, 2015: 201). Further details can be found in online Appendix.

[19]The border was set out in the terms of the Convention of Aliwal North (1869), where a treaty established a new border between the OFS and Basutoland after years of conflict between the two.

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

was established, which was the same unit used in the Cape Colony. Standard measuring sticks were also made available to surveyors from the Treasury (Liebenberg, 1973: 137).

The creation of the Office of the Surveyor General and implementation of a general survey law in 1877 appear to have improved the standards for surveys and were enforced.[20] It formalized a system of examining surveyors. The Surveyor General was authorized to check and approve all surveyed properties before deed registration. Surveyors were required to include additional measurements, such as the azimuth of the longest boundary line and the magnetic meridian, calculated from compass surveying) (Liebenberg, 1973: 138). Any approved land titles and diagrams were to be published monthly in the government newspaper. The general survey was completed on a more scientific base using cadastral measurement of blocks of farms in districts. Each district was surveyed by a separate surveyor, however, and it was practically difficult to compile the separate surveys because each surveyor used their own baseline. The surveying reform efforts appear to have been enforced and improved the quality of maps, though they were still limited without accurate topographical information (Liebenberg, 1973: 139).

We hypothesize that, though Troye may have tried to record all farms of the ZAR, the information he relied on, a result of incentives of inspectors to inaccurately record farm boundaries, made his map less accurate than the original survey of the OFS. We expect there to be differences within the ZAR because some areas were farther away from the capital and faced significant resistance to mapping. Other macro factors would also lead the ZAR to have less capacity than the OFS. Until the discovery of gold in 1884 in the ZAR, the OFS was generally wealthier than the ZAR after the discovery of diamonds in 1867. The OFS also benefitted from close trade with the British Cape Colony (Keegan, 1987: 196; Giliomee, 1981: 116). The ZAR was politically unstable. It saw ongoing conflict with three smaller independent Boer Republics—Lydenburg (an area we include in the analysis), Utrecht and Soutpansberg—that fought to maintain their independence from 1856.[21] Governance did not improve and, by 1877, the British annexed the ZAR. The annexation was initially unopposed. Three years later, however, local political authorities (burgers) in the ZAR proclaimed, fought for, and regained their independence.

4.2 Military maps: Imperial Survey of South Africa, 1900 *and* Orange River Colony Degree Sheet Series, 1901

We use maps created by the British military during the South African or Anglo-Boer War (1899–1902) to compare accuracy with the 19th-century maps. Similar to *Troye's 1892* map, the military maps we use, the *Imperial Map of South Africa* (1900) and the *Orange River Colony Degree Sheet Series* (1901), are compilation maps based on local farm surveys. Thus, their map accuracy is a function of two countervailing forces: (1) the incentives of the actual map compilers and (2) the quality of surveys available to them. The British military, specifically the trained surveyors it employed and those it partnered with, had incentives to accurately construct maps even though the military had a different objective function than the OFS and ZAR administrations (and therefore likely a different calculus from our model).[22] The extent of the improvement may have been limited by the existing records available to the military officials.

It seems likely the military map creators had incentives to reconcile local survey differences to map farm parcels as accurately as possible. The war was primarily 'fought on horseback, [thus] farm

[20]Under the general law, owners of previously surveyed and un-surveyed farms were to erect beacons and a commission of inspection was appointed to decide land disputes.

[21]They were all eventually incorporated to the ZAR.

[22]The maps contain disclaimers that they are not absolutely accurate and are viewed as insufficient for military purposes (Liebenberg, 2007). The military primarily sought information on topography. The mapping efforts can be seen as part of British imperial expansion and rule in southern Africa, in which accurate information, particularly for administrative and engineering purposes, was crucial (Liebenberg, 1997: 133). The British held the Cape and Natal colonies. After the discovery of gold in Witwatersrand in the ZAR in 1884, British and Cape politicians, such as Cecil Rhodes, sought to further expand their influence in the area. The expansion and conflict ultimately culminated in the Anglo-Boer War.

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

boundaries and farm names were considered important' to include (Liebenberg, 2007). Further, the mapping branch of the Field Intelligence Department contracted with a local surveying firm, Wood and Ortlepp of Cape Town, to produce the *1900 Imperial Map* series. The Field Intelligence Department, and therefore the British military, covered the expenses and ownership of the map would revert to the compiler John T. Wood after the war. The map appears to have been valuable because copies were sold and it was used for commercial purposes.[23] If the company expected the map to be valuable in the future, it is reasonable to conclude they would have an incentive to try to accurately reconcile existing surveys. Their ability to do so, however, may have been constrained by the type of information available in local surveys. The magnitude of the difference of parcel accuracy between the 19th-century maps and the military maps, if there are any differences at all, is one way we can test for this.

The *1900 Imperial Map* covers the ZAR and the OFS, but we only use it for the ZAR because sheets of the areas in the OFS are not digitally available. We use the *Orange River Colony Degree Sheet Series* (1901) for information on parcels in the OFS. A new Mapping Section of the British military installed in Bloemfontein, the capital of the OFS, created the series after the British took over in 1900 (Liebenberg, 2007). Officials found the information in the *1900 Imperial Map of South Africa* for the OFS inadequate. The new mapping section consisted of five Royal Engineers and eight civilians (Liebenberg, 2007). The series was created using farm diagrams in the Office of the Surveyor General. Compared to the 1886 plan of survey of Ladybrand, we expect the 1901 map to show improvement in accuracy. But, because the map creators may have used surveys like the 1886 Ladybrand survey in its construction, the change in 'accuracy' of parcels may not be a large or statistically significant change.

4.3 2019 Deeds shapefiles

We expect property boundaries to be accurate in current (2019) records. The Anglo-Boer War and the beginning of the 20th century ushered in comprehensive surveying and mapping of British South Africa (Liebenberg, 1997). A substantial geodetic framework, which allowed surveyors to correct for the curvature of the earth's surface through triangulation, was implemented in South Africa by 1906 (Liebenberg, 1997).[24] The British Imperial government underwrote the cost of the primary geodetic triangulation carried out between 1903 and 1906. Topographical surveying and secondary triangulations developed unevenly thereafter across the former colonies (Braun, 2015: 229).

A national mapping project was planned from 1936 to 1956 under the Trigonometrical Survey Office. After World War II, aerial photographs produced by the South African Airforce facilitated the creation of accurate national maps. The 1950s and 1960s saw further demand for accurate surveys from the Departments of Water, Transport and Telecommunications for infrastructure development. The government adopted new technologies, such as GPS, to facilitate surveying. Today, the office of the Department of Rural Development and Land Reform houses the National Geo-spatial Information (NGI), founded by the Land Survey Act 8 of 1997. The NGI is South Africa's national mapping organization. The NGI established an integrated survey system and contributes to South Africa's standards for geographic information. It manages South Africa's geodetic and topographic surveys and produces publicly available coordinate reference systems, known as the New South African Datum or the Hartebeesthoek94 Datum based on the World Geodetic System 1984 (WGS84), for GIS. The NGI describes this service as supporting South Africa's 'status of possessing one of the most up to date and advanced integrated survey reference systems in the world'.[25]

[23]For example, some of the maps show advertisements for the United Provident and Assurance Association of South Africa, Limited, for 'interest-free loans' on farm property.

[24]Triangulation allowed detailed surveys to be founded on a systematic set of points, which enabled surveys to be accurately brought together (Liebenberg, 1997: 133). The geodetic framework followed a plan made by Sir David Gill in 1879.

[25]NGI, 'History' (2013): http://www.ngi.gov.za/index.php/home/history. The ability of South Africa's government to be a continent leader in geoinformatics while having a generally low capacity in other areas is illustrative of a successful bureaucratic organization in a relatively weak state (Williams, 2021: 3).

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

To summarize, we argue that the OFS had greater capacity than the ZAR from 1860 to 1900, and therefore should have more accurate 19th-century maps. The OFS not only had more capacity in terms of its administrative structure and personnel incentives, but it was also relatively more politically stable and had greater wealth than the ZAR. There may be heterogeneity within the ZAR because officials had weaker incentives to accurately map areas farther from the capital and where farmers opposed mapping. We argue that the British military had better incentives to construct relatively more accurate maps in 1900 than the 19th-century maps, so maps of farms in the OFS and ZAR should both 'improve'. We expect maps of farms in areas of the ZAR to show the largest improvement given its initially lower starting point in terms of map quality. The magnitude of the change may not be large, however, because military officials relied on maps of farm parcels created by the OFS and ZAR. Last, we expect the 2019 shapefiles to be the most accurate because South Africa has a system of mapping using modern technologies and based on internationally established scientific standards.

5. Data and method

5.1 Data and summary statistics

We digitize farm parcels in areas of the OFS (Ladybrand) and the ZAR (Nylstroom; Lydenburg) from the historical maps discussed above.[26] We also use shapefiles of farm portions, which reflect 2019 deeds to land, provided by NGI and the Chief Surveyor General Office. We chose Ladybrand in the OFS because it was the earliest map showing farms we could find in the Western Cape Archives. For the ZAR, we chose Nylstroom because it is approximately the same distance from the state capital of the ZAR (Pretoria) as Ladybrand is from the capital of the OFS (Bloemfontein). Last, we chose the Lydenburg region of the ZAR because it was at the frontier of the state and the historical literature emphasizes that farmers in the region were especially resistant to central control and mapping.

Figure 2 shows parcels from the 1892 and 1900 maps and 2019 shapefiles for Lydenburg (ZAR). Figure 3 shows parcels for Ladybrand (OFS) from the three sources. Figure A1 in the online Appendix shows parcels from Nylstroom (ZAR). There are two important points about the digitized maps. First, the number of parcels from each source is not consistent. In particular, there is a proliferation of properties in the 2019 shapefiles from subdivision of the original properties. Second, the available *1900 Imperial Map* of Nylstroom and Lydenburg do not cover the exact area we digitized from *Troye's 1892* map. We present results using all digitized parcels and using only parcels in areas that 'overlap' (see Figure A2 in the online Appendix for overlapping regions between the 1892 and 1900 maps of Lydenburg). The online Appendix describes the digitization process.

5.1.1 Outcome: farm parcel shape

We construct measures of 'boundary accuracy' for each farm. For consistency with previous work, we used "square" in the preceding discussion in describing parcel shape. In the analysis, we technically calculate measures of parcel rectangularity. We argue that farms that are more square will be less accurate conditional on terrain. To construct measures of farm parcel squareness, we use Procrustes analysis, which compares the shape of two or more objects. The objects are 'superimposed' optimally,

[26]For the OFS, the 1886 survey of Ladybrand is found in the Western Cape Archives and Records Services (M3/114). Sheets of the same area of Ladybrand in the *Orange River Colony Degree Sheet Series* (1901) are available from the Military Map collection of the UCT Africana library. We digitize parcels found in the Ladybrand map (https://digitalcollections.lib.uct.ac.za/collection/islandora-24900) and the Zastron map (https://digitalcollections.lib.uct.ac.za/collection/islandora-24957). The two maps cover the area on the 1886 map. For the ZAR, *Troye's Map of the Transvaal* (1892) is available from the Central Library of Zurich (available at https://www.e-rara.ch/zuz/maps/content/pageview/10198462). Sheets from the *Imperial Map of South Africa* (1900) are also available from the Military Map collection of the UCT Africana library (Nylstroom: https://digitalcollections.lib.uct.ac.za/collection/islandora-24856; Lydenburg: https://digitalcollections.lib.uct.ac.za/collection/islandora-24823). Not all adjoining sheets in the *1900 Imperial* map are digitally available so we were not able to digitize all sheets from the *1900 Imperial* map that cover the exact same areas of Nylstroom and Lydenburg as *Troye's 1892* map.

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

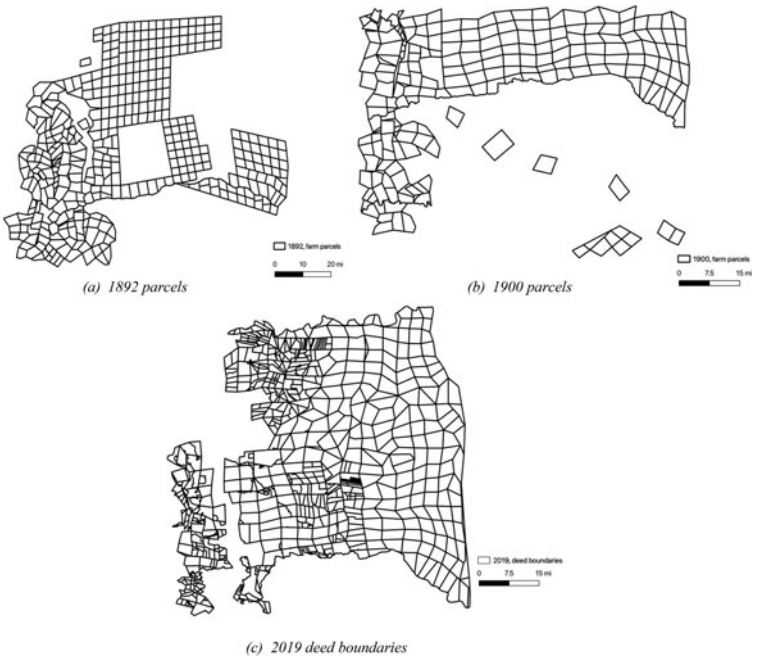

Figure 2. Lydenburg farm parcels in 1892, 1900, and 2019. Sources: *Troye's 1892 Map of Transvaal* (Lydenburg); Wood, JT, Lydenburg, *Imperial Map of South Africa* (1900), Military Map Collection, UCT Digital Africana Program; Farm Portion shapefiles, NGI, Chief Surveyor General Office, RSA, retrieved January 2021.

by translating, rotating, and uniformly scaling them. Both the placement in space and the size of the objects are freely adjusted in order to obtain a similar placement and size by minimizing a measure of shape difference, called the Procrustes distance, between the objects. The squared Procrustes distance between two shapes is the sum of the squared point distances (Gower, 1975; Stegmann and Gomez, 2002). The greater the deviation from a rectangle (a lower correlation) will capture the extent to which the map included real-world features and is thus interpreted as more accurate. The measure ranges from 0 to 1 and farm parcels with a correlation equal to 1 are rectangles. We conducted the Procrustes analysis for the blocks of farms shown in Figures 2, 3 and Figure A1 in the online Appendix in MATLAB to construct a measure of rectangularity for each farm parcel. The process of the algorithm is visually shown in Figure A5 and described in an online Appendix section A4. The code is available at https://github.com/fduple/maps-procrustes.

Figure 4 shows the distribution of parcel shapes for each division by map years. Farm parcels tend to be less rectangular in the 1900 military maps and the 2019 shapefiles compared to the 19th-century maps. The 19th-century maps (top row) are left skewed with a cluster of parcels close to 1, indicating most parcels are near perfect rectangles. The distributions generally become more normal with a lower median measure of accuracy in the 1900 military maps (middle row) and the 2019 shapefiles (bottom row).[27]

5.1.2 Ruggedness

It is optimal for farm parcels to be square under an MB system if the terrain is relatively flat. To help control this issue, we use the average terrain ruggedness index (TRI) for each farm parcel. We create elevation rasters from the ASTER Global Digital Elevation Map (GDEM). The ASTER GDEM is the

[27]For the 19th century maps, the median correlation for Ladybrand is 0.91, the median correlation for Lydenburg is 0.942, and the median correlation for Nylstroom is 0.935. For the 1900 military maps, Ladybrand has a median correlation of 0.877, Lydenburg has 0.928, and Nylstroom has 0.91. For the 2019 shapefiles, Ladybrand has a median correlation of 0.869, Lydenburg has 0.89, and Nylstroom has 0.912.

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

(a) 1886 parcels (b) 1901 parcels

(c) 2019 deeds boundaries

Figure 3. Ladybrand farm parcels in 1886, 1901, and 2019. Sources: Western Cape Archives and Records Services, M3/114; Duncan AHF, Ladybrand & Wepener and Zastron, *Orange River Colony Degree Sheet Series* (1901), Military Map Collection, UCT Digital Africana Program; Farm Portion shapefiles, NGI, Chief Surveyor General Office, RSA, retrieved January 2021.

underlying source standard in the literature to calculate ruggedness (e.g. Nunn and Puga, 2012; Riley *et al*., 1999). We use this elevation data because it has a resolution of 30 m, which is important given the relatively small farm parcels in our analysis. The TRI is then calculated as is standard in the literature (Nunn and Puga, 2012; Riley *et al*., 1999).

5.2 Method

Using OLS, for a farm parcel i in a division d from a map year t, we estimate models of the form:

$$\text{shape}_{idt} = \beta_i + \delta_t + \gamma \text{ruggedness}_{idt} + \epsilon_{idt},$$

where shape_{idt} is a parcel's correlation with a rectangle, β_i contains indicators for a map division (Ladybrand, Nylstroom, or Lydenburg), δ_t contains indicators for a map year[28], and ruggedness_{idt} is a parcel's average TRI.

[28]We technically compare across periods (e.g. 19-century maps to the early 20-century military maps) by assigning the 19-century maps the same indicator and assigning the military maps the same indicator.

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

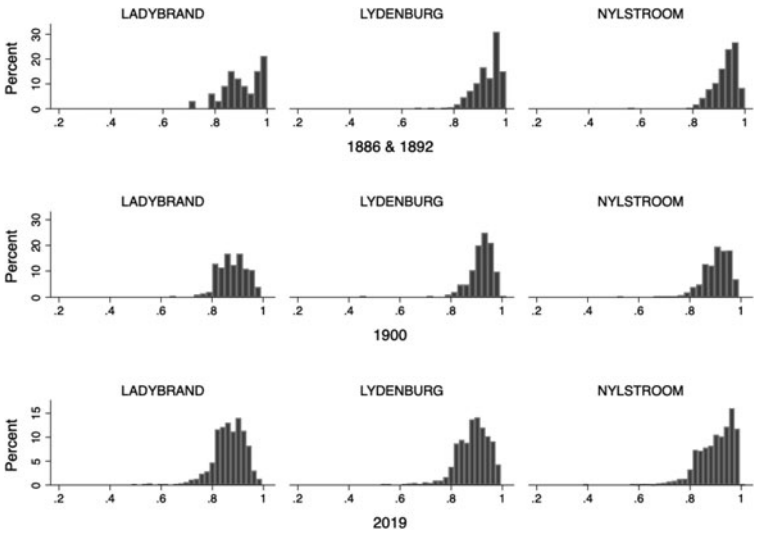

Figure 4. Distributions of parcel shapes. Notes: Distribution of the farm parcel shapes across maps and regions. Shape is defined as a correlation with a perfect square. Parcels with a higher correlation (closer to 1) are more square.

We generally expect the estimated coefficient on γ to be negative: farms in more rugged areas will have a lower correlation with a square. We are interested in comparing average parcel shape across divisions (β_i). Conditional on ruggedness, we expect Nylstroom and Lydenburg to have more rectangle parcels than Ladybrand. Within the ZAR, we also expect Lydenburg to have more rectangle parcels than Nylstroom because the ZAR had less capacity to accurately survey Lydenburg as discussed above. We generally expect farm parcels to be more accurate (less rectangle on average) in the 1900 military maps and the 2019 shapefiles compared to the 19th-century maps. Because the sample of farms is not consistent across maps, we also report results restricting the analysis to farms in areas where the maps overlap.

6. Results

Table 1 reports the estimated coefficients of β_i and γ. Column 1 includes only indicators for the map region. Ladybrand is always the omitted category. Column 2 introduces map year indicators. Column 3 introduces parcel ruggedness and column 4 restricts the analysis to only the overlap sample. The last row reports the *F*-statistic for the test that estimated coefficients on Lydenburg and Nylstroom are significantly different from one another.

The estimated coefficient on ruggedness (γ) is negative and significant: more rugged areas have less rectangular farms. The evidence supports the prediction that square/rectangular parcels are efficient in relatively flat areas in an MB system (Libecap *et al.*, 2011; Libecap and Lueck, 2011). Our analysis and results add evidence that state capacity also plays a significant role in parcel shape, the construction of maps and, ultimately, the provision of *de jure* property rights.

Across all specifications, parcels in Lydenburg and Nylstroom are significantly more rectangular than parcels in Ladybrand. The differences hold conditional on ruggedness (column 3) as well as restricting to only parcels in areas that are generally found on both maps (column 4). There is a statistical difference between farm shapes in Lydenburg and Nylstroom, with Nylstroom having *more* rectangular parcels on average not controlling for ruggedness (column (2)). After controlling for ruggedness, Lydenburg has more square parcels on average though the difference is not significant (column (3)). The evidence suggests that parcels in Nylstroom may have been more tailored to the terrain. For the overlap sample, parcels in Lydenburg are significantly more rectangular than parcels

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

Table 1. Differences in parcel shape by region

	Full sample			Overlap sample
	(1)	(2)	(3)	(4)
Ladybrand (OFS)	0	0	0	0
	(.)	(.)	(.)	(.)
Lydenburg (ZAR)	0.034***	0.026***	0.030***	0.041***
	(0.003)	(0.003)	(0.003)	(0.004)
Nylstroom (ZAR)	0.036***	0.031***	0.027***	0.032***
	(0.003)	(0.003)	(0.002)	(0.004)
Ruggedness			−0.010***	−0.011***
			(0.001)	(0.001)
N	4,306	4,306	4,306	2,778
Y mean	0.897	0.897	0.897	0.901
Map year indicator		Yes	Yes	Yes
F-stat	0.61	5.84**	1.84	7.67***
βNylstroom = βLydenburg				

Notes: The outcome of a farm parcel's correlation with a square. Correlations equal to 1 are parcels that are rectangles. Ruggedness is a parcel's average terrain ruggedness index (TRI). Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

in Ladybrand and in Nylstroom (column (4)). Thus, the evidence indicates that maps of parcels in the ZAR are significantly less informative about the property than those in the OFS. With the narrative evidence discussed above, the differential administrative capacity of the two states can explain this difference.

To investigate how parcel shapes are depicted under different administrations, Figure 5 and Figure A3 in the online Appendix show the predicted parcel shape for each map year across map regions. Predicted parcel shapes are obtained from an OLS regression including each parcel's TRI and interactions between indicators for map year and map region. Figure 5 shows the average predicted shape for the full sample. Figure A3 shows the average predicted shape for the overlap sample. The patterns generally support the ordering and change we hypothesized above though some of the differences are not statistically significant.

For the full sample (Figure 5), Lydenburg's parcels tend to be more rectangular across all maps. They tend to be less rectangular in the *1900 Imperial* map and the 2019 shapefiles compared to parcels in *Troye's 1892* map. The difference between 1892 and 1900 is not significant, but it is significant between 1892 and 2019 and between 1900 and 2019. Nylstroom tends to have less rectangular parcels than Lydenburg and more square parcels than Ladybrand across all maps, though the difference is not precise in the 19th-century maps and the 2019 maps. Nylstroom parcels are slightly less rectangular in the *1900 Imperial* maps relative to *Troye's 1892* map. Parcels in Ladybrand tend to be the least rectangular across all maps. The difference is imprecisely estimated for the 19th-century maps (1886 and 1892) likely because the 1886 Ladybrand survey only has 33 parcels. Parcels are significantly less square in the *1901 Degree Series* military map and the 2019 shapefiles.

A central pattern is that the 1900 military maps show a slight decrease in average parcel squareness, which is not precisely estimated. With the historical narrative, it seems likely that this is because 1900 military maps were compilation maps using the inaccurate local inspection diagrams and farm surveys. Thus, even if the map makers had better incentives to accurately construct maps, they were limited by

https://doi.org/10.1017/S1744137421000266 Published online by Cambridge University Press

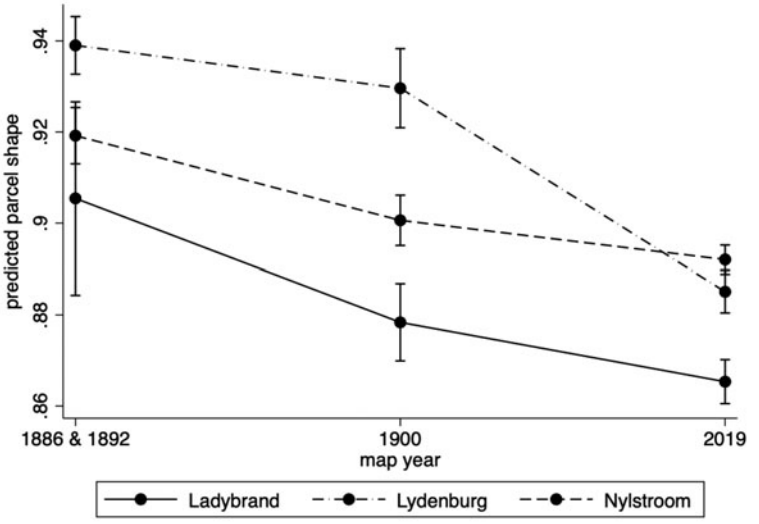

Figure 5. Predicted parcel shape, full sample. Notes: see text.

the inspection reports available to them. The 2019 shapefiles, which were made with modern surveying tools and methods, are the most accurate.

7. Conclusion

This paper compares the development of the specification of *de jure* property rights to land in two historical states, the Boer Republics of the OFS and the ZAR. We argue that the differential administrative capacity of the two can explain the provision of *de jure* property rights to land. We compare the states' ability to accurately survey farms after land had already been settled. Drawing on the historical narrative, we argue that the different administrations and incentives of map compilers led to less accurate maps in the ZAR compared to the OFS in 19th-century maps. We expected maps created by the British military in 1900 to be more accurate than 19th-century maps because of the military's resources, expertise, and incentives to create accurate maps. The differences, however, are not statistically significant, suggesting that the military maps compilers were constrained by the existing information available in local survey departments. Last, we find that shapefiles provided by the current, 2019 South African government, which adheres to international standards of geospatial information and uses new technologies, are the most accurate.

The analysis and results shed light on how administrative capacity facilitate or hinder the provision of *de jure* property rights to land for European settlers as recorded in maps. The narrative suggests it took efforts spanning 100 years from the founding of the Boer Republics to accurately survey land. According to the historical narrative, the most significant investments in this capacity came with increased demand for infrastructure. At the same time, however, it went with further dispossession and relocation of black Africans (Braun, 2015), which we have not incorporated in our analysis. Digitization of historical maps can be used to further understand this part of the process.

Acknowledgements. We would like to thank Christie Swanepoel, Mark Hup, Johan Fourie, and Professor Martin Kidd for valuable comments and discussions. Hanu Mostert and Paige Smith provided invaluable research assistance. We are also grateful to Marieta Buys (Special Collections, Stellenbosch Library), Erika Le Roux (Western Cape Archives and Records Service), and Ilze Boonzaier and Lauren McCarthy (Centre for Geographic Analysis, Stellenbosch University) for assistance finding and accessing maps and shapefiles. All errors are our own.

References

Alston, L. J., E. Harris and B. Mueller (2012), 'The Development of Property Rights on Frontiers: Endowments, Norms, and Politics', *Journal of Economic History*, **72**(3): 741–770.

Besley, T. and M. Ghatak (2010), 'Property Rights and Economic Development', in D. Rodrik, and M. Rosenzweig (eds), *The Handbook of Development Economics*, vol. 5, Amsterdam: Elsevier, pp. 4525–4595.

Besley, T. and T. Persson (2009), 'The Origins of State Capacity: Property Rights, Taxation and politics', *American Economic Review*, **99**(4): 1218–1244.

Besley, T. and T. Persson (2011), *Pillars of Prosperity: The Political Economics of Development Clusters*, Princeton: Princeton University Press.

Brambor, T., A. Goenaga, J. Lindvall and J. Teorell (2020), 'The Lay of the Land: Information Capacity and the Modern State', *Comparative Political Studies*, **53**(2): 175–213.

Braun, L. F. (2005), 'Spatial Institutionalisation and the Settler State: Survey and Mapping in the Eastern Transvaal, 1852–1905', *South African Historical Journal*, **53**(1): 146–178.

Braun, L. F. (2008), The Cadastre and the Colony: Surveying, Territory, and Legibility in the Creation of South Africa, c.1860–1913. PhD Dissertation, Rutgers University.

Braun, L. F. (2015), *Colonial Survey and Native Landscapes in Rural South Africa 1850–1913*, Leiden: Brill.

Carruthers, J. (2003), 'Friedrich Jeppe: Mapping the Transvaal, c.. 1850–1899', *Journal of Southern African Studies*, **29**(4): 955–976.

Christopher, A. J. (1970), 'The European Concept of a Farm in Southern Africa', *Historia*, **15**(2): 93–99.

Christopher, A. J. (1983), 'Official Land Disposal Policies and European Settlement in Southern Africa, 1860–1960', *Journal of Historical Geography*, **9**(4): 369–383.

Cingolani, L. (2013), 'The State of State Capacity: A Review of Concepts, Evidence and Measures' MERIT Working Papers 2013-053, United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT).

Coase, R. H. (1960), 'The Problem of Social Cost', *Journal of Law and Economics*, **3** (Oct., 1960): 1–44.

Cogneau, D., Y. Dupraz and S. Mesplé-Somps (2020), 'Fiscal Capacity and Dualism in Colonial States: The French Empire, 1830–1962', Working Paper: Halshs-001818700.

Colson, E. (1971), 'The Impact of the Colonial Period on the Definition of Land Rights', in V. Turner (ed), *Colonialism and Africa, 1870–1960*, Volume III, Cambridge: Cambridge University Press, pp. 193–215.

de Soto, H. (2000), *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else*, New York: Basic Books.

Dincecco, M. and M. Prado (2012), 'Warfare, Fiscal Capacity, and Performance', *Journal of Economic Growth*, **17** (Sep. 2012): 171–203.

Dye, A. and S. La Croix (2013), 'The Political Economy of Land Privatization in Argentina and Australia, 1810–1850: A Puzzle', *Journal of Economic History*, **73**(4): 901–936.

Dye, A. and S. La Croix (2021), 'Institutions for the Taking: Property Rights and the Settlement of the Cape Colony, 1652–1750', *The Economic History Review*, **73**(1): 33–58.

Gardner, L. (2012), *Taxing Colonial Africa: The Political Economy of British Imperialism*, Oxford: Oxford University Press.

Giliomee, H. (1981), 'Processes in Development in the Southern African Frontier', in H. Lamar, and L. Thompson (eds), *The Frontier in History: North America and Southern Africa Compared*, New Haven and London: Yale University Press, pp. 76–122.

Gower, J. C. (1975), 'Generalized Procrustes Analysis', *Psychometrika*, **40**(1): 33–51.

Gwaindepi, A. and K. Siebrits (2020), 'Hit Your Man Where You Can: Taxation Strategies in the Face of Resistance at the British Cape Colony, c.1820 to 1910', *Economic History of Developing Regions*, **35**(3): 171–194.

Hup, M. (2020), 'Corvee Labor and State Expansion in Colonial Indonesia', Working paper.

Jerven, M. (2013), *Poor Numbers*, Cape Town: UCT Press and Cornell University.

Johnson, N. and M. Koyama (2014), 'Tax Farming and the Origins of State Capacity in England and France', *Explorations in Economic History*, **51** (Jan. 2014): 1–20.

Johnson, N. and M. Koyama (2017), 'States and Economic Growth: Capacity and Constraints', *Explorations in Economic History*, **64** (Apr. 2017): 1–20.

Keegan, T. (1987), 'Dispossession and Accumulation in the South African Interior: The Boers and Tlhaping of Bethulie, 1833–1861', *The Journal of African History*, **28**(2): 191–207.

Lamoreaux, N. (2011), 'The Mystery of Property Rights: A U.S. Perspective', *Journal of Economic History*, **71**(2): 275–306.

Libecap, G. and D. Lueck (2011), 'The Demarcation of Land the Role of Coordinating Property Institutions', *Journal of Political Economy*, **119**(3): 426–467.

Libecap, G., D. Lueck and T. O'Grady (2011), 'Large-Scale Institutional Changes: Land Demarcation in the British Empire', *Journal of Law & Economics*, **54**(1): S295–S327.

Liebenberg, E. C. (1973). Die Topograpfiese Kartering van Suid-Afrika, 1879–1972: 'n Histories-Geografiese Ontleding. Master's thesis: University of Stellenbosch.

Liebenberg, E. C. (1997), 'Mapping British South Africa: The Case of C.S.G.S. 2230', *Imago Mundi*, **49** (1997): 129–142.
Liebenberg, E. C. (2007), 'The Use of Compilation Maps in the Anglo-Boer War, 1899–1902', XXIII International Cartographic Conference Proceedings (Moscow, Russia).
Muller, C. F. J. (1993), *500 Years: A History of South Africa*, Pretoria: Academica.
North, D. C. (1990), *Institutions, Institutional Change and Economic Performance*, Cambridge: Cambridge University Press.
Ntsebeza, L. and R. Hall (2007), *The Land Question in South Africa: The Challenge of Transformation and Redistribution*, Cape Town: HSRC Press.
Nunn, N. and D. Puga (2012), 'Ruggedness: The Blessing of Bad Geography in Africa', *The Review of Economics and Statistics*, **94**(1): 20–36.
Pelzer, A. N. (1950), *Geskiedenis van di Suid-Afrikaanse Republiek*, Kaapstad: Balkema.
Riley, S. J., S. D. DeGloria and R. Elliot (1999), 'A Terrain Ruggedness Index That Quantifies Topographic Heterogeneity', *Intermountain Journal of Science*, **5**(1–4): 23–27.
Stegmann, M. B. and D. D. Gomez (2002), 'A Brief Introduction to Statistical Shape Analysis', WP Informatics and Mathematical Modelling. Technical University of Denmark.
Williams, M. J. (2021), 'Beyond State Capacity: Bureaucratic Performance, Policy Implementation and Reform', *Journal of Institutional Economics*, **17**(2): 339–357.
Yoo, D. and R. H. Steckel (2016), 'Property Rights and Economic Development: The Legacy of Japanese Colonial Institutions', *Journal of Institutional Economics*, **12**(3): 623–650.

Cite this article: Dimitruk K, Du Plessis S, Du Plessis S (2021). *De jure* property rights and state capacity: evidence from land specification in the Boer Republics. *Journal of Institutional Economics* **17**, 764–780. https://doi.org/10.1017/S1744137421000266