Mapping the State:
Measuring Infrastructural Power through Cadastral Records

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SUMMARY

State capacity – the ability of states to implement political decisions – has become a core concept in social sciences; however, the development of the field has been hampered by poor empirical indicators of the concept. To fill this gap we developed a new measure that captures the infrastructural dimension of the concept. The paper discusses at length the construction of the *Cadaster* indicator for 159 countries for the period over 1000 years. Then *Cadaster Index* – a measure of the accumulated history or stock of state capacity – is validated through correlational analysis with some standard measures of state capacity. The paper concludes by discussing limitations and outlining the possible application of the new measure for comparative research.[i]

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1. INTRODUCTION

State capacity, broadly understood as the ability of states to implement political decisions, has become a core concept in social sciences. A large interdisciplinary literature has empirically established the independent effects of state capacity on a number of important outcomes. However, the development of the field has been hampered by poor empirical indicators of state capacity, which often do not satisfy the modern standards of validity and reliability, have limited spatial and temporal coverage, and are frequently conflated with the outcomes.

Having reviewed the existing conceptualizations and prevailing measurements of state capacity, the paper develops a new measure that captures the infrastructural dimension of the concept. It discusses at length the construction of *Cadaster* – hg a longitudinal indicator of the presence, quality and implementation of state-administered cadaster – for 159 countries for the period over 1000 years. Then *Cadaster Index* – a measure of the accumulated history or stock of state capacity – is validated through correlational analysis with some standard measures of state capacity.[ii] The paper concludes by discussing limitations and outlining the possible application of the new measure for comparative research.

2. STATE CAPACITY AND ITS MEASURES

The scientific study the power of the state has a distinguished history (Weber 1978). Its most recent chapter goes back to Huntington's (1968) insight that the most important distinction between countries concerns not their *form* of government but their *degree* of government. Although the conceptualization of state capacity continues to be a subject of debate, there is a broad consensus that one of the key powers of the state pertains to the quality of implementation after a rule is made.

The growing recognition that implementational or power-deploying institutions are different from power-constraining institutions (for example, regular elections or a system of check and balances) has led in recent decades to the proliferation of research on the effects of state capacity. It has demonstrated the independent effect of state capacity on economic development (Evans and Rauch 1999; Dincecco and Katz 2016), civil war (Fearon and Laitin 2003; Fjelde and De Soysa 2009; Braithwaite 2010) and public service provision (Cingolani et al 2015; D'Arcy and Nistotskaya 2017; Muralidharan et al 2016).

State capacity has been most often measured empirically through the quality of bureaucracy (Cingolani et al 2015; Evans and Rauch 1999; Knutsen 2013). While competent and effective public bureaucracy is certainly a prerequisite for implementing most policies, it is neither necessary to all implementation projects, nor sufficient on its own. For example, upholding public order depends critically on organizations other than the public bureaucracy, such as the police and military. Efficient implementation of political decision may require not only that the bureaucracy is professionally organized, but also that it is able to penetrate throughout the territory (Mann 1984; Herbst 2000; Soifer 2008). Mann (1984, 113) recognized the ability of the state "actually to penetrate civil society, and to implement logistically [political] decisions throughout the realm" – what he calls "infrastructural power" – as a quintessential characteristic of state capacity.

In comparison to bureaucratic quality, research is less clear on how to measure the infrastructural dimension of state capacity. Infrastructural power has previously been measured via single generic (Fearon and Laitin 2003) or broad composite (Fortin 2012) measures. For example, Fearon and Laitin (2003) argue that the inability of the central state to project power, know and control local populations creates the conditions for insurgency and test this using GDP per capita as the proxy for state capacity. However, GDP is misaligned with their concept, which requires a measure that captures unevenness in the state's territorial reach, and is too broad to accurately capture state capacity (Soifer 2008, 246).

In a recent work Acemoglu et al (2016) conceptualize state capacity as the presence of state functionaries and agencies, which is in line with the Mann's notions of penetration and reach, and measure it through the number of post offices. Although it is a neat indicator for the empirical milieu of their paper – the 19th century USA – the density of postal offices may not be a suitable indicator for state capacity across spaces and time, pointing to yet another hurdle in conceptualization and measurement of state capacity.

The pioneering work of James Scott (1998) has recently been used by scholars to provide a clearer way of recognizing what the infrastructural power looks like and thus providing a way to measure it. Scott argues that in order to successfully perform government tasks, states strive to 1) make their people, territories and sources of wealth "legible" and 2) transform/reorder social reality (usually in the direction of its simplification) to create a consistent social space across the state's physical terrain. For example, in order for the state to extract resources from land, the state has to make the attributes of the land legible, and also to simplify numerous local tenurial practices into a smaller and, therefore, more comprehensible set of tenurial relations. As Scott (1998, 35-36) points out, prior to cadasters – comprehensive registers of land and its owners – local tenure practices were legible to local inhabitants, but neither to the central state or outsiders.

Building on Scott, several scholars suggested to view information gathering efforts by the state (rendering "the governed" legible) as the basis of state capacity and used the presence of a national census (Brambor et al 2016; Soifer 2013) and its accuracy (Lee and Zhang 2017) as a measure of thereof. Censuses provide information that the state needs to raise taxes, maintain public order and deliver public services. Further, in the process of collecting census information, the state re-orders the established relationship within the society and between

society and the state through the creation of social categories (such as class), standardization of occupations, addresses, family relations and such like (Baffour et al 2013; Emight et al 2016).

However, so far census-based measures of state capacity have not been able to tap into the quintessential dimension of state capacity – the territorial reach of the state. Our work addresses these limitations by producing a measure of state capacity that captures the territorial reach of the state and also the extent of the state's knowledge about a fundamental asset of any economy – land.

To sum, the conceptual separation of power-deploying institutions of the state – state capacity – from power-constraining institutions has produced a body of research showing its independent effect on important outcomes. Between the two major approaches in the conceptualization of state capacity – bureaucratic quality and infrastructural power – the latter is presently more advanced both conceptually and empirically, and the need for conceptual models and measures that recognize other dimensions of state capacity is necessary to arrive at a more a holistic understanding of the phenomenon. We engage with this challenge by focusing on the infrastructural power of the state and building on the existing work that measures this concept through the information gathering activities of the state.

3. MEASURING STATE CAPACITY THROUGH CADASTERS

Building on Mann's and Scott's insights about territorial reach and legibility as key to high state capacity, we produced a measure capturing the extent of both the territorial penetration of the state and state's knowledge about of one of the primary economic assets – land. Specifically, we produced a measure capturing the age, extent and quality of state-administered cadasters. Cadasters are "parcel-based information systems underpinning functions of land registration, valuation or multiple purposes" (Haldrup and Stubkjaer 2013, 653).[iii] Therefore, for the purpose of our research aim we define cadaster as state-administered, methodically arranged records that identify land holdings within a country or region, through the presentation of their location, land parcel dimensions and land features, and land owners/users. Cadasters identify land holdings and link them to the land's owners/users for a variety of objectives: fiscal (e.g. early European cadasters, the British Revenue Surveys in colonial India), property rights registration (e.g. Torrens titling systems established in many colonial countries),[iv] land redistribution (e.g. the Down Survey in Ireland) or the management of state resources (e.g. the US Federal Land Survey of 1785 or the Soviet cadasters).

Cadasters are a fitting measure of state capacity. First, cadasters are an important information resource for key tasks such as taxation, upholding public order and resource management. Second, cadasters are instrumental for the state's ability to enforce property rights, which is essential for functional market and effective land administration (Se Soto 2000; Williamson et al. 2010). Third, cadasters are explicitly spatial in their nature, and thus are a good measure of a state's territorial reach. Finally, the process of making cadasters weighs heavily on local communities. As land ownership is a sensitive issue, directly related to local power relations,

the ability of the state to record and remake tenurial practices reflects an ability to impact on and exert control over local communities (Scott 1998, 24).

The potential utility of cadastral data as an indicator of state capacity has been recognized in the past (Soifer 2013), but the scarcity of cross-country data on cadasters is a long-standing issue, acknowledged by the community of professional surveyors (Haldrup and Stubkjaer 2013). To fill this gap we undertook a 5-year research project aimed to document the evolution of state-administered cadastral records for a large number of countries for over 1000 years. In this effort, we build on a large body of reputable sources, ranging from specialized academic literature to technical reports by professional associations and international organizations. Among these the following three sources of information were of particular importance: 1) *Cadastral Template* – a collection of standardized descriptions of the historical and contemporary cadasters in 60 countries around the globe, developed by the International Federation of Land Surveyors; 2) documents from the Permanent Committee in Cadaster in the European Union (*PCC*) and the Comité Permanente sobre el Catastro en Iberoamérica (*CPCE*); and 3) specialized academic literature that examines cadasters historically and/or presently, such as Kain and Baigent (1992), which provides a thick description of historical cadasters in a large number of European states. A 100-page codebook with information on key cadastral history events, sources of information and coding decisions for each of 159 countries is available upon request.

4. CONSTRUCTING THE *CADASTER* INDICATOR

We assign a score for each country (in its contemporary borders) and each year from 1000 AD[v] to 2015, if there was a cadaster in place. The basic score reflects whether the cadaster was narrative (.75) or cartographic (1). The basic score is then weighted by the extent to which the cadaster is implemented across the territory of a polity (between .1 and 100%).[vi] The maximum possible annual score is 1, which stands for a cartographic cadaster implemented across the entire territory of a country.

4.1 Criteria for coding an event as a cadaster

Cadasters have operated in a variety of economic, legal and fiscal systems and for a variety of purposes (Kain and Baigent 1992; Ting and Williamson 1999). To code consistently we apply three criteria that must be fulfilled for an event to qualify as a cadaster:

1) A record of a land parcel must be linked to the land parcel's owner/user.

Cadasters' "…essential feature is that they identify property owners, usually by linking properties on a map to a written register on which details of the property, such as the owner's name and its area, are recorded" (Kain and Baigent 1992, xviii). Since the essential feature of cadasters is that they link the object (land) and the subject (owners/users), thereby establishing the relationship between the two records, this informed the following two

decisions. First, where the land recording is not supported by a corresponding register of land owners/users, no basic score is assigned. Second, in order to enable the comparison across countries and time periods, the concept of "property ownership" does not necessitate individual freehold ownership. The owner can be an individual, a company, a community or a state, as in the case of cadasters of public land or under the socialist regimes (e.g. the Soviet cadaster). Consequently, the notion of "land parcel" does not necessarily imply a small-sized land holding as some of such parcels could be quite large (for example, in the Down Survey of Ireland, US Federal Land survey, Soviet cadaster or in contemporary cadasters of communal land in some African and Asian countries).

2) A land parcel must be externally observed or measured.

Despite the varying objectives of cadasters (fiscal, property rights registration, property redistribution or management of state resources), in all cases observation and measurement are performed externally. Early cadasters, like for example the Norwegian tax registers of c. 1514, were based on observations that could be called "social conventions": members of a local community would agree about the precise location, size and features of land holdings, using features of local geography (Kain and Baigent 1992, 98; Stubkjaer 2016). Only from about mid-17th century, the Norwegian cadaster became based on assessments performed by the state officials (Kain and Baigent 1992, 98).

3) A cadaster must be administered by the state.

As our interest is in state capacity, cases of privately-administered cadasters are coded as zero. There are, however, situations where cadasters are conducted privately and then handed over to the state. For example, in Argentina in the early 19th century many private landlords undertook cadastral mapping, and then central Topographical Commission checked and stored cadastral records (Gautreau and Garavaglia 2012). Known as a "weak-state cadaster" model, cases such as this receive the basic score. However, cases where estate surveys conducted by landowners were not utilized by the state, as happened, for example, in 17th century England (Scott 1998, 45), are coded as zero.

4.2 Assessing Quality

Once a cadaster is detected, according to the criteria outlined above, we assess its quality based on how the information about the land is represented in the record – narratively (in sequence of words) or cartographically.

Narrative cadasters are records, containing lists of land owners/users and written narrative description (in sequence of words) of land (e.g. location, size, use, quality). Early cadasters, such as, for example, the Chinese cadasters before 1143, the Ottoman *tahrir defterleri* or the Moscow *pistsovye knigi*, were narrative cadasters. Cartographic (mapped) cadasters are records, containing cartographic identification of the land. Cartographic cadasters present the information about a land holding's location, dimensions and features diagrammatically, i.e. in

a drawing or sketch, accompanied by a legend. Figure 1 presents images of historical examples of narrative and cartographic cadasters.

We assign higher scores to cartographic (mapped) cadasters for a number of reasons. At the most general level, as classic research in cognitive science suggests, while sentential representation is better at presenting temporal relations or logical sequence, diagrammatic representation "preserves explicitly the information about the topological and geometric relations among the components" (Larkin and Simon 1987, 66). In other words, in the case of cadasters the proverb "a picture is worth 10,000 words" holds not because maps have more information, but because maps are superior to words in conveying spatial information. Consequently, this improves the likelihood of drawing correct inferences from evidence, and also drawing them more easily and quickly (Larkin and Simon 1987).

Furthermore, there are also fundamental differences between the two types of cadasters in terms of scientific epistemology. Although both types of cadaster are rooted in the assumption that observation and measurement is the only way to know the objects of the world being mapped (Harley 1989), the extent to which the production of narrative and cartographic cadasters was congruent with the scientific method was drastically different. By the 17th century European mapmaking was associated with a body of explicit (often published) rules and procedures for surveying land and the production of maps. As Harley, one of the foremost authorities on the issue, notes, from at least the 17th century "The procedures of both surveying and map construction came to share strategic similarities to those in science in general…" (1989, 4). For example, cartographers increasingly used more and more precise instruments (such as surveyor's compasses or circumferentors to measure horizontal angles without reliance on features of local geography) and measurement (in particular triangulation, which came into systematic use in Europe in the seventeenth century). In other words, the data input for cartographic cadaster is based on observations and measurements of a more systematic character than that of narrative cadasters. The methods of cartography have delivered a "true, probable, progressive, or highly confirmed knowledge" (Laudan 1977, 2), and therefore provide more accurate information.

Narrative and cartographic cadasters could be seen from an evolutionary point of view, as a gradual process of change towards a more complex and usually better form. If earlier cadasters, such as those of the Chinese or Ottoman empires, were narrative, today nearly all the cadasters are cartographic. While having a narrative cadaster was a monumental step forward in terms of state capacity building from the "no cadaster" situation, a step between a narrative and cartographic cadaster is less dramatic from a state capacity building point of view. Therefore, we consider the difference between narrative and cartographic cadasters is more of degree than kind,

To quantify the difference between the types of cadaster we draw on a finding from Libecap and Lueck (2011a). In the context of a natural experiment in 19th century Ohio, they find that areas where land was described by a version of narrative cadasters, known as *metes and bounds*, have had fewer mortgages, conveyances and approximately 40% lower land value, compared to areas where cartographic cadasters were used. The main reason for this is that under metes and bounds "outsiders have little knowledge of local conditions and topography

to determine the exact location and nature of parcels" (Libecap and Lueck 2011b, 259). In other words, narrative cadasters are not as good at making land legible to the state and non-locals as cartographic cadasters, measured and presented in a standardized way. Based on this, we assign the score .75 to narrative cadasters and 1 to cartographic cadasters (which is 40 percentage points improvement compared to narrative cadasters as per Libecap and Lueck 2011a).

We acknowledge that the quality of cadaster may be assessed in more fine-grained ways, taking into consideration a number of legal, technological, institutional and organizational parameters put forward by specialized scholarship (Ali et al 2013). However, this effort will be meaningful only in relation to more recent cadastral records, which constitute a relatively small number in our sample, and also would require considerable research effort. For these reasons we leave this undertaking for future research.

4.3 Assessing Implementation

In the third step the basic scores are assigned a weight, which captures the extent of implementation of cadasters across the state's territory. We apply a number of different approaches, depending on the available data and the time period:

1) For pre-1900 (historical) cadasters in Europe and in some colonies (e.g. Egypt, British India and Burma, Japanese Korea) and the surveys conducted in the Western offshoots (USA, Canada, Australia and New Zealand) as well as in Russia, the implementation weight is the percentage of the current territory of the country in question that was covered by the cadaster. Building on the literature on cadasters initiated for fiscal purposes, which presents the overwhelming majority of such cadasters as covering all economically active land (Kain and Baigent 1992; Leckie and Simperingham 2009), we assign 100% implementation weight. However, where reputable sources present us with specific evidence of implementation of historical cadasters, this information is incorporated into the scores. We acknowledge that we are likely to overestimate the implementation of historical cadasters, and therefore we flag this issue up as requiring further investigation.[vii] The full implementation weight is less problematic for the cadasters in the Western offshoots, as their very purpose was to survey and distribute all land, with the creation of maps and distribution of land being part of the process of taking control of these territories.

2) Parcel-based weight is applied for the majority of recent (post-World War II) cadasters. The basic score is weighted by the percentage of land parcels that are properly surveyed and registered (PSR) parcels over the total number of parcels, as estimated by the professional community of surveyors (*Cadastral Template*, *PCC*, *CECE*) or documented in other reputable sources (above all, international organizations involved in cadastral projects). Although parcel-based is arguably the most accurate measure of coverage, the information on both the surveyed/registered and total parcels is not available for all countries.

3) In many cases the information on the PSR land is available in hectares. In such cases the implementation weight is calculated as the share of the titled land in total land over the share

of agricultural land in total land. To illustrate, Azerbaijan's implementation rate for the period 2005-2015 is 34%, calculated as the share of total land covered by cartographic cadaster (20%) after land reform in 2004 (Ahn and Son 2011, 2) over the share of agricultural land in total land area in 2015 (58%). We consider this approach to be a functional equivalent to the parcel-based weight, as it the "the total number of parcels" is typically highly correlated with the amount of economically active land. Taking into account the share of economically active land in the calculations of the implementation weight (rather than simply taking titled hectares over total hectares) also has the advantage of not penalizing states with large amounts of economically inactive land (as, for example, Algeria where desert makes up to 90% of the territory).

4) Finally, in some cases information is available on the number of PSR parcels separately for urban and/or rural areas, but not on the total number of parcels. Here the implementation weight is calculated as follows: (% of PSR rural parcels % rural population) + (% of PSR urban parcels × % urban population). In cases where the information is available only on the share of PSR rural parcels *and* the urbanization rate is below 50%, only the first part of the formula is applied for the calculation of the implementation weight. Furthermore, for some rural societies (like Myanmar) the only available information on implementation is a share of PSR rural households, which we take as a rough proxy for the implementation weight until further evidence becomes available.

It is important to note that more than one calculation is typically employed for each country, depending on the available data. The implementation weight does not capture the efficiency of cadastral systems. In some cases, despite substantive coverage, a cadaster is not used to its full advantage. For example, although 86% of all landed properties are registered in Albania the vast majority of land transactions are informal (USAID 2011, 7).

While we acknowledge that the estimates of the implementation weight may contain a measurement error, we take a lot of confidence from the fact that where multiple sources of information are available (PSR parcels, including rural and urban, hectares, households) we arrive at the implementation weight's values of similar magnitude, irrespective of the method of calculation. While these first estimates need to be improved, our research will certainly serve as a reference point for future efforts.

4.4 Accounting for decay and discontinuation

As cadasters not only develop, but may also decay, we account for both deterioration and discontinuation of cadastral records where reputable sources present us with evidence of such events. For example, the British colonial government in Myanmar implemented a full cadastral for revenue collection from 1879 (Leckie and Simperingham 2009). While we found no evidence in the literature regarding deterioration of these records, but we did find evidence that the cadastral records in contemporary Myanmar are not up to date as only about 25% of agricultural households are properly registered (USAID 2013, 14). Consequently, we assign the score of 1 (a mapped cadaster with full implementation) from 1879 to 1952, and the score

of .25 from 1953, when the state introduced a new system for land registration replacing the British cadaster.

In some instances cadastral records were discontinued or destroyed, either as a result of a change in the fiscal or land registration system, or because of political upheaval. An example of the former is the Ottoman Empire, which initiated a fiscal cadaster c. 1400 (Shinder 1978, 516), but discontinued it c. 1600 as the tax collection was farmed out to private individuals (Darling 2006, 118-120). In 1858 narrative cadaster was re-established as part of Land Code (Sait and Lim 2006, 67-69). Thus, in the period between 1600 and 1857 the score of zero is assigned to the countries under Ottoman rule.

Examples of the destruction or discontinuation of records because of political upheaval include, but not limited to: Cambodia under the Pol Pot regime, 1975-79 (Cadastral Template); the discontinuation of the Soviet cadaster (1970 Land Use Cadaster) after the dissolution of the Soviet Union in 1991; the removal of land records from Timor-Leste with Indonesian withdrawal in 1999 (Cryan 2015, 142). In these cases the score of zero is assigned for the period between the year when cadastral records are destroyed/discontinued and the year when new cadastral systems are in place.

The resulting data, *Cadaster*, is an annual unbalanced panel that comprises 159 countries from 1000 to 2015. Figure 2 depicts a considerable variation in *Cadaster* scores for the world's regions over time, and suggests that even presently a fully implemented cadaster is rather than exception than the rule with countries of the African continent considerably lagging behind other regions.

5. VALIDATION

Given that standard measures of state capacity, such as roads density or bureaucratic quality, reflect the accumulated history or stock of thereof, for validation purposes we use the *Cadaster Index* indicator, calculated as a sum of the yearly scores for the entire period. To account for the argument that the influence of the early cadasters may diminish over time and to minimize the influence of a possible measurement error of the earlier scores a discount rate, diminishing the contribution of the earlier periods to the *Cadaster Index* is applied. The raw data is skewed to the right, and log transformation makes the score to approximate normal distribution, which will be used in the validation exercise.[viii]

Similarly to the overtime trend, there is a considerable variation in *Cadaster Index* across countries (Figure 3). The mean value in the full sample of 159 countries is 121, exemplified by such countries as Argentina, Latvia or Taiwan. Twenty-four countries enter with a score less than 1, including seven countries with zero score. There is a considerable variation between and within the global regions too (Table 1). East Asia is the global leader (also with the largest standard deviation), followed by Western Europe and the North America, South Asia and North Africa and the Middle East. Sub-Saharan African is in the end of the league table with the average value of 12.

To demonstrate the validity of our measure, we examine the empirical relationship between *Cadastral Index* and a number of commonly used stock indicators of state capacity. We expect the associations to be statistically significant, but moderate in their strength as our measure taps into a dimension, which is captured by none of the existing measures. Indeed, as results reported in Table 2 suggest, all association are significant at the 99% level, signed as expected and moderate in their strength. *Cadaster Index* is associated negatively with the Fragile States Index as a whole and its "Risk of external intervention" component. The cadaster indicator is also positively significantly associated with two different measures of the quality of roads, measured in two different ways. Similarly, *Cadaster Index* is associated with the most prevalent measures of bureaucratic quality from the Worldwide Governance Indicators, International Country Risk Guide (ICRG) and the Bertelsmann Transformation Index. Finally, *Cadaster Index* is positively correlated with an indicator, capturing the accumulated history of the statehood over the territory of present-day states, but the strength of this correlation (r =.47 (raw scores) and .42 (log-transformed scores)) suggests that having a long history of statehood is not the same as to have a greater stock of accumulated cadastral history. This suggests that our estimates of state capacity are not biased by the longevity of the statehood.

By way of illustration, we also provide four scatterplots visualizing the relationships between *Cadaster Index* and four policy areas where we believe this type of state capacity matters the most: property rights protection, level economic development and taxation. Figure 4 shows a link between *Cadaster Index* and property rights protection, government tax revenue and levels of economic development.

6. CONCLUSION

Following a conceptual work by Mann (1984) and Scott (2008), we have argued that the ability of the state to "see" "the governed" – people, economic assets and economic activities across the entire territory of the state – is the quintessential characteristic of state capacity.

We have therefore developed a new measure capturing the infrastructural dimension of state capacity. Having systematically researched a large number and variety of historical and comparative sources, we documented 1) when states initiated the collection of information on landed resources of their citizens through cadastral records; 2) the quality of these records and 3) the extent of implementation of cadastral registration of land within their territories. The resulting longitudinal measure (*Cadaster*) spans over 1000 years, and covers the overwhelming majority of historical polities and contemporary states.

We have presented the results of the empirical validation of the *Cadaster Index* indicator, finding that at its core it captures the same core phenomenon as other stock measures of state capacity, yet also fulfils expectations about its distinctiveness. Furthermore, *Cadaster Index* correlates with such important outcomes as security of property rights, state revenue and the GDP.

Given the scope of the project, we recognize a potential for measurement errors and call all interested individuals and organizations to contribute to this first attempt to build a systematic body of knowledge of state-administered cadasters. Having said this, our data is an important contribution to comparative empirical research across disciplines. First, the cadastral data is distinct from policy outcomes, which enables methodologically sound exploration of the effects of state capacity. Second, it clearly taps into the spatial dimension of state capacity, which so far scholars failed to produce. Thirds, to the best of our knowledge, this is the most comprehensive measure of state capacity in both spatial and temporal terms.

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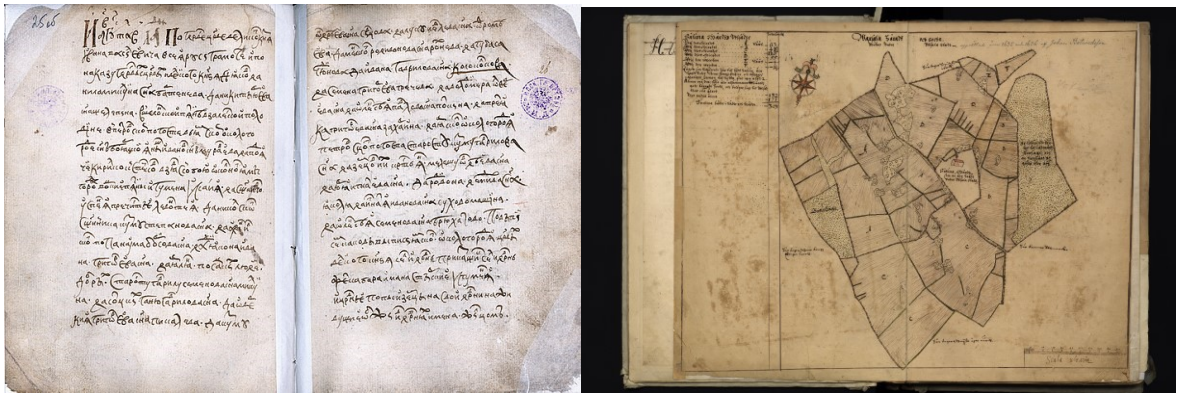
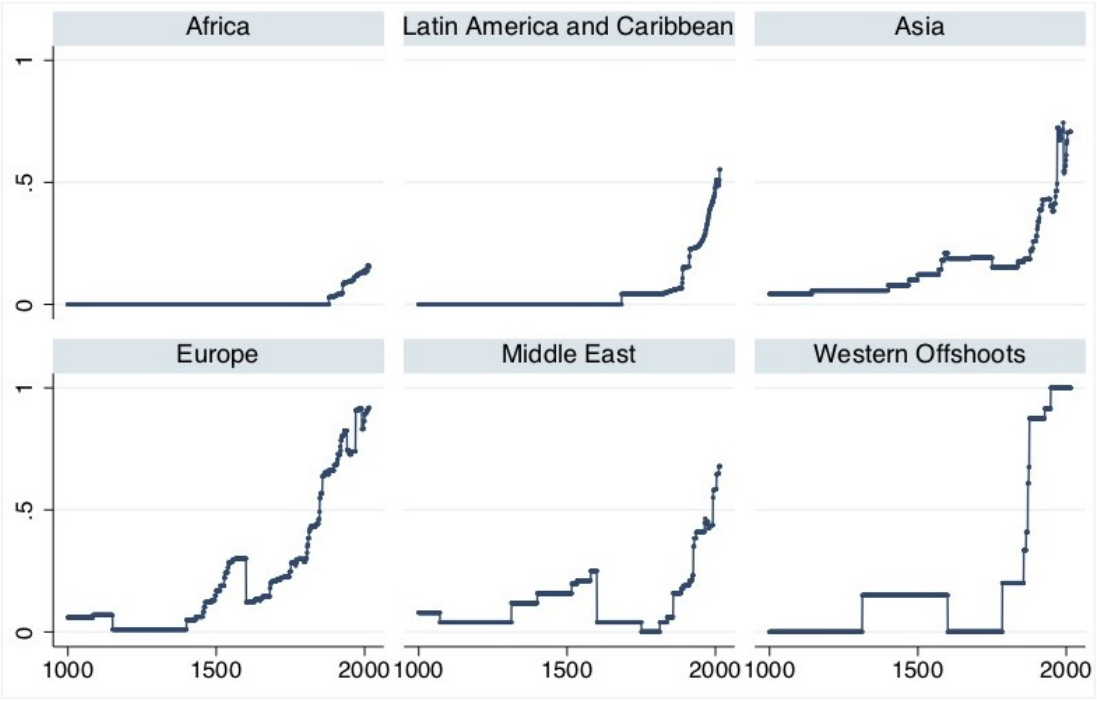
Figure 1. Narrative cadaster, Novgorod, Russia, 1571-72 (left panel); Cartographic cadaster, Uppsala, Sweden, 1635 (right panel)



Source: images are from Wikimedia Commons and the Swedish National Land Survey (Lantmäteriet).

Figure 2. Annual score of *Cadaster* across world regions 1000-2015



Note: the figure depicts cumulative scores of the countries by five world regions and the Western offshoots (USA, Australia, Canada and New Zealand). Maximum annual score is 1, higher values stand for higher infrastructural power.

Figure 3. *Cadaster Index* (sum of annual scores of *Cadaster*, 1000-2015)

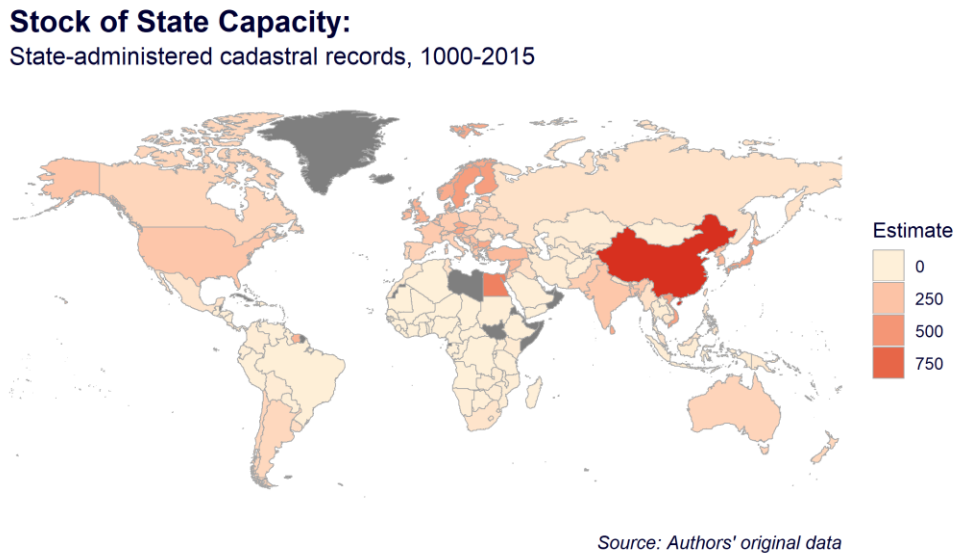
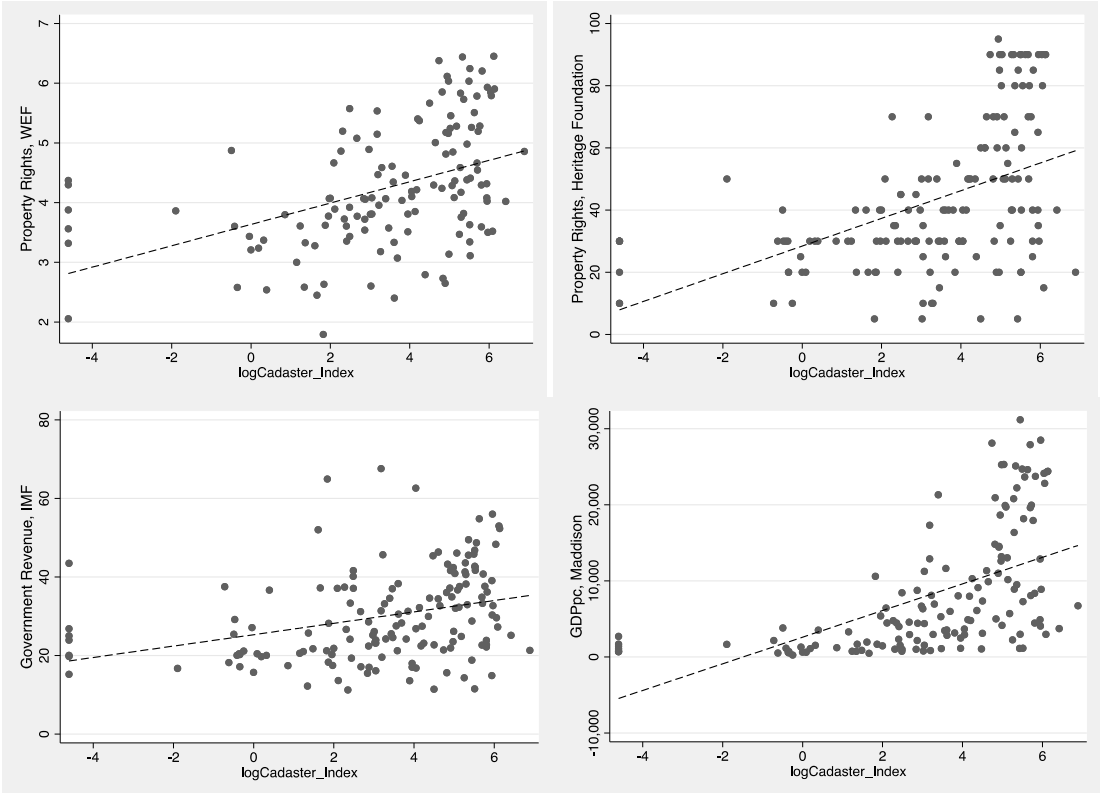


Figure 4. *Cadaster Index* and Property Rights (top panels) government revenue and economic development (bottom panels)



Note: Property Rights = wef_pr and hf_prights, tax Revenue = imf_rev and GDPpc = mad_gdppc.

Table 1. *Cadaster Index* (sum of annual raw scores between 1000 and 2015)

World region	Obs	Mean	SD	Min	Max
East Asia	6	344.4	342.4	12	980
Western Europe & the North America	21	253.3	103.6	135.6	461.5
South Asia	7	172.1	129.3	4.4	380
North Africa & the Middle East	17	153.1	171.1	0	612.8
Eastern Europe	28	150.1	117.9	21	390.8
The Caribbean	4	106.4	151.9	6.5	332
Latin America	19	34	45	0	144.4
The Pacific	3	45	13.2	30.9	57
South-East Asia	10	87	129.1	6.3	439.5
Sub-Saharan Africa	39	11.6	24.7	0	136
	154*	116.4	148.8	0	980
	159	120.7	162.5	0	980

Note: World region = ht_region variable from the Quality of Government Basic Dataset (Dalhber et al 2018); ht_region does not classify Hong Kong, Macao, Kosovo, Puerto Rico and Sudan into a world region.

Table 2. Validity Checks for the *Cadaster Index*

Variable	Observations	*Cadaster Index* (raw)	*Cadaster Index* (log)
		Pairwise Correlations	
Failed states index	154	-.45	-.52
Risk of external intervention	154	-.43	-.51
Paved roads	108	.46	.64
Road quality	132	.33	.45
Quality of government	129	.52	.61
Basic administration	121	.37	.55
Government effectiveness	155	.51	.59
State Antiquity Index	136	.47	.42

Note: all correlation coefficients are significant at the 99% level and signed as expected. Failed states index = ffp_fsi ; Risk of external intervention = ffp_ext; Roads, paved (% of total roads) = wdi_roadpaved; Quality of roads = wef_qroad; Quality of government = icrg_qoq; Basic administration = bti_ba; Government effectiveness = wbgi_gee; State Antiquity Index = sai_statehist05v3.

BIOGRAPHICAL NOTES

Dr. Michelle D'Arcy is an Assistant Professor in Political Science at Trinity College Dublin. She holds a PhD in Political Science from University College Dublin. She researchers the effects of institutions on development with special focus on developmental trajectories of both contemporary developing countries (with special focus on Kenya) and European states in historical context. She published in leading political science and African studies journals.

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[ii] The validation exercise employs the data from the Quality of Government Institute (Dahlberg et al 2018). This dataset does not include a number of states (specifically, Hong Kong, Macao, Kosovo, Puerto Rico and Sudan) for which cadastral data is also collected, making the effective number of observation 154.

[iii] Conversely, a "land title registration system" is "a public register of rights than may be asserted against third parties over land parcels, which are identifiable through a cadastre, a connected map or other method of description" Raff (2003, 14).

[iv] The Torrens system is a system of land titles in which a register of land holdings is maintained by the state and involves the submission of a survey of the land parcel's boundaries, which, while not necessarily carried out by state officials, is legally protected by the state. We include Torrens titling systems within our definition of cadasters because they are state-administered records of land holdings and users, even though land surveys are not always produced directly by the state.

[v] For the period before 1000 AD historical information is poor. Collecting data for this period would require high research effort for sub-standard quality data. There are also very few examples of cadasters before 1000 (one of the few being in China).

[vi] In cases the coverage is above 90%, a cadaster is considered to be fully implemented ("full cadaster"), and the assigned implementation weight is 100%. This is because it proved particularly difficult to find reliable detailed information on implementation for situations approximating full cadasters. Very small numbers for coverage are rounded to 0.1 and values below five decimal places are disregarded.

[vii] For example, in two specific instances of historical cadasters – the Ottoman Land Code of 1858 and pre-colonial Korea – there is evidence of less than full implementation (see Quataert 1994, 858-859; Ruedy 1971; Tute 1929; Yoo and Steckel 2010). However, further details of what constitutes less than full implementation are not available. In the absence of any more accurate information a 50% weight is applied in both cases, but must be revisited as soon as new historical evidence becomes available.

[viii] We sum country/year indicators for each 50-year period since the inception of the cadaster. For each half a century, following the first observational period, we attach an exponent$(1+\delta)^{-t}$, where $0 < \delta > 1$ functions like a discount rate, showing the depreciation of the impact of the past upon the present, and t is the number of 50-years periods preceding the date at which we measure the cadaster stock (for example, t = - 6 if a cadaster begin in 1530 and the date at which we measure its stock is 1800). The 5% discount rate is most commonly applied (D'Arcy and Nistotskaya 2017).