Colonial Legacy and Land Market Formality *

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Abstract

We study the role of Dutch colonial institutions on urban development for the megacity of Jakarta, Indonesia. Using historical maps of Dutch settlements and a rich granular database, we implement a boundary discontinuity design comparing locations on either side of Dutch boundaries. We find that historical Dutch areas today have significantly lower parcel density, are more likely to have formally registered parcels, and have more regular parcel layout, pointing to the importance of planning and cadastral mapping. Dutch settlements are also more likely to appear formal, as per a photographic index that ranks the appearance of neighborhoods. We highlight the role of land market institutions over alternative channels, such as direct Dutch investments or natural advantage.

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1 Introduction

Developing countries are urbanizing rapidly, amidst significant institutional challenges. Weak land market institutions are one of the key frictions (Henderson and Liu, 2023) and have been associated with lack of investment, slums, and sprawl. Economists have pointed to property rights as being paramount to promote investments in durable capital, which in turn have long-lasting implications for the spatial distribution of economic activity (Djankov et al., 2022).

This paper sheds light on the persistent effects of land market institutions on urban development by studying the role of Dutch settlements in Jakarta, Indonesia. Following the establishment of a Dutch East India Company trading post in the 17th century, as the Dutch settled in Batavia (present-day Jakarta), they established individual property rights and cadastral mapping according to the European legal tradition in Dutch settlements, while leaving the local customary land rights in place elsewhere, leading to a dual tenure system.

It is challenging to identify the causal impact of land market institutions because institutions typically vary across countries rather than within cities. We make progress by studying historical Dutch settlements within the city of Jakarta. We draw upon historical maps detailing boundaries of areas under Dutch land rights at independence, allowing us to implement a boundary discontinuity design comparing modern development outcomes on either side of the Dutch boundaries. The identifying assumption is that modern determinants of location quality change smoothly across Dutch boundaries, conditional on controls and granular fixed effects.

Our research design centers around high-resolution and comprehensive data from several sources. We measure multiple aspects of land market formality using cadastral maps of land parcels, legal status in the land registry, and administrative data on land use patterns. We also collected an innovative photographic sample to develop a rank-based index of formality (Harari and Wong, 2024). We overlay Jakarta with a grid of 75-meter pixels and draw a representative sample of pixels from this grid. We then collect and hand-code street-view photos from online repositories or taken by our own field team (in areas inaccessible to vehicles). Other auxiliary data capture historical and modern amenities. Our primary units of analysis are 75-meter pixels and the estimation sample restricts comparisons to pixels within the optimal bandwidths.

Our first finding is that historical land tenure patterns continue to shape urban development in modern Jakarta. Dutch settlements have lower parcel density (less fragmented land) compared to observably identical adjacent non-Dutch areas on the other side of the boundary. The effect size is large, with 11 fewer parcels per pixel relative to the control group mean of 27 parcels. Intuitively, more fragmented land can complicate the land assembly process as developers require contiguous land parcels for formal buildings (Brooks and Lutz, 2016). Moreover, Dutch settlements are 4 percentage points more likely to have parcels that are registered in the cadastral system, relative to a mean of 81 percent for non-Dutch areas. Dutch settlements are also more likely to appear formal from our photo index (effect size of 0.07 relative to a control group mean of 0.66, where higher values correspond to greater formality). We use optimal bandwidths à la Calonico et al. (2014) (respectively, 291 meters, 283 meters, and 334 meters for parcel density, the share of registered parcels, and the photographic index).

Next, we explore channels through which Dutch settlements can have persistent impacts on urban development. One key way in which the Dutch system may have affected urban patterns is through the persistent role of land market institutions, including a bundle of cadastral mapping, a formal registration system with individual property titles, and neighborhood planning. We find that Dutch settlements have land parcels that are more regular in sizes and layout, which can facilitate land assembly and coordination (Libecap and Lueck, 2011). In particular, parcels in Dutch settlements are more aligned, with less variability in their angle orientations (the effect size is -4.86 degrees relative to a control mean of 32.10). Similarly, Dutch areas have less fragmented parcels as per the K land fragmentation index (effect size of 0.12, relative to a control mean of 0.45). These findings are consistent with Dutch land markets institutions facilitating the urban planning and land assembly process (Henderson and Liu, 2023).

We also consider alternative channels of persistence, for which we find more limited support. One possibility is that Dutch areas are more formal today because of direct effects of Dutch physical investments. To assess this, we consider surviving colonial buildings. The vast majority of the original Dutch buildings has been demolished, suggesting that the persistence is not mechanically driven by differences in colonial structures across the boundary. In fact, we continue to find similar estimates after dropping pixels within 500 meters of the (few) surviving colonial structures, suggesting that our main effects are not driven by these durable investments.

Second, we consider infrastructure and amenities from colonial times that are documented in our historical maps but no longer relevant in modern Jakarta. These include public amenities, such as concert halls and academies, and private amenities, such as hotels, that were catalyzing economic activity during Dutch times. Additionally we consider historical sanitation and health infrastructure, like wells and pipes. These investments could have attracted higher-income residents and spurred more formalization and titling at the time, which could have persisted to today. However, proximity to these investments is similar on either side of Dutch boundaries, within our boundary analysis.

In addition, economies of density can contribute to persistence by coordinating economic activity, leading to network effects and spillovers (Bleakley and Lin, 2012). We investigate this channel by estimating spatial decay patterns away from Dutch boundaries. For example, Dutch settlements could have attracted high-income residents, giving rise to positive spillovers and encouraging gentrification and formalization of nearby non-Dutch settlements. Alternatively, crowded informal settlements outside Dutch boundaries could have been associated with negative congestion externalities, leading to worse outcomes just inside Dutch settlements. Both sources of spatial spillovers will likely give rise to spatial decay patterns away from Dutch boundaries. We do not detect a significant enough decay pattern to change our conclusions.

One threat to identification is that the Dutch chose to settle in more desirable locations, so that the findings above could be confounded by unobserved location quality. We establish that Dutch and non-Dutch settlements are indeed significantly different for a set of pre-determined geographic attributes, but these differences disappear once we include boundary fixed effects and restrict the sample to pixels close to the Dutch boundaries. Plausibly, while neighborhood quality could have differed discontinuously at the Dutch boundary during colonial times, modern determinants of urban development are likely common across Dutch boundaries, once we restrict to pixels within the optimal bandwidth. We also perform a bounding exercise to quantify how large unobserved selection would have to be to explain away our main estimates (Oster, 2019).

We further probe confounding due to unobserved quality by comparing early versus late Dutch settlements. It is possible that the Dutch chose to settle in the best locations first, before expanding. The historical maps indicate that early Dutch settlements were more central, whilst later settlements were farther south from the city center. To the extent that the Dutch settled preferred locations first, if the impacts were driven by unobserved quality we should see greater formality in earlier settlements, but we do not. We also examine heterogeneity by the historical land use of non-Dutch areas. Areas that were not under the Dutch legal system at independence were (i) empty (ii) cultivated with rice or orchards or (iii) "kampungs", i.e. traditional native settlements.[1] Outcomes for Dutch areas today

[1] *Kampung* is a colloquial term used in Indonesia to describe traditional (rural and urban) villages and, today,

are similar to those in former orchards, while we see less formality today in former rice areas and the least formality in kampung settlements. Interestingly, while all non-Dutch areas had customary land rights, land rights associated with orchards were individual while those associated with rice were collective.

Finally, we find that modern urban development outcomes are also stronger in Dutch settlements. Access to present-day amenities such as schools, hospitals, and bus stops are better in Dutch settlements, as measured by distance. There is also a 5 percentage point higher density of office buildings, relative to a control group mean of 6 percentage points.

We reinforce our findings with a number of robustness checks. We show that the main results of Dutch settlement impacts on formality continue to hold if we drop boundaries that coincide with waterways or railways. We also considered alternative ways to construct boundary segment fixed effects. Our results are also robust to allowing spatial correlation in standard errors (Conley, 1999).

Put together, we make three contributions to the literature on land market institutions and urban development. First, we implement a boundary discontinuity analysis to provide causal evidence of the persistent impacts of Dutch institutions within the megacity of Jakarta. Second, we assemble rich measures of land market formality and urban form. Third, we leverage the setting of historical Dutch colonial settlements to highlight the persistent role of land market institutions,, including land registration and planning.

Our findings are relevant for policy makers in developing country cities debating land use patterns and how to configure cities to accommodate massive urbanization. There are severe shortages of housing and commercial developments, as well as a need for transit infrastructure to improve mobility and address traffic congestion. For example, the most recent Jakarta Master Plan highlights the crucial role of land use underlying the ensuing urban transformation process. Our results point to the importance of addressing persistent frictions in land markets to support Jakarta's growth in the coming decades.

We are closely related to the literature on land market institutions and urban form in developing countries. Baruah et al. (2021) show a persistent legacy of colonial planning institutions on urban structures across former French versus British colonies while Fredriksson et al. (2023) find that common law legal origin is associated with fewer slums. Aside from colonial institutions, there are also studies exploring other pathways to enhance property rights institutions through titling programs (Field, 2007; Galiani and Schargrodsky, 2010), sites and services (Michaels et al., 2021), or the role of local leaders (Manara and Regan,

informal settlements.

2022). Another strand of the literature examines urban development in a context with dual, formal and informal land markets in Nairobi (Henderson et al., 2020), Kampala (Bird and Venables, 2019), and Chile (Gonzales and Undurraga, 2024).

We are also related to the literature on the persistent implications of colonial institutions for developing countries. There is an established literature documenting the negative impacts of extractive colonial institutions (Acemoglu et al., 2001, 2002; Dell, 2010; Lowes and Montero, 2017). Other work considers impacts on legal institutions (La Porta et al., 2008), state capacity (Ali et al., 2018), land taxation (Banerjee and Iyer, 2005), and long-run development outcomes through investments and manufacturing (Dell and Olken, 2019).

The rest of the paper proceeds as follows. Section 2 discusses the background, Section 3 describes the data, Section 4 describes the empirical strategy and presents our main results, Section 5 explores potential channels, Section 6 discusses impacts on overall urban development, Section 7 describes robustness tests, and Section 8 concludes.

2 Background

Dual land markets, formal and informal, are a tangible manifestation of weak land market institutions that is common to many cities in developing countries, with important implications for urban growth (Henderson and Liu, 2023). This duality often has its roots in the colonial past of cities and the ensuing overlap of legal domains, where customary land rights coexist with those introduced by the colonizers. This section focuses on the history of Dutch settlements and land markets institutions in Jakarta.

2.1 History of Dutch Settlements

Dutch presence in Indonesia dates back to the 17th century, when the Dutch East India Company established a trading base in the port of Batavia (present-day Jakarta) to facilitate and control commodity trade in the region. The Dutch settlements in our study were largely built in the 19th through early 20th centuries, during a period of inland territorial expansion by the Dutch to promote agricultural production and the colonial plantation economy. Malaria and other disease outbreaks induced the Dutch to expand further away from the coast, and spurred investments in water management and sanitation. Settlements followed Dutch urban planning practices and the “garden city” principle, with grid-like roads, canals, and low density. Outside Dutch settlements were orchards, rice fields, and traditional "kampung" settlements, where different ethnic groups segregated into different enclaves. The early 20th century marked a program of *kampung verbetering* (kampung improvement), providing sanitation in the traditional non-Dutch settlements, with the goal of managing negative externalities from crowding.

During World War II, Jakarta was occupied by Japan. As part of an effort to dismantle remnants of European governance, Dutch nationals were expropriated and detained in camps. In 1949, Indonesia formally gained independence from the Netherlands. Dutch nationals were expelled, and Dutch property that had been initially appropriated or occupied during the war was nationalized (Domke, 1960).

The newly formed government prioritized nation-building and breaking ties with its colonial past. Urban planning efforts in the capital city of Jakarta focused on the creation of a National Monument and other landmarks related to Indonesia's history, to replace colonial ones. Until recent years, there were limited efforts to preserve Dutch structures, leading to only few colonial buildings remaining in place today (Colombijn, 2022).

2.2 Land Markets and Urban Development in Jakarta

In Jakarta, the Dutch implemented a system of indirect rule, whereby the municipality governed the Dutch settlements only, while the surrounding areas were controlled indirectly subcontracting the government to local leaders. Under this dual system there were two different types of land: *bebouwede-kom* (literally "built-up" areas) under Dutch land rights and *niet bebouwde-kom* ("not built") under local Javanese land rights (*Adat* law) (Kusno, 2015).

Dutch areas were characterized by Western land titling, featuring secure and tradeable ownership rights, institutionalized land registration, and cadastral mapping. By 1874 the land registry system included a cadastral office featuring an engineer, value assessor, and land surveyor (Fakih, 2023). Following the English deeds system, transfer of ownership for each parcel had to be recorded in the register. The customary rights system featured a variety of land rights, including communal use rights. Customary titles were recorded by village chiefs and not surveyed by an official surveyor (Leaf, 1993). These institutional differences resulted in native Indonesians having weaker claims to their land compared to Europeans. The Dutch also implemented extensive mapping, partly to enforce the segregation of different groups in ethnic enclaves (Cowherd, 2021). The historical maps we use (Figure A1) report the boundaries of *bebouwede-kom* areas in Jakarta at independence.

After independence, the 1960 Basic Agrarian Law was passed, with the intent of establishing a unified land rights system that superseded Dutch and customary land rights. The Law created Indonesian counterparts for the various types of rights held under the Dutch Civil Code and recognized customary rights under *Adat* law. The Law also introduced a National Land Agency charged with facilitating the implementation of this new system by registering and administering land rights for all of Indonesia. The Dutch cadaster was inherited by the Indonesian administration and became the basis for the land registry. The first land parcels to be incorporated were those registered under Dutch laws.

The goal was to eventually register all land parcels, including those held under customary rights. However, the registration process to convert informal land rights to formal has been challenged by significant transaction costs and fees, difficulty verifying tenure status and resolving disputes, and courts that are backlogged (Leaf, 1993). Today, Indonesia is still characterized by dual land markets (Leitner and Sheppard, 2018). Land under customary rights continues to be transacted following traditional practices. Customary titles (*hak girik*) are unofficially secured by property tax records, sales receipts, and other documents. Transactions are recorded in local administrative offices (localities known as *kelurahan*), rather than in the National Land Agency's registry.

This dual system of land markets has direct implications on the urban development process for Jakarta. Urban planners' approaches towards formal and informal settlements have evolved through Jakarta's Master Plans. The 1960 Master Plan prioritized upgrading kampungs through investments in sanitation and roads, as more Indonesians began to move into Jakarta after the Dutch left. As the city grew, the 1985-2005 Master Plan began to envision the redevelopment of kampungs and the creation of business districts beyond the city's historic center. However, this transition was interrupted by an oil crisis in 1986 and by the Asian Financial Crisis in 1997, with the economy only recovering by the mid-2000's. Today, modern Jakarta is facing increasing land scarcity amidst rapid population growth. The city has been expanding into the sprawling metropolitan area of Jabodetabek,[2] the world's second-largest. The most recent Jakarta Master Plan aims to address concerns of overpopulation, a severe shortage in housing, and traffic congestion.

[2]Jabodetabek comprises Jakarta and the adjacent municipalities of Bogor, Depok, Tangerang, and Bekasi.

3 Data

Our primary units of observation are 75-meter by 75-meter pixels, which we obtained by overlaying a grid of 95,000 pixels over the city of Jakarta.[3] For our empirical analyses we also consider localities (comparable in area to census tracts in the U.S.), the local administrative units responsible for collecting property taxes and registering property transfers of ownership.[4]

Maps of Dutch Settlements. We identify Dutch areas from a 1959 U.S. Army map (U.S. Army Map Service, 1959) (with 25 meters resolution), which covers the entire city of Jakarta and reflects the city's land use at independence. We validate this baseline map using a higher resolution map from 1937 (G. Kolff & Co, 1937) (11 meters) that shows the early settlements in the center. These maps clearly distinguish *bebouwde-kom* areas that were settled by the Dutch under European land rights from areas that were under cultivation, empty, or *kampungs*.

Figure 1 displays a map of the city of Jakarta with Dutch settlements (black polygons) as well as locality boundaries (gray). For each pixel, we calculate the distance to the closest Dutch boundary and the second closest. We then use these distances to determine the control group for the boundary discontinuity analysis (outside the Dutch settlements but within the optimal bandwidth for the closest Dutch boundary) and to avoid contamination (we drop observations that are within 100 meters of the second closest Dutch boundary). We assign a boundary fixed effect to each polygon in the map. Our results are robust to different approaches to define boundary fixed effects and are robust to excluding the smallest Dutch polygons.

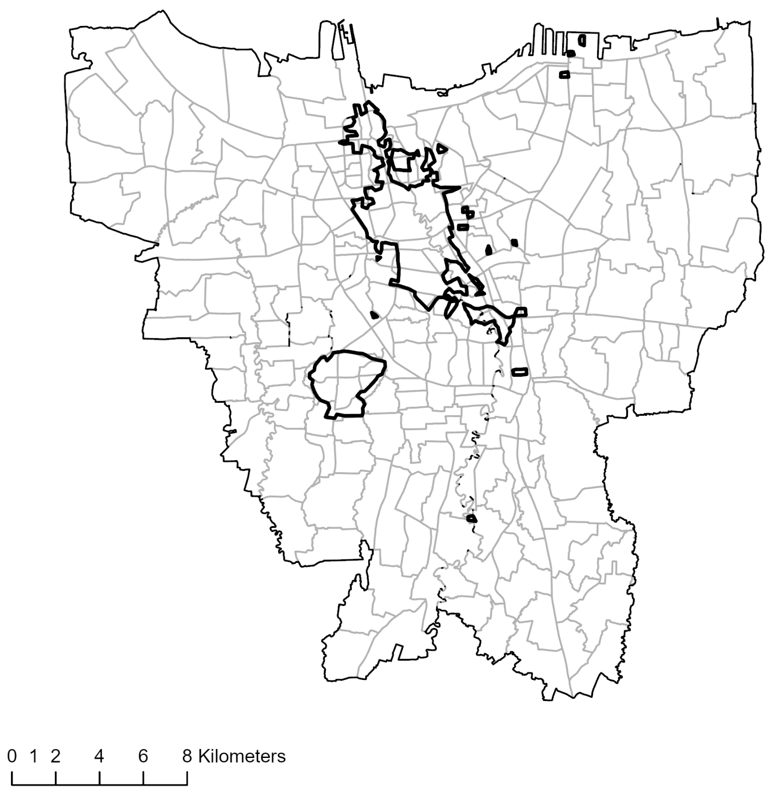
Measuring Formality. There is no standardized metric to quantify formality in land markets. We develop three proxies that capture several dimensions in which formal and informal areas differ. First, we consider parcel density (number of parcels in each pixel) based on digital cadastral maps created by the Jakarta Department of Housing in 2011. Second, we calculate the area share of each pixel corresponding to unregistered parcels, from a unique digital land map created and made public in 2020 by the Indonesian National Land Agency.

Third, as described in Harari and Wong (2024), we hand-coded a rank-based index of

[3] This is the unit of analysis we used to construct our photographic sample (see Harari and Wong (2024) for more details of the sampling procedure).

[4] The replication package for this paper is available at openICPSR (Harari and Wong, 2025)

Figure 1: Map of Historical Dutch Settlements in Jakarta



Notes: Map showing Dutch boundaries (thick black border) and locality boundaries (gray).

formality ranging from 0 to 4, from an innovative photographic sample. We rescale it for ease of interpretation, so that 0 corresponds to “very informal” and 1 to “very formal”. Research assistants were instructed to rank photos based on characteristics of the neighborhood (including the density and irregularity of structures, and cleanliness) and of the buildings (such as the durability of materials and the size of windows). Our sample of photos is representative of the entire city of Jakarta and is drawn from a combination of on line repositories (90% of all pictures) and photos taken by our team in the field (10%), for locations that are inaccessible by vehicles (e.g. *kampungs*).

Current Amenities. We observe modern public amenities in 2016 from OpenStreetMap, measuring distances of each pixel to the closest school, hospital, police station, and bus stop. In addition, we also compute the land share of each pixel corresponding to retail and office buildings respectively, based on a 2014 administrative land use map from the Jakarta

Government website.

Historical Amenities. We capture the distance, in logs, from a number of historical landmarks that were catalyzing economic activity during Dutch times. We utilize three historical maps (Visser Co te Batavia, 1887; Officieele Vereeniging voor Toeristenverkeer, Batavia, 1930; U.S. Army Map Service, 1959) that report the location of notable buildings from colonial times, including businesses, public buildings, and amenities. These landmarks are concentrated in a few parts of the city that appear to have the most economic activity at the time. We consider a number of key historical landmarks that plausibly served as "anchors", specifically: the 1821 Concert Hall (later used as the Japanese headquarters during the occupation), the 1829 Hotel des Indes (at the core of the expat community, where most embassies were), the 1932 Bioscoop Metropool (Jakarta's first cinema), and the Akademi Nasional (which would host in 1949 the oldest private university in Jakarta), located in suburban South Jakarta.

We also digitize the location of artesian wells and pipes, built by the Dutch as part of their water management efforts, from a 1922 map (Smitt, 1922).

Surviving Dutch Structures. We hand-collected the location of Dutch buildings that are still in place in today's Jakarta. We consulted a number of on-line sources including travel blogs, tourism websites, and a Wikipedia page on colonial architecture in Jakarta and verified the presence of each building from Google Street View. The resulting database includes 72 buildings in 69 pixels, concentrated in the northern part of the central Dutch areas. These include Dutch administrative buildings which have continued on as museums or government buildings, but also a number of private residences and warehouses that tend to be in dilapidated condition.

Heights and Land Values. From our photographic sample, we code the number of floors of the tallest building in a pixel. Pixels with no buildings (4% of the sample), corresponding to large roads, parks, or empty lots, were assigned a height of 0 and a "no building" dummy. For assessed values, we obtained a digital map in 2015 through the Smart City Jakarta initiative. We have assessed land values in Rupiah per square meter for nearly 20,000 sub-blocks (the smallest zoning unit in Jakarta). Harari and Wong (2024) describe validation exercises to compare assessed values with market data.

Topography controls. We consider a number of pre-determined controls to capture natural advantage. We include slope and elevation from the ASTER Global Digital Elevation Model (NASA and METI, 2011). We capture the hydrological determinants of local flood proneness through three proxies (Jati et al., 2019): log distances from the coast and from the nearest permanent or semi-permanent water body, from the ECJRC Global Surface Water Dataset (Pekel et al., 2016), and flow accumulation, a measure of exposure to flooding based on relative slopes.[5] Finally, we include bedrock depth, which affects the engineering costs of building high-rises (Ahlfeldt et al., 2023), from the SoilGrids 250-meter dataset (Hengl et al., 2017).

4 Empirical Strategy

4.1 Boundary Analysis

As our main estimating equation, we consider a boundary discontinuity design (BDD) where we restrict the sample to pixels on either side of Dutch boundaries, within the optimal bandwidth:

$$\begin{aligned} Y_{ijb} = & \beta_1 \text{Dutch}_{ijb} + \beta_2 \text{Dist}_{ijb} + \beta_3 \text{Dist}_{ijb} \times \text{Dutch}_{ijb} \\ & + \beta_4 \text{Dist}^2_{ijb} + \beta_5 \text{Dist}^2_{ijb} \times \text{Dutch}_{ijb} + \beta_6 \mathbf{X}_{ijb} + \gamma_j + \delta_b + \varepsilon_{ijb} \end{aligned} \tag{1}$$

where unit i is a 75-meter pixel in locality j, assigned to boundary b. We allow for separate quadratic distance controls ($Dist_{ijb}$) to the nearest Dutch boundary, on either side (Michaels et al., 2021). For the treatment group, we assign a value of one to $Dutch_{ijb}$ for pixels inside a Dutch settlement, within the optimal bandwidth distance from the boundary. We calculate the optimal bandwidth distances for each dependent variable using the Calonico et al. (2014) procedure. For our primary outcomes, the bandwidth ranges between 291 and 334 meters (Table 2). For the control group, we include pixels that are not in Dutch settlements, within the optimal bandwidth distance to the closest Dutch boundary (to be comparable to Dutch settlements) and more than 100 meters away from the second closest Dutch boundary (to avoid contamination). We explored robustness to considering alternative specifications, such as linear distance controls, alternative no-contamination thresholds, and narrower bandwidths. Additionally, we exclude pixels that intersect the area of the current Merdeka Square (formerly *Koningsplein*), since this area has always been set aside for purely public use as a ceremonial square and parading ground. While it is in the

[5] We verify that our hydrology controls are strong predictors of flood damage in Jakarta, as measured by whether a hamlet is classified as "flood-prone" in OpenStreetMap.

middle of the Dutch zone our historical maps do not consider it as *bebouwde-kom*.

$\mathbf{X}_{ijb}$ is a vector of pre-determined controls capturing location advantage. Our primary specification additionally includes fixed effects for localities (γ_j) and for the closest boundary to pixel i (δ_b). For robustness, we also consider finer boundary fixed effects (see Section 7). ε_{ijb} is assumed to be an idiosyncratic error term. Standard errors are clustered by localities but we also demonstrate robustness by allowing for spatial autocorrelation (Conley, 1999).

The key parameter of interest is β_1, which we interpret as the causal impact of being in a Dutch settlement on formality today. Our identifying assumption is that, conditional on controls, unobserved neighborhood quality changes smoothly across Dutch boundaries when we compare pixels within the optimal bandwidth.

A key threat to identification is persistence of historical quality differences, as the Dutch likely chose to settle in neighborhoods that were higher-quality in the past. In order to illustrate the role of historical Dutch factors versus potential confounders, let ξ represent location quality for pixel i in locality j, assigned to boundary b. Assume location quality evolves over time according to the following process (Lee and Lin, 2018): $\xi_{ijbt} = \rho \xi_{ijb,t-1} + u_{jbt} + \varepsilon_{ijbt}$ where $\rho < 1$, u_{jbt} is a contemporaneous neighborhood component, and ε_{ijbt} is a mean 0 idiosyncratic shock. Furthermore, to trace back to historical differences, let the period right before the Dutch settled be $t = 0$ and modern Jakarta be T years later. We can then decompose the difference between Dutch (D) and non-Dutch (ND) settlements, $E(\xi_{ijbt}|D_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b)$ - $E(\xi_{ijbt}|ND_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b)$, into two components stemming from historical and contemporaneous factors:

$$\underbrace{\rho^T \left[E\left(\xi_{ijb0}\middle|D_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b\right) - E\left(\xi_{ijb0}\middle|ND_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b\right)\right]}_{\text{Historical factors}}$$
$$- \underbrace{\left[E(u_{jbt}\middle|D_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b) - E(u_{jbt}\middle|ND_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b)\right].}_{\text{Common contemporaneous shocks}}$$

It is possible that the Dutch chose to settle in better locations and that ξ_{ijb0} could have been discontinuously different across Dutch boundaries during colonial times. Our identifying assumption is that pre-Dutch differences in quality are less important now (ρ<1) and unobserved contemporaneous factors are common across Dutch and non-Dutch locations, once we restrict to pixels within the optimal bandwidth of Dutch boundaries and condition on controls, boundary, and locality fixed effects (δ_b and γ_j). The next sub-sections unpack potential ways in which historical Dutch settlements could lead to persistent differences today. Some factors are likely obsolete by now while other factors may persist.

Table 1 compares pre-determined characteristics across Dutch and non-Dutch pixels. Column 1 includes the full sample of 95,000 pixels with no fixed effects, showing that Dutch pixels are associated with lower elevation (3.69 meters), steeper slope (0.5 degrees), and are closer to the coast (-0.32). Column 2 shows that these differences disappear when we implement our BDD analysis. Specifically, we use the estimation sample of 6,349 pixels that are within 291 meters of Dutch boundaries, as per the optimal bandwidth for parcel density (see Table 2), including boundary and locality fixed effects and the quadratic distance controls. The results are similar using the estimation samples corresponding to the optimal bandwidths for the other main outcomes. Columns 3 and 4 report means and standard deviations in the control group and in the Dutch areas, for the sample in column 2.

Table 1: Comparing Dutch and non-Dutch Locations

Sample:	OLS	BDD	Non-Dutch Mean (St.Dev.)	Dutch Mean (St.Dev.)
	(1)	(2)	(3)	(4)
Elevation, m	-3.69**	0.45	16.28	18.14
	[0.02]	[0.46]	(7.28)	(8.33)
Slope, Degrees	0.50***	0.40	4.89	5.42
	[0.01]	[0.20]	(3.18)	(3.37)
Flow Accumulation	0.05	0.64	2.99	2.95
	[0.63]	[0.30]	(7.38)	(7.53)
Log Distance to Coast	-0.32***	0.003	8.76	8.70
	[0.01]	[0.71]	(0.82)	(0.78)
Bedrock Depth, m	-0.29	-0.56	42.14	39.00
	[0.76]	[0.28]	(6.82)	(6.73)
Log Distance to Surface Water	-0.05	0.02	7.45	7.47
	[0.73]	[0.42]	(0.94)	(0.78)
N	95235	6349	3910	2439

* 0.10 ** 0.05 *** 0.01

Notes: Columns 1 and 2 report regressions with our controls as the dependent variables and the Dutch settlement indicator as the key regressor. For each variable, the top row reports the coefficient, and the bottom row reports the p-value in brackets. The unit of analysis is a pixel. Column 1 includes the full sample of 95,235 pixels with no fixed effects. Column 2 restricts the sample to 6,349 pixels within 291 meters of the closest Dutch boundary (the optimal bandwidth for parcel count), includes quadratic distance controls and boundary and locality fixed effects. Standard errors are clustered by locality. Columns 3 and 4 report the mean and standard deviation (in brackets) for each control variable for the control and Dutch group respectively, within the sample in column 2.

4.2 Impacts on Formality

Table 2 reports our main estimates of the impact of historical Dutch settlements on formality today. Column 1 restricts the sample to 6,349 pixels within 291 meters of Dutch boundaries. We include boundary fixed effects, quadratic distance controls to Dutch boundaries (separately on each side), locality fixed effects, and topography controls. Standard errors are clustered by locality.

Column 1 indicates that Dutch settlements have lower parcel density (-11.05 parcels per pixel) compared to otherwise comparable pixels just outside the Dutch boundary. Intuitively, greater parcel density tends to be associated with more fragmented land ownership. This adds complexity to the land assembly process, to the extent that a developer requiring contiguous land will need to negotiate with more owners, potentially exacerbating holdout problems. This is a large effect relative to the control group mean of 26.72. Here, we also include the log lengths of all the roads in a pixel as an additional control to address the concern that the presence of roads will mechanically lead to more fragmentation in land parcels.

Table 2: Effect of Dutch on Formality

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
	(1)	(2)	(3)
Dutch	-11.05***	0.04*	0.07**
	(1.98)	(0.02)	(0.03)
N	6349	6187	2315
R-Squared	0.39	0.28	0.26
Control Group Mean	26.72	0.81	0.66

* 0.10 ** 0.05 *** 0.01

Notes: The unit of analysis is a pixel. The key regressor is an indicator equal to 1 for a pixel in Dutch settlements. This table uses the optimal bandwidths for parcel density (291 m), share registered (283 m), and photo index (334 m), respectively. All columns include pixels within their respective optimal bandwidth of a Dutch settlement boundary while excluding those within 100 meters of a second Dutch boundary. All columns control for quadratic distances to the Dutch boundary by treatment status, Dutch boundary fixed effects, locality fixed effects, and the topography controls listed in Table 1. Column 1 reports the effect of Dutch on parcel density, with the log lengths of all the roads in a pixel as an additional control. It includes 114 locality fixed effects, of which 60 have within-group variation, and 25 boundary fixed effects. Column 2 reports the effect of Dutch on the share of a pixel that has registered parcels. Column 3 reports the effect of Dutch on the photo index (greater values are more likely formal), with controls for strata fixed effects from our photographic survey and an indicator for pixels with no photo index. Standard errors in all columns are clustered by locality.

Column 2 utilizes a sample of 6,187 pixels within 283 meters of Dutch boundaries and shows that Dutch settlements have a 4 percentage point higher share of registered land (relative to a mean of 81 percent). This captures the legal registration status of land parcels. Finally, column 3 utilizes a sample of 2,315 pixels included in our photos sample, for which we have coded our rank-based formality index. Higher values of the photo index correspond to more formal areas. We find an effect of 0.07, relative to a control mean of 0.66. Here, we also include strata fixed effects from our photographic survey and an indicator for pixels with no index (empty land, interior photos, or roads where we cannot code the index). We discuss spatial spillovers and other robustness below.

5 Potential Channels

Why might the presence of Dutch settlements many decades ago still matter for land markets today? We begin by considering the role of land market institutions, which comprise a bundle of individual property rights, a formal registration system, cadastral mapping, and urban planning. We argue that these Dutch practices had persistent impacts on land market institutions in Jakarta. One strength of our analysis is the ability to measure the implications of this by examining the registration status, densification, and regularity of land parcels.

Our empirical setting also allows us to consider important channels suggested by the literature on persistence in cities, such as natural geographic advantage or economies of density and agglomeration spillovers. There is also an important role due to durable investments from the past, including the physical built legacy in addition to the institutional legacy (neighborhood boundaries, zoning codes, and rule of law). Our conclusions point to land market institutions as an important driver of the observed differences.

5.1 Land Market Institutions

One of the prerogatives of the Dutch administration in the *bebouwede-kom* areas was the creation of a land registry, the establishment of cadastral mapping, and neighborhood planning. The presence of a land registry represents a formal record of ownership of land parcels, while cadastral maps help dictate the boundaries of each parcel. Both contribute to clarifying ownership and help minimize disputes. The finding discussed above that parcels in Dutch areas are more likely to be recorded in the land registry suggests an important role for the land registration system.

Table 3 below further explores whether areas within Dutch boundaries exhibit features associated with formal, planned neighborhoods. We consider two metrics of regularity, one based on the area sizes of parcels and one based on their orientation.

The K land fragmentation index (Januszewski, 1968) combines information on parcel count per pixel and average parcel area as follows:

$$K = \frac{\sqrt{\sum_{i=1}^{n} a_i}}{\sum_{i=1}^{n} \sqrt{a_i}}$$

where n is the number of parcels and a is the parcel size, and i indexes parcels in a pixel. This index ranges from 0, in the limit case of an infinite number of parcels, to 1, for the case of a single parcel; lower values indicate a higher degree of fragmentation. Fragmentation as captured by the K index increases when the range of parcel sizes is small and decreases as the area of large parcels increases and that of small parcels decreases.

Second, we consider the extent to which land parcels have similar orientation (Michaels et al., 2021). Regularity in the placement of land parcels is associated with cadastral mapping, as maps define the boundaries of each parcel and facilitate the laying out of regularly arranged land parcels, and with the practice of neighborhood planning. We calculate the standard deviation, in degrees, among the main angles of all parcels within a pixel. Higher values of this metric imply more variability in parcel orientation. Parcels with similar orientation are associated with grid-like development, which was one of the principles of Dutch urban planning (Ehoe, 2015).

Column 1 of Table 3 reports that Dutch pixels have a higher K-index by 0.12 (relative to a control mean of 0.45). Column 2 shows Dutch settlements are more likely to have regularly oriented parcels, with a standard deviation lower by 4.86 degrees (relative to a control mean of 32.10). We utilize optimal bandwidths of 298 and 391 meters respectively. These results echo those in Yamasaki et al. (2021) on the persistence in lot sizes in Japan.

5.2 Durable Capital

We now turn to some of the channels of persistence commonly considered in the literature, beginning with capital investments. Past investments in buildings and infrastructure in Dutch areas could have lasting impacts because of the durability of the capital stock. In

Table 3: Effect of Dutch on Parcel and Building Regularity

Dependent variable:	**K Index**	**Angle Variation**
	(1)	(2)
Dutch	0.12***	-4.86***
	(0.03)	(1.39)
N	6486	6435
R-Squared	0.33	0.26
Control Group Mean	0.45	32.10
Topography	Y	Y
Locality FE	Y	Y
Boundary FE	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: This table repeats the specifications in Table 2 focusing on building regularity metrics. Column 1 reports the effect on the K index, a measure of spatial consistency among buildings, utilizing an optimal bandwidth of 298 m. Column 2 reports the effect on the angle variation, defined as the standard deviation of building angles within a pixel, with an optimal bandwidth of 391 m. We do not include pixels that have no buildings. Standard errors are clustered by locality.

Jakarta, this is unlikely to be at play because the vast majority of the original colonial buildings were demolished or abandoned, in line with the nation building strategy pursued at independence. We further probe this channel by collecting information on the location of the 72 Dutch structures still in place in the city.

Table 4 repeats Table 2 but drops from the sample pixels within 500 meters of these surviving Dutch structures. If our main effects were driven by the enduring presence of colonial buildings, our estimated effect could be drastically muted after dropping nearby pixels. Instead, we find similar impacts for parcel density (-9.72 relative to -11.05), registered share (0.03, albeit with a slight loss of power, relative to 0.04), and the photo index (0.11 relative to 0.07). One limitation of this test is that we do not have information on Dutch buildings that persisted for many years and were only recently demolished.

Table 4: Robustness to Excluding Surviving Dutch Buildings

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
	(1)	(2)	(3)
Dutch	-9.72***	0.03	0.11***
	(2.24)	(0.02)	(0.04)
N	4881	4743	1850
R-Squared	0.41	0.26	0.28
Control Group Mean	26.38	0.82	0.67

* 0.10 ** 0.05 *** 0.01
Notes: This table is similar to Table 2 but drops pixels that are within 500 m of a surviving Dutch colonial building.

5.3 Economies of Density

Economies of density can make it valuable to keep agglomerating in one place (e.g. even long after historical factors stopped being relevant (Bleakley and Lin, 2012)). The concentration of Dutch residents during colonial times may have been associated with more foreign businesses and economic activity that led to persistent agglomeration continuing after the Dutch left. Additionally, the Dutch introduced physical improvements to neighborhoods, such as drainage and water management, that may have attracted high-income households and lead to positive neighborhood spillovers persisting even after the original infrastructure was replaced by modern one. We consider both sources of persistence in Table 5 below.

Agglomeration from Dutch Investments. Table 5 investigates whether historical amenities and historical public goods are statistically significantly different for Dutch versus non-Dutch pixels. Columns 1 to 4 examine distances to the 1821 Concert Hall, the 1829 Hotel des Indes, the 1932 Bioscoop Metropool, and the Akademi Nasional. These are all colonial landmarks that mark the areas with the most amenities and economic activity during colonial times. Column 5 considers the presence of artesian wells or pipes in the early 20th century. We find no significant differences, suggesting that our results are not driven by Dutch amenities or infrastructure.

Spatial Decay from Dutch Boundaries. As an additional test for economies of density, we consider spatial decay patterns. It is possible that Dutch locations attracted higher-

Table 5: Proximity to Historical Dutch Investments

Dependent: variable	Log distance to Concert Hall	Hotel	Metropool	University	Presence of Wells or Pipes
	(1)	(2)	(3)	(4)	(5)
Dutch	-0.02	0.01	-0.02	0.01	0.02
	(0.02)	(0.02)	(0.02)	(0.004)	(0.01)
N	10058	10783	11558	11984	10749
R-Squared	0.98	0.90	0.86	0.99	0.93
Control Group Mean	8.49	8.58	8.42	9.11	0.46

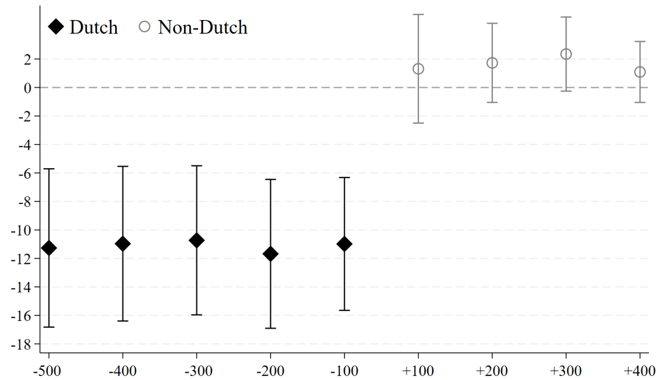
* 0.10 ** 0.05 *** 0.01

Notes: The dependent variables are log of distance to the 1821 Concert Hall, 1829 Hotel des Indes, 1932 Bioscoop Metropool (Jakarta's first cinema), and the university, Akademi Nasional (columns 1 through 4), and an indicator for the presence of 1920s wells or pipes within 1000 meters of a pixel (column 5). Standard errors are clustered by locality. All columns include locality fixed effects, boundary fixed effects, quadratic distance controls, and controls for topography. This table uses the optimal bandwidths for log distance to concert hall (509 m), hotel (553 m), Metropool (604 m), and university (632 m), and presence of wells or pipes (551 m).

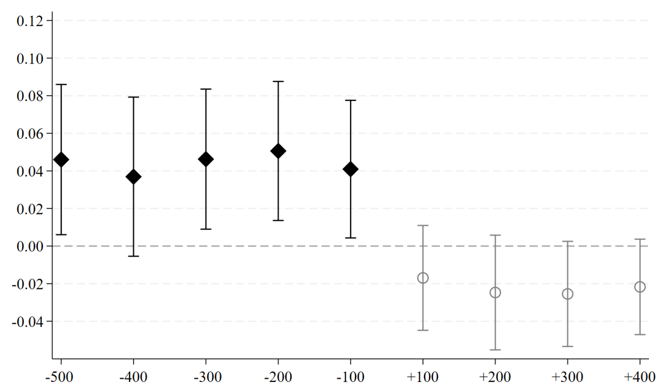
income households, leading to more gentrification and formalization. If this were the case, we would likely see spillovers from Dutch to non-Dutch pixels nearby, with more formality just outside Dutch boundaries. Along the same lines, non-Dutch pixels could be more likely to attract informal settlers, leading to crowding and negative congestion externalities, which could reduce formality in adjacent Dutch areas. Both sources of spatial spillovers would lead to a spatial decay pattern moving away from Dutch boundaries.

Figure 2 shows spatial decay plots that extend our BDD analysis to 500 meters and estimate effects for each 100-meter bin. The omitted group is the outermost bin outside the Dutch settlement. We do not find conclusive evidence of decay patterns.

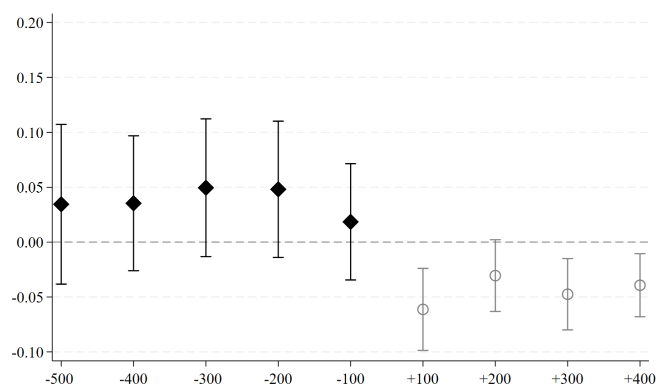
Figure 2: Spatial Decay: Distance from Dutch Boundaries



(a) Parcel Density



(b) Share Registered



(c) Photo Index

Notes: We employ a similar specification as our BDD analysis in Table 2, replacing distance to the Dutch boundary with dummies for different 100m-wide distance bins. The omitted group is the outermost distance bin outside Dutch settlements.

Historical Land Use. In Appendix Table A1, we compare Dutch settlements to different types of non-Dutch locations. From our historical maps, we observe whether non-Dutch locations were *kampung* settlements where the locals resided, orchards, rice fields, or empty land (the omitted group). To explore heterogeneity, we expand to a 500-meter boundary sample with 9,951 pixels within 500 meters of the Dutch boundaries (but more than 100 meters from the second closest boundary to avoid contamination).

Column 1 shows that Dutch pixels continue to have the lowest parcel density (-6.03) followed closely by orchards (-4.84). The Dutch coefficient is not statistically different from the coefficient for orchards. Next, we find a weak positive effect for rice fields (1.28) followed by the highest parcel density for kampungs (9.20). This pattern echoes historical accounts associating orchards with individual land rights and traditional rice farms with communal land use rights (Boys, 1892), and with kampungs being the least formal.

Next, column 2 shows the largest effect for registration status in Dutch settlements (4 percentage points) followed by orchards (3), statistically indistinguishable from each other. The estimates are close to 0 for rice fields. The estimates for the photo index (column 3) are noisier.

5.4 Natural Advantage

Finally, we consider natural advantage. Natural features (e.g. mountains or rivers) can have persistent value in attracting households and firms (Lee and Lin, 2018). We control for observable natural amenities through our controls and fixed effects. However, there could be unobserved sources of natural advantage.

Unobserved Selection. One threat to identification is that unobserved determinants of formality may also change discontinuously at the boundary. To quantify how large this potential bias can be, we follow Oster (2019) to produce two metrics. First, we infer how important unobserved factors have to be (relative to observed factors) to explain away our main estimates in Table 2. Second, we calculate a bias-corrected estimate of β_1, assuming observed and unobserved factors are equally important. Table A2 in the Appendix reports a parsimonious version of the specifications in Table 2, without locality fixed effects and without controls. We report these two metrics at the bottom of the table.

For parcel density, the parsimonious specification delivers an estimate of -13.46 and an R-squared of 0.18, relative to -11.05 for our preferred estimate (R-squared of 0.39). We calculate a ratio of 8.23, implying that unobserved factors have to be eight times more important than observed factors to explain away the estimated effect. We use the formula $\frac{\beta_C}{(\beta_U-\beta_C)} * \frac{R_C-R_U}{R_{Max}-R_C}$, where U denotes uncontrolled and C denotes controlled.[6] Intuitively, this ratio will be large if the Dutch effect is stable (first term), the R-squared improves a lot with controls (numerator of second term), or there is less remaining variation to explain (denominator of the ratio in the second term). We also report a bias-corrected estimate of β_1, where -9.71 assumes both observed and unobserved factors have equal importance. Our conclusions are similar for the other outcomes. For share registered, the ratio is 1.52 (above the heuristic threshold of 1 (Oster, 2019)) and the bias-corrected estimate is 0.01. For the photo index, the ratio is 3.37 and the bias-corrected estimate is 0.05.

Early versus Late Dutch Settlements. We further consider selection by the Dutch, comparing early versus late Dutch settlements. The Dutch first settled near the port in the North of Jakarta, then expanded to inner areas. In Figure 1, early Dutch settlements correspond to those in the North and Center of Jakarta, while the later settlements are in the South-West.

Interestingly, when we examine differences in the means of our outcomes, we do not find a pattern that suggests our effects are driven by unobserved quality due to Dutch sorting patterns. If this were the case, we would find greater formality in early versus late settlements, but we do not. In fact, parcel density is comparable (14.8 in early settlements, relative to 13.2 in later ones). The share of land that is registered and the photo index are, if anything, better in late settlements (0.88 and 0.94 registration share in early and late, respectively; 0.76 and 0.79 for the formality index in early and late, respectively). We are underpowered to conduct a formal regression test because only 6% of the boundary segments correspond to "late" settlements.

Taken together, our investigation of channels points to an important role of land market institutions, such as land registration, mapping, and planning.

[6] We calculate 8.23 from $\frac{-11.05}{(-13.46+11.05)} * \frac{0.39-0.18}{0.51-0.39}$. We assume $R_{Max} = 1.3R_C$ with $R_C = 0.39$ (Oster, 2019). It is unlikely that our outcomes will have a maximum R-squared of 1, given measurement error (Alesina et al., 2016).

6 Impacts on Urban Development

This section investigates whether Dutch settlements are associated with better urban development outcomes today.

Access to Modern Amenities. Panel A in Table 6 demonstrates that Dutch settlements have better access to modern amenities, as measured by distances to the closest school (-0.20), hospital (-0.11), police station (-0.6), and bus stop (-0.26).

Urban Form and Land Use. Panel B in Table 6 reports Dutch impacts for land use patterns. In columns 1 and 2 we find no difference in retail density and 5 percentage points higher office density. In Column 3 and 4 we consider building height (in number of floors), from our photographic sample, and assessed land values. Both are higher in Dutch areas today, but the effects are not significant.

Overall, these patterns are suggestive that Dutch settlements have more formal urban amenities today.

7 Robustness

We discuss additional robustness checks in this section.

Coinciding boundaries. Table A3 drops 14 boundaries that coincide with historical waterways and railways. The corresponding regression estimates for Table 2 are similar to our baseline ones: -12.08 for parcel density (relative to -11.05 in the main estimates), 5 percentage points for share registered (relative to 4 percentage points), and 0.08 for the photo index (relative to 0.07).

Construction of Dutch boundary segments. Table A4 implements an alternative approach to assign Dutch boundary fixed effects. Figure 1 shows that the sizes of Dutch polygons are uneven. As an alternative to including Dutch polygon fixed effects, we superimpose a fishnet of 1 squared km grid cells spanning Jakarta and use it to arbitrarily split the Dutch polygons into boundary segments. We then assign a unique boundary identifier to each line segment which we use for boundary segment fixed effects. We then recalculate the distance from each 75-meter pixel to the nearest and second nearest boundary segment and implement a BDD design comparing pixels within the optimal bandwidth from Dutch boundaries, dropping contaminated observations that are close to other segments.

There are now 98 boundary segment fixed effects. Reassuringly, our estimates are similar to those in Table 2.

Table 6: Effect of Dutch on Modern Urban Development

Panel A: Access to Modern Amenities

Dependent variable:	Log distance to			
	School	Hospital	Police	Bus stop
	(1)	(2)	(3)	(4)
Dutch	-0.20*	-0.11**	-0.06	-0.26***
	(0.10)	(0.05)	(0.05)	(0.08)
N	9585	8319	9440	9256
R-Squared	0.25	0.56	0.59	0.46
Control Group Mean	-1.42	-0.35	-0.16	-0.80

Panel B: Urban Form and Land Use

Dependent variable:	**Retail density**	**Office density**	**Nr. of floors**	**Land values**
	(1)	(2)	(3)	(4)
Dutch	-0.005	0.05***	0.03	0.12
	(0.01)	(0.02)	(0.83)	(0.09)
N	6420	8704	2764	2227
R-Squared	0.22	0.27	0.34	0.77
Control Group Mean	0.05	0.06	4.29	16.45

* 0.10 ** 0.05 *** 0.01

Notes: This table reports specifications similar to Table 2. Panel A reports pixel-level regressions where the dependent variables are log of distance to the nearest school, hospital, police station, and bus stop. The optimal bandwidths for these outcomes are, respectively, 478 m, 397 m, 464 m, and 434 m. In Panel B, column 1 and 2 consider the share of retail and office development within a pixel, for a sample with optimal bandwidths of 290 m and 424 m, respectively. Column 3 considers number of floors of the tallest building in a pixel, including strata fixed effects for our photographic sample and an indicator for pixels with no buildings, for a sample with optimal bandwidth of 407 m. Column 4 reports a sub-block level regression for the impacts on assessed land values, for optimal bandwidth of 661 m. All columns include locality fixed effects, boundary fixed effects, quadratic distance controls, and controls for topography. Standard errors are clustered by locality.

Conley standard errors. Table A5 replicates the analyses for the main outcomes in Table 2, allowing for spatial autocorrelation in standard errors over a range of distances, including 500 meters, 700 meters, and 900 meters (the implied radius of a locality). The p-values for the Dutch coefficient continue to be below conventional levels for statistical significance.

8 Conclusions

Land market institutions are central to the planning and functioning of cities. It is challenging to study the impact of institutions because they tend to vary across countries or cities. This paper makes progress using a boundary discontinuity design and a rich database of high-resolution outcomes within the city of Jakarta. We establish persistent impacts on formality and urban form in modern Jakarta when comparing Dutch versus non-Dutch settlements. Notably, Dutch locations have lower parcel density, are more likely to have registered parcels, and are more likely to be ranked formal per our photo index. We highlight an important role for institutions, including registration and regularity in the layout of parcels in Dutch settlements. We also show that the effects are unlikely to be explained away by differences in unobserved quality, spatial spillovers, or durable investments by the Dutch.

This paper focuses on the impact of historical Dutch settlements on land market formality and urban form in Jakarta. Directions for future research include shedding light on the bundle of property rights institutions and how different components influence urban development. It will also be important to explore broader avenues to enhance land market institutions and urban development, including titling programs, sites and services, and the role of urban planning and zoning regulations. As many cities in developing countries are characterized by a dual system of property rights, it would be interesting to study the evolution of these systems and how they shape the spatial distribution of economic activity in cities.

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Appendix Tables

Table A1: Heterogeneity by Historical Land Use

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
Sample:	BDD 500m	BDD 500m	BDD 500m
	(1)	(2)	(3)
Dutch	-6.03**	0.04	0.06
	(2.10)	(0.02)	(0.03)
Orchard	-4.84	0.03	-0.07
	(8.08)	(0.08)	(0.10)
Rice	1.28	0.00	0.02
	(1.51)	(0.02)	(0.03)
Kampung	9.20***	-0.02	-0.01
	(1.69)	(0.01)	(0.02)
N	9951	9951	3267
R-Squared	0.42	0.28	0.98
Control Group Mean	25.41	0.81	0.71

* 0.10 ** 0.05 *** 0.01

Notes: This table extends the BDD analysis in Table 2 to 500 meters and splits the non-Dutch areas to define mutually exclusive indicators for primary crop planted within each pixel (orchard or rice) versus historical kampung settlements. The omitted group is empty areas. All columns include locality fixed effects, boundary fixed effects, quadratic distance controls, and controls for topography. Standard errors are clustered by locality.

Table A2: Effect of Dutch on Formality, Parsimonious Specification

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
	(1)	(2)	(3)
Dutch	-13.46***	0.09***	0.11***
	(1.73)	(0.01)	(0.02)
N	6349	6187	2427
R-Squared	0.18	0.12	0.11
Control Group Mean	26.72	0.81	0.66
Delta	8.23	1.52	3.37
β_{adjusted}	-9.71	0.01	0.05
Topography	N	N	N
Locality FE	N	N	N
Boundary FE	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: This table is similar to Table 2 but drops controls and locality fixed effects. Standard errors are clustered by locality.

Table A3: Drop Boundaries Near Railways and Waterways

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
	(1)	(2)	(3)
Dutch	-12.08***	0.05**	0.08**
	(2.38)	(0.02)	(0.04)
N	5319	5158	1978
R-Squared	0.40	0.28	0.26
Control Group Mean	26.48	0.81	0.66

* 0.10 ** 0.05 *** 0.01

Notes: This table is similar to Table 2 but drops 14 boundaries overlapping with either historical railways or waterways. All columns include locality fixed effects, boundary fixed effects, quadratic distance controls, and controls for topography. Standard errors are clustered by locality.

Table A4: Alternative Construction of Dutch Boundary Segments

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
	(1)	(2)	(3)
Dutch	-11.54***	0.05**	0.06*
	(1.82)	(0.02)	(0.03)
N	6349	6187	2320
R-Squared	0.44	0.32	0.32
Control Group Mean	26.72	0.81	0.66

* 0.10 ** 0.05 *** 0.01
Notes: This table is similar to Table 2 but assigns observations to boundary segments using a 1 square-kilometer fishnet to subdivide Dutch polygons. The number of boundary fixed effects is 98 in all three columns. All columns include locality fixed effects, boundary fixed effects, quadratic distance controls, and controls for topography. Standard errors are clustered by locality.

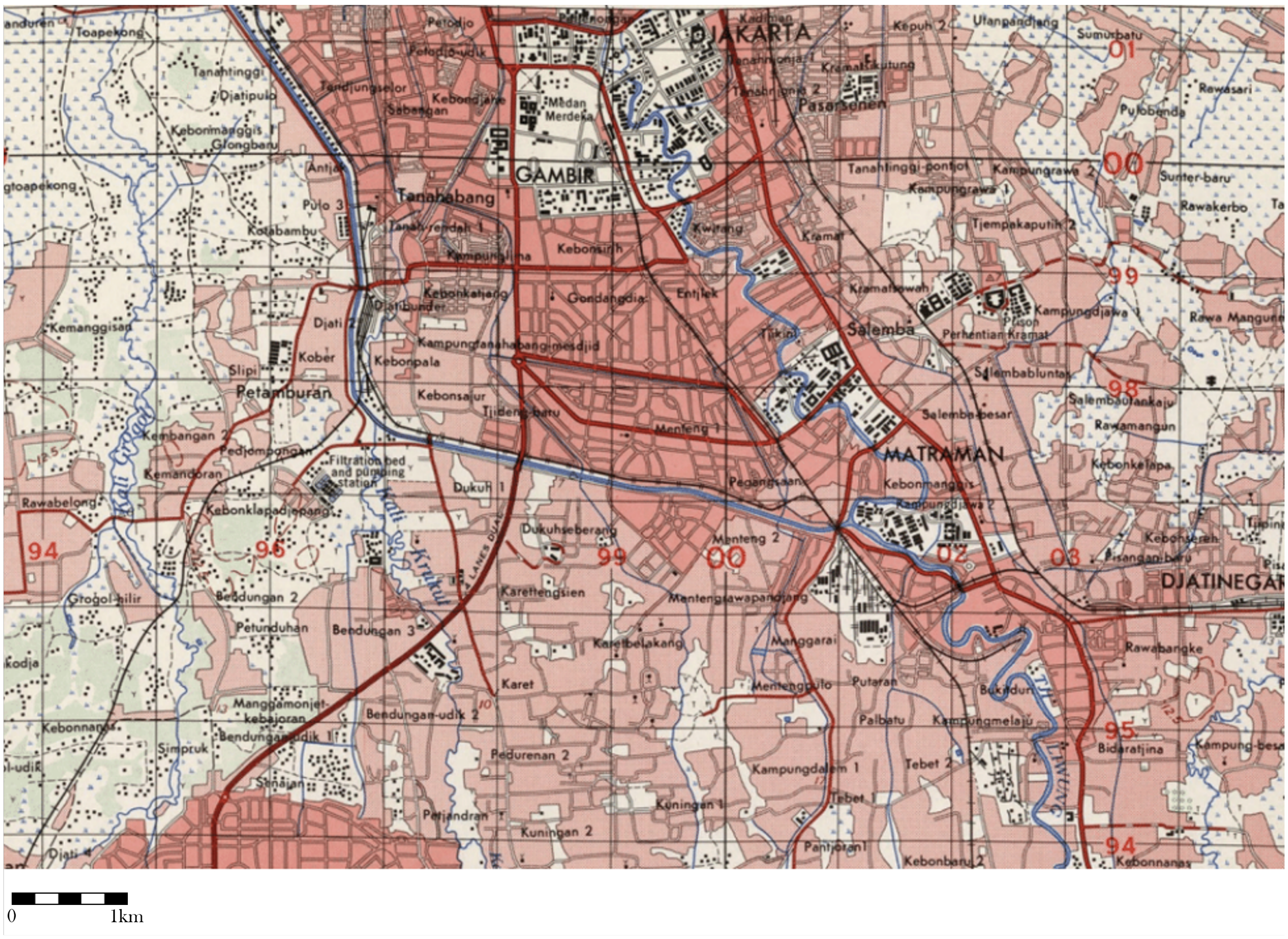
Table A5: Robustness to Spatial Correlation in Standard Errors

	P-values of ATE		
Dependent variable:	500m cutoff (1)	700m cutoff (2)	900m cutoff (3)
Parcel Density	0.00	0.00	0.00
Share Registered	0.03	0.03	0.04
Photo Index	0.01	0.00	0.00

* 0.10 ** 0.05 *** 0.01
Notes: We repeat the analysis in Table 2 allowing for spatial autocorrelation in standard errors (Conley, 1999). We consider correlation within 500, 700, and 900 meters, respectively. 900 meters corresponds to the implied radius of a locality (the spatial unit we use for clustered standard errors).

Appendix Figures

Figure A1: Example of One Historical Map of Jakarta



Notes: An example of a historical map (U.S. Army Map Service, 1959). The darkest red areas are Dutch settlements, the lighter areas are traditional *kampung* settlements. Other areas that are coded include rice farms (blue symbol of *padi*) and orchards (light green circles).