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Evolving practice in land demarcation

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Abstract

This paper analyzes social choice with respect to the demarcation of land boundaries, distinguishing between physical and legal demarcation. In contrast with the influential “land administration” literature and the World Bank’s policy guidelines, the analysis supports voluntary—instead of mandatory—demarcation as well as non-integrated services for land administration. Consistent with these theoretical arguments, the paper empirically verifies that demarcation conflicts play a lesser role in title-, land- and property-related litigation, which seems to increase in all these areas after physical demarcation is made mandatory. Relying on World Bank data, it also observes that linking and merging cadastres and land registries does not correlate with lower transaction costs.

Keywords: land, property, boundaries, surveying, cadastres, land registry, land administration.

JEL codes: D73, K11, K25, K34, K41, L85, O17, O18, Q15, Q24.

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1. Introduction

Efforts to plan economic development tend to apply uniform and supposedly optimal solutions, increasingly expressed in terms of targets, such as, in the area of interest here, the percentage of registered and properly mapped land.¹ The present paper contends that the reason why these centralized and expert-led efforts tend to fail massively is because they still fail to adapt to local circumstances (Easterly 2014). They therefore disregard the value of “knowledge of the particular circumstances of time and place” underscored by Hayek (1945:521) which, even after the fall of Socialist economies, has widely been ignored in development.

1.1. Established policy

The survival of this planning misconception has affected land titling projects, which often aim at *universal* coverage in a given area, a policy often optimistically referred to as “systematic”, while the policy defended in this paper based on voluntary and, therefore, selective titling and demarcation is dismissed as “sporadic”. Thus, according to the World Bank’s good practice guidelines summarizing lessons learned since it started investing seriously in this area in the 1990s: “Systematic registration identifies, adjudicates, and registers rights to all adjacent land parcels in a selected locality and within a given period of time. Sporadic registration processes land rights on an ad hoc basis, usually when customers request registration of their parcels of land” (World Bank 2005:397).²

¹ For instance, one of the UN’s Sustainable Development Goals for 2030 aims to “ensure that all... have... access to... ownership and control over land and other forms of property”, and then it estimates countries’ achievements in this regard with an indicator measuring the “proportion of total adult population with secure tenure rights to land” (UN Sustainable Development Knowledge Platform, <https://sustainabledevelopment.un.org/sdg1>, accessed July 15, 2017).

² In their terminology, the guidelines seem to be assuming that there is no system in “sporadic” titling. It seems reasonable, however, to think that such “ad hoc” decisions by owners are *systematically* made when the value of land titling is greater than its costs, that is, they are not “occurring occasionally, singly, or in irregular or random instances” (the definition of “sporadic” by the Merriam-Webster dictionary). There is also a tendency to forget that “systematic registration is used only for initial registration, and whether initial registration is systematic or sporadic, the registration of subsequent transactions is sporadic, on application” (Bruce 2012:50, n. 16).

The extreme version of this systematic-titling argument even led part of the “land administration” literature to propose “holistic” objectives, according to which surveying each land parcel was considered a requirement for good titling.³ Such land administration systems must not only provide complete information on land, including the different types of private rights and public restrictions, but ideally they must also be managed in an integrated manner to facilitate governments’ control of resources. It is claimed, for example, that “governments must proceed further and integrate the actual management processes of land use, tenure and development” (Bennet *et al.* 2008:127, summarizing Enemark *et al.* 2005).

Similarly, the World Bank advised in 2005 that “cadastre and registration functions should be connected and managed by a single institutional entity wherever possible” (World Bank 2005:398). This single-agency policy—despite some more nuanced judgments by the evaluation unit of the Bank (IEG 2016:28)—is still advised by the Bank’s *Doing Business 2018* report, when it considers as best practice in property transactions “to bring all agencies involved in property transfer under one roof”,⁴ and when the “coverage” component of its “Quality of Land Administration” index also scores countries higher if their mapping agency covers the largest business city in full and even higher if it covers the whole economy.

Consistent with these recommendations, which have deserved little attention in the law and economics literature,⁵ for decades most land titling projects and land registration reforms have been trying to implement exhaustive, even mandatory, land titling and demarcation based on delineating boundaries and representing parcels graphically, often in conjunction with attempts to integrate land registries with cadastres to reap the benefits of alleged synergies.

More recently, these policies have been more or less implicitly criticized by alternative “fit-for-purpose” proposals (Enemark *et al.* 2014, 2016), by internal evaluations of the performance of World Bank projects which, having been designed under the traditional paradigm, lead evaluators to defend a more contingent approach (IEG 2016), and also by the launch of some land titling projects that aim to avoid precise surveying to minimize costs.⁶

³ See, for instance, the initiative “Cadastre 2014” at Kaufmann and Steudler (1998).

⁴ “Registering Property: Good Practices,” World Bank, Doing Business Website (<http://www.doingbusiness.org/data/exploretopics/registering-property/good-practices>), accessed March 28, 2018).

⁵ An exception being the discussion between Lueck (2017), Smith (2017) and Arruñada (2017a, 2017b).

⁶ See, for example, Deininger *et al.* (2008) for the case of Ethiopia and Ali *et al.* (2014, 2017) for that of Rwanda, as well as references to other projects in Enemark *et al.* (2016:2).

However, the effective degree of change in terms of policy is debatable. Both the fit-for-purpose and contingent approaches, rather than focusing on the owners' choice whether or not to title their land and with what precision and relying on different means and providers, still focus on the planners' choice about which geographic areas to title and what level of demarcation precision to apply (usually, for physical demarcation, a uniform level, given by a particular technique and supplied by a given provider, as well as most often a mandatory degree of legal demarcation). They are therefore bound to reach adaptation at most at a general instead of the individual level.⁷

More importantly, no significant change is visible as yet in terms of resource allocation. Considering a proportional allocation of administration and management costs, at least 53.45 percent of the unit costs of these land titling projects was spent on physically identifying and demarcating land parcels (my own estimation, based on Burns 2007:94–95). Admittedly, this figure is based on old projects, but is in accordance with more recent estimates. For instance, in his study of African projects, Byamugisha concludes that “geodetic referencing, large-scale base mapping and cadastral surveying... constitute more than 50 percent of total investments in land administration projects” (2013:121). Among developed countries, the case of the Greek National Cadastre, which persists, as it has over the last three decades and despite repeated failure, in developing a functional single-agency, also reveals the resilience of this old paradigm (e.g., Taylor and Papadimas 2015; Seeling 2018).

1.2. Historical lessons

Similarly, reforms of land conveyancing and registration in developed countries still invest considerable resources to improve boundary demarcation, mandate the provision of surveys in conveyancing and try to link and merge the databases of cadastres and land registries, two institutions that had traditionally pursued different goals and consequently organized themselves differently and remained separate.

⁷ Lack of individual adaptation can be seen as an instance of a larger issue, the tendency in some of these grand proposals to avoid facing tradeoffs and insist instead on absolute and contradictory objectives. For example, under fit-for-purpose, “new solutions are required that can deliver security of tenure for all, are affordable and can be quickly developed and incrementally improved over time” (Enemark *et al.* 2016: vii). However, in a world of scarce resources these three objectives are incompatible because (1) security for all implies affordability and in fact subsidized titling, which is often unsustainable; (2) security cannot be at the same time effective, low-cost and quick; and (3) quick solutions are hard to improve because of path dependencies. Understandably, minimizing average costs becomes a priority, distorting the choices of technology and output level (Jensen and Meckling, 1998).

These efforts are far from new. For example, Section 7 of the Land Transfer Act enacted in England in 1862 already required an exact description of the plot to be registered, as well as its boundaries and neighbors, in order for the registrar to trigger a legal determination of the boundaries. In the same vein, when Scotland's Land Registration Act created the new Land Register in 1979, it mandated a physical description of each plot, based on the Ordnance Survey map. Similarly, when Greece, with co-financing from the European Union, decided in 1995 to improve land registration, instead of upgrading the old mandatory recordation of deeds based on personal grantor-grantee indexes with a mere tract index (as other countries using land recordation did in the past, including France in 1955), it opted for creating a new cadastre, with entirely new registrations. These required matching the specific survey of the parcel with the general cadastral chart of the area, but without making sure that entries were in accordance with the legally valid information in the land books (Tzinieri 2014). More recent efforts have followed the same policy, introducing changes only at organizational and legal levels but without substantially re-designing the project (Seeling 2018).

Most of these efforts in developed countries were unmitigated failures. Surveying in developing countries is also often abruptly interrupted and the initial efforts shown to be meaningless when subsequent transactions remain unregistered (Bruce *et al.* 2007:42, Bruce 2012:44, Ali *et al.* 2017). A common reaction has been to reduce surveying requirements in order to lower registration costs to make the system sustainable. For instance, in England, after a Royal Commission concluded that mandatory specification of boundaries triggered undesirable litigation of latent conflicts, the 1875 Act mandated applicants to identify the plots but gave them considerable leeway when demarcating boundaries: they could rely on "general" (in essence, imprecisely defined) boundaries,⁸ using traditional methods and without even mentioning the neighbors (Simpson 1986:282, Nogueroles 2008). The 2002 Land Registration Act retains the traditional focus on general boundaries. In Scotland, only 19 percent of the landmass and 55 percent of its titles had been transferred into the new registry after thirty years (ROS 2010a:5). Transition to the new registry was slow, as it suffered from long turnaround times and a considerable backlog, in which mapping issues figured prominently (ROS 2010b:10 and 16). Mapping had caused frequent refusals and delays in registration (ROS 1999), often because of discrepancies between the plan in the deed and the Ordnance Survey map. It had also been the largest category of error in terms of indemnities (ROS 2010b:26). In Greece, development of the National Cadastre has been appalling (Taylor and Papadimas 2015). Despite poor legal security (Tzinieri 2016), coverage advanced slowly, reaching

⁸ There is considerable ambiguity in the literature about the use of these terms. In some cases, "general" and "fixed" boundaries refer to the lesser or greater degree of precision in physical demarcation. In other cases, they refer to the absence or presence of legal demarcation, as when fixed boundaries are a synonym of conclusive boundaries in the Torrens registries. Even worse, some reports mix the two criteria (UN-ECE 1996:107–108). On the origins of these terms, see Simpson (1976:134, 155).

29% of property titles, most of them in the cities, which amounted to only 8% of the territory in 2018 (Seeling 2018).

These failures should have been expected, because both the historical record and the established institutional solution suggest that land registries work effectively with imprecise demarcation and that both registries and cadastres are typically separate entities pursuing different objectives and organized under different principles. Indeed, in most developed countries land registries have been operating effectively with voluntary demarcation of boundaries. Land surveys are generally voluntary for conveyancing or registering real property transactions, relying instead on approximate identification of parcels and at most the listing of neighbors. According to a study carried out for the European Commission, surveyors and other technical experts were commonly used in the United Kingdom, Ireland, Denmark and France but on a voluntary basis (ZERP 2007:33, Schmid and Hertel 2005:29). In a similar vein, of the 186 countries with data in the *Doing Business 2017* report (World Bank 2016), only 11.83% had merged their land registry and cadastre, with the rest having separate organizations. Most (54.27%) had not linked them, although 62.37% of the total did share a common identification number for each parcel. The “dismissal of history” critique on development economics by Easterly (2014) therefore seems applicable to land administration.

1.3. The argument

I submit here that a common root cause of these policy mistakes is their interrelated emphases on *universal* (meaning all parcels in the intervention area) and *physical* demarcation (a precise definition of physical as opposed to *legal* demarcation will be given momentarily). Emphasis on universal demarcation means that policy is oriented towards achieving maximum coverage in the relevant treatment area without paying proper attention to the tradeoffs involved and, in particular, to the fact that, due to the presence of fixed per-parcel demarcation costs, more extensive and precise demarcation (as well as titling, generally) is often only suitable for higher value land. This is an aspect that owners are in a privileged position to evaluate.

Moreover, this goal of universal coverage often ends up aiming for low *average* cost while sacrificing legal quality and emphasizing the physical dimension of land demarcation, which in practice often means the measurement and delineation of boundaries by one or more of the parties that have an interest in the land (including Government agencies). Correspondingly, these initiatives often pay little, if any, attention to the legal dimension of land demarcation: the fact that, in order for demarcation to produce effects on third parties, such party-led physical demarcation must be accepted by all other interested parties—which in this case mainly means the neighbors of each particular parcel.

This emphasis on physical and partial demarcation often leads to mistakes, such as (1) pursuing the above-mentioned objective of universal demarcation, even if the consequent need to lower average costs and shorten times leads to valueless lower quality; (2) overestimating the value of physical demarcation, which is behind excessive expenditure

on mapping and surveying and the enactment of allegedly inefficient, mandatory demarcation rules; and (3) considering that the information needed for different decisions on property (e.g., the judicial evidence on which judges rule and parties rely for their contractual decisions versus administrative filings used for tax and other planning and regulatory purposes) is the same “data”, wrongly subjecting it to similar quality specifications and without requiring any specific incentives or specialization in its production. Consequently, it is thought, for instance, that both sets of information can easily be shared by government agencies, that duplications can easily be avoided, and that substantial economies can be fruitfully reached by sharing databases and even merging the agencies (that is, merging land registries and cadastres in integrated “land administration” bodies).

The main contributions of the paper are (a) the conceptual distinction between property-legal and physical demarcation and (b) providing a comprehensive framework for the main social decisions on property demarcation, which are of two types. On the one hand, with respect to the overall rules governing it, governments must decide on: whether or not to create a demarcation infrastructure system that, by incurring a fixed cost, enables individuals to demarcate their land more effectively; and either allowing voluntary demarcation or enacting a mandatory demarcation rule that forces individuals to incur a variable cost to demarcate their land either physically and/or legally. On the other hand, with respect to the provision of demarcation services, governments may either keep separate organizations or merge the cadastre with the land registry, with the intermediate option of linking their databases.

Section 2 develops the theoretical framework to assist in the above decisions by first defining the concept of “legal demarcation”, of which “physical demarcation”—the task of identifying parcels and measuring their boundaries—is an input; and then developing a simple model of optimal demarcation based on individual and social decisions. Section 3 analyzes the factors that drive the main costs and benefits in these optimal social choices—mainly, the statistical distribution of land parcels’ value, the cost of legal demarcation and possible externalities. Sections 4 and 5 provide two empirical assessments, pertinent to these choices, which are broadly supportive of the theoretical argument in favor of applying voluntary titling and demarcation as a general rule, with the only exception of clear public-good externalities (such as, e.g., demarcation infrastructure). Section 6 concludes with a summary and some policy remarks.

2. Theoretical framework: Key concepts and decisions on land demarcation

2.1. Legal demarcation, an intrinsically legal concept in property

The “well-defined” property rights in the foundational article by Ronald Coase (1960:19) require specification of at least *who* holds *which* rights on *what* property—that

is, identification of (1) the person holding the right; (2) the content of the right, in terms of both possible uses and, especially, enforcement remedies; and (3) the asset on which the right is held.

The legal-property nature of the first two dimensions (*who* and *which* rights) is clear enough. It includes defining who is the holder of a particular right and what is the content of the right. Such content must be defined both in terms of possible uses (for instance, the right to occupy land or to appropriate its fruits) and, especially, the legal remedies available. The key distinction between property and mere contractual rights is given by such remedies: a property right is enforced *in rem*, meaning that it is enforced against the whole world (Merrill and Smith 2000, Hansmann and Kraakman 2002) while a contract right is only enforced *in personam*, against certain specific persons, often a previous seller.

In practical terms, to achieve such property, *in rem*, rights in the first two dimensions, what is needed is a particular set of institutions that add to the conventional consensual agreement between two parties a second step in which all other affected parties grant their consent (Arruñada 2003). For example, to transfer full unburdened ownership of a plot *P* of land from person *A* to person *B*, the legal system must make sure that *A* is the owner and there are no burdens on the land. This can be achieved by different means: including, e.g., public ceremonies and possessory prescription in Ancient Rome (Arruñada 2015, 2016), summary judicial procedures such as the French *purge* or the US “quiet title” suit (Arruñada 2012:56), or the registration of rights characteristic of the most developed titling systems (Arruñada 2003).

For our purposes, the essential point is that the same happens in the third, *what*, dimension. Reserving the term demarcation for the third *what* dimension, the paper will distinguish between two concepts, which will be labeled “physical” and “legal” demarcation:

- *Physical demarcation* includes any activity for identifying a parcel of land and delineating its boundaries, *performed by any of the parties* related to the parcel.⁹
- *Legal demarcation* consists of reaching a social consensus on physical demarcation, such that it will be enforced *in rem*.

The distinction holds for any type of physical demarcation. Parcels are identified by relying on parcel names and, more generally, by specifying where they are located within a series of geographical units such as the municipality, the zone and the more specific area, street addresses, post codes, etc. Boundaries were traditionally delineated by reference to natural geographical features; by their abutments or relation to natural or artificial elements such as roads or adjacent lands; by statements of length, bearing and

⁹ This is usually linked to an intended private or public transaction, including, e.g., selling or burdening the land with a mortgage, or the start of condemnation procedures; but not necessarily. For instance, an owner may be interested in identifying the boundaries of a given plot.

distance (the “metes and bounds” system); by reference to geodesic lines (as in the US “rectangular survey”); etc. Today, greater precision can be easily obtained by using modern global positioning systems. Moreover, many other techniques allow low-cost drawing of boundaries, including Google Earth.

After some degree of physical demarcation, legal demarcation involves two additional steps. First, it requires checking for possible contradictions with all relevant evidence, which might come from the cadastre or the land registry, or be obtained by consulting neighbors’ titles or opinions, or by examining possessory indications in the field. Secondly, full legal demarcation also requires eliminating all contradictions and overlaps, either by reaching private agreements with neighbors or by pursuing some type of litigation and adjudication procedure.

This distinction holds important consequences, as the effects of physical and legal demarcation are determined by which parties are involved in the corresponding decisions. Crucially, social consensus allows legal demarcation to produce stronger, *in rem*, effects. It is only after the land has been legally demarcated that boundaries are “conclusive”—meaning they have legal force *in rem*: that is, they have effects against third parties. For example, without legal demarcation, whatever the physical demarcation accompanying a deed and whatever the promises given by the seller with respect to boundaries, neighbors can still enforce *in rem* their boundary claims against the buyer, who, if neighbors are shown right in court, will at most have an *in personam* claim against the seller—and possibly the surveyor—for any deficiencies with respect to the promised demarcation.

Moreover, as with the other two dimensions in the definition of property rights (on which person and which rights), the definition of the *what asset* dimension is also the product of both purely private contractual exchange and the functionally “public” gathering of consents characteristic of property transactions (Arruñada 2003).

However, this public stage can be performed by different *means* and at different *times* for different dimensions. For instance, not only for land recordation but also for land registration it is enough if parcels are identified even if their boundaries are not well demarcated. This in fact means that both registration and possession are used for titling this third, *what asset*, dimension. When boundaries are less precisely defined, they are not abandoned in the public domain, as might happen in other dimensions for costly-to-measure attributes of property rights (Barzel 1982), but are defined by the informal mechanisms of adverse possession and acquisitive prescription, which allow an implicit definition of boundaries to take place *ex post*, instead of by a formal, explicit and costlier settlement procedure taking place *ex ante* (Arruñada 2015).

Even the International Federation of Surveyors (FIG) admits that property rights can be secured and land markets developed without precise surveying of boundaries (e.g., Onsrud 2002:9). Similarly, the fit-for-purpose “approach uses aerial or satellite imagery in the field to identify, delineate, and adjudicate the visible land parcel/spatial unit boundaries, and the rights are determined and entered directly into a register” (Enemark *et al.* 2016: ix). However, given that adjudication still requires a gathering of consents, the images *by themselves* may be more directly useful for building index maps than for adjudication.

Lastly, while physical demarcation is a continuous phenomenon, legal demarcation is relatively discrete. Parties can demarcate land with a variable degree of precision, from mere verbal identification to detailed and precise drawing and location of boundaries. However, whatever the physical demarcation, legal demarcation derives its effects from the granting of consent, which is an intrinsically discontinuous event. Consequently, legal demarcation is compatible with different degrees of precision in physical demarcation. Neighbors can agree on the boundaries whatever the method used to define them and whatever precision the method provides. Obviously, their agreement is granted for that given degree of precision. A classical example is given by the ceremonial conveyancing of land used in classical Rome, known as *mancipatio*, “though not a legal requirement, it was standard practice to call the neighbours to witness a conveyance by delivery. This allowed the transferee to verify that the transferor and his neighbours agreed on the boundaries, or, if they did not, to pinpoint the area/s of dispute” (Honoré 1989:139). This is therefore a case of legal settlement of boundaries even if they remain quite imprecisely defined.

2.2. Socially-optimal land demarcation

To organize the analysis, Figure 1 represents the optimal individual and social decisions on land demarcation. Following Arruñada and Garoupa (2005:716–19), the value of land is represented on the vertical axis and is assumed to depend on the probability that claimants with a better legal right may get the land. It is therefore a fraction of its value in an ideal world with no conflicting claims, represented on the horizontal axis. This fraction, which is graphically represented by the slopes of the lines in Figure 1, depends on the availability of institutions and services (registration, demarcation) and individual decisions to use them or not. It is lower if the land remains unregistered and is instead enforced under private titling based on custom and possession (“privacy,” for short). Similarly, it is also lower when land is not properly demarcated.

To simplify matters, Figure 1 represents all the land of a certain type (e.g. rural land) in the relevant policy area under intervention. It also assumes that land registration is already in place. Therefore, any fixed cost incurred to create the registry is considered sunk. Registering means that, by incurring an additional unit cost (given by the intercept of the registration line, the distance *or*), the probability of a conflicting claim being successful falls with respect to privacy. In other words, by registering a parcel of land, its value increases by a certain percentage: with respect to the privacy line, the registration line has a negative intercept, but is steeper.¹⁰ Landowners choose between incurring a

¹⁰ As a sideline, in terms of the model, the argument that universal titling (and demarcation) efforts benefit the poor more (e.g., World Bank 2003) would mean that the benefit of better titling is greater for lower-value land (assumed to be owned by the poor) than for higher-value land. This widely-held belief is doubtful, however, if one pays more heed to the revealed preferences of the poor than to experts’ opinions: after massive

cost to register their land or holding it under privacy. Under voluntary registration, high-value parcels are registered while low-value parcels remain under privacy.

Similarly, demarcation would first incur a fixed cost F_d for making it viable in the jurisdiction by setting the infrastructure for parcel identification and some sort of high-level demarcation and “monumentation” that provide references needed for lower-level demarcation of individual parcels. Then, for each parcel, by incurring an additional cost rd , it is possible to attain a greater level of boundary assurance. In Figure 1, this effect is visible in that the demarcation line is steeper than both the privacy and registration lines.

Under a voluntary regime, owners will optimize private costs and benefits when choosing between privacy and registration with and without demarcation. Given the likely presence of fixed demarcation costs unrelated to land value, low-value parcels (oa) will remain under privacy, mid-value parcels (ab) will be registered but not demarcated; and high-value parcels (those to the right of b) will be both registered and demarcated. This simple logic explains, for instance, why urban land is more precisely demarcated than rural land, and surveying and other due diligence studies are customary for commercial transactions in the United States but are rare for residential ones (Madison, Zinman, and Bender 1999:14). It also explains that land is more precisely demarcated when land values rise, which moves the distribution of land to the right along the horizontal axis of Figure 1.

Area B defines the social gross benefit of demarcation. Comparing it to the fixed cost F_d renders the socially optimal decision: it makes sense to put in place the demarcation infrastructure if $B > F_d$.

Voluntary demarcation is therefore optimal in the absence of positive externalities. Introducing a rule of mandatory demarcation in which registration requires having the land boundaries properly demarcated, would have two effects: (1) “undertitling” of land ac , which, without that rule, would be registered and, with the rule, will be held under privacy; and (2) “overdemarcating” of land cb , which, without the rule, would be registered but not demarcated and, with the rule, will still be registered but also forcibly demarcated.¹¹ In addition to the fixed cost F_d , mandatory demarcation will incur an

titling efforts, subsequent transactions tend to remain informal (Bruce *et al.* 2007:42, Bruce 2012:44), especially lower-value ones (Ali *et al.* 2017:382). Moreover, even a universal or “systematic” approach often fails to benefit the poor (IEG 2016:19–24). The IEG report sees this as a failure but it could also be understood as an efficient outcome. By different means, it is the most valuable land that ends up better titled, as the model advises: the report cites side payments, lack of subsidies, and planners’ choice to intervene in the most developed regions. To these should be added the voluntary decision to keep subsequent transactions informal. Overall, in this case the tyranny-of-experts argument of Easterly (2014) does not seem far-fetched.

¹¹ Note that these effects are under voluntary titling and mandatory demarcation. Under mandatory titling, losses would be much bigger, as explained in Arruñada (2012:145–52). The analysis assumes $a < c < b$, which will generally be the normal situation

additional social cost given by the area A . Therefore, such a rule of mandatory demarcation could only be justified on the basis of externalities (as analyzed in section 3.2).

3. Drivers of the costs and benefits of demarcation

The balance of social costs and benefits of land demarcation depends on several factors that determine (a) individuals' costs and benefits, given by the location of the breakeven points a , c and b in the previous model (section 3.1), and the type of demarcation— physical or legal —being performed; and (b) the possible presence of positive and negative externalities (section 3.2).

3.1. Internalized cost and benefits

Mere physical demarcation should incur a small variable cost rd but may also cause a small benefit, slightly moving the value line up in Figure 1. It would remain close to that of registration, with tiny effects on the indifference points (that is, b would remain very close to a). This is consistent with empirical estimates of explicit costs. In Europe, the cost of surveying residential properties has been estimated at about 500€ varying little with property value.¹² As a percentage of legal transaction costs (fees charged by lawyers, notaries, conveyancers and the land registry), surveying fees represent on average 41.81% of legal fees for a 100,000€home and 17.71% for a 500,000€home in the EU countries considered.

Moreover, both the costs and benefits of surveying vary with the type of land and with measurement precision. On the one hand, physical identification and demarcation of real estate assets are relatively easy for buildings but harder for undeveloped land, especially in areas in which, in the absence of distinctive natural or man-made landmarks, the traditional metes-and-bounds method of identifying and delimiting tracts of land is not reliable. In urban real estate, it is also much easier to identify and demarcate the boundaries of apartments than those of detached or even town houses.

because, for demarcation to be effective (in terms of the figure, to have a steep slope), it has to be not merely physical but also legal. This also increases the variable cost (greater od), so the two effects cancel each other out.

¹² These are the averages of the cost estimates of “technical services” given by ZERP (2007) for 11 EU countries. These numbers are consistent with an Internet sample of surveying services advertisements in Spain, which yielded an average of 455€ with six observations (performed on April 9, 2017).

On the other hand, precise physical demarcation alone, without legal demarcation, is costly but adds little value (Deiningner and Feder 2009:244, Bell 2009:7). Precision may even be detrimental when it is based on aerial images that are not properly rectified without a topographical survey being made in the field. However, governments often require precise physical demarcation without a corresponding legal demarcation. For instance, in Greece, “topographic drawings *signed by the contracting parties* and the civil engineer must be attached to all transfer deeds of real estate property” (Papamichalopoulos and Iconomidou 2016, emphasis added). They are signed by the parties but not by neighbors; therefore, they lack legal demarcation and their value is debatable. However, according to *Doing Business 2017*, the procedure still takes seven days and costs 400€ (World Bank 2016b:52).

In addition to these explicit costs, mandatory physical demarcation incurs implicit costs. The most obvious is the additional time required for closing a transaction, but the most important is that it may stimulate premature legal demarcation. Indeed, it is likely that under mandatory physical demarcation, potential boundary conflicts are made more salient, as parties are forced to observe them. They might therefore feel compelled to perform allegedly suboptimal legal demarcation which they would otherwise have postponed had they remained ignorant of the conflict. Some of the empirical indications presented in section 4.2 below support this negative incidence of mandatory demarcation even when the mandatory element is limited to physical demarcation. This possibility is costly because overlaps are very common even after extensive surveying: for instance, in Australia, which has relied on surveying for more than a century, boundary discrepancies between titles and occupational boundaries are still very common, even in urban areas (Butt 1996:756, O’Connor 2016:354). (Interestingly, in cases of conflicting evidence in the determination of boundaries, courts there adhere to a hierarchy with natural boundaries at the top, followed by monumented lines, old undisputed occupation, abuttals and statements of length, bearing or direction [Hallmann 1994:13.13]).

Whether the land registry is a recordation of deeds or a registration of rights, physical demarcation—that is, merely adding a graphical representation or proceeding to survey the land—has no effects on third parties. This is obvious in recordation, which does not even guarantee legal title, but also holds in registration. For a register of rights—or the state behind it—to provide conclusive in rem title or a mere indemnity with respect to boundaries, legal demarcation is required. In fact, even Torrens registries usually exempt from their conclusive effects errors in the description of parcels and boundaries. When they provide conclusive boundaries, they do so only to the extent that courts do not allow boundary amendments to adversely affect subsequent purchasers for value. Such a solution does not protect in rem all affected owners when their registered boundaries are mistaken. Moreover, boundaries often remain unprotected against changes in occupation, which tend to be decided based on adverse possession (O’Connor 2016)

Understandably, gathering neighbors’ consents in order to produce legal demarcation is more costly and additionally slows down conveyancing and registration, especially if it triggers adversarial litigation. Legal demarcation is costly because it requires conflicting rights to be adjudicated to eliminate overlaps—that is, collisions between the claims of owners of neighbouring parcels. In the absence of an agreement and whatever the type of organization carrying it out, this adjudication can only result from some sort of judicial

process that hears all interested parties. This is necessarily the case in countries with recordation of deeds, but even when handled by a registrar (or, exceptionally, by a surveyor, as in Sweden) as is common in countries with registers of rights, the registrar is acting as a court of first instance, but often with very limited powers. For example, in the Australian state of Victoria, “the registrar’s powers of amendment are exercised on application by a registered owner, and after giving notice to other affected persons. If an objection is lodged, the registrar may not proceed until the objection is withdrawn or has been ruled upon by a court” (O’Connor 2016:347). Anyway, if the parties disagree, the final decision is made by a judge.

An indirect reference to both monetary and time costs is also given by the *Doing Business* report. In particular, its “Enforcing Contracts” index estimates the average cost of litigating a contract at between 21.3% of the claim for OECD countries to 49.1% for countries in the East Asia and Pacific area, requiring on average 631 days.¹³ Even if the cases are not fully comparable, it is not obvious why legal demarcation should cost substantially less money or take less time. In fact, detailed data on lawsuits provided by *Doing Business* suggests that land cases may take longer: the ordinal answers to one of the questions in the index suggests more than two years. It is worth noting that these percentages and times are much higher than those given for land registration by the *Doing Business*’ “Registering Property” indicator. Therefore, it is safe to conclude that, whatever the effects of legal demarcation on future litigation, it substantially increases ex ante transaction costs and the time required to close deals.

Understandably, some land titling projects aiming for universal but low-cost regularization opt to apply imprecise physical demarcation and voluntary legal demarcation. For example, in Rwanda, costs were contained by the sensible step of limiting physical demarcation (relying on modern imagery) to identifying parcels and to building parcel index maps (Ali *et al.* 2014:268). A more doubtful choice was that of limiting legal demarcation to undisputed land (which, consistently with our argument, was legally demarcated by identifying the fields and to some extent demarcating their boundaries “in the presence of land owners and all adjoining neighbors”). This exclusion of disputed land avoids the most costly but also the most valuable titling. Instead of universal titling, it amounts to a sort of negative selection, investing resources in the type of land that—for a given land value—benefits the least from titling.¹⁴

¹³ Numbers taken from the website of the *Doing Business* project at <http://www.doingbusiness.org/data/exploretopics/enforcing-contracts> (accessed December 7, 2016).

¹⁴ This seems to be a constant in the World Bank’s efforts: its *Doing Business* “Registering Property” indicators have been measuring the cost and time of formalizing transactions in land “free of title disputes”, which biases results in favor of countries with low-cost-low-quality titling systems (Arruñada 2007b).

3.2. Demarcation externalities

The key argument against mandatory demarcation is that transactors are in a better position than legislators to evaluate the tradeoff of costs and benefits. This is so because they have both better information and better incentives. Better information, because the tradeoff depends on the particular circumstances of each set of parties, rights and assets. Better incentives, because, in the absence of externalities, it is they who are bearing the costs and enjoying the potential benefits.

However, externalities may be present in demarcation decisions about, first, creating the infrastructure for demarcation and, second, choosing whether or not to demarcate a given parcel, a decision usually made in the context of a transaction. In terms of the previous model, these sources of externalities are connected, respectively, to the fixed cost F_d (i.e., the presence of positive externalities would reduce it) and the variable cost rd (the social cost may also be lower than the private cost, r_d).

The infrastructure for land demarcation includes general identifiers (the most basic, a list of place and street names), as well as the references needed to survey individual parcels (survey maps and plans, monumentation and GPS systems, and even aerial or satellite imagery). All these assets are characterized by substantial externalities, as the information that they provide is a public good: there is no rivalry when it is consumed and, since it causes mainly fixed costs, it poses the usual difficulties for efficient pricing.¹⁵

Moreover, individual decisions may not be socially optimal if externalities occur as a consequence of individual transactions. In the context of property, the main externalities are caused by the enforcement of rights in rem in the presence of sequential exchange and contract interaction. Suppose, for example, that a landowner O grants a secret lien to L at time t_1 , sells the parcel to B at time t_2 , and then L seeks to seize the parcel to satisfy the lien at time t_3 . As analyzed by Merrill and Smith (2000), Hansmann and Kraakman (2002) and Arruñada (2003), this sequence of exchange creates a negative externality in the form of the secret liens that might be held by potential lien holders, of which potential acquirers such as B are not aware when buying from O . If all private contracts are enforced, including secret liens, potential buyers in the position of B will be reluctant to buy from any O unless they can be assured that there are no L s lurking in the background ready to assert prior claims to the asset, thus reducing its value. Moreover, anyone in the position of L , fearing the possibility of prior liens, will also be reluctant to rely on the collateral value of the asset when lending to O . Crucially for the emergence of externalities, these possibilities will reduce the value of all assets, whether they have secret liens or not.

¹⁵ An argument for externalities can also be made about centrally demarcating land in homogeneous, easy-to-measure units. When allocating state land, this procedure has been found by Libecap and Lueck (2011) to facilitate enforcement and reduce conflict and transaction costs in the future, thus producing positive externalities and increasing land value. See, for a discussion, Arruñada (2017a, 2017b).

One could argue that the same problem arises when information on boundaries is hidden. The difference with liens lies in the greater difficulty to keep boundary disputes secret, due, first, to the fact that boundaries often provide possessory evidence while liens are fully abstract. Second, the buyer cannot only inspect the land for possessory evidence but can also ask neighbors about possible boundary conflicts. Sellers will often enjoy an informational advantage regarding boundaries over buyers but this advantage is lower than with respect to legal rights, especially those of an abstract nature such as liens. To the extent that the informational problem is not one of asymmetry but ignorance, it merely involves a risk-allocation issue.

Therefore, there seem to be significant externalities in the identification of land parcels and their neighbors but not in the demarcation of boundaries at the time of transacting. This is consistent with the prevalent practice of mandatory identification of both elements: by, first, public provision of a system of geographic identification and general boundaries; and, second, by enacting a rule for the compulsory listing of neighbors in the deeds and in entries in the land registry.

Certainly, externalities may be more significant in particular circumstances, especially when litigation and judicial services are mispriced and in the context of land titling efforts. If land demarcation reduces litigation and recourse to litigation is underpriced, mandatory demarcation could be justified as a way of reducing inefficient litigation, and more so the greater the weight of boundary litigation. This, however, disregards the possibility that mandatory demarcation might also be costly because it unduly anticipates conflicts.

Moreover, with respect to titling efforts, within a project of universal titling of formally untitled but already possessed (and therefore pre-allocated) land, mapping and even surveying all individual parcels could make more sense because of externalities derived from the simple fact that parcels share boundaries and their legal determination also enjoys economies of scale.¹⁶ However, these externalities are present only in the context of massive titling, when all or most land in the given area is formally titled. If this strategy of universal titling is not optimal—and there are good reasons why this might be the dominant situation (Arruñada 2017c)—, the rationale for mandatory surveying (as opposed to mandatory identification) disappears even in this case. Moreover, this judgment is also confirmed empirically, as “no project in the developing world has been able to implement and sustain high-accuracy surveys over extensive areas of their jurisdiction” (Burns 2007:96). Moreover, as mentioned above, boundary discrepancies are still very common in Australia even though extensive surveying has been performed there for a long time.

¹⁶ This is the case modeled by Miceli and Kieyah (2003), whose conclusions are additionally limited by other unrealistic and narrow assumptions, such as a titling cost that decreases with the number of titled parcels and identical land parcels which differ only in title defects.

Within massive titling efforts, another particular case arises when the land is not only being titled but is also being allocated, as occurred in the 18th and 19th centuries in the frontier areas of Australia and the USA (as in the case mentioned in footnote 15). In such situations, using surveying for land titling benefits from the fact that it is also necessary for proper allocation. However, the presence of externalities in ulterior transactions remains an open question (see, for instance, Lai 2015).

In sum, optimal public intervention would probably provide a mix of state and private decisions, with state action being useful for providing the elements necessary for parcel identification and high-level demarcation (e.g., the general monumentation traditionally needed as a starting point for surveying, or even some aerial or satellite imagery); but with private choice prevailing in decisions about the precision and type (mainly, if physical or legal) of boundary demarcation. (With respect to legal demarcation, the problem is the same as with other judicial services).

4. Evidence on how demarcation affects litigation

Moving now into empirical analysis, this section assesses, first, what is the incidence of boundary conflicts on land litigation; and, second, what impact mandatory demarcation may have on land-related litigation, even when theoretically limited to physical demarcation. Findings suggest that the impact of boundaries on litigation may be relatively minor and that mandatory demarcation may increase litigiousness.

4.1. The weight of land demarcation on overall litigation

To estimate the incidence of the demarcation of land boundaries on litigation, I used a similar methodology to that applied by Baker *et al.* (2016) by performing automated Boolean text searches in the repository of civil court judgments of the Spanish judiciary.¹⁷ In particular, I counted the number of judgments mentioning particular

¹⁷ This repository, known as CENDOJ, for *Centro de Documentación Judicial*, is a department of the judiciary's independent governing body, the *Consejo General del Poder Judicial*. At the time the data were captured, it included 1,311,840 judgments dated from 1979 to December 31, 2016, most of them issued by the appellate courts at the provincial (*Audiencias*) and regional (*Tribunales Superiores de Justicia*) levels, as well as by the Supreme Court. It is available at <http://www.poderjudicial.es/search/indexAN.jsp>. See, for details, CENDOJ (2012). The searches were made online on April 17-22, 2014, for the years up to 2013, and June 12-July 28, 2017, for later years. They are constrained to the fields “*jurisdicción civil*” and “*sentencias*”.

combinations of keywords that can be considered as indicators of the presence in each case of (1) boundary issues and (2) four broader indicators of land-related litigation activity, against which boundary cases are then compared to assess their relative importance.¹⁸

Boundary-related cases are identified by the presence of any of several legal terms: the Spanish equivalent of “demarcat*”, “first regist*”, “double registration”, “ownership procedure”, “excess in meterage” and “parcel*”; words or strings which are truncated with an asterisk when this serves as a wildcard symbol for all words with the same root. (The Spanish search terms used are: $B = (deslind* O inmatricul* O “doble inmatriculación” O “expediente de dominio” O “exceso de cabida” O parcelac*)$).

The four broader indicators of land-related litigation activity are: (a) the total number of civil judgments, R_1 ; (b) the number of cases with a land-titling issue, estimated by the presence of the string “Land Register” (in Spanish, $R_2 = “Registro de la Propiedad”$); (c) the number of cases with a real-estate issue, estimated by the presence of any of four keywords describing buildings and land (“immovable OR land OR plot OR ground”; in Spanish, $R_3 = (inmueble O finca O solar O terreno)$); and (d) the number of cases with a property-law issue, estimated by the presence of any of four legal keywords “ownership OR possession OR mortgage OR servitude” (in Spanish, $R_4 = (propiedad O posesión O hipoteca O servidumbre)$).

The incidence of boundary-related conflict is then estimated by the four boundary litigation-incidence ratios ($BLIR_i$) calculated by dividing the count of each pair of Boolean searches:

$$BLIR_i = \text{Count}(B \text{ AND } R_i) / \text{Count}(R_i) \quad \text{with } i = 1, 2, 3, 4$$

According to the percentages presented in Table 1, the incidence of boundaries on litigation is comparatively modest, both with respect to overall litigation activity (columns [2] and [4]) and to specific areas of land-related litigation (rows [3], [6], [9] and [12]). First, only 2.33% of all civil judgments and 4.11% of those by the Supreme Court are related to boundaries, much lower than the cases related to the land register (6.27 and 17.95%, respectively) and, especially, the whole of real estate (30.51 and 47.32%) and property law (35.56 and 52.61%). Second, boundary-related cases weigh little in these three areas of law, representing only 14.41% of the cases affecting the land register, 6.32% of those involving real estate and 5.30% of those with property law issues. The numbers for litigated cases at the Supreme Court are broadly similar (respectively, 12.68,

¹⁸ In principle, the salience of boundary information should not influence the likelihood of winning these cases at court, so it is possible to disregard potential selection effects of the type studied in the literature on litigation decisions—e.g., Priest and Klein (1984), Shavell (1996) and Hubbard (2013).

7.23 and 6.62%). (No significant differences are observed between first-instance cases and those that reach appeals courts).¹⁹

4.2. The incidence of mandatory demarcation on litigation

The model in section 2.1 showed why mandatory legal demarcation could cause two types of inefficiencies linked to undertitling (land *ac* in Figure 1) and overdemarcation (land *cb*), with a total loss represented by area *A*. This section explores the presence of this effect in a real case, examining the evolution of boundary-related litigation after a legal change enacted in Spain in 1997.

Spain's land register provides conclusive legal title but this conclusiveness does not cover boundaries—that is, third-party acquirers are not protected in rem with respect to the physical description of the land. Traditionally, boundaries were surveyed for tax purposes but surveying and maps were not required for filings in the land register, which relied on general boundaries: in particular, parcels were identified and demarcated with their names, addresses and a verbal description based on topographical features and references to the adjoining parcels and their owners.

New rules were enacted in January 1997 by Law 13/1996 mandating greater reliance on parcel identification and boundary information produced by the tax cadastre. This provides an opportunity to examine the effect of mandatory demarcation of land on legal conflicts. The main legal change was that for, most land transactions, both the deed and the entry in the land register must include the cadastral identification number, and the identity of the transacted plot must tally with that reflected in the cadastre with respect to its location and name, and, with respect to surface area, must exhibit a difference not greater than 10%. In case the identification number is omitted, the transaction is registered with a caveat and the registrar notifies the cadastre about the identity of the parties.

In the common case of disagreement between possessory and cadastral boundaries, this implicit “georeferencing” of plots via their cadastral ID and the cadastral boundaries assigned to such ID might make owners in peaceful possession uneasy about their position. Possessors are happy about their boundaries until a third party draws them and points out a contradiction. One may hypothesize that, when contradictions are made salient, they motivate some parties to litigate. Moreover, contradictions tend to abound when this third party is the tax cadastre, for several reasons. First, entries in cadastres are often not properly reviewed. Instead, given that they only create obligations, not rights (Arruñada 2012:205), they are based, about title, on what a single party admits or

¹⁹ Even if the numbers are not comparable due to the different methodologies, these findings are broadly consistent with the low incidence of boundary-related litigation documented in New South Wales by Wallis (2010).

declares (tax authorities everywhere are more than happy for anyone to be willing to pay taxes); and, about surface and boundaries, on unilateral assessments by the tax authority itself, often based on aerial images that are geometrically rectified without performing a topographical survey in the field. Owners want their title to be secure but, given that cadastral levy taxes based on plots' surface areas, they are willing to trade off some security for lower taxes.

The empirical test will examine the evolution of the ratios discussed in section 4.1 after the legal change. The available data has several limitations. First, for the years before the legal change they contain only the cases decided by the Supreme Court, whose mix of cases underwent serious changes during the period. Second, the data refer to the time the sentences are issued, but we do not know either the date when the lawsuit was filed or the time spent between filing and ruling. Lastly, while mandatory use of the cadastral reference number had initially been restricted to urban land, Act 52/2002 expanded it to all land. Lack of data before the legal change makes a "before and after" comparison impossible; however, the fact that the data mixes sentences on cases filed under the two legal regimes, starting the first year with practically a hundred percent of cases in the old regime, makes it possible to identify some likely effects of the legal changes.

The evolution of the four ratios follows a similar pattern, rising sharply in the years after the legal change, decreasing much more gradually later on and, crucially, remaining at substantially higher levels. The two main hypotheses to explain this evolution are the change in the law and the cycle of the real estate market. First, as argued, the incidence of boundary cases on litigation might have increased in parallel with mandatory identification of parcels in accordance with cadastral demarcation. Second, there is a possibility that the cycle in the real-estate market affects the ratios' numerators and denominators differently. Therefore, in addition to the legal change hypothesis, the evolution of these ratios could be attributed to changes in real estate activity and, in particular, in real estate development, especially considering that Spain experienced a huge housing bubble in the years before 2008, followed by an equally spectacular slump afterwards.

The test faces the problem that the relation between annual real estate activity and annual sentences is uncertain because lawsuits decided in a given year were filed years earlier and, in most cases, appealed to higher courts later on. Moreover, before litigation, parties often spent some time unsuccessfully bargaining between themselves. Considering these uncertainties, I will estimate the following equations with different time specifications:

$$BLIR_i = a + b_a After(n) + b_l Licenses(n)$$

where each dependent variable, $BLIR_i$ represents one of the four boundary litigation-incidence ratios ($i = 1, 2, 3, 4$), and the independent variables are: $After(n)$, a binary variable equal to 1 for years after n , and zero otherwise; and $Licenses(n)$, this being the proxy for land-related development activity, calculated for each year as the number (in

hundreds of thousands) of buildings subject to municipal construction licenses which were issued in the preceding n years.²⁰

Table 2 presents the equations estimated using values for n of between three and seven, giving an average n of five years, in line with an assumption for the mean litigation time of four years (including both first-instance and appeal²¹) plus assuming one additional year for parties' bargaining before they litigate.

Coefficients in Table 2 are highly consistent for the four ratios and across the different values assumed for n . In particular, practically all coefficients for the two variables of interest are statistically significant and show the hypothesized positive signs. (The only exception is the still positive but statistically insignificant estimated coefficient for *After*(7) in the equation of the R_3 ratio). Moreover, they are economically significant: considering average value across the five, *After* = 1 is associated with increases in the ratios used as dependent variables of between one and two standard deviations. The number of building licenses is also linked to substantive changes: one standard deviation in the number of licenses brings about changes in those ratios of 36, 14, 74, and 63%, respectively for R_i ($i = 1, 2, 3, 4$).

The significance of the licenses' coefficients supports that, as expected, substantial determination of boundaries takes place before real estate development. One may assume that this litigation triggered by imminent real estate development is timely. However, the significance of the *After* coefficients suggests that mandatory physical demarcation may be leading to anticipated legal demarcation—via bargaining and litigation, even if we observe only the outcome of litigation—unrelated to future real estate development. These results are therefore consistent with the hypothesis that rules mandating physical demarcation may cause unnecessary legal demarcation that could have been postponed or otherwise solved by the joint action of possession and the lapse of time. The phenomenon

²⁰ Source: Ministerio de Fomento, "Construcción de edificios. Licencias municipales de obra. Licencias. Información histórica nacional. Número de edificios según tipo de obra. Total, edificios de nueva planta."

<http://www.fomento.gob.es/BE/?nivel=2&orden=1000000> (accessed July 25, 2017).

²¹ According to official statistics summarized, e.g., by Dubois, Schurrer and Velicogna (2013:528), between 2006 and 2010, the time to obtain a judgement in noncriminal litigious civil and commercial cases in Spain was between 261 and 296 days at first-instance courts and between 189 and 193 at appellate courts. Adding both durations, the total lag would amount to only about 15,5 months. However, these numbers are based on self-reported filings of activity by judges and are believed to grossly underestimate real disposition time. The same report estimates average disposition time for successfully enforced, first-instance court decisions at between 990 for 2006 and 1,242 days for 2010 (Dubois, Schurrer and Velicogna 2013:532). The *Doing Business 2017* "Enforcing Contracts" indicator reports 510 days as the average duration to enforce a contractual debt judicially while the "Property Registration" indicator reports between one and two years as the time needed to obtain a first-instance court sentence on a land case.

is similar to the effect on title “clouds” of land registration as compared to land recordation: under recordation, such clouds can more easily survive while, under registration, they must often be eliminated, losing the benefit of having them insured on a casualty basis (Arruñada 2003:433).

Given the limitations in the data, these estimates are mere indications of the possibility of such effects in the Spanish context. (External validity is obviously an additional concern). However, these significant estimates are remarkable considering such limitations plus the fact that the mandatory element in the legal change was relatively modest. Moreover, robustness tests indicate that some alternative explanations are inconsistent. For instance, it is unlikely that the surge in litigation after the legal change could have been driven by an expectation of future development, as additional tests using the number of licenses issued in the same year show this to be practically insignificant. Hidden variables may also be active. However, an obvious candidate to capture some of them via a time trend does not substantially modify the conclusion, even when its interaction with the *After* variable is considered.

5. Organization and performance of the land administration system

As explained above, it has been considered best practice to coordinate and even merge under a single organizational roof the land registries used to define property rights and reduce transaction costs (i.e., “contractual” registries), with cadastres and, more generally, all agencies planning and regulating the allocation and use of land resources (i.e., “administrative” registries), building with them an integrated “land administration system” (World Bank 2005:398).

A recent review of the World Bank’s projects found that most had been designed following this principle, which was also dominant among land administration experts even though the review found that “[t]here is no single best institutional model for carrying out registry and cadastre functions” (IEG 2016:28).

5.1. Pros and cons of integrated land administration

The objectives of such integration can go from merely achieving synergies, avoiding duplication in the use of information, to ensuring tax collection and regulatory enforcement, subjecting land to public control and planning. Sometimes, the possibility

of subsidizing the cadastre with the fees charged by the land registry was also seen as an advantage.²²

To evaluate the merits of this integration argument, it is important to have a clear understanding of the respective functions of the two types of registries—that is, contractual registries (for simplicity, the “land registry”) and administrative registries (the “cadastre”).²³

For our purposes, rather than going deeper into the theory of property rights (e.g. Arruñada 2012), it suffices to examine the abovementioned World Bank’s guidelines, which, despite defending the single-agency argument, define the function of both registries in strikingly different ways:

the two main instruments of a land titling and registration program are the land registry and the cadastre. The registry provides authoritative information on all properties within a jurisdiction. The cadastre provides information on boundaries, use, and value of properties and is used as a basis for *land use planning, valuation, taxation, and the generation of maps* (World Bank 2005:397, emphasis added).

The key distinction between both organizations therefore seems to be that the main function of the land registry is to enable private tenure and contracting (that is, the sale and mortgage of land) while the cadastre serves public functions.²⁴

Given that these public functions—whatever the value of their services for the community—impose burdens and limitations on individual land owners, they can be assimilated to taxes with respect to their impact on individual decisions. Whatever its scope, integration tends to pose a conflict between developing either the institutions enabling land and credit markets or the apparatus of the state. When politics leads to inefficiently high taxation or inadequate land regulation, stronger tax and regulatory enforcement may easily hinder the development of land registries that are indispensable

²² E.g., “another potential advantage was that a single agency could enhance financial self-sufficiency by subsidizing cadastre costs with revenue generated by the registry and reducing dependence on transfers from the government budget” (IEG 2016:7).

²³ For simplicity, hereafter I will follow the language of the World Bank’s guidelines (2005) by referring to “land registries” and “cadastres” instead of the more precise “contractual” and “administrative” registries, even if in some jurisdictions there are administrative registries which are not cadastres.

²⁴ Any hint of this private-public duality disappears in formulations such as the ambitious “Land Administration Domain Model,” developed within the International Federation of Surveyors to create an ISO standard for geographic information. Its design aims to respond to such overarching societal drivers as “poverty eradication, gender equality, indigenous recognition, adequate housing, sustainable agriculture, food security, climate change response, and good governance” (Lemmen *et al.* 2015:535). It seems clear that all these “drivers” fit squarely in the sphere of planned public action.

to enable full-fledged private property rights and low transaction costs in land and mortgage markets. Even the most modest objective of pursuing information synergies faces a similar risk but in a weaker and surreptitious form.

The benefits of this greater integration, which may affect the user interface, the back office, or both, stem from the fact that land registries and cadastres rely on the same information and perform some similar activities on the same or similar parcels. Separate agencies duplicate both entry and control procedures, as well as some of the information on record. For instance, land owners may have to file documents in two or more offices, and some of the information in these documents may be the same. For example, part of the data on land parcels is the same for conveyancing, tax and regulatory purposes. Moreover, duplication may occur in both single and repeated filings.

However, integration involves substantial risks because, given their different masters and purposes, land registries and cadastres have different demands and often rely on different resources and organizations. In particular, they use different types of specialized knowledge and implement different incentive structures. For a start, the data on file often serve different functions for different economic agents. For example, land registries serve rightholders and work effectively with less precise geographical identification than cadastres, which are often used for planning purposes, such as building roads. Therefore, the type of knowledge necessary for exercising their functions is substantially different. And their different purposes also entail different demands. First, land registries and cadastres, respectively, support bilateral contracting and unilateral enforcement. Hence, delays in land registries preclude further transactions, whereas in cadastres they merely postpone enforcement. Second, entry in land registries can usually be kept on a voluntary basis, whereas entry in cadastres and other administrative registries must often be mandatory, as they are designed to avoid negative externalities.

Consequently, priorities, organizational constraints and incentive structures for different types of registries are also different. Registration procedures need to be stricter in land registries to ensure independence, because they bestow rights, not only obligations, on the filing users or their future contractual parties. Conversely, most cadastres are declarative: if someone claims to be in possession of land, cadastres will have no trouble believing that person because their entries only create obligations for declarers. In contrast, land registries have to implement rigorous registration procedures to check the quality of title or attest the date of filing because they bestow rights on filers or, more commonly, concede economic benefits to filers by bestowing rights on subsequent third-party innocent acquirers. In addition, the incentives necessary to operate their processes are also different: land registries need to be impartial with regard to the transacting (and, in general, all interested) parties, on the one hand, and third parties, on the other; whereas administrative registries serve and are run by one of the parties, the government.

This conflict is most startling with respect to taxation. Creators of public titling systems in the eighteenth and nineteenth centuries were well aware of the risk of relying on land registries to enforce taxation and other legal rules. Their decision to place the registry within the realm of the Ministry of Justice (as in Germany or Spain) was germane to their primary goal of making the registry an instrument for private contracting instead of tax collection (as in Napoleonic France, where it was placed under the Ministry of

Finance). The relative performance of registries across developed countries is still conditioned by such decisions (Arruñada 2012:156–60) even though, once registries became consolidated, they have all been used to perform extensive legal gatekeeping.

Full integration, which was attempted in some developing and transition economies, pays little attention to these historical lessons, endangering the birth of registries by burdening them with public duties. More recent proposals have wisely aimed to reach synergies by, e.g., keeping registries' functions separate, sharing a common database or using the same parcel identification code. Even these policies pose doubts, however. For instance, formal integration that retains separate functions within the same agency may be subject to mistaken priorities and cross-subsidies. Similarly, it is unclear if the alleged synergies are reachable, as shown by the evaluation of projects that theoretically had merged agencies (e.g., IEG 2016:7–8).

5.2. Empirical test

All these proposals share some of the abovementioned tradeoffs of costs and benefits (Arruñada 2012:202–208), which often hinge on the specifics of each application. To explore these policy choices in the absence of the data required for a full cost-and-benefits analysis, this section examines the correlation between how land registries and cadastres are organized and some metrics of their performance, therefore focusing on the alleged benefits of greater integration. The analysis is based on the “Registering property” indicators and the detailed data of the *Doing Business 2017* report, which itself has been defending integration policies. Performance is measured using as dependent variables the main components of the “Registering property” indicator,²⁵ which try to identify the procedures necessary for a business to purchase a real estate property and to measure the time and cost incurred to complete the purchase; as well as the duration of land litigation as estimated by the *Doing Business* survey. In particular, these four variables are: *Procedures*, the number of interactions with external parties (including government agencies, inspectors, notaries and lawyers) that buyers, sellers or their agents must make to complete a land purchase; *Time*, the total number of days necessary to complete all procedures necessary for such a purchase; the *Cost* incurred, measured as the percentage of the property value (which is assumed to be 50 times the income per capita of each country), and including all official costs required by law (such as transfer taxes, stamp duties and fees paid to the property registry, notaries, public agencies or lawyers but not capital gains or value added taxes); and *Land_Case_T*, the average time (in years) it takes for a first-instance court to decide on a standard land dispute between two local businesses over tenure rights of a property worth 50 times gross national income per capita and located in the largest business city.

²⁵ See, for details, “Registering Property: Methodology,” World Bank, Doing Business Website (<http://www.doingbusiness.org/methodology/registering-property>, accessed May 23, 2017).

The independent variables of interest are two triads of variables indicating the organizational features of the land administration system in each country. Given that land demarcation is usually promoted and mandatory demarcation enforced in connection with organizational solutions that merge or link cadastres and land registries, the first three independent variables, built with data from the “Reliability of infrastructure index” also compiled by *Doing Business*, are binary variables that describe the policy applied in each country with respect to the interaction between land registries and cadastres: (1) *Single*, equal to one if the information recorded by the land registry and the cadastre is kept in a single database; zero, otherwise. (2) *Linked*, equal to one if the information recorded by the land registry and the cadastre is kept in linked databases; zero, otherwise. (The default is that this information is kept in separate databases without any linkage). (3) *Same_ID*, equal to one if the majority of land parcels has been assigned a unique identification number that is used by the land registry and the cadastre; zero, otherwise.

The second set of variables describes three main features of each country’s titling system: (1) *Computerization* measures its investment in information technology, proxied by an index built as the first principal component of three binary variables: *E_records_full*, equal to one if the majority of land title or deed records at the registry of the largest business city are kept in a fully digital format; zero, otherwise. *E_records_scan*, equal to one if the majority of land title or deed records at the registry of the largest business city are kept in a computerized scanned format; zero, otherwise. *E_charges*, equal to one if there is an electronic database for checking for property encumbrances such as liens, mortgages, restrictions and the like; zero, otherwise. (2) *Coverage* proxies the geographic coverage of the land registry, built as the principal component of two binary variables: *Univ_title*, equal to one if all privately held land plots in the economy are formally registered at the land registry; zero, otherwise. *Univ_city*, equal to one if all privately held land plots in the largest business city are formally registered at the land registry; zero, otherwise. (3) *Indemnity* capture the reliability of the land registry through a binary variable equal to one if there is a specific system to compensate for losses incurred by good-faith parties who engage in a property transaction based on erroneous certification provided by the land registry; zero, otherwise.

Three additional control variables are used: (1) judicial performance, considered with the variable *Contract_Case_T*, which measures the years it takes to resolve a standardized commercial dispute between two domestic businesses through local first-instance courts;²⁶ (2) overall institutional quality, proxied by the 2015 “Rule of Law” indicator of the World Bank’s *Worldwide Governance Indicators, 2016 Update: Aggregate Governance Indicators 1996-2015*, which measures the perceptions of

²⁶ See, for details, “Enforcing Contracts: Methodology,” World Bank, *Doing Business* Website (<http://www.doingbusiness.org/methodology/enforcing-contracts>, accessed May 23, 2017).

governance of a large number of expert survey respondents;²⁷ and (3) the degree of economic development, measured by the 2015 International Monetary Fund's estimate of gross domestic product per capita, based on purchasing power parity.²⁸ To consider if the connections between organization and performance may differ for different levels of economic and institutional development, some of these variables will be interacted with the main independent variables.

As a first approximation and without introducing any titling or control variables, the estimated coefficients in equations (1), (4) and (10) of Table 3 would seem to suggest that the number of procedures, registration time and litigation time (but not registration cost) are connected in the policy-prescribed direction to merging land registries and cadastres, linking them and having them use the same ID: that is, these policies appear to be correlated to a lower number of procedures and shorter times required to register and litigate. However, equations (2), (5) and (11) reveal that these correlations (especially that of registration time) may well be spurious, because once additional variables are introduced their significance mostly disappears.

Interestingly, investment in computerization is significantly correlated with shorter registration times (a reduction of almost 17 days for a change of one standard deviation in the index) but not with a reduction in the number of procedures, while the opposite happens with linking cadastres and land registries, which is negatively correlated with procedures but not at all with registration time. These differential results are consistent with the possibility that developing such linkages, instead of eliminating or simplifying procedures, may simply be hiding them from users and taxpayers by vertically integrating procedures within the land administration system, as argued in previous works (Arruñada 2007b, 2016).

Similarly, titling coverage and indemnity for registration errors are significantly correlated with shorter litigation times, which is consistent with the tradeoff between ex ante and ex post transaction costs, also argued in Arruñada (2007b, 2016). Estimating, for simplicity, an OLS model instead of an ordered probit model, a change of one standard deviation in coverage would “reduce” this time by about two months and a half, while registration indemnity would reduce it by more than three months.

Coefficients of the variable measuring the time it takes to litigate a debt contract (*Contract_Case_T*), which can be interpreted as controlling for judicial performance, is weakly but significantly correlated, with the expected positive signs, with the number of procedures and registration time, and more significantly so with the time it takes to litigate a land case (*Land_Case_T*). Its coefficient in equation (11) reveals that, as might

²⁷ See, for information on data sources, the aggregation method and its interpretation, Kaufmann, Kraay and Mastruzzi (2010). The data was downloaded from www.govindicators.org on June 5, 2017.

²⁸ The source is the International Monetary Fund's World Economic Outlook Database (<https://www.imf.org/external/pubs/ft/weo/data/assump.htm>, accessed June 7, 2017).

have been expected, lower times to litigate contract cases significantly correlate with lower times to litigate land cases.

By including interactive variables, equations (9) and (12) also show some interesting connections. In particular, according to equation (12), linking land registries and cadastres is associated with shorter times to litigate over land only in countries where contract litigation takes more than approximately ten months. On the contrary, according to equation (9), merging land registries and cadastres seems on average to be related to lower monetary transaction costs but the interaction compensates for this in countries with slower courts, with the threshold at 25 months (direct causality is unlikely here, given the presence of transfer taxes among such costs). Moreover, the effect is partly balanced out by the positive interaction with GDP. Coefficients for the interaction of the rule of law index turn out to be insignificant.

Overall, all these empirical indications provide no support for the merger and linking policies often prescribed, even by *Doing Business* itself, for registries and cadastres, as applying them is costly because the alleged synergies seem to be absent. These results do provide some limited support, however, for the “reliability of infrastructure” component of the *Doing Business* “Quality of Land Administration” index, which grants higher scores to countries that hold information electronically instead of on paper and use a unique number to identify properties for the majority of land plots, but grants the same score whether the information about land ownership and maps is kept in a single database or in linked databases.

6. Concluding remarks

Relying on a conceptual distinction between physical and legal demarcation and a simple model, this paper illuminates two main deficits in land administration policies: lack of adaptation to individual circumstances, and little concern for legal demarcation. The model suggests that, in the presence of fixed costs and the absence of externalities, it is individually optimal to subject low-value land to less precise demarcation, and it is socially optimal to allow voluntary demarcation. On the contrary, mandatory demarcation may lead to undertitling and overdemarcation. In particular, it may lead owners to inefficiently anticipate boundary-related litigation. Moreover, it is essential to distinguish between mere physical demarcation, in which some parties identify land parcels and measure and draw their boundaries, and legal demarcation, which, by gathering the consent of neighbors, more perfectly defines property rights in the physical dimension.

Empirical analyses provide some support for this critique of common practices in land administration, as they indicate that (1) land demarcation plays a relatively minor role in litigation, (2) mandatory demarcation is associated with increases in demarcation-related litigation which are unjustified by real-estate development, and (3) merging cadastres and land registries is not associated with better performance. These descriptive indications call for further research, in particular with respect to the effect of mandatory demarcation on litigation.

Implicit in this critique lies a recommendation to prioritize adaptation to local circumstances. It partially coincides with recent tendencies towards fit-for-purpose and contingent planning in the land administration literature. However, instead of keeping adaptation at the regional or area levels, the analysis in this paper advises that this adaptation imperative be applied at the individual level. In practice, this means, as a general rule, moving towards voluntary land titling and parcel demarcation, and moving away from what, within the intervention area, are universal efforts. The only exception should be driven by the clear presence of public-good externalities, which, in this domain, justify state action to provide the necessary elements for parcel identification and high-level physical demarcation and, most important, reliable on-demand legal demarcation services.

The paper's results also pose an intriguing positive question about what might be driving such allegedly bad policies. A possible answer is that their consequences are misunderstood by donors, a misunderstanding that this paper has tried to clarify. Alternatively, these policies may provide an opportunity to extend the monopoly position of land registries (considered necessary, for instance, by Hayek 1982:44) to other providers, be they private, such as conveyancing lawyers and notaries (Arruñada 2007a), or, as in the case at hand, a mix of private (surveyors) and public (tax cadastre) agents. In support of this conjecture, it is worth noting that all policies may well share similar consequences: increasing the demand of surveyors and cadastres (mandatory demarcation), and transferring resources from registries to cadastres (by merging and linking them). Further work would be necessary to test these conjectures.

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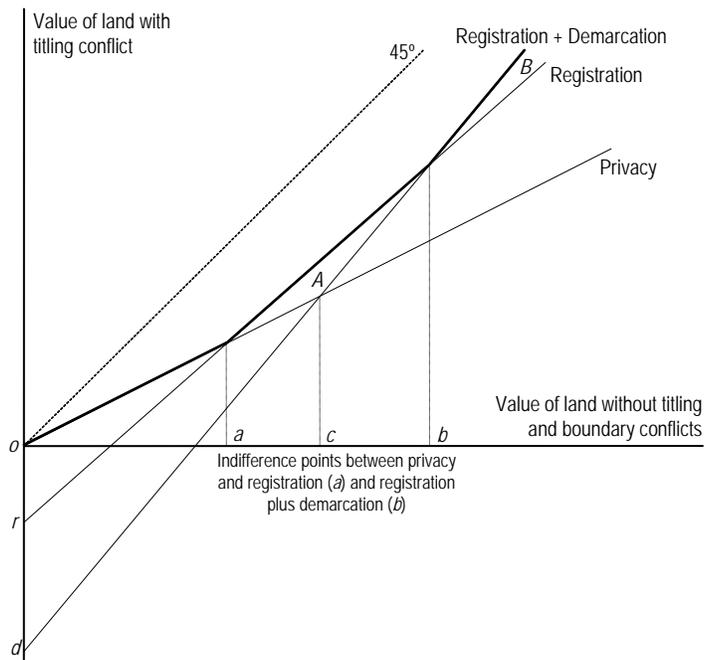
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8. Figures and tables

Figure 1. The social impact of land demarcation



Note: The Figure represents the impact on the social value of land of voluntary and mandatory demarcation. The individual value of land (vertical axis) is seen as a function of its theoretical value, assuming no title conflict (horizontal axis) and the availability of different institutions and services—i.e., land registration and demarcation. Social choice is driven by the costs of the alternative institutions and the statistical distribution of the value of land parcels in the economy along the horizontal axis. *Source:* Adapted from Arruñada and Garoupa (2005:717, Figure 2). See the article for further details on the model.

Table 1. The weight of litigation on land boundaries

<i>Sets of sentences containing the corresponding keywords</i>	<i>All courts</i>	<i>% of total</i>	<i>Supreme Court</i>	<i>% of total</i>
	(1)	(2)	(3)	(4)
<i>(a) Weight of boundaries in all civil sentences:</i>				
1. All civil sentences (no keywords)	1,311,840	100.00%	50,240	100.00%
2. Boundary-related keywords ^a	30,547	2.33%	2,066	4.11%
3. Percentage of all civil sentences with boundary issues ([3] = [2]/[1])	2.33%		4.11%	
<i>(b) Weight of boundaries in land-register sentences:</i>				
4. "Land Register" (in Spanish, "Registro de la Propiedad")	82,212	6.27%	9,020	17.95%
5. Boundary-related keywords ^a AND "Land Register"	11,843	0.90%	1,144	2.28%
6. Percentage of land register sentences with boundary issues ([6] = [5]/[4])	14.41%		12.68%	
<i>(c) Weight of boundaries in real-estate sentences:</i>				
7. Real estate keywords ("immovable OR land OR plot OR ground") ^b	400,266	30.51%	23,773	47.32%
8. Boundary ^a AND real estate-related keywords	25,281	1.93%	1,718	3.42%
9. Percentage of real estate sentences with boundary issues ([9] = [8]/[7])	6.32%		7.23%	
<i>(d) Weight of boundaries in property-law sentences:</i>				
10. Property keywords ("ownership OR possession OR mortgage OR servitude") ^c	466,478	35.56%	26,432	52.61%
11. Boundary ^a AND Property-related keywords	24,726	1.88%	1,749	3.48%
12. Percentage of property sentences with boundary issues ([12] = [11]/[10])	5.30%		6.62%	

Source: Created by the author using the database of the Spanish *Consejo General del Poder Judicial*. Notes: ^a Boundary-related sentences are identified with the string "demarcat" OR "first regist" OR "double registration" OR "ownership procedure" OR "excess in meterage" OR parcel*", using the Spanish terms "deslind" O "inmatricul" O "doble inmatriculación" O "expediente de dominio" O "exceso de cabida" O parcelac*". ^b Spanish land-related keywords are "inmueble O finca O solar O terrend". ^c Spanish property-related keywords are "propiedad O posesión O hipoteca O servidumbre".

Table 2. Evolution of boundary-related litigation after mandatory physical demarcation

Dependent variables:	<i>n</i> =	Independent variables: ^e		Constant	R-squared
		<i>After(n)</i>	<i>Licenses(n)</i>		
Number of boundary-related sentences ^a / all civil sentences (%)	3	0.721*** (0.155)	0.0335 (0.029)	1.530*** (0.174)	0.557
	4	0.708*** (0.112)	0.0417** (0.018)	1.501*** (0.132)	0.707
	5	0.677*** (0.084)	0.0468*** (0.013)	1.481*** (0.104)	0.809
	6	0.608*** (0.080)	0.0499*** (0.011)	1.486*** (0.104)	0.806
	7	0.502*** (0.093)	0.0529*** (0.013)	1.501*** (0.130)	0.711
Number of boundary- ^a / register-related sentences ^b (%)	3	4.206*** (0.855)	-0.0549 (0.158)	10.82*** (0.958)	0.577
	4	4.251*** (0.607)	0.0477 (0.100)	10.60*** (0.714)	0.732
	5	3.911*** (0.550)	0.107 (0.083)	10.67*** (0.681)	0.741
	6	3.758*** (0.460)	0.147** (0.066)	10.57*** (0.603)	0.795
	7	3.372*** (0.494)	0.181** (0.069)	10.56*** (0.690)	0.743
Number of boundary- ^a / real estate-related sentences ^c (%)	3	0.912*** (0.223)	0.208*** (0.041)	4.715*** (0.250)	0.693
	4	0.809*** (0.171)	0.181*** (0.028)	4.722*** (0.201)	0.772
	5	0.649*** (0.159)	0.163*** (0.024)	4.772*** (0.197)	0.768
	6	0.457** (0.168)	0.148*** (0.024)	4.842*** (0.220)	0.708
	7	0.189 (0.182)	0.138*** (0.025)	4.944*** (0.254)	0.629
Number of boundary- ^a / property-related sentences ^d (%)	3	1.155*** (0.254)	0.157*** (0.047)	3.651*** (0.284)	0.63
	4	1.068*** (0.187)	0.149*** (0.031)	3.634*** (0.220)	0.748
	5	0.958*** (0.151)	0.142*** (0.023)	3.630*** (0.187)	0.807
	6	0.808*** (0.148)	0.137*** (0.021)	3.650*** (0.193)	0.792
	7	0.555*** (0.173)	0.134*** (0.024)	3.716*** (0.242)	0.687

Notes: OLS estimated equations in rows, with sentences dated before July 23, 2017; 21 observations (years). Standard errors in parenthesis. *** $p < 0.01$. Independent variables: ^a Boundary-related sentences were identified with the string "(demarcat* OR "first regist*" OR "double registration" OR "ownership procedure" OR "excess in meterage" OR parcel*)", using the Spanish terms "deslind*" O "inmatricul*" O "doble inmatriculaci3n*" O "expediente de dominio*" O "exceso de cabida*" O "parcelac3n*"; ^b Identified by using the string "Land Register"; that is, in Spanish, "Registro de la Propiedad"; ^c Real-estate sentences were identified with the Spanish translation of keywords "immovable OR land OR plot OR ground"; that is "inmueble O finca O solar O terreno"; ^d Property-related sentences were identified with the Spanish translation of keywords "ownership OR possession OR mortgage OR servitude", that is "propiedad O posesi3n O hipoteca O servidumbre"; ^e Dependent variables: *After(n)* is a binary variable equal to one for all years after *n*, equal to zero otherwise; while *Licenses(n)* are the number of building licenses in the previous *n* years.

Table 3. Organization and performance of land registries and cadastres

Independent variables (below):		Number of procedures needed to purchase land (<i>Procedures</i>)			Months required to complete a land purchase (<i>Time</i>)			Total transaction costs divided by purchase value, in % (<i>Cost</i>)			Average number of years it takes to litigate a land case (<i>Land_Case_T</i>)		
Name	Description	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Merging and linking land registry and cadastre:													
<i>Single</i>	Single database for land registry and cadastre = 1; otherwise = 0	-1.069*	-0.805	-0.897	-36.695**	-9.463	8.994	-1.633	0.176	-9.146***	-0.782***	-0.433	0.642
		(0.543)	(0.576)	(1.551)	(16.331)	(17.289)	(46.096)	(1.120)	(1.186)	(3.070)	(0.289)	(0.325)	(0.894)
<i>Linkea</i>	Linked databases for land registry and cadastre = 1; otherwise = 0	-0.885**	-0.895**	-0.285	-16.889	-3.243	21.239	-0.87	0.295	-3.377	-0.555***	-0.517**	0.648
		(0.365)	(0.382)	(1.054)	(10.970)	(11.459)	(31.325)	(0.752)	(0.786)	(2.086)	(0.191)	(0.211)	(0.602)
<i>Same_ID</i>	Same ID for land registry and cadastre = 1; otherwise = 0	-0.929**	-0.414	-1.317	-12.716	-5.074	-18.184	-0.905	-0.549	-0.087	-0.415**	-0.024	-0.316
		(0.367)	(0.383)	(1.081)	(11.037)	(11.511)	(32.112)	(0.757)	(0.790)	(2.139)	(0.191)	(0.210)	(0.614)
Titling system:													
<i>Computerization</i>	PC index of the intensity of electronic investment in land titling		0.092	0.117		-14.174***	-13.102**		-1.154***	-1.154***		-0.037	-0.06
			(0.174)	(0.177)		(5.212)	(5.261)		(0.358)	(0.350)		(0.096)	(0.097)
<i>Coverage</i>	PC index of the geographic coverage of the land registry		-0.071	-0.076		1.133	0.598		-0.038	0.01		-0.259***	-0.247***
			(0.154)	(0.157)		(4.616)	(4.657)		(0.317)	(0.310)		(0.087)	(0.088)
<i>Indemnity</i>	If the land registry indemnifies users for its errors = 1; otherwise = 0		-0.253	-0.254		-7.424	-7.841		-0.008	0.124		-0.435**	-0.471**
			(0.354)	(0.359)		(10.619)	(10.659)		(0.729)	(0.710)		(0.199)	(0.201)
Control variables:													
<i>Contract_Case_T</i>	Years it takes to litigate a contract case		0.541***	0.463*		9.842*	12.566		0.363	-0.608		0.729***	0.923***
			(0.191)	(0.260)		(5.738)	(7.711)		(0.394)	(0.514)		(0.121)	(0.186)
<i>Rule_of_Law</i>	Perceptions assessed by the World-wide Governance Indicators (2016)		-0.460*	-0.452*		-3.902	-3.934		0.431	0.218		-0.018	0.006
			(0.245)	(0.253)		(7.370)	(7.525)		(0.506)	(0.501)		(0.137)	(0.140)
<i>GDPpc</i>	Gross Domestic Product per capita of purchasing power parity (2015)		0.093	-0.005		1.041	-1.948		-0.218	-0.265		0.057	0.249**
			(0.107)	(0.221)		(3.211)	(6.561)		(0.220)	(0.437)		(0.060)	(0.127)
Interactive variables:													
<i>SingleXCc</i>	Interaction <i>Single</i> x <i>Contract_Case_T</i>			0.261			-9.27			4.362***			-0.414
				(0.810)			(24.056)			(1.602)			(0.494)
<i>LinkeaXCc</i>	Interaction <i>Linked</i> x <i>Contract_Case_T</i>			-0.138			-1.515			1.823*			-0.653**
				(0.476)			(14.140)			(0.942)			(0.287)
<i>SameIDxCc</i>	Interaction <i>Same_ID</i> x <i>Contract_Case_T</i>			0.255			-4.053			-0.05			0.307
				(0.494)			(14.689)			(0.978)			(0.298)
<i>SingleXGDPpc</i>	Interaction <i>Single</i> x <i>GDPpc</i>			-0.177			-7.291			1.266*			-0.134
				(0.339)			(10.065)			(0.670)			(0.193)
<i>LinkXGDPpc</i>	Interaction <i>Linked</i> x <i>GDPpc</i>			-0.222			-13.396**			0.333			-0.02
				(0.226)			(6.714)			(0.447)			(0.125)
<i>SameIDXGDPpc</i>	Interaction <i>Same_ID</i> x <i>GDPpc</i>			0.299			14.537*			-0.262			-0.208
				(0.270)			(8.029)			(0.535)			(0.151)
<i>Adj R²</i>	<i>Adjusted R² (Seudo R² for column [12])</i>	0.119	0.166	0.148	0.05	0.115	0.113	0.026	0.09	0.141	0.062	0.1973	0.216

Notes. Estimated equations in columns. Constants omitted, 186 observations. OLS for all regressions but for *Land_Case_T* (Oprobit). Standard errors in parenthesis. * p<0.10, ** p<0.05, *** p<0.01.

9. Annex

Table 4. Descriptive statistics for analysis of the evolution of boundary-related ratios after mandatory demarcation as presented in Table 2

Variables	N	Mean	Std. Dev.	Min	Max
Boundary-related sentences ^a / all civil sentences (%)	21	2.256	0.354	1.582	2.657
Boundary- ^a / register-related sentences ^b (%)	21	14.25	1.997	10.51	16.84
Boundary- ^a / real estate-related sentences ^c (%)	21	6.168	0.611	5.091	7.228
Boundary- ^a / property-related sentences ^d (%)	21	5.148	0.634	4.111	6.014
<i>After(3)</i>	21	0.857	0.359	0	1
<i>After(4)</i>	21	0.762	0.436	0	1
<i>After(5)</i>	21	0.762	0.436	0	1
<i>After(6)</i>	21	0.714	0.463	0	1
<i>After(7)</i>	21	0.667	0.483	0	1
<i>Licenses(3)</i>	21	3.232	1.942	0.715	6.206
<i>Licenses(4)</i>	21	4.371	2.453	1.004	8.048
<i>Licenses(5)</i>	21	5.537	2.882	1.299	9.720
<i>Licenses(6)</i>	21	6.732	3.223	1.594	11.17
<i>Licenses(7)</i>	21	7.951	3.472	1.984	12.62

Notes: See Table 2.

Table 5. Descriptive statistics for analysis of the organization and performance of land registries and cadastres presented in Table 3

Variables	N	Mean	Std. Dev.	Min	Max
<i>Procedures</i>	186	5.849462	2.198015	1	14
<i>Time</i>	186	50.73925	63.67456	1	513
<i>Cost</i>	186	5.583871	4.311212	0	27.9
<i>Land_Case_T</i>	186	2.397849	.9431378	1	4
<i>Single</i>	186	.1182796	.3238105	0	1
<i>Linked</i>	186	.3978495	.4907751	0	1
<i>Same_ID</i>	186	.6236559	.4857756	0	1
<i>E_records_full</i>	186	.1935484	.3961453	0	1
<i>E_records_scan</i>	186	.4301075	.4964272	0	1
<i>E_charges</i>	186	.5376344	.4999273	0	1
<i>Computerization</i>	186	.0088892	1.192762	-1.13542	2.046154
<i>Univ_title</i>	186	.2258065	.4192408	0	1
<i>Univ_city</i>	186	.4301075	.4964272	0	1
<i>Coverage</i>	186	.0307385	1.287572	-.9717512	2.17605
<i>Indemnity</i>	186	.2956989	.457588	0	1
<i>Contract_Case_T</i>	186	1.732376	.8314446	.4493151	4.69863
<i>Rule_of_Law</i>	185	-.0487568	.9717796	-2.34	2.07
<i>GDPpc</i>	186	1.933482	2.07225	.062764	13.28702
<i>SingleXCc</i>	186	.164796	.5059854	0	3.356164
<i>LinkedXCc</i>	186	.6494329	.9296091	0	4.69863
<i>SameIDxCc</i>	186	.9576521	.8999913	0	3.890411
<i>SinglexGDPpc</i>	186	.2955723	.9949186	0	6.580607
<i>LinkedxGDPpc</i>	186	1.049049	2.05674	0	13.28702
<i>SameIDxGDPpc</i>	186	1.468259	2.146427	0	13.28702

Sources: World Bank's *Doing Business 2017* report (World Bank 2016) for all but the rule of law (World Bank's Worldwide Governance Indicators) and GDP (International Monetary Fund) variables.