Spillovers in State Capacity Building: Evidence from the Digitization of Land Records in Pakistan*

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Abstract

Digitization reforms have been hailed as an effective way to strengthen state capacity. However, digitization can also disrupt the organization of bureaucracies. Using a unique administrative dataset on agricultural taxation and surveys of local bureaucrats from Punjab, Pakistan, we show that digitization reforms can have unintended consequences for state capacity. We exploit the staggered rollout of the digitization of land records in Punjab to show that digitization had a negative effect on tax collection. The fall in taxes was not due to a decrease in the tax base. Instead, digitization affected the bureaucracy's capacity to collect taxes. The paper thus sheds light on the importance of understanding state capacity development from an organisational perspective.

JEL codes: D73, H11, H71, O12, O17

Keywords: Digitization, property rights, taxation, bureaucratic agency, bureaucracy, civil service, corruption, Punjab, Pakistan

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1 Introduction

Strong state capacity is essential for economic development. An effective approach to strengthening it is to introduce technology in bureaucracies. In addition to easing market frictions (Beg, 2020), technology can improve the productivity of bureaucrats and address a range of asymmetric information issues. It has helped to reduce agency problems between bureaucrats and their principals (Duflo et al., 2012; Lewis-Faupel et al., 2016; Callen et al., 2020a; Dal Bó et al., 2021; Debnath et al., 2023), to improve the reliability of information on taxpayers (Ali et al., 2021; Okunogbe and Pouliquen, 2022; Brockmeyer and Sáenz Somarriba, 2022; Dzansi et al., 2022), or the identification of welfare recipients (Muralidharan et al., 2016a).

However, the introduction of technology can also disrupt the organization of bureaucracies. As public administration scholars have noted, digitization "reconfigures public sector organizations in fundamental, although uneven, ways" (Plesner et al., 2018). Technology can change the relationships between different bureaucratic agencies (Di Giulio and Vecchi, 2023) and increase specialization (Gundhus et al., 2022). This in turn can affect bureaucrats' sense of autonomy and their relationship with the public (Pors and Pallesen, 2021). While technology can lead to less corruption by reducing bureaucrat discretion (Muralidharan et al., 2016b), it can also result in the displacement of corruption onto other activities (Yang, 2008; Muralidharan et al., Forthcoming) or onto different individuals (Dzansi et al., 2022). Whether these changes are sufficiently disruptive to limit the benefits of digitization remains an open empirical question.

In this paper, we seek to understand whether the introduction of technology in bureaucracies can reduce their effectiveness and weaken state capacity. We study this question in the context of the digitization of land records in Punjab, Pakistan and show that the reform had a negative impact on the ability of the state to collect taxes. This negative relationship is not due to the effect of the digitization reform on the tax base but instead is due to its effect on the capacity of bureaucrats to collect taxes.

Digitizing land records has been a particularly popular way of leveraging technology to strengthen state capacity. From 2010 to 2019, fifty-two economies

computerized their land registries both in developing and developed countries, mobilising significant resources in the process.[1] These digitization reforms are particularly promising as they can strengthen property rights, encourage investment into productive activities (Field and Torero, 2006; Field, 2007; Beg, 2020; Chari et al., 2021), and in turn affect the capacity of the state to collect fiscal revenues (Besley and Persson, 2009, 2010, 2014a).

We exploit the staggered rollout of the digitization of land records across districts of Punjab. Since this reform was carried out in three phases between 2011 and 2014, we can use a difference-in-difference design to identify the causal effect of the digitization reform on the amount of tax collected by the state. We digitized a novel administrative data set of rural agricultural taxes and combine it with data on the rollout of the reform to test the effect of the reform on tax collection. We complement this data with satellite data on vegetation cover, survey data from local farmers, and unique data on the career trajectory of individual bureaucrats to separate the effect of the reform on the tax base from its effect on the bureaucrats' capacity to collect taxes.

We begin by documenting how the digitization reform affected the bureaucracy. First, bureaucrats who were in charge of tax assessment and collection and the management of land records before the reform were no longer responsible for land records after the reform. Second, a large portion of bureaucrats (46%) reported that digitization negatively impacted tax collection. Of those, 57% reported that this was due to lower influence on taxpayers. Finally, bureaucrats lost a lucrative source of bribes: the proportion of bureaucrats who agreed that citizens bribed officials for land titles dropped from 48% to 33% after digitization. This effect aligns with the broader trend observed in technology-driven reforms (Muralidharan et al., 2016b; Debnath et al., 2023).

We then show our main result: that this reform had a significant impact on the state's ability to collect taxes. Digitization of land records led to an 84% decrease in tax collection in districts in the first two phases of the program relative to those in the third phase, which were not yet digitized. The modernization of state

[1]Source: Doing Business Database, World Bank, https://subnational.doingbusiness.org/en/data/exploretopics/registering-property/good-practices.

capacity not only failed to translate into higher tax revenues for the state, it actually reduced them. These results are robust to using different definitions of the timing of digitization, to different assumptions about differential pre-treatment trends (Rambachan and Roth, 2023), and to using estimators that account for treatment effect heterogeneity in staggered difference-in-differences designs (Callaway and Sant'Anna, 2021; Sun and Abraham, 2021; Borusyak et al., Forthcoming).

A decrease in tax revenue does not necessarily indicate a decrease in fiscal capacity. It is possible that the tax base decreased while the ability to collect taxes remained unchanged. We show that this was not the case here. The tax we study is levied on farmers based on the maximum of the tax due on cultivated area and profits generated. We find that the reform had a positive, but not statistically significant, effect on vegetation cover and irrigated cultivated area and a large and significant positive effect on farm profits.

Instead, we show that the decrease in tax revenues is driven by a change in the bureaucrats' performance. The bureaucrats we surveyed reported that digitization led to a decrease in their influence over taxpayers, which they identified as having a negative effect on tax collection. They also identified corruption as one of the reason the reform hindered tax collection. We propose a simple model to formally capture how these two channels can affect fiscal revenues. The model highlights two mechanisms. First, by losing responsibility over land record management, bureaucrats lost leverage over taxpayers. Before the reform, tax collectors could offer to process land permits or resolve land disputes in exchange for tax payments. After the reform, this was no longer possible. The reform should therefore lead to lower tax collection as a fraction of tax demands if land issues were sufficiently important to farmers. Second, bureaucrats lost a lucrative source of bribe from land permits. If some of these bribes are instead exchanged against lower tax assessment after the reform, then this displacement can lead to lower tax demands and therefore lower tax revenues.

We find results consistent with this framework. Firstly, after digitization the district-level cultivated area reported by bureaucrats in digitized districts is lower than the cultivated area reported in non-digitized districts. This is despite the fact

that we find no significant decrease in the tax base using satellite and household survey data. Additionally, district-level tax demands issued by these bureaucrats were also lower in the digitized districts after digitization relative to non-digitized districts. Second, bureaucrats in the digitized districts collected 29.5 percentage points lower taxes as a percentage of tax demands after digitization. This corresponds to about 56% of the average tax collection performance in non-digitized districts. The proportion of bureaucrats collecting at least 50% of their target and the proportion collecting at least 75% both fell. We also find a positive but not statistically significant increase in the number of months in which zero taxes were collected. In sum, the digitization reform both led bureaucrats to issue lower tax demands and to collect a smaller portion of these demands.

Our results highlight a novel channel through which digitization reforms can affect state revenues: while these reforms can positively affect the tax base, they can also affect the interaction between bureaucrats and the local population and, as a result, reduce their performance. We find that the second effect can be sufficiently strong to generate an overall decline in tax collection.

These findings have important implications for the design of state capacity reforms. First, reforms to different dimensions of state capacity cannot be studied in isolation. In our context, digitizing land rights had a negative effect on fiscal capacity because it removed existing complementarities between tasks. In other contexts, reforms could harness these existing complementarities to increase the returns on investments in state capacity.

Second, investments in technology alone may not be sufficient to improve overall state capacity. In our context, technology did have a positive impact on the tax base and empowered the citizens, in line with the existing literature (Muralidharan et al., 2016b; Beg, 2020; Dzansi et al., 2022; Okunogbe and Pouliquen, 2022). However, technology also disrupted the relationship between the bureaucracy and its users, which reduced its ability to collect taxes. This suggests that the human and social dimensions of the bureaucracy are important and can be affected by investment in technology. Digitization reforms should therefore consider alternative means for bureaucrats to interact with citizens to maintain important social

connections, and the influence over citizens that comes with them.[2] They should also consider changes in human resources policies: if digitization reforms lead to corruption displacement, as in our context, then the reforms should be accompanied by a shift in corruption monitoring. More generally, anticipating how the reform will affect the behavior of bureaucrats could allow organisations to prevent these issues with the right incentive schemes.

Our results contribute to three strands of literature: the literature on digitization and development, the literature on state capacity and bureaucracies, and the literature on public finance in developing countries.

We contribute to the rapidly growing literature that examines the effects of digitization on economic development (Aker and Mbiti, 2010; Suri, 2017) by showing that digitization can have unintended consequences on state capacity. A strand of that literature has focused on the direct effect of technology on the productivity or accountability of bureaucrats and front line providers (Duflo et al., 2012; Lewis-Faupel et al., 2016; Callen et al., 2020a; Dal Bó et al., 2021; Muralidharan et al., 2021; Callen et al., 2023; Debnath et al., 2023; Barnwal, Forthcoming; Muralidharan et al., Forthcoming). Other studies have found beneficial effects of introducing technology on tax collection. The technology studied either helped improve tax filing (Okunogbe and Pouliquen, 2022) or VAT records (Ali et al., 2021; Brockmeyer and Sáenz Somarriba, 2022), helped identifying taxpayers and welfare recipients (Muralidharan et al., 2016a), or helped tax collectors geo-locate taxpayers (Dzansi et al., 2022). Our work is most closely related to the studies that highlight the importance of organizational or management practices in the success of technological reforms (Milgrom and Roberts, 1990; Banerjee et al., 2008). Garicano and Heaton (2010) show that the introduction of IT systems in police stations only resulted in higher productivity when coupled with other organizational changes such as resource allocation and management practices. Our results are consistent with a similar 'complementarity' hypothesis: fiscal capacity can suffer from digitizing land rights if no further organizational changes are introduced.

We contribute to the literature on state capacity building (Besley and Persson,

[2]See Ashraf and Bandiera (2018) for a review of the importance of social connections at work.

2009, 2010; Bardhan, 2016) by presenting micro evidence on the negative spillover effects of an improvement in property rights on tax collection. Because the reform we study reduced the scope of the bureaucrats' work, our paper is most closely related to studies focusing on task design, particularly multitasking in public organizations (Holmstrom and Milgrom, 1991; Dewatripont et al., 1999a; Rasul and Rogger, 2018; Chen et al., 2018). We contribute to that literature by showing that reducing the number of tasks can reduce the performance of bureaucrats. Contrary to the existing literature, we also show that changes in the scope of tasks do not just affect the relationship between bureaucrats and their supervisor (Dewatripont et al., 1999b), but also between bureaucrats and the population. Our paper therefore also contributes to understanding how the "embeddedness of the bureaucrat" - the social connections of the bureaucrats with the local population - affects the functions of the state.[3] Together, these results contribute to a growing literature on the organizational economics of the state that highlights organization design as a determinant of state capacity building (Vannutelli, 2022).[4]

Finally, we also contribute to the large literature on public finance in developing countries that seeks to identify the obstacles that developing countries face in collecting taxes (Besley and Persson, 2014b; Gadenne and Singhal, 2014). This literature has identified issues with tax enforcement, either due to lack of formal records (Pomeranz, 2015; Okunogbe et al., 2021; Jensen, 2022), the choice of tax rates or the design of the tax code (Best et al., 2015; Brockmeyer et al., 2021; Bergeron et al., Forthcoming; Basri et al., 2021), corruption (Le et al., 2020), and citizens' misreporting or their lack of trust in the state (Carrillo et al., 2017; Naritomi, 2019; Besley and Dray, 2022). Our work is most closely related to papers that highlight

[3]Frequent interactions between bureaucrats and citizens can reduce transaction costs and increase trust (Pepinsky et al., 2017), increase the flow of information and influence of the bureaucrat (Evans, 1995; Bhavnani and Lee, 2018), and allow communities to hold bureaucrats to account through informal means (Tsai, 2007).

[4]Several studies show that the incentives of bureaucrats matter for public service delivery. These can be in the form of explicit incentive schemes (Khan et al., 2016, 2019), career concerns (Bertrand et al., 2020), monitoring (Callen et al., 2013), or autonomy in decision making (Rasul and Rogger, 2018; Duflo et al., 2018; Bandiera et al., 2021). Others show that the selection of bureaucrats is an important determinant of state effectiveness (Callen et al., 2020b), where selection can be affected either at the recruitment stage (Dal Bó et al., 2013; Bai and Jia, 2016; Deserranno, 2019; Ashraf et al., 2020; Colonnelli et al., 2020; Moreira and Pérez, 2022), or through the assignment of bureaucrats across jobs or promotions (Iyer and Mani, 2012; Jia et al., 2015; Bergeron et al., 2022; Best et al., 2023; Aman-Rana, 2023).

the incentives and the ability of tax collectors as important determinants of fiscal capacity (Khan et al., 2016, 2019; Bergeron et al., Forthcoming, 2022). We contribute to this literature by showing that introducing technology through piecemeal state capacity building can have unintended consequences for fiscal capacity because of its effect on tax collectors.

2 Background and data

2.1 Background

Agricultural Income Tax. We focus on the collection of a tax, the Agricultural Income Tax (AIT), which is levied on landowners in rural areas of the province of Punjab. This tax is one of the main sources of revenues to the government from agriculture. The amount of tax due is based on either the area of cultivated land or the profits of the farm. Specifically, farmers owe whichever of the cultivated area-based tax and the profit-based tax is largest (*Punjab Agricultural Income Tax Act*, 1997, section 3.4). When land is rented out by landowners to farmers, the landowner is liable for the tax (*Punjab Agricultural Income Tax Act*, 1997, sections 2.1 and 3.1).

The cultivated area-based tax is progressive and varies based on factors such as the size of the cultivated area, whether it is irrigated, and whether it is an orchard. The tax ranges from 300 to 600 PKR per acre, with irrigated areas and orchards subject to a higher tax rate (*Punjab Agricultural Income Tax Act*, 1997, section 3.1). The profit-based tax is also progressive and starts with a flat amount of 1,000 PKR for the first tranche (profits between 400,000 and 800,000 PKR), progressively increasing to 300,000 PKR plus 15% of the amount of profits exceeding 48,00,000 PKR (*Punjab Agricultural Income Tax Act*, 1997, section 3.3).[5] In practice, due to the difficulty of measuring income, the profit-based tax is restricted to large landowners who own more than 50 acres of land, which only applies to 12% of farms (The Agricultural Census, 2010).

[5]Income below 400,000 PKR is exempt.

The tax is collected by a team of local bureaucrats called *revenue officers*. Each team covers a jurisdiction comprising 2 to 3 villages called a *revenue circle*. The taxable amount in a fiscal year, which runs from the 1st of July to 30th of June the following year, is assessed by the same bureaucrats who collect the tax. At the start of a fiscal year, bureaucrats assess whether an agricultural land has been cultivated and also note its characteristics (irrigated or not, type of crops) during crop inspections (*Girdawari*). This is done in order to calculate the cultivated area-based tax which varies based on these characteristics. Once tax is assessed, the bureaucrats issue tax demands around November and collect taxes over the remaining course of the fiscal year.[6] Income-based tax is calculated using self-reported profits.[7]

Bureaucrats do not receive any performance-based compensation for tax assessment or tax collection. Senior officials in the revenue department are required to oversee crop inspections conducted by junior officials (the unit of analysis in this paper) and are expected to conduct random checks on a minimum of 25% of the land under their jurisdiction. In cases where a junior official is found to be under performing, they may face suspension from their position.[8] In the case of tax collection, managers monitor the progress of the team. Similar disciplinary action can be taken if the official systematically fails to collect enough taxes. The bureaucrats' promotions are based on tenure in the bureaucracy according to a pre-determined schedule. However, senior officials and politicians can informally influence the timing of promotions to allow high-performing bureaucrats to be fast-tracked. As in other bureaucracies (Iyer and Mani, 2012; Khan et al., 2019), transfers of bureaucrats across different revenue circles serve as an additional means of recognizing and incentivizing performance. These mechanisms introduce some potential career incentives for bureaucrats to achieve a high performance.

[6]Bureaucrats are expected to carry out two crop inspections: during the fall (*Kharif*) and spring (*Rabi*) cropping season. In principle, taxes should be levied separately based on the two cropping seasons. However, in practice, tax demand for the entire year is created for each landowner based on the first cropping season. Bureaucrats do this to allow themselves enough time to collect taxes by the end of the fiscal year. A community representative (*Lambardar*) helps coordinate tax collection and works closely with the bureaucrats on tax collection.

[7]Landowners are expected to file their tax returns by the end of December for the respective fiscal year.

[8]A suspension does not involve a wage cut but the removal of the revenue official from the job and its associated perks.

Digitization of land records. In 2005, the government of Punjab began a reform of the land record management system to digitize the records with the support of the World Bank. The main objective of the reform was to increase the reliability and the transparency of a system that was prone to errors and corruption.

The government planned to rollout the digitization program in three phases. In each phase, 10-12 districts were selected to be digitized. This staggered design was driven by the financial difficulty of rolling out a reform of this size across the whole province at once. Figure 1 shows that there were no statistically significant differences in baseline characteristics between districts digitized in the first two phases of the rollout and those digitized in the last phase.[9] This lends support to the use of the *planned* rollout of digitization reform as an exogenous source of variation in the digitization of land records. The initial schedule was to roll out the digitized system in 2009 for phase 1, 2010 for phase 2, and 2011 for phase 3. The actual roll out was delayed and Figure 2 shows the proportion of villages that were digitized in each phase over time. We use the actual dates of the start of the roll out in each phase in our estimation, as discussed in the next section.

The reform had two effects. First, it secured property rights and decreased disputes between landowners.[10] Second, it changed the type of tasks carried out by the local bureaucrats that we study. Prior to the digitization reform, bureaucrats were responsible for recording sales or exchanges of land and properties and for issuing land titles, as well as for assessing and collecting taxes, as described above.

The main effect of the reform on the bureaucrats was to relieve them of one of their duties, namely, managing land records. The reform therefore affected both the set of tasks they carried out and their interactions with the local population. Overall, 69% of bureaucrats reported that the reform changed their tasks, of which 75% said that some tasks were removed but 59% indicated that some tasks were also added (see Figure C.1 in appendix). The tasks added were mostly about

[9] Figure C.8 in appendix shows a similar balance test but splits digitized districts into phase 1 and 2 districts. We can see that phase 1 districts were statistically significantly smaller in population size and have less factories. This suggests that the government planned to start out the program in smaller less developed districts, but did not otherwise select districts in systematic ways.

[10] Beg (2020) shows that the reform led to an improvement in the security of property rights and resulted in the re-allocation of land to more productive farmers and, in turn, increased profits of farmers.

record correction and additional paper work, which was part of the transition from manual to digitized land records (see Figure C.2 in appendix). Therefore, the new tasks were mostly relevant in the short-term. On net, the number of hours worked reported by the bureaucrats did not increase. Figure 3 shows that 72% of bureaucrats reported no change in hours worked, 4% reported a decrease, and 24% reported an increase. This suggests that the majority of bureaucrats either used the time freed up from land records to work on other tasks or simply worked less after the reform. Our survey data further confirms that the net reported decrease in hours is not significantly different from the net reported increase (see Figure 4) .

The bureaucrats also reported two interesting changes following the reform. First, they indicated that digitization negatively affected their ability to collect taxes (Figure 5). The main reason cited for this is a loss of influence over taxpayers as shown in Figure 6. Second, the bureaucrats lost an important source of bribe income. Obtaining bribes or 'tips' in exchange for a speedy processing of land records was common before the reform. In a survey of households carried out before the reform, 82% of respondents indicated that the way to "remedy the problems faced in accessing land records" was to give a bribe, and 65% reported that they could not access land record services without unofficial payments (Gallup, 2009). Because the bureaucrats no longer had control over the land record process, they lost this lucrative source of bribe. Figure 7 shows that 48% of bureaucrats agreed that citizens want to tip to get land titles in revenue circles before digitization compared to 33% in revenue circles after digitizion.

2.2 Data sources and key variables

Digitization rollout. The data on digitization includes both the planned and actual rollout of the digitization reform. We obtained data on the planned rollout of the program from the Land Record Management Information System (LRMIS) project office in Lahore. This data indicates which districts were intended to be digitized in phase 1, 2 or 3 of the program. We obtained data on the actual progress of the digitization program from the Punjab Land Records Authority (PLRA) in February 2018. This data describes the digitization status for each revenue circle:

whether and on which date the land records for each of the villages in the revenue circle have been digitized.

We define a *phase* as the set of districts that were intended to be digitized at the same time as each other in the rollout plan. We consider a phase as being *digitized* in a given year if at least 5% of villages in that set of districts have been digitized by that year.[11] This allows us to define our treatment variable, 'digitization of land records' as a dummy variable that takes value 1 in a district and year if the district belongs to a phase that has been digitized by that year. Based on this definition, the treatment years are defined as follows: Phase 1 is treated in fiscal year 2012, phase 2 in fiscal year 2013, and phase 3 in fiscal year 2014. In Appendix Table B.4, we show that our results are robust to using alternative thresholds of proportion of villages than 5% to define a phase as digitized.

Agricultural tax collection. We carried out a large-scale data digitization exercise of the agricultural tax collection records of the Board of Revenue (BOR), the agency in charge of tax collection (see Appendix D for the record room and the proforma on which this information is collected). The data contains both the total amount of taxes collected (combining cultivated area-based tax and income-based tax) and the total tax demands issued to taxpayers, at the revenue circle level.[12] The latter is based on the tax assessment carried out by the bureaucrat and serves as the target amount of taxes that bureaucrats aim to collect.

The records have monthly information at the revenue circle level from 2006-2013 (28,572 revenue circle-months).[13] We aggregate the taxation data at the

[11] We combine the planned rollout (for the definition of phases) and the actual rollout (for the definition of dates) for two reasons. First, because the actual rollout was significantly delayed relative to the plan. Second, the delays in the rollout can depend on characteristics of the district and therefore be endogenous. We therefore use the planned set of districts to reduce these concerns.

[12] Tax collection is available for both the ongoing fiscal year, as well as arrears from past years. We only use the current year's tax collection, as that record is most up-to-date. The data also contains information on remissions, suspensions and notifications of irrecoverable tax, but those are rare events in the data.

[13] This data is an unbalanced panel of revenue-circles and months since some of the tax files were destroyed in flooding of the archives. To ensure that the data is representative at a district level, we created inverse probability-weighted sums. For each time period, the weights are calculated based on the number of revenue circles for which we have data, relative to the total set of revenue circles in a Tehsil and district. Due to the presence of outliers, we dropped a revenue circle-fiscal year if the annual tax targets were at least two standard deviations or higher for that revenue circle. This

district-year level.[14] The resulting data is a balanced panel of tax collection in 212 districts-fiscal years. This data forms the basis of the main analysis.

Actual tax base. To evaluate the effect of the reform on the tax base (cultivated area or farm income), we rely on three sources of data. First, we compiled satellite data on the vegetation cover of the area we study to measure cultivated area. Specifically, we use the Normalized Difference Vegetation Index (NDVI) (see Appendix G for details), a commonly-used proxy for crop yield in developing countries (Rasmussen, 1992; Vrieling et al., 2011; Beg, 2020) which allows meaningful comparisons of year-on-year changes in vegetation growth (Huete et al., 2002).

We complement the satellite data with survey data from the Pakistan Living Standards Measurement Survey (PSLM) which includes questions on agricultural land owned (in acres) and agricultural land irrigated from a repeated cross-section of households across Punjab.[15] We use the 2006, 2008, 2010 and 2012 waves of this survey. The data is representative at the district level.

Finally, we use Household Income and Expenditure Surveys (HIES) data from Beg (2020) to investigate the effects of digitization on agricultural profits, the other possible element of the tax base. This data collects demographics, employment, expenditure, and saving information from a repeated cross-section of households across rural areas in districts of Punjab. We use the 2005, 2007, 2011, and 2013 waves of the survey and, as in Beg (2020), restrict attention to the farm level data provided by cultivating households.

Tax base reported by bureaucrats. While we cannot directly observe tax demands issued by bureaucrats to each taxpayer, we can observe two aggregate measures of the tax base assessed by bureaucrats. First, we use data compiled by the Directorate of Agriculture (Economics and Marketing) of Punjab who used the

resulted in a drop of 65 revenue circle-fiscal years out of 3,492 (1.9%) and one observation at the district-fiscal year level out of 220 (0.5%).

[14] We aggregate the monthly data at the year level since tax assessments are issued annually and the monthly tax collection data is therefore noisier.

[15] We restrict the analysis to rural households in PSLM as we are interested in agricultural outcomes.

cultivated area reported by the bureaucrats we study to report average cultivation across districts for 2007-2013.[16] Second, we use the administrative data on the assessment of cultivated area made by the bureaucrats at the revenue circle-fiscal year level, which we aggregate at the district-fiscal year level to ensure comparability with the first measure.

Bureaucrat career history and performance. For the last part of our analysis, we complement the administrative tax collection data with a retrospective survey of the bureaucrats involved in tax collection around the time of the reform.[17] This survey gives us the career history of the bureaucrats across different revenue circles and their perception of the reform, its effects on tax collection, and how the reform affected their interactions with superiors and with the population.

We carried out a string matching exercise to merge the tax, digitization, and bureaucrats' careers datasets as there were no unique revenue circle identifiers in any of these datasets. Merging the tax and digitization data with the bureaucrats' career data allows us to identify the tax performance of a bureaucrat and whether they worked in a revenue circle that was digitized at any given point in time.[18][19] The data, therefore, exploits within-bureaucrat variation in different districts (digitized and manual) over time, allowing us to study the bureaucrats' performance while controlling for bureaucrat specific unobserved heterogeneity.

[16]This data is available at http://www.amis.pk/Agristatistics/DistrictWise/DistrictWiseData.aspx. There is no data available for the year 2006.

[17]The survey was first carried out in person in September 2020. We carried out a separate telephonic survey focusing on the bureaucrats' career histories in November 2020. Appendix E describes the details of the sampling methodology. For a random subset of the data, we confirm the accuracy of the responses by comparing them to official records of bureaucratic transfers. The bureaucrats recall of their careers was consistent with the administrative data.

[18]Bureaucrats do not move across districts (see Appendix figure C.4).

[19]Appendix F describes how we string-matched the tax and bureaucrats' survey data to create a panel of bureaucrats-revenue circles-fiscal year and how we matched the tax and digitization data. In summary, we string-matched the two data sets using revenue circle, Tehsil and district names and cleaned them manually. This data was further verified through other government documents from the relevant local offices.

3 Did the digitization reform affect tax collection?

We now turn to testing our main question: how did the digitization reform affect tax collection?

3.1 Identification strategy

There are several difficulties in measuring the effect of digitization reforms on fiscal capacity. Policy makers could introduce digitization reforms at times where bureaucracies are underperforming due to structural issues. Alternatively, some districts might be targeted for the implementation of the reform because bureaucrats in these districts face difficulties collecting taxes and need technological support in other tasks.

Our differences-in-differences strategy helps us to address these concerns. Since the actual rollout of the reform across districts could depend on time-varying district characteristics which correlate with tax collection, we exploit the *planned* rollout of the digitization reform.[20] Throughout the paper we present intent-to-treat analysis, which estimates the average return to "as-is" implementation of the digitization reform following the "intent" to implement the new digitized land record system. These estimates reflect the impact of the the government's decision to digitize land records net of the logistical and political economy challenges of implementing this project in practice. This is the relevant policy parameter.

Our strategy compares the difference in tax collection before and after digitization between districts where digitization was planned to be introduced and those where land records remained manual. The identification assumption motivating this estimation strategy is that early digitized districts and later digitized districts have parallel trends: districts in phases 1 and 2 of the reform would have experienced, on average, the same changes in tax collection over time as those in phase 3, were it not for the digitization of their land records.

[20] Figure 2 shows the cumulative proportion of villages digitized by month in each set of districts and appendix Table B.1 shows the correlation of our digitization variables with the number of villages that have been actually digitized land records. Being in a planned digitized district results in 173 more villages with digitized land records than being in a phase 3 district,indicating a strong effect of the plan on the actual roll-out.

Event Study. Following the existing literature, we assess the evidence in support of the parallel trends assumption using an event-study plot prior to conducting the main analysis. Specifically, for district d and fiscal year t between 2006-2013, we estimate the following regression:

$$y_{dt} = \alpha_d + \alpha_t + \sum_{k=-6}^{k=2} \rho_k D_{k(dt)} + \epsilon_{dt} \tag{1}$$

where y_{dt} is the inverse hyperbolic sine (arcsinh) of the total tax collected in district d, during fiscal year t, that is, $y_{dt} = \ln(tax_{dt} + \sqrt{1 + (tax_{dt})^2})$, α_d are district fixed effects, α_t are fiscal year fixed effects, and $D_{k(dt)}$ is a set of indicator variables that takes value one if district d in fiscal year t was k years away from being digitized. The error terms are clustered at the district level as that is the level of the treatment (Abadie et al., 2023). The coefficients ρ_k estimate the effect of being treated k years before and after digitization. The omitted time period is the one right before the digitization year. If ρ_k is statistically insignificant for all the years before treatment, then this lends support to the validity of the parallel trends assumption.

We use the inverse hyperbolic sine (arcsinh) transformation for both the event study and our main specification below, because our dependent variable follows a right-skewed distribution. We are less concerned about the variable having a large probability mass at zero (another common reason for using this transformation, see Chen and Roth (2023)): the proportion of observations with zeros is just 5% (11 out of 212 district-year observations). Treatment effect estimates using arcsinh transformations are sensitive to changes in the units of the outcome (De Brauw and Herskowitz, 2021; Aihounton and Henningsen, 2021).[21] In Appendix Table B.3, we present separate estimates for the extensive and intensive margin effects, as suggested in Chen and Roth (2023). Our results are mainly driven by the intensive margin effect. The extensive margin effect is very small and statistically insignificant. We also show that our main results are comparable when running

[21]The problems identified with log-like transformations are more prominent when there is a large probability mass at zero and the extensive margin effect is prominent (Mullahy and Norton, 2022; Chen and Roth, 2023).

a median regression and when the outcome variable is expressed in levels in thousands of rupees.

Figure 8 plots ρ_k for each period k and their corresponding 95% confidence intervals.[22] Two-way fixed effects (TWFE) regressions have been shown to deliver consistent estimates only under relatively strong assumptions about homogeneity in treatment effects (Goodman-Bacon, 2021). We therefore also plot coefficients generated from recently-proposed estimators that are robust to treatment effect heterogeneity (Borusyak et al., Forthcoming; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021). The results presented in Figure 8 are robust to treatment effect heterogeneity[23] and provide support to the parallel trend assumption: irrespective of the estimator used, the coefficients for the years preceding the digitization reform are near zero and do not exhibit any significant pre-trends.

3.2 Estimation and results

To obtain the causal effect of digitization on tax collection, we use a staggered difference-in-differences estimation by running the following regression at the district-year level:

$$y_{dt} = \eta_d + \eta_t + \beta \text{Digitization}_{dt} + \varepsilon_{dt} \tag{2}$$

Our outcome variable, y_{dt} is the inverse hyperbolic sine (IHS) of the total tax collected in district d during fiscal year t, in thousand of Rupees. That is, $y_{dt} = \ln\left(tax_{dt} + \sqrt{1 + (tax_{dt})^2}\right)$. Our treatment variable, Digitization_{dt}, is a dummy that takes the value of one if a district d belongs to a phase that has been digitized by year t.[24] Finally, η_d and η_t are district and fiscal year fixed effects, respectively.

[22] Phase 1 districts were digitized in FY2012 while phase 2 districts were digitized in FY2013. Therefore, we can estimate the effects of digitization for two years after the reform (2012-2013) for districts in phase 1, but only for one year after digitization (2013) for districts in phase 2. The control districts are phase 3 districts which were digitized starting from FY2014.

[23] Appendix Table B.5 replicates Equation 2 using only the never-treated phase 3 districts as the control group. This avoids the 2 × 2 difference-in-differences comparisons between newly treated and already treated units and gives consistent estimates even in the presence of heterogeneous treatment effects across time or treated units. The results show that the effects are of similar magnitude to the main results (see Table 1) and significant at conventional levels when comparing the digitization phases separately.

[24] Recall from Section 2.2 that we define a phase as digitized in a given year if at least 5% of villages located in districts belonging to that phase have been digitized by that year.

Standard errors are clustered at the district level as that is the level of the treatment (Abadie et al., 2023). To account for the number of clusters[25], we also report *Wild* clustered bootstrapped p-values, with 10,000 replications (Cameron and Miller, 2015) throughout the analysis .

Table 1 shows our main result: the digitization reform led to an 84% decrease in tax collection relative to districts that were not digitized.[26] Instead of increasing fiscal revenues, the modernization of state capacity therefore caused a large and statistically significant decrease in tax collection.

The decrease in tax collection due to the digitization reform is substantial. Even when measured in Rupee terms, the decrease of 8,053,000 Rupees following the reform in phase 1 and 2 districts relative to phase 3 ones represents a 49% decrease relative to the mean of tax collection before digitization (see Appendix Table B.3). The magnitudes of these effects is in line with other findings in the literature. For instance, Okunogbe and Pouliquen (2022) find that corporate tax payments decreased by 40% following the introduction of electronic filings among firms classified as presenting a lower risk of tax avoidance.[27] Knebelmann et al. (2023) find that the tax base for property tax is 83% lower when the assessment is carried out at the discretion of bureaucrats relative to when it follows an algorithm. The magnitude of the decrease should also be assessed in the context of the tax we study. Given that there can be a lot of variations in agricultural tax collection, the decrease of 8,053,000 Rupees represents 40% of the historical standard deviation in tax collection prior to the reform.[28]

Finally, the decrease in tax collected can have important economic consequences. While the tax that we study is not the largest source of revenue for the government, the loss of 8,053,000 Rupees due to the reform still represents a significant shortfall. Extrapolated across all 36 districts, the amount of lost taxes could have funded cash transfers for an additional 15,428 families on the

[25]There are 36 districts in Punjab.

[26]The percentage change is approximated as usual by $\exp(\hat{\beta}) - 1 = \exp(-1.826) - 1 = -0.839$.

[27]The decrease they measure, however, is not statistically different from zero at conventional levels. The intuition they suggest for this result is that these firms used to pay more in the physical presence of the tax collector.

[28]The standard deviation of our outcome variable, tax collection, across all districts between FY2006 and FY2011 is 20,124,000 Rupees.

government's main social welfare program (Benazir Income Support Programme (BISP)).[29]

This decrease in tax collection could be due to two reasons. First, the tax base (the cultivated area and the farmers' profits) could have decreased as a result of digitization. Second, digitization could have decreased the bureaucrats' capacity to collect taxes. Before turning to these mechanisms in the next section, we discuss a number of robustness tests we carried out.

3.2.1 Robustness

Robustness using the "more credible approach". Instead of requiring that parallel trends hold exactly, we investigate the robustness of our results to alternative assumptions about differences in trends in tax collection between digitized and non-digitized districts. We follow Rambachan and Roth (2023) and use the "more credible approach" to parallel trends. They suggest that restrictions on the possible violations of parallel trends depend on the economic context. To determine these restrictions, we use pre-digitization data to create a linear trend that is extrapolated to post-digitization (see Appendix Figure C.9). Since the coefficients are close to the linear trend in the pre-treatment period, we impose that the differential trends evolve smoothly over time by bounding the extent to which its slope may change across consecutive periods. We therefore use the following formula suggested by Rambachan and Roth (2023):

$$\Delta^{SD} := \{\delta_t : |(\delta_{t+1} - \delta_t) - (\delta_t - \delta_{t-1})| \leq M, \forall t\}$$

where δ_t refers to the difference in trends between the districts with digitized and manual land records at time t. M governs the amount by which the slope of δ can change between consecutive periods. If M=0 the difference in trends between digitized and manual districts would be exactly linear, while $M > 0$ relaxes the assumption of exact linearity.

[29] The annual transfer for families eligible to the BISP was 18,792 Rupees in 2015 (Cheema et al., 2016). The loss of 289,922,000 Rupees (8,053,000 Rupees multiplied by 36 districts) would therefore cover $\frac{289,922}{18,792} = 15,428$ famillies.

The results are summarized in Figure 9. This figure shows that the main results remain robust up to a value of M=0.14. To benchmark this upper bound on the parameter M, we follow the methodology in Dustmann et al. (2021) and Aman-Rana et al. (2023b). We compare the parameter M with the absolute deviations of the coefficient ρ (see Equation 1) from the linear trend in pre-treatment periods. The median value of that deviation is M=0.17 and the 45^{th} percentile is M= 0.07. Our results therefore remain robust to a deviation from a linear trend as large as the 45^{th} percentile of the pre-treatment deviations from the linear trend.

Bureaucrat transfers across districts. One might worry that the digitization reform drove bureaucrats to move out of digitized districts to non-digitized ones or vice versa. These transfers could explain the decrease in tax collection if bureaucrats that were systematically collecting less taxes were relocating to digitized districts or bureaucrats collecting more taxes to non-digitized ones. While such transfers are not allowed by law, we also verify that this was indeed the case by using our data on careers of the bureaucrats. This data confirms that only 2 out of the 118 bureaucrats have ever been posted outside the districts where they started their careers (see Figure C.4 in appendix). The situation was similar for their subordinates: only 2 out of 440 subordinates were ever transferred out of their original districts. We also rule out that transfers at higher levels in the hierarchy could have driven the results by systematically changing how these bureaucrats were managed. We show in Table B.8 in appendix that our results remain robust when controlling for the proportion of the bureaucrats' managers in each district whose ability was above median.[30] Together, these results indicate that such spillovers do not threaten our identification strategy.

Anticipation effects. Another concern is that either the bureaucrats or the citizens could have anticipated the digitization reform and changed their behavior as a result. These anticipation effects could bias our results if they systematically

[30]We measured ability using four incentivized measures. The first two were incentivized ability tests based on Hanna and Wang (2017). These included a cognitive ability matrix test and a digit span memory test. The third and fourth measures were based on their general knowledge and knowledge of rules and laws related to their jobs as revenue officials.

impact tax collection more in phases 1 and 2 districts relative to phase 3 districts. Appendix Table B.6 uses two alternative definitions of the timing of digitization as a placebo test. In Column (1) the digitization reform is defined as starting in 2006 for phase 1 districts and 2007 for phase 2 districts, while in Column (2) these timings are defined as 2009 and 2010, respectively. In both Columns we can see that there are no statistically significant effects, (*Wild* clustered bootstrapped p-value is 0.79 and 0.59). The magnitudes of the effects are also much smaller than the main effects in Table 1.

Randomization-based inference tests. Finally, in Appendix Table B.7 we replicate Table 1, but report the p-values from permutation test similar to the randomization based inference test (Athey and Imbens, 2017; Young, 2019). This tests whether the effects of digitization are simply due to chance owing to the selection of districts that were assigned to be digitized in phase 1 and 2 relative to phase 3. We re-assign digitization over districts 10,000 times and compute the estimates under the null hypothesis that the reform has no effect. We then locate the point estimates coming from our real data in the distribution of the 10,000 treatment assignment simulations. The p-value we report at the bottom of the table comes from the share of estimates from the 10,000 reassignments based on simulations that are higher in absolute value than our point estimates in Table 1. The p-value is 0.021, increasing confidence in our main analysis.

4 Why did tax collection decline?

We now turn to investigating two possible channels behind the decrease in tax collection: that the tax base decreased and that the capacity of bureaucrats to collect tax decreased. Our analysis suggests that the effect is more likely to come from the bureaucrat's performance.

4.1 Changes in the tax base

The tax collected by bureaucrats is based on two measures: the area cultivated by farmers and the profits of the farmers, as described in Section 2. The amount of tax due is calculated based on the maximum of the tax due on cultivated area and the tax due on profit.

The digitization reform could have directly impacted both of these dimensions of the tax base. As digitization makes property rights more secure and transparent, it can lead farmers to start cultivating plots of lands whose ownership was previously disputed or encourage landowners to rent out uncultivated land to more productive farmers (see e.g., Beg, 2020). Finally, more secure property rights reduce risks of expropriation and can encourage farmers to invest in better technology. While neither of these mechanisms should a priori lead the reform to increase the tax base we confirm this empirically. We show in this section that digitization indeed increased farmers' profits and had no significant effect on cultivated area.

To show this, we use four different outcome variables: the log of farm-level profits, the satellite vegetation cover index, a measure of whether land owned was irrigated or not, and the log of agricultural land owned.[31] For each measure, we run the following regression:

$$y_{dt} = \mu_d + \mu_t + \gamma \text{Digitization}_{dt} + \nu_{dt} \tag{3}$$

where y_{dt} is either a measure of cultivated area, or farm profits in Pakistani Rupees, $Digitization_{dt}$ is a dummy that takes value 1 if district d was digitized in year t, μ_d and μ_t are district and year fixed-effects, respectively. Standard errors are clustered at the district level.

Table 2 shows the results. Column (1) estimates the effect of digitization on profits, while column (2)-(4) estimate the effect on cultivated land by using the

[31] As described in Section 2.2 the farm-level profit data comes from a survey of farmers which is only available for 5 waves (2007–2008, 2011–2012, 2013–2014, and 2015–2016) and not yearly. We therefore need to modify our definition of the treatment year for the estimation based on this outcome: we pool phase 1 and phase 2 districts and define them as digitized from the 2013-2014 wave onward while phase 3 districts remain the control group. For the rest of the outcomes the definition of the treatment year remains the same as in Section 3.1.

satellite vegetation cover index and the survey data on land owned and irrigation as proxies. The coefficient in column (1) shows that digitization had a statistically significant positive effect on profits. Column (2) to (4) show instead that digitization had a small and insignificant effect on cultivated land. These results are consistent with the findings of Beg (2020) who exploits the same reform to measure its effects on land and labor markets. Beg (2020) shows that digitization increased the productivity of farmers due to two effects: a re-allocation of land to more productive farmers and an improvement in the use of inputs and investments. This productivity mechanism could explain why we detect an effect of digitization on profits but not on cultivated area.

Together, these results imply that digitization did not lead to a decrease in the tax base: cultivated area remained unchanged while profits went up significantly as a result of it.

4.2 Effect on performance of bureaucrats

If tax collection decreased, as shown in Section 3, but the tax base did not, as shown in Section 4.1, then the digitization reform might have reduced the bureaucrats' capacity to collect taxes. That is, the reform reduced fiscal capacity. In this section, we first propose a theoretical framework to analyse how the reform could have impacted fiscal capacity and guide our interpretation of the empirical results. We then provide evidence that the reform did decrease the tax assessment and collection by bureaucrats.

4.2.1 Theoretical framework

We propose a simple model of the effect of the digitization reform on the bureaucrats' capacity to collect taxes. The model captures the main opposing forces created by the reform. On the one hand, the introduction of technology freed up some time for bureaucrats to focus on tax collection. On the other hand, it disrupted their relationship with the taxpayers.

Our model is informed by the responses provided by bureaucrats in the survey.

The bureaucrats indicated two channels through which the digitization reform reduced their ability to collect taxes: a lower influence on taxpayers (57% of respondents who felt that digitization of land records made tax collection worse) and higher corruption (9% of respondents). The local population also reported that corruption was very prevalent before the reform with 82% of respondents in a Gallup survey indicating that the way to "remedy the problems faced in accessing land records" was to give a bribe, and 65% reported that they could not access land record services without unofficial payments (Gallup, 2009) but that these bribes reduced after the reform.[32] The model allows us to formally define the influence that bureaucrats exert on taxpayers and how this influence interacts with the changes in corruption.

Model. We consider a three-stage game between a bureaucrat (B) and a farmer (F). In the first stage, the bureaucrat assesses the amount of tax due by the farmer. The bureaucrat can choose to either report the true level of tax demand, denoted $\bar{T}$ or to collude with the farmer and report a lower demand $\hat{T} < \bar{T}$ against the payment of a bribe, denoted b_T. Let $T \in \{\hat{T}, \bar{T}\}$ denote the amount of tax demand agreed in the first stage. In the second stage, the farmer can choose between paying his tax demand directly and in full, $\tau = T$ or not paying it, $\tau = 0$.

While the first and second stages are identical before and after the digitization reform, the third stage differs. Prior to the digitization reform, the bureaucrat decides at that stage how to allocate her time between collecting tax that is overdue (if any) and dealing with land issues for the farmer (e.g., resolving land disputes, issuing land records). Let h_T denote the proportion of time she spends on collecting taxes and h_L the proportion of time she spends on land issues, with $h_T + h_L = 1$. Spending a proportion of time h_L on land issues gives a probability h_L of resolving these issues. If the issues are resolved, the bureaucrat receives a bribe, or 'tip', denoted b_L, from the farmer. If the farmer paid his tax demand in full in the second stage, $\tau = T$, the bureaucrat does not need to spend time collecting taxes. As a result, she can spend all her time dealing with land issues and $h_L = 1$.

[32]The implementation report of the World Bank notes that "The majority of respondents in 65 Focus Group Discussions mentioned that dealing with the Patwari involved huge bribes, but that these costs no longer exist under the new system." (World Bank, 2017)

If the farmer refused to pay his tax bill in the second stage, the bureaucrat can recover some (but not all) of the demand if she spends enough time. We assume that the bureaucrat can recover a proportion $\frac{\tau}{T} = \lambda(h_T)^\alpha$ of the tax demand when she spends h_T of her time on tax collection. The bureaucrat cannot recover all the tax even if she spends all her time on it, so $\lambda < 1$, and faces diminishing returns so $\alpha \in (0, 1)$. We assume for simplicity that the amount of bribe on land issues, b_L, is determined exogenously (e.g., determined by norms or capped by the budget constraint of the farmers), but the amount of bribe on tax assessment, b_T, is determined through bargaining between the bureaucrat and the taxpayer.

After the digitization reform, the bureaucrat can no longer deal with land issues. We therefore capture the digitization reform by imposing that, after the reform, $h_L = 0$ and $b_L = 0$ in the third stage.

The bureaucrat receives a reward, normalised to 1 proportional to the percentage of the tax demand she recovers, $\frac{\tau}{T}$. This captures her career concerns incentives to perform well on the job. She also values receiving bribes b_T and b_L, but faces a cost of collecting bribes that is increasing and convex in the total amount of bribes she receives. We assume that this cost is equal to $(b_T + b_L)^2$. Finally, the bureaucrat can get caught if she misreports the tax demand owed by the farmer. The bureaucrat therefore faces a cost $C(\bar{T} - \hat{T})$ of reporting $\hat{T} < \bar{T}$ with $C(\cdot)$ increasing and convex and such that $\lim_{\hat{T} \to \bar{T}} C'(\bar{T} - \hat{T}) = 0$ and $\lim_{\hat{T} \to 0} C'(\bar{T} - \hat{T}) = +\infty$. The bureaucrat's utility is therefore:

$$\begin{aligned} U_B(h_T, h_L, b_T, T) = & \underbrace{\lambda(h_T)^\alpha}_{\text{Tax collection}} + \underbrace{h_L(b_T + b_L - (b_T + b_L)^2)}_{\text{Net benefit of bribes if land issue resolved}} \\ & + \underbrace{(1 - h_L)(b_T - b_T^2)}_{\text{Net benefit of bribes if land issue unresolved}} \\ & - \underbrace{C(\bar{T} - \hat{T})}_{\text{Cost of misreporting tax assessment}} \end{aligned} \tag{4}$$

The farmer values his income, denoted w, net of taxes and of bribes. He also

faces a cost L of facing an unresolved land issue. His utility is therefore:

$$U_F(b_T, T, \tau) = w - b_T - \tau - (1 - h_L)L - h_L b_L \tag{5}$$

Analysis. We relegate the formal analysis of the model to the appendix and present here the main theoretical predictions and their intuition.

We begin with the pre-reform solution. In the last stage, if the farmer has not paid his tax in full ($\tau = 0$), the bureaucrat weighs the marginal benefit of collecting more taxes (due to career concerns) and that of collecting more bribes on land issues and optimally allocates an interior proportion of her time on each task: $h_T^* = \left(\frac{\alpha\lambda}{b_L(1-2b_T)-b_L^2}\right)^{\frac{1}{1-\alpha}}$ and $h_L^* = 1 - h_T^*$. In the second stage, the farmer anticipates the bureaucrat's optimal time allocation when choosing whether to pay her taxes and faces the following trade-off. If he refuses to pay his tax in full, he will face a lower overall tax bill as the bureaucrat will not recover the entire amount: $\lambda(h_T^*)^\alpha T < T$. On the other hand, if the farmer refuses to pay his tax in full, the bureaucrat will need to allocate time to recovering this tax and will therefore spend less time resolving the farmer's land issues: $h_L^* < 1$. The farmer therefore pays his tax demand in full in the second stage if resolving the land issue is sufficiently valuable:

$$L \geq b_L + T\left[\frac{1}{h_T^*} - \frac{\lambda}{(h_T^*)^{(1-\alpha)}}\right] \tag{6}$$

Condition 6 captures the *influence*, or leverage, that bureaucrats can exert on taxpayers when they are in charge of both tax collection and land records. If the farmer puts a sufficiently high value on the resolution of land issues (L large), he feels compelled to pay his tax demand promptly, $\tau = T$, so that the bureaucrat dedicates enough time to resolving the land issue ($h_L = 1$). After the digitization reform, the bureaucrat loses this leverage. The farmer anticipates that the bureaucrat will allocate all her time to recovering taxes, $h_T = 1$. As a result, there is no benefit to paying her tax demand in full. Doing so increases her tax payment from λT to T and does not have any side-benefits for land issues. After the digitization reform, the farmer therefore always refuses to pay her tax demand in full in stage

2. Let $\overline{L}(T) = b_L + T\left[\frac{1}{h_T^*} - \frac{\lambda}{(h_T^*)^{(1-\alpha)}}\right]$ denote the right-hand side of inequality 6. We obtain the following implication:[33]

Proposition 1. *If resolving land issues is sufficiently valuable to the farmer, $L \geq \overline{L}(\bar{T})$, then the digitization reform should lead to lower tax collection as a percentage of the tax demand:*

$$\frac{\tau_{Digital}}{T_{Digital}} - \frac{\tau_{Manual}}{T_{Manual}} = \lambda - 1 < 0$$

We now turn to the effect of the reform on the assessment of the tax demand. Suppose that the land issue is sufficiently important that the bureaucrat has some leverage over the farmer, $L \geq \overline{L}$. Following Proposition 1, the farmer pays his tax demand in full in this case, so a decrease in tax demand, T, translates directly in a lower tax payment. The farmer thus accepts to pay a bribe at most equal to the reduction in tax demand. Given this constraint, the bureaucrat chooses the optimal level of tax demand and bribes. The bureaucrat faces the following trade-off: lowering the tax demand allows her to extract a larger bribe, but comes at two costs: first it increases the potential punishment $C(\bar{T} - \hat{T})$ for misreporting. Second, it increases the potential punishment for taking bribes which is equal to $(b_L + b_T)^2$.

The digitization reform does not affect the first cost. The potential punishment for misreporting is still present. However, it affects the second: because the bureaucrat no longer collects bribes from land record, the marginal cost of taking a bribe for a lower tax demand decreases. As a result, the bureaucrat's willingness to accept a bribe against a lower assessment of the tax demand increases. This mechanism captures a *bribe displacement effect*: as the bureaucrat loses a valuable source of bribe from dealing with land issues, she displaces some of these bribes onto her tax activities, which translates into a lower assessment of the tax demand.

[33]One assumption driving this result is that the bureaucrat cannot be as efficient at recovering taxes than when the taxpayer voluntarily pays his full tax demand. While it is captured in a reduced form in the model by assuming that $\lambda < 1$, more realistic modelling choices would also generate this result. For instance, the bureaucrat may have other tasks than the two considered here, so that $h_T < 1$ even after the reform, or the bureaucrat may face a convex cost of working so that choosing $h_T = 1$ is never optimal. Finally, she may have to allocate her effort across different farmers so that she cannot allocate $h_T = 1$ on all farms.

This effect is partially offset by a second effect, however. When the reform leads the bureaucrat to collect a lower fraction of tax demands (Proposition 1), decreasing the tax demand is relatively less valuable to the farmer. The farmer is therefore less willing to pay bribes in exchange for a lower tax assessment. The bribe displacement effect outweighs this second effect when the bribe income lost following the reform is sufficiently large. We therefore obtain the following results:[34]

Proposition 2. *If resolving land issues is sufficiently valuable to the farmer, $L \geq \overline{L}$, and the bribes obtained on land issues are large enough, $b_L \geq \bar{b}$, then the digitization reform should lead to a lower assessment of the tax demand: $T_{Digital} < T_{Manual}$.*

Our model therefore generates two empirical predictions about the effect of the digitization reform summarised in the following remark:

Remark 1.

1. *The digitization reform should lead to a lower assessment of the tax demand due to bribe displacement.*

2. *The digitization reform should lead to lower tax collection as a percent of tax demand due to a loss of leverage.*

4.2.2 Changes in tax assessment

Bureaucrats determine the size of the cultivated area and its characteristics (irrigation, type of crops) during their crop inspection in fall. This assessment is then used to determine the tax demands that are issued to farmers. The model shows that if bureaucrats displace some of the bribes they obtained from land records onto tax assessment as a result of the digitization reform, we should expect this assessment to fall. The resulting fall in tax demand could explain why tax collected decreased following the reform.

[34]The main assumption driving this result is that the bureaucrat faces a cost of taking bribes (a potential punishment) which is convex in the total amount of bribes obtained across different activities. While we make this assumption to make the model more tractable, the same logic would apply if the bureaucrat faced separate costs across different sources of bribes but had a concave utility over money.

To investigate whether this was the case, we use two sets of data: data from the Directorate of Agriculture which records district level *cultivated areas* based on reports provided by the bureaucrats we study, and administrative data on *tax demands* issued by these bureaucrats to taxpayers following their assessment of cultivated areas, aggregated at the district level.[35] We use these two outcome variables to run the following regression:

$$y_{dt} = \pi_d + \pi_t + \phi \text{Digitization}_{dt} + \xi_{dt} \tag{7}$$

where y_{dt} is one of the two outcome variables described above (reported cultivated area or tax demand) in district d and year t, $Digitization_{dt}$ is a dummy that takes value 1 if district d was digitized in year t, π_d and π_t are district and year fixed effects. Standard errors are clustered at the district level.

Table 3 shows the results: after the digitization reform, districts with digitized land records had 10% lower reported cultivated areas (Column 1), as well as 45% lower tax demands (which includes both cultivated-area based tax and profit-based tax, see Column 2), relative to districts with manual land records.[36] This is despite the fact that neither the vegetation cover index nor the agricultural land irrigated or owned decreased significantly, as shown in Column (2)-(4) of Table 2. These results therefore indicate that the digitization reform led bureaucrats to under-report the tax base, which in turn reduced the tax demands they issued to farmers.

These results are consistent with the digitization reform increasing collusion between bureaucrats and taxpayers as captured by the model. Results from our survey of the bureaucrats also support this description. Figure 7 shows that bribes were common before the reform, as 48% of respondents in our survey either agreed or completely agreed that citizens wanted to 'tip' bureaucrats to obtain land titles. Only 33% agreed or completely agreed with that statement when considering

[35] As described, in the tax records we observe this at the revenue-circle level, and not at the taxpayer level. For consistency with the previous analysis we also aggregate this data at the district level.

[36] These effects are approximated using the transformations $\exp(-0.106) - 1 = -0.10$ and $\exp(-0.600) - 1 = -0.45$ respectively, as we did for the main result in Table 1

areas where the reform had taken place.[37][38] As noted above, this behavior is also confirmed in independent household surveys. Before the reform, 82% of respondents in a Gallup survey indicated that they gave bribes to "remedy the problems faced in accessing land records" and 65% that they could not access land record services without unofficial payments (Gallup, 2009). After the reform, the World Bank's implementation report noted that "The majority of respondents in 65 Focus Group Discussions mentioned that dealing with the Patwari involved huge bribes, but that these costs no longer exist under the new system." (World Bank, 2017). The digitization reform could have therefore led bureaucrats to try and make up for this lost income by increasing collusion on tax assessment. This is in line with other instances of 'bribe displacement' found in other contexts. (Yang, 2008; Sequeira, 2011, 2016; Dávid-Barrett and Fazekas, 2020).

The decrease in the *reported* tax base and the corresponding lower tax demand can explain part of the decrease in tax income shown in Table 1. However, we show in the next subsection that tax collection decreased even relative to this reduced tax demand. Collusion between bureaucrats and taxpayers in assessing cultivated areas can therefore not explain all of the decrease in tax collection.

4.2.3 Change in performance relative to tax demand

While a decrease in the reported tax base and the associated tax demand can explain the overall decrease in fiscal revenue, it is also possible that the digitization reform led bureaucrats to *collect* less tax. That is, it is possible that the *performance* of bureaucrats decreased. Our model suggests that this can happen when farmers put a sufficiently high value on resolving land issues (e.g. obtaining land titles or resolving land disputes). When bureaucrats are in charge of land issues, they have some leverage over farmers and can use it to encourage them to pay their

[37] Given that admitting to this behavior reflects badly on the bureaucracy, these responses likely underestimate the true magnitude of bribery. We expect the under-reporting to be similar before or after the reform. Figure 7 supports this interpretation since the proportions of respondents that refused to answer the question on tips before and after the reform are similar.

[38] The non-zero proportion of bureaucrats indicating bribe-taking after the reform can be explained by the fact that even within a revenue circle which has been digitized not every village has been digitized.

tax bill. We investigate whether performance declined by looking at four different measures of performance.

First, we look at the effect of the digitization reform on the tax collected by bureaucrats as a percentage of the tax demands they need to collect. The tax demands issued by bureaucrats correspond to the tax due by farmers and therefore the target that bureaucrats are expected to collect by their superiors.[39] We confirm this measure with two alternative variables: whether bureaucrats achieved at least 50% of their targets, and whether they achieved at least 75% of their target. These binary variables allow us to confirm that the results from the continuous measure are not driven by outliers with particularly low performance. Finally, we also analyze whether the reform affected the ability to collect taxes at the bottom-end of the performance distribution by looking at the share of months per year in which the bureaucrats collected no taxes at all.

Combining the bureaucrat survey data with tax collection records allows us to carry out the analysis at the individual bureaucrat level instead of the district level analysis in the previous section. We therefore, use the within-bureaucrat variation in tax collection and run the following regression:

$$y_{idt} = \theta_i + \theta_t + \psi \text{Digitization}_{dt} + u_{idt} \tag{8}$$

where y_{idt} is one of the measures described above for bureaucrat i in district d and year t, $Digitization_{dt}$ is a dummy that takes value 1 if district d was digitized in year t, θ_i are bureaucrat fixed effects and θ_t are fiscal year fixed effects. Standard errors are clustered at the district level.

Table 4 shows the results of this regression. Column (1) shows that the digitization reform led to a substantial decrease in the bureaucrat's performance. Bureaucrats in digitized districts collected almost 30 percentage points less of their collection target after digitization, relative to non-digitized districts (56% of control mean, *Wild* clustered bootstrapped p-value<0.05). We can exclude the possibility that this is due to the denominator increasing since Table 2 shows that tax

[39]Since the bureaucrat's objective is to collect the tax due, it is not possible for bureaucrats to over perform based on our measure of performance: once the tax due is collected, bureaucrats cannot collect more tax from that farmer.

demands decreased, if anything, as a result of the digitization reform. In other words, tax collection decreased even more than the tax demands did, implying that the capacity of bureaucrats to collect taxes went down.

One could worry that this is driven by bureaucrats whose tax collection dropped completely, given that targets (i.e. collecting all the tax due) were rarely met even before digitization and that the percentage of tax demand collected was quite low.[40] However, columns (2) and (3) show that the digitization reform also affected the ability of bureaucrat to achieve higher levels of tax demands: bureaucrats were 34 percentage points less likely to collect at least 50% of the tax demands in their area, and 39 percentage points less likely to collect at least 75% of these tax demands (*Wild* clustered bootstrapped p-values<0.05). Finally, column (4) shows that digitization also affected the bottom of the performance distribution: the share of months in which no tax was collected at all increased in digitized districts after the reform, although the effect is not statistically significant.

These results are consistent with the digitization reform reducing the leverage that bureaucrats had over taxpayers as captured by the model. Before the reform, bureaucrats had influence over the taxpayers' decision to pay their taxes because they could allocate less time to land issues if taxes were not paid in full. After the reform, bureaucrats lost this source of influence and their capacity to collect taxes decreased. This description is also in line with the large portion of bureaucrats who reported in our survey that the digitization reform made tax collection more difficult because it reduced their influence over the population (see Figure 6).

Further results from our survey of the bureaucrats also support this type of mechanism. Bureaucrats reported an important decline in their interactions with politicians (see Figure C.5 in appendix). In our context, politicians are often large landowners and would therefore benefit from the bureaucrat's help with resolving land issues (Javid, 2011). Following the reform, these politicians no longer need to interact with bureaucrats as much if these bureaucrats cannot help them resolve land issues. Politicians can help bureaucrats collect taxes but bureaucrats reported that they were less likely to do so following the reform (see Figure C.7 in appendix).

[40] The mean tax collection as a fraction of the target in districts with manual land records is 54%.

Within our model, we can interpret this type of exchange of favor as a form of influence that bureaucrats lost as a result of the reform. Before the reform, they could promise to help politicians with their land issues in exchange for help collecting taxes from farmers. After the reform, bureaucrats lose this leverage and no longer receive help with their tax collection.

The decline in bureaucrats' performance, together with the analysis of the tax base presented in Section 4.1, indicate that the responsibility for the decrease in fiscal revenues lies with the capacity of bureaucrats to collect tax rather than changes in the actual tax base. This decrease in performance can be attributed to both under-reporting of the tax base and lower tax collection relative to tax demands. As discussed in Section 3, the results are unlikely to be driven by a change in the composition of the bureaucracy as there were extremely few transfers across districts (see Figure C.4 in appendix). Instead, the results are likely to capture a change in the behavior of bureaucrats.

4.3 Discussion

In this section, we discuss other channels through which the digitization reform could have affected tax collection.

Temporary disruptions in bureaucrats' tasks. The bureaucrats were required to support the reform by helping correct records that had been digitized when necessary. Indeed, 59% of bureaucrats reported that some tasks were added as a result of the reform (see Figure C.1 in appendix). Of those, 60% reported that they were expected to correct records for digitized centers (see Figure C.2 in appendix). If these record corrections distracted bureaucrats from collecting taxes, this disruption could partly explain the decrease in collection. However, this channel seems unlikely to explain the large fall in tax collection that we observe for two reasons. First, Figure 3 illustrates that 72% of bureaucrats did not report any change in hours worked. Among the remaining, 24% reported a net increase in hours worked, while 4% reported a net decrease. Figure 4 shows that, while the average number of hours added following the reform is slightly higher than the

average number of hours removed following the reform, the difference between the two is relatively small (not statistically significant at the 5% level). Second, Figure 6 shows that, of the 46% of bureaucrats who reported that digitization made tax collection worse, only 2% indicated that this was due to additional tasks.

Changes to information available to bureaucrats. The reform could have affected the information available to bureaucrats in two ways. First, the reform could have led bureaucrats to lose access to information on land records, which might be necessary to determine the owner of a plot of land. Without this information, bureaucrats might be unable to issue tax demands to the right taxpayer, which in turn could reduce tax demands and tax collection. Qualitative interviews with the bureaucrats reveal that this was not the case in this context. After the reform, bureaucrats were able to access the latest land records from the digitized record centers. These records helped them to continue to carry out crop inspections and subsequent tax related activities.

Second, if the reform reduced interactions between the bureaucrats and taxpayers, bureaucrats could have lost information about the ability of different farmers to pay their tax. Existing studies (Dzansi et al., 2022; Balan et al., 2022) show that tax collectors can use this information to better allocate their tax collection effort. While we cannot completely rule out this possibility, we note that the bureaucrats still frequently interacted with the local population after the reform: besides carrying out two crops inspection per year they are also active members of the community (Aman-Rana et al., 2023a). These interactions allow them to easily obtain information about the farmers' ability to pay.

Changes in monitoring of bureaucrats. The reform could have affected the way supervisors monitored the bureaucrat which in turn would have affected their incentives to perform. This would be in line with theoretical explanations of multitasking problems such as Dewatripont et al. (1999a). While we cannot rule out that the reform led supervisors to change the type of information they used to assess the bureaucrats' performance, we note that there was no change in the incentive or monitoring structure of the bureaucrats. Moreover, bureaucrats did

not report significant changes in their interactions with supervisors following the reform (see Figure C.5 in appendix).

5 Conclusion

Building strong state capacity is a prerequisite for sustainable economic development. However, state capacity is not simply the sum of the technologies and processes that governments invest in. The capacity of states to raise taxes and protect property rights also depends on the behavior of state officials.

We show that reforms introducing technology to improve the effectiveness of bureaucracies can have unintended consequences by disrupting the relationship between bureaucrats and taxpayers. Despite the positive effect of digitization on property rights and agricultural productivity, we find that the collection of agricultural tax decreased as a result of the reform.

Because the reform affected the organization of the bureaucracy and changed the interactions between local bureaucrats and citizens our results highlight the need to consider informal social relationships as key dimensions of state capacity (Besley and Dray, 2022; Best et al., 2023).

Our results also have important implications for the design of state capacity reforms. These reforms should be accompanied by appropriate changes to the incentives of bureaucrats, pay close attention to complementarities between different forms of state capacity and whether the reform enhances or reduces these complementarities, and find ways to replace interactions with the local population that might be removed by the introduction of technology.

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Tables

Table 1: Did the digitization reform affect tax collection?

Dependent variables:	IHS Tax collection
	(1)
Digitization of land records	-1.827***
	(0.634)
	[0.01]
Dep. var. mean (in 000 PKR)	16278.9
District fixed effects	Yes
Fiscal year fixed effects	Yes
Observations	212

Notes: The unit of observation is a district-fiscal year. 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in every year from FY2012 and FY2013 respectively, and remains zero otherwise. IHS tax collection is the inverse hyperbolic sine of the amount of taxes, in thousand PKR, collected by the government in a district-fiscal year. Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table 2: Did the digitization reform affect the agricultural tax base?

	Log farm level profit per acre (1)	Satellite vegetation cover index (2)	Whether agri land irrigated? (3)	Log agricultural land owned (4)
Digitization of land records	0.923***	0.00597	-0.00945	0.0645
	(0.0591)	(0.00571)	(0.0510)	(0.0445)
	[0.000]	[0.262]	[0.789]	[0.174]
Dep. var. mean	15.5	0.53	0.12	7.69
District fixed effects	Yes	Yes	Yes	Yes
Fiscal year fixed effects	Yes	Yes	Yes	Yes
Controls	Yes	No	Yes	Yes
Observations	5,958	288	161,796	161,836

Notes: The unit of observation is a district-fiscal year or a district-survey wave. 'Farm-level profit per acre' is calculated as the difference in the value of output per acre and the total expenses per acre (following Beg (2020)) and is based on HIES data from cultivating households for the 2005, 2007, 2011, and 2013 waves of the survey. For this measure, 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts from the 2011 and 2013 waves onwards respectively, and remains zero otherwise. 'Satellite vegetation cover index' is the Normalized Difference Vegetation Index (NDVI) with values ranging from -1 to 1. This data is from NASA's MODIS land products. For this measure, 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in every year from FY2012 and FY2013 respectively, and remains zero otherwise. 'Whether agricultural land irrigated' is a dummy variable that takes value 1 when the agricultural land of the household is irrigated and is based on PSLM survey data. 'Agricultural land owned' measures the acres of agricultural land that is owned by households also based on the PSLM survey. We use the 2006, 2008, 2010 and 2012 waves of the survey. For these two measures, 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in the 2012 wave and remains zero otherwise. Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) p-values in square brackets. The dependent variables in Columns (1) and (4) are in logs, but their means at the bottom of the table are presented in levels of the outcome variables. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table 3: Bureaucrats' assessments of the tax base (district-level)

	Log assessed cultivated area	Log admin tax demands
	(1)	(2)
Digitization of land records	-0.106***	-0.600**
	(0.0379)	(0.232)
	[0.004]	[0.015]
Dep. var. mean	1069.2	28685.6
District fixed effects	Yes	Yes
Fiscal year fixed effects	Yes	Yes
Controls	No	No
Observations	214	203

Notes: The unit of observation is a district-fiscal year. 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in every year from FY2012 and FY2013 respectively, and remains zero otherwise. The reported cultivated area is measured in thousand acres, while the administrative tax targets is in thousand PKR. We take the natural logarithms of both measures. Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

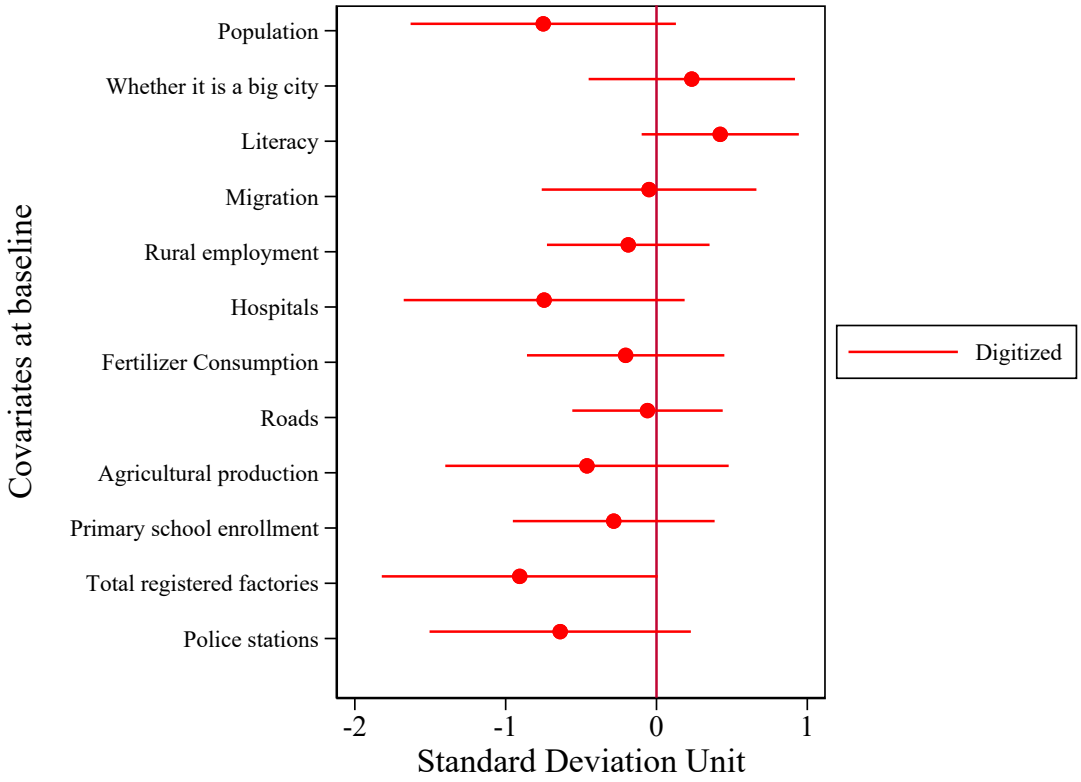
Table 4: Did the digitization reform affect the performance of bureaucrats?

Dependent Variables:	**Performance of bureaucrats**			
	$\frac{Tax\ collected}{Tax\ demand}$(%)	Whether atleast 50% tax demand was collected	Whether atleast 75% tax demand was collected	Share of months with zero collection
	(1)	(2)	(3)	(4)
Digitization of land records	-29.54**	-0.338**	-0.394**	0.225
	(14.09)	(0.158)	(0.152)	(0.139)
	[0.041]	[0.031]	[0.012]	[0.111]
Dep. var. mean	53.9	0.53	0.43	0.19
Bureaucrat fixed effects	Yes	Yes	Yes	Yes
Fiscal year fixed effects	Yes	Yes	Yes	Yes
Controls	No	No	No	No
Observations	304	304	304	304

Notes: 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in every year from FY2012 and FY2013 respectively, and remains zero otherwise. The first measure is the ratio of the tax they collected to the tax demand they issued. The second and third measure are dummy variables that take values 1 if at least 50% (75%) of the annual tax demand was achieved, and remains zero otherwise. The final measure is the share of months in the fiscal year in which no tax was collected. Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

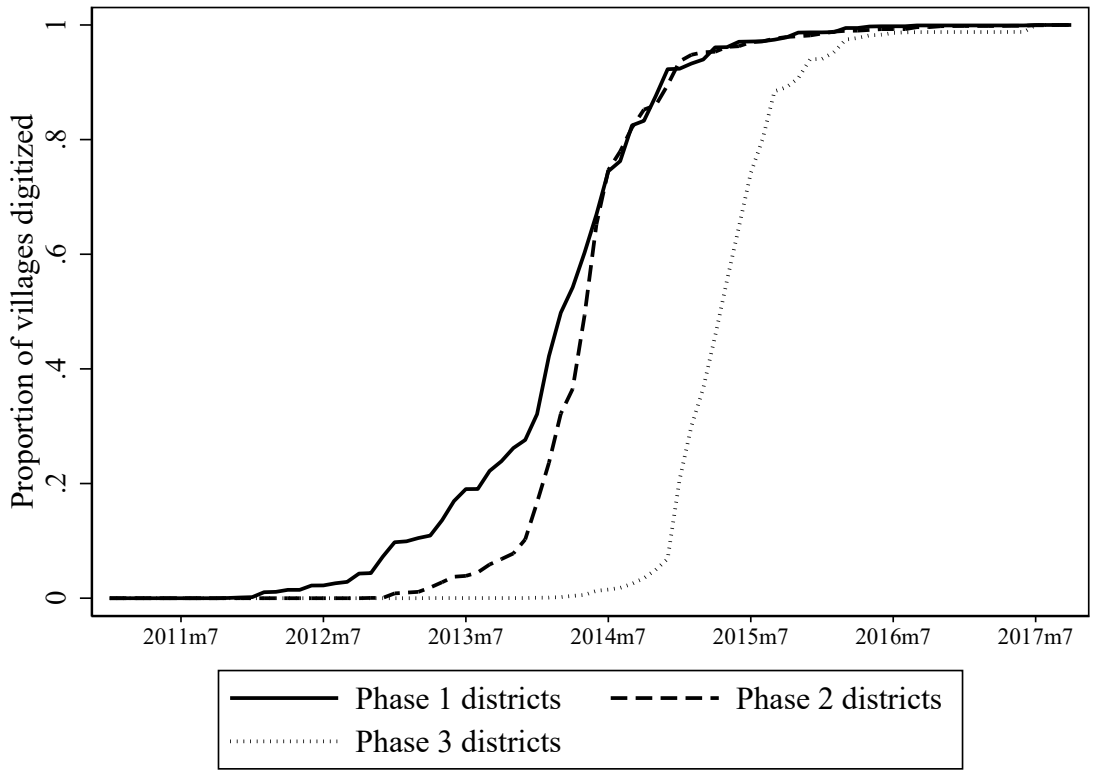
Figures

Figure 1: Balance test of baseline characteristics between digitized and non-digitized districts



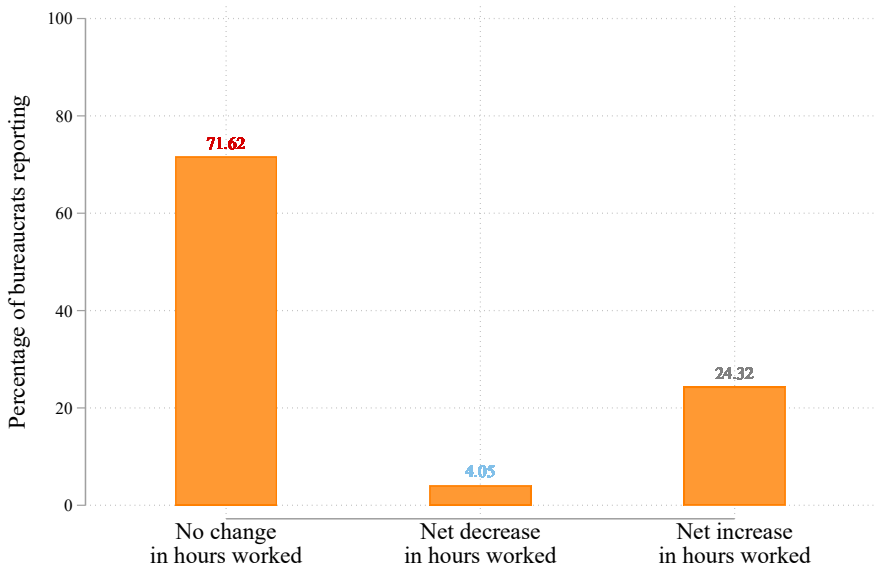
Notes: Data on baseline characteristics is from the Development Statistics of the Pakistan Bureau of Statistics 1997-2010. The point estimates are from a regression of the respective covariates on a dummy that takes value 1 if the district is in phase 1 or 2 of the digitization reform, and remains zero otherwise. The reference category are phase 3 districts. Intervals are 95% confidence intervals.

Figure 2: Phase wise rollout of the digitization reform over time



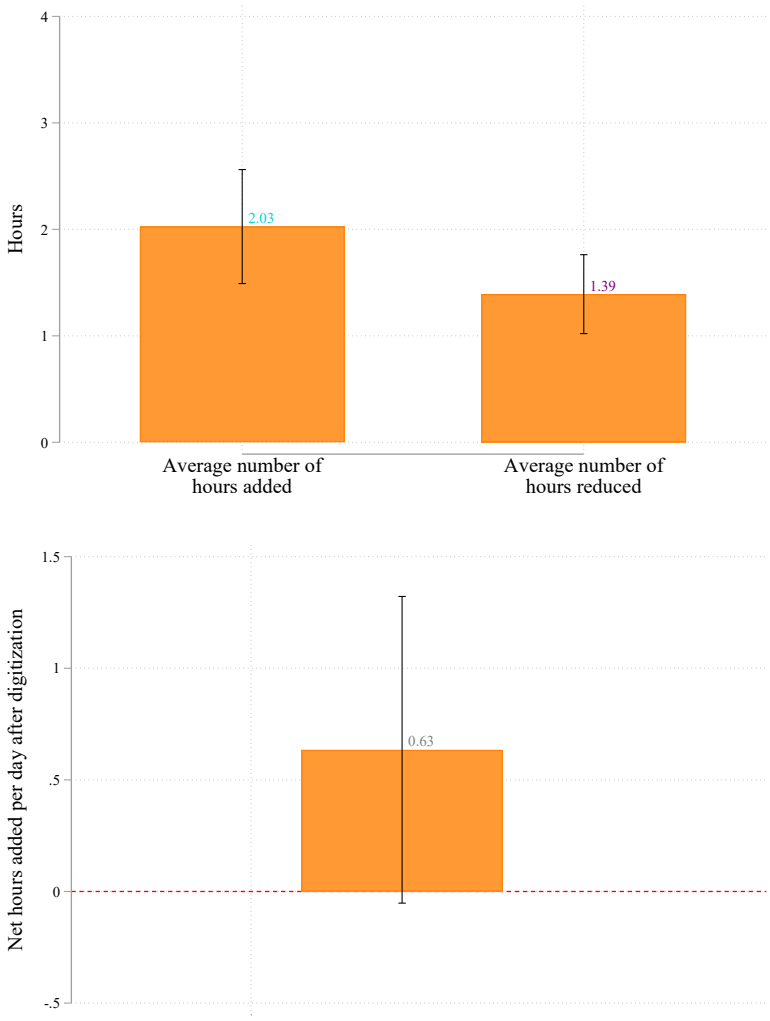
Notes: Districts that were planned to be digitized in phase 1 are Lahore, Lodhran, Hafizabad, Mandi Bahauddin, Nankana Sahib, Jhelum, Gujrat, Sialkot, Chakwal, Attock, Rawalpindi. Districts that were planned to be digitized in phase 2 are Bahawalpur, Gujranwala, Jhang, Layyah, Kasur, Multan, Muzaffargarh, Narowal, Okara, Rahim Yar Khan, Sargodha, Sheikhupura, Toba Tek Singh. Districts that were planned to be digitized in phase 3 were Bahawalnagar, Bhakkar, Chiniot, Dera Ghazi Khan, Faisalabad, Mianwali, Khanewal, Khushab, Pakpattan, Rajanpur, Sahiwal, Vehari.

Figure 3: Changes in hours worked by bureaucrats after the digitization reform



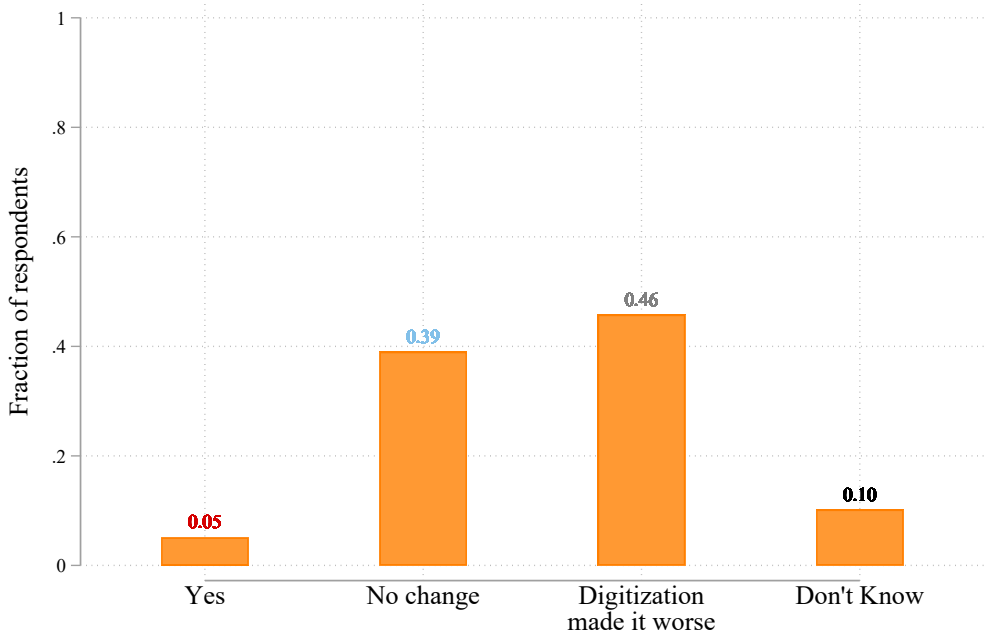
Notes: The figure is based on the bureaucrat survey restricted to the 118 bureaucrats who served as *Qanungo* between 2006-2013. The figure is based on responses to the question "Do you think LRMIS (the digitization reform) has changed the official tasks that you are supposed to do? If so, what is the number of hours per day that were added / reduced because of these changes?" Based on these answers, we calculate the difference between hours added and hours removed. The first bar is the proportion that either responded 'No' to the first question or whose net difference was zero. The second (third) bar is the proportion of respondent for whom that difference was negative (positive).

Figure 4: Changes in number of hours worked after the digitization reform



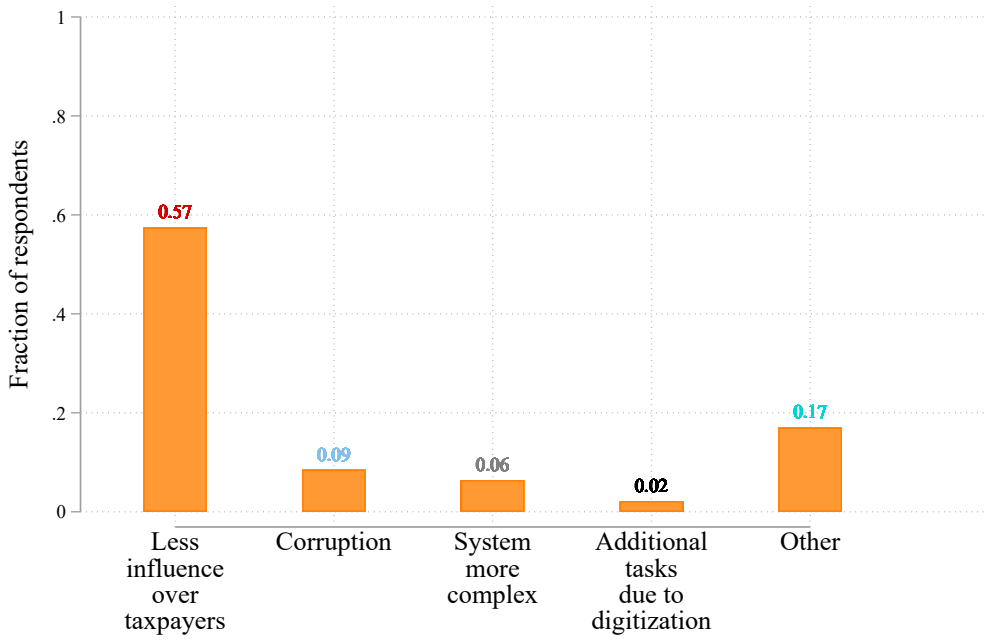
Notes: The figure is based on the bureaucrat survey restricted to the 118 bureaucrats who served as *Qanungo* between 2006-2013. The figure is based on responses to the question "Do you think LRMIS (the digitization reform) has changed the official tasks that you are supposed to do? If so, what is the number of hours per day that were added / reduced because of these changes?" Based on these answers, we calculate the average number of hours added and the average number of hours reduced across respondents. These are reported in the left panel. In the right panel we report the average net change in hours with 95% confidence intervals. The number is calculated by subtracting the number of hours reduced per day from the number of hours added per day, as reported by the bureaucrats.

Figure 5: Bureaucrats' views on the effect of digitization on tax collection



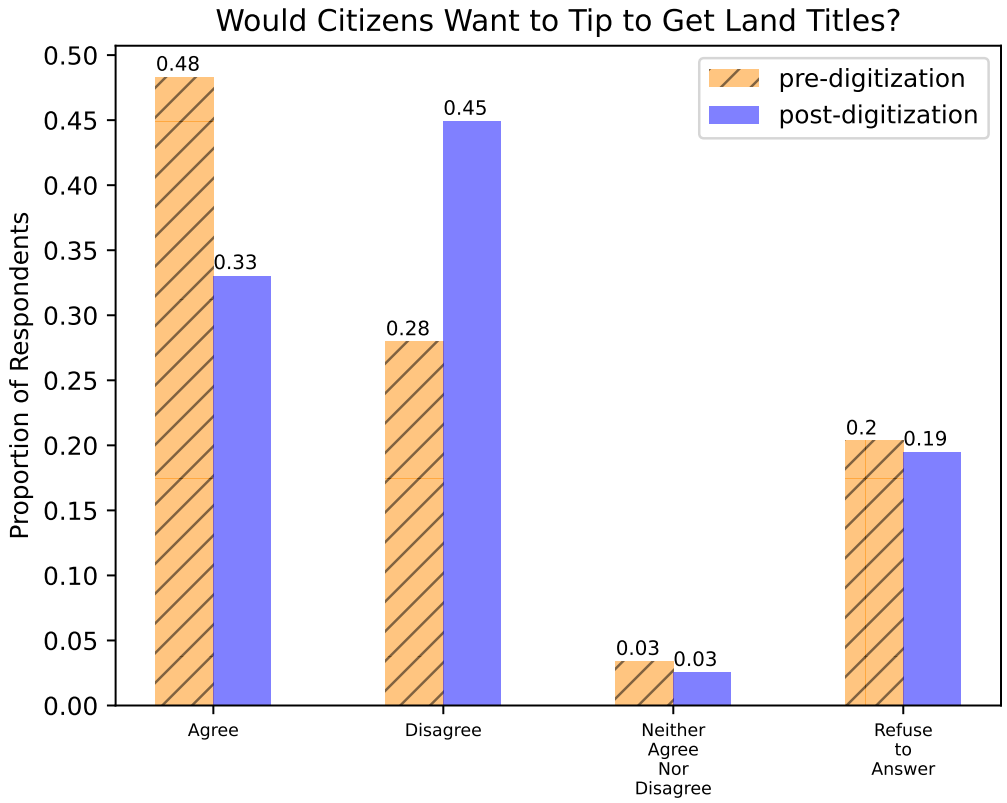
Notes: The figure is based on the bureaucrat survey restricted to the 118 bureaucrats who served as *Qanungo* between 2006-2013. The survey questions used to create the figure include "Do you think digitization has improved overall tax collection?" followed by "Please explain how?"

Figure 6: Bureaucrats' views on why digitization made tax collection worse



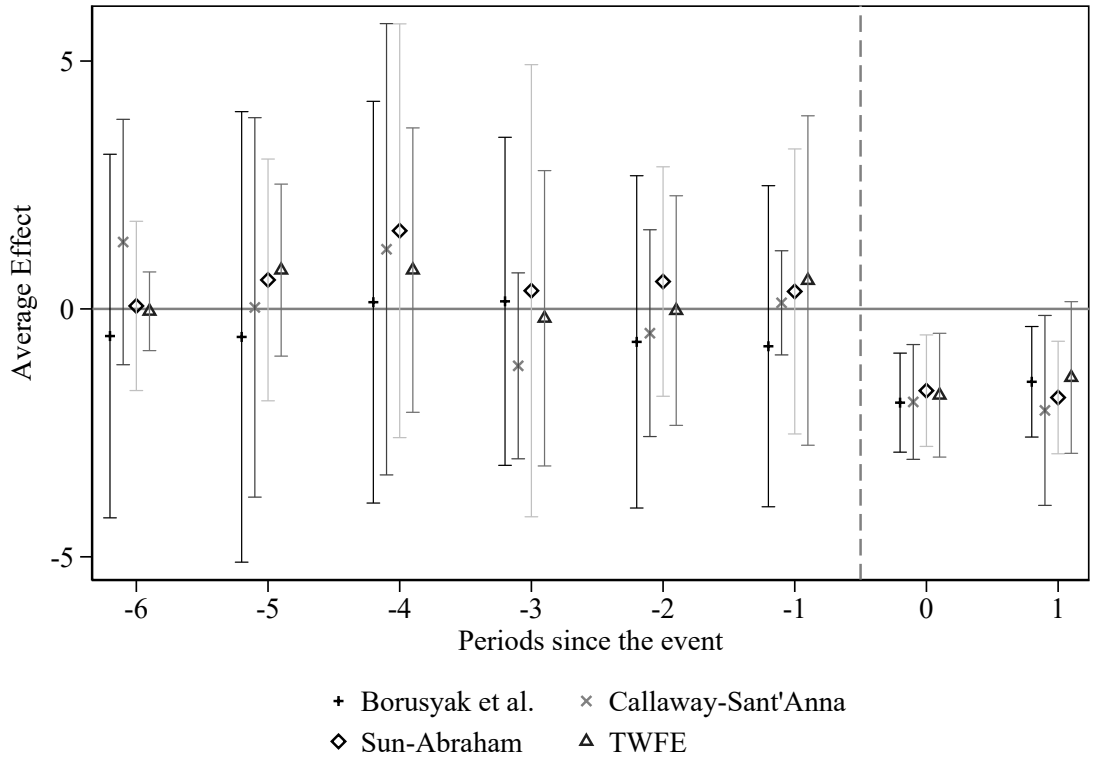
Notes: The figure is based on the bureaucrat survey restricted to the 54 bureaucrats that served as *Qanungo* between 2006-2013 and who responded that digitization made tax collection worse to the question "Do you think digitization has improved overall tax collection?"

Figure 7: Do bureaucrats in charge of land titles receive bribes or "tips" for issuing them?



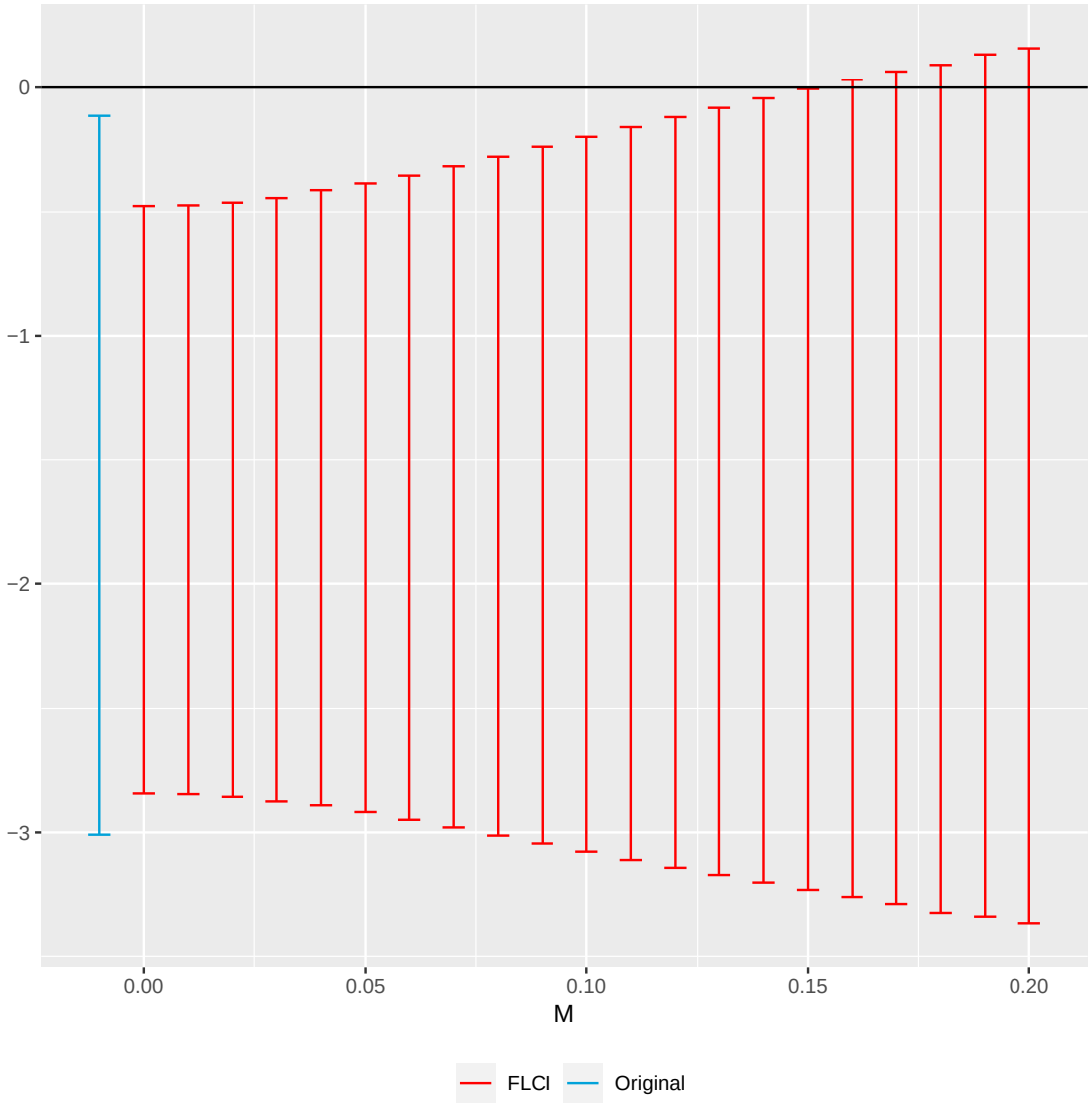
Notes: The figure is based on the bureaucrat survey. The figure shows the proportion of respondents that responded to, "People over there (in a revenue circle) would tip or want to tip a Patwari (bureaucrat's subordinates) for issuing Fard (land title)" measured on a Likert scale. 'Agree', 'completely agree' were grouped into 'agree', while 'disagree', 'completely disagree' were grouped into 'disagree'.

Figure 8: Event study plot for the district-level IHS tax collection



Notes: Data is at the district-fiscal year level. Each coefficient is obtained from a set of indicator variables that take values one if, in a given fiscal year, phase 1 or phase 2 districts were k years away from the introduction of digitized land records, as described in Equation 1. The reference year is FY2011 for phase 1 and FY2012 for phase 2. District and year fixed effects are included. Standard errors were clustered at the district level.

Figure 9: Robustness of the DID estimates to using the "more credible approach" (Rambachan and Roth, 2023)



Notes: The plot was created using the 'second differences' (Δ^{SD}) approach. FLCI refers to 'fixed length confidence intervals'. The blue line is the confidence intervals for the coefficient obtained from the interaction term between digitization and post in an event-study regression similar to Equation 1. The reference year is FY2011 for phase 1 and FY2012 for phase 2.

Appendices

A Proofs of theoretical results in the text

We solve the model by backward induction starting from the third stage. We first prove Lemma 1 below to obtain the bureaucrat's optimal allocation of time between land issues and tax collection in the final stage. We then solve for the decision of the farmer to pay his taxes in full in the second stage. Finally, we solve for the tax assessment offered by the bureaucrat to the farmer against some possible bribe.

We first solve the model before the digitization reform, where the bureaucrat can allocate time to managing land issues and obtain bribes for doing so. We then solve the model after the digitization reform when the bureaucrat is only in charge of collecting taxes. Finally, we compare the tax collection and the tax demand across the two situations.

A.1 Before the digitization reform

A.1.1 Stage 3

The best-response of the bureaucrat in the final stage is characterized in the following Lemma:

Lemma 1. *If $\tau = T$ in the second stage, then $h_T^* = 0$ and $h_L^* = 1$. Suppose instead that $\tau = 0$ in the second stage, then:*

- *If $1 > 2b_T + b_L$ and $\alpha\lambda < b_L(1-2b_T) - b_L^2$, then $h_T^* = h_T^* = \left(\frac{\alpha\lambda}{b_L(1-2b_T)-b_L^2}\right)^{\frac{1}{1-\alpha}}$ and $h_L^* = 1 - \left(\frac{\alpha\lambda}{b_L(1-2b_T)-b_L^2}\right)^{\frac{1}{1-\alpha}}$.*
- *If $1 \leq 2b_T + b_L$ or if $\alpha\lambda > b_L(1-2b_T) - b_L^2$ then $h_T = 1$.*

Proof of Lemma 1. In the final stage, if the farmer paid his tax in full in the previous stage, then the bureaucrat does not need to allocate time to collecting taxes. Therefore $h_T^* = 0$ and $h_L^* = 1$.

If the farmer did not pay his tax in full, the bureaucrat solves the following problem: given some tax demand T, the bureaucrat chooses h_T and h_L to solve:

$$\max_{h_T, h_L} \quad \lambda(h_T)^\alpha + h_L \times (b_T + b_L - (b_T + b_L)^2) + (1 - h_L)(b_T - b_T^2) - C(\bar{T} - \hat{T})$$
$$\text{s.t. } h_T + h_L \leq 1$$

Setting the constraint to equality and substituting it in the objective function gives:

$$\max_{h_T, h_L} \quad \lambda(h_T)^\alpha + (1 - h_T) \times (b_T + b_L - (b_T + b_L)^2) + h_T(b_T - b_T^2) - C(\bar{T} - \hat{T})$$

The first-order condition is:

$$\alpha\lambda(h_T)^{\alpha-1} - (b_T + b_L - (b_T + b_L)^2) + b_T - b_T^2 = 0$$

The second-order condition is satisfied since: $\alpha(\alpha - 1)\lambda(h_T)^{\alpha-2} < 0$ for $\alpha < 1$. The first-order condition gives the following solution:

$$h_T^* = \left(\frac{\alpha\lambda}{b_L(1 - 2b_T) - b_L^2} \right)^{\frac{1}{1-\alpha}}$$

and therefore $h_L^* = 1 - h_T^* = 1 - \left(\frac{\alpha\lambda}{b_L(1-2b_T)-b_L^2} \right)^{\frac{1}{1-\alpha}}$.

This solution is interior as long as $b_L(1 - 2b_T) - b_L^2 > 0 \Leftrightarrow 1 > 2b_T + b_L$ and $\alpha\lambda < b_L(1 - 2b_T) - b_L^2$. If the first condition is violated, then the objective function is increasing everywhere in h_T so it is optimal to set $h_T = 1$. If the second condition is violated, then the optimal level of h_T is above 1 so again $h_T = 1$. We can never have $h_T = 0$ since the marginal benefit of increasing h_T at $h_T = 0$ is infinite. □

A.1.2 Stage 2

In stage 2, the farmer anticipates how many hours the bureaucrat will spend on collecting taxes in the last stage and decides whether to pay his taxes in full accordingly. This decision is characterized in the following Lemma:

Lemma 2. *Given a level of tax assessment T agreed in the first stage, there exists a threshold $\overline{L}(T)$ such that the farmer pays his tax demand in full, $\tau = T$ if and only if $L > \overline{L}(T)$.*

Proof of Lemma 2. The expected utility of the farmer from paying his tax in full is:

$$U_F(\tau = T) = w - b_T - T - b_L$$

The expected utility of the farmer from not paying his tax bill in stage 2 is:

$$U_F(\tau = 0) = w - b_T - \lambda(h_T^*)^\alpha T - h_T^*(L - b_L) - b_L$$

Therefore, the farmer pays his tax in full if:

$$\begin{aligned} & w - b_T - T - b_L \geq w - b_T - \lambda(h_T^*)^\alpha T - h_T^*(L - b_L) - b_L \\ \Leftrightarrow \quad & h_T^*(L - b_L) \geq T - \lambda(h_T^*)^\alpha T \\ \Leftrightarrow \quad & L - b_L \geq T\left[\frac{1}{h_T^*} - \frac{\lambda(h_T^*)^\alpha}{h_T^*}\right] \\ \Leftrightarrow \quad & L \geq b_L + T\left[\frac{1}{h_T^*} - \frac{\lambda}{{h_T^*}^{1-\alpha}}\right] \end{aligned}$$

Therefore, defining $\overline{L}(T) = b_L + T\left[\frac{1}{h_T^*} - \frac{\lambda}{{h_T^*}^{1-\alpha}}\right]$ gives the result. □

A.1.3 Stage 1

In stage 1, the bureaucrat anticipates that the farmer will pay his tax in full if and only if $L \geq \overline{L}(T)$ and chooses T and b_T to maximize her own expected utility subject to the farmer accepting to pay the bribe.

Lemma 3. *Suppose that $L \geq \overline{L}(\bar{T})$, then the bureaucrat offers to take a bribe b_T^M such that $c(b_T^M) + 2b_T^M = 1 - 2b_L$ to reduce the tax assessment to $\hat{T} = \overline{T} - b_T^M < \overline{T}$.*

Proof of Lemma 3. Given that $L \geq \overline{L}(\bar{T})$, then for any T that the bureaucrat and farmer negotiate in the first stage, the farmer pays his tax in full in the second

stage, $\tau = T$ since $\overline{L}(\bar{T}) \geq \overline{L}(T)$ for any $T \in [0, \bar{T}]$.[41] As a result, the bureaucrat spends all her time on land issues in the third stage, $h_L^* = 1$ and $h_T^* = 0$. In the first stage, the bureaucrat therefore solves the following problem:

$$\max_{T, b_T} \quad U_B(h_T, h_L, b_T, T) = 1 + (b_T + b_L - (b_T + b_L)^2) - C(\bar{T} - T)$$
$$\text{s.t. } w - b_T - T - b_L \geq w - \overline{T} - b_L$$

The bureaucrat should set the bribe such that the farmer's constraint binds: $\overline{T} - T = b_T$, otherwise she could increase T to decrease the cost of misreporting while keeping the bribe constant. Substituting into the maximization problem gives:

$$\max_{b_T} b_T + b_L - (b_T + b_L)^2 - C(b_T)$$

Taking first-order condition gives: $1 - 2(b_T + b_L) - c(b_T) = 0 \implies c(b_T) + 2b_T = 1 - 2b_L$. The second-order condition is satisfied since: $-2 - c'(b_T) < 0$Therefore, the bureaucrat sets $b_T = b_T^*$ such that $c(b_T^*) + 2b_T^* = 1 - 2b_L$ and $\widehat{T} = \overline{T} - b_T^*$. □

A.2 After the digitization reform

After the digitization reform, the bureaucrat cannot work on any land-related issues, so $h_T = 1$ in the third stage.

Anticipating that $h_T = 1$, the farmer prefers not to pay his tax in stage 2:

Lemma 4. *After the digitization reform, the farmer always chooses $\tau = 0$ in the second stage.*

Proof of Lemma 4. This follows directly from comparing the farmer's utilities: $w - b_T - T < w - b_T - \lambda(1)^\alpha T \Leftrightarrow \lambda < 1$. □

[41] The condition $L \geq \overline{L}(\bar{T})$ is sufficient but not necessary. If it is not satisfied, then the bureaucrat would consider the possibility that if they do not reduce the assessment by a large enough amount, then the farmer might prefer to not pay his tax in full in the second stage. The bureaucrat would choose the optimal bribe and assessment in that case, given that the farmer does not pay his full tax bill and given the bureaucrat's optimal time spent on tax collection. Finally the bureaucrat would compare the expected utility from that outcome to the expected utility from the lower tax assessment which induces the farmer to pay her tax bill in full.

In the first stage, the bureaucrat offers the following combination of misreporting and bribe:

Lemma 5. *After the digitization reform, the bureaucrat offers to take a bribe* b_T^D *such that* $\frac{1}{\lambda}c(\frac{b_T^D}{\lambda}) + 2b_T^D = 1$ *to reduce the tax assessment to* $\hat{T} = \overline{T} - b_T^D < \overline{T}$.

Proof of Lemma 5. Given that the farmer never pays his tax in full in the second stage, $\tau = 0$ and the bureaucrat spends all her time on tax issues in the third stage, $h_T^* = 1$, the bureaucrat solves the following problem:

$$\max_{T, b_T} \quad U_B(h_T, h_L, b_T, T) = \lambda + (b_T - (b_T)^2) - C(\bar{T} - T)$$
$$\text{s.t. } w - b_T - \lambda T \geq w - \lambda \overline{T}$$

The bureaucrat should set the bribe such that the farmer's constraint binds: $\lambda(\overline{T} - T) = b_T$, otherwise she could increase T to decrease the cost of misreporting while keeping the bribe constant. Substituting into the maximization problem gives:

$$\max_{b_T} b_T - (b_T)^2 - C\left(\frac{b_T}{\lambda}\right)$$

Taking first-order condition gives: $1 - 2b_T - \frac{1}{\lambda}c(\frac{b_T}{\lambda}) = 0 \Rightarrow \frac{1}{\lambda}c(\frac{b_T}{\lambda}) + 2b_T = 1$. The second-order condition is satisfied since: $-2 - \frac{1}{\lambda}c'(\frac{b_T}{\lambda}) < 0$.Therefore, the bureaucrat sets $b_T = b_T^D$ such that $\frac{1}{\lambda}c(\frac{b_T}{\lambda}) + 2b_T = 1$ and $\widehat{T} = \overline{T} - b_T^*$.

□

A.3 Change in tax collection and assessments due to the reform

We can now turn to the proof of Propositions 1 and 2.

Proof of Proposition 1. From Lemma 2, we know that, in equilibrium, the farmer pays her tax in full in stage 2 if $L \geq \bar{L}$ before the reform. The tax collection as a percentage of tax demand before the reform is therefore: $\frac{\tau^{Manual}}{T^{Manual}} = 1$.

From Lemma 4, we know that, in equilibrium the farmer never pays his tax in full in stage 2 before the reform. By definition, the bureaucrat spends all her time collecting taxes after the reform, so $h_T^* = 1$. Therefore, the tax collection as a percentage of tax demand after the reform is: $\frac{\tau^{Digital}}{T^{Digital}} = \lambda(h_T^*)^\alpha = \lambda$.

We can therefore conclude that, if $L \geq \bar{L}$, then

$$\frac{\tau^{Digital}}{T^{Digital}} - \frac{\tau^{Manual}}{T^{Manual}} = \lambda - 1 < 0$$

□

Proof of Proposition 1. From Lemma 3, we know that the equilibrium tax assessment before the reform is $\hat{T}^{Manual} = \overline{T} - b_T^M$ with b_T^M such that $c(b_T^M) + 2b_T^M = 1 - 2b_L$. From Lemma 5, we know that the equilibrium tax assessment after the reform is $\hat{T}^{Digital} = \overline{T} - b_T^D$ with b_T^D such that $\frac{1}{\lambda}c(\frac{b_T^D}{\lambda}) + 2b_T^D = 1$.

Therefore, tax assessment is lower after the reform if and only if: $b_T^M < b_T^D$. We next show the following result:

Lemma 6. *There exists $\bar{b}_L$ such that $b_T^M < b_T^D$ if and only if $b_L > \bar{b}_L$.*

Proof of Lemma 6. Let $\Delta(b_L) = b_T^M(b_L) - b_T^D$. First note that since b_T^M solves $c(b_T^M) + 2b_T^M = 1 - 2b_L$ and the left-hand side of that condition is increasing and continuous given that $C(\cdot)$ is increasing, continuous, and convex. Therefore, the equilibrium b_T^M is strictly continuously decreasing in b_L. In addition, since b_T^D, which solves $\frac{1}{\lambda}c(\frac{b_T^D}{\lambda}) + 2b_T^D = 1$, is independent of b_L, we can conclude that $\Delta(b_L)$ is continuously decreasing in b_L.

Next, note that the function: $LHS(\lambda) = \frac{1}{\lambda}c(\frac{x}{\lambda}) + 2x$ is decreasing in λ, since its derivative with respect to λ is:

$$\frac{\partial LHS(\lambda)}{\partial \lambda} = -\frac{1}{\lambda^2}c\left(\frac{x}{\lambda}\right) - \frac{x}{\lambda^3}c'\left(\frac{x}{\lambda}\right) < 0$$

Which is negative for any $x \geq 0$ since $c > 0$ and $c' > 0$ given that $C(\cdot)$ is increasing and convex.

When $b_L \to 0$, b_T^M solves $c(b_T^M) + 2b_T^M = 1$ and b_T^D solves $\frac{1}{\lambda}c(\frac{b_T^D}{\lambda}) + 2b_T^D = 1$. Since $LHS(\lambda) = \frac{1}{\lambda}c(\frac{x}{\lambda}) + 2x$ is decreasing in λ, we have $\frac{1}{\lambda}c(\frac{x}{\lambda}) + 2x > c(x) + 2x$ for any x given that $\lambda < 1$. Therefore, as $b_L \to 0$, the value of x that solves $\frac{1}{\lambda}c(\frac{x}{\lambda}) + 2x = 1$ must be strictly lower than the value of x which solves $c(x) + 2x = 1$. So $\Delta(b_L) = b_T^M(b_L) - b_T^D > 0$ as $b_L \to 0$.

When $b_L \to \frac{1}{2}$, b_T^M solves $c(b_T^M) + 2b_T^M = 0$. Given $c(0) = 0$, this means $b_T^M = 0$. Instead, when $b_L \to \frac{1}{2}$, b_T^D still solves $\frac{1}{\lambda}c(\frac{b_T^D}{\lambda}) + 2b_T^D = 1$, so $b_T^D > 0$. Thus, $\Delta(b_L) = b_T^M(b_L) - b_T^D < 0$ as $b_L \to \frac{1}{2}$.

Therefore, we have (1) $\Delta(b_L)$ is continuously decreasing in b_L, (2) $\Delta(b_L) = b_T^M(b_L) - b_T^D > 0$ as $b_L \to 0$, and (3) $\Delta(b_L) = b_T^M(b_L) - b_T^D < 0$ as $b_L \to \frac{1}{2}$, so we can apply the intermediate value theorem and conclude that there exists $\bar{b}_L$ such that $b_T^M < b_T^D$ if and only if $b_L > \bar{b}_L$. □

From Lemma 6, we can directly conclude that if $b_L > \bar{b}_L$, then $b_T^M < b_T^D$ and therefore $\hat{T}_{Manual} > \hat{T}_{Digital}$. Since in equilibrium, $T = \hat{T}$ both before and after the reform, then $T_{Manual} > T_{Digital}$. □

B Appendix tables

Table B.1: Correlation of planned and actual rollout of the digitization reform

Dependent Variables:	Number of villages digitized	
	(1)	
Digitization of land records	173.3***	
	(24.00)	
	[0.000]	
Phase 1		129.1***
		(20.50)
		[0.000]
Phase 2		243.2***
		(41.84)
		[0.000]
Dep. var. mean	34.14	34.14
District fixed effects	Yes	Yes
Fiscal year fixed effects	Yes	Yes
Observations	219	219

Notes: Data is at the district-fiscal year level. 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in every year from FY2012 and FY2013 respectively, and remains zero otherwise. Phase 1 is a dummy that takes the value one after FY2012 for all the districts that were planned to be digitized in phase 1, and remains zero otherwise. Phase 2 is a dummy that takes the value one after FY2013 for all the districts that were planned to be digitized in phase 2, and remains zero otherwise. Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table B.2: OLS regression of tax collection on digitized villages

Dependent variable:	IHS Tax collection
	(1)
IHS num of digitized villages	-0.27**
	(0.12)
	[0.021]
Dep. var. mean (in 000 PKR)	16278.9
District fixed effects	Yes
Fiscal year fixed effects	Yes
Observations	212

Notes: Data is at the district-fiscal year level. 'IHS number of digitized villages' is the inverse hyperbolic sine of the number of villages that have digitized their land records. IHS tax collection is the inverse hyperbolic sine of the amount of taxes. Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table B.3: Did the digitization reform affect district level tax collection? (robustness to the use of inverse hyperbolic sine of tax collection)

	Median regression	Levels of tax	Intensive Margin	Extensive Margin
Dependent variables:	IHS tax collection	Tax collection (000 PKR)	Log tax collection	Whether any tax collected?
	(1)	(2)	(3)	(4)
Digitization of land records	-0.780*	-8053.4*	-1.457***	-0.0349
	(0.429)	(4120.2)	(0.440)	(0.0376)
	[0.0069]	[0.028]	[0.0026]	[0.32]
Control mean of outcome	16278.9	16278.9	16278.9	0.93
District fixed effects	Yes	Yes	Yes	Yes
Fiscal year fixed effects	Yes	Yes	Yes	Yes
Observations	212	212	201	212

Notes: Data is at the district-fiscal year level. 'IHS tax collection' is the inverse hyperbolic sine of the amount of taxes. 'Tax collection' is the amount of taxes collected by the government in thousand PKR. 'Log tax collection' is the natural logarithm of tax collection. '*Whether any tax collected*' is a dummy variable that takes value 1 if the tax collected in a district-year is positive, and remains zero otherwise. 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in every year from FY2012 and FY2013 respectively, and remains zero otherwise. While the dependent variables in Columns (1) and (3) are in IHS and log, respectively, their means are presented at the bottom of the table in levels (000 PKR). Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table B.4: Did the digitization reform affect district level tax collection? (robustness to different thresholds defining the beginning of a phase of digitization)

Dependent variables:	IHS Tax collection		
Timing of phases:	First 1% villages digitized in a phase	First 2% villages digitized in a phase	First 5% villages digitized in a phase
	(1)	(2)	(3)
Digitization of land records	-0.571	-0.980*	-1.827***
	(0.572)	(0.508)	(0.634)
	[0.27]	[0.04]	[0.01]
Dep. var. mean (in 000 PKR)	16679.9	16679.9	16278.9
District fixed effects	Yes	Yes	Yes
Fiscal year fixed effects	Yes	Yes	Yes
Observations	178	212	212

Notes: The unit of observation is a district-fiscal year. In Columns (1), and (2) 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts starting in years FY2010 and FY2011 respectively, and remains zero otherwise. The difference between the two columns is the number of years in which the control group of districts (phase 3) remains untreated. In Column (1), phase 3 becomes digitized in 2013, while in column (2) phase 3 becomes digitized in 2014. Column (3) replicates Table 1 in which phase 1 becomes digitized in FY2012, phase 2 becomes digitized in FY2013 and phase 3 becomes digitized in 2014. IHS tax collection is the inverse hyperbolic sine of the amount of taxes in thousand PKR collected by the government in a district-fiscal year. Standard errors clustered at district level in parentheses. Wild clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table B.5: Comparison of districts whose land records were digitized in phase 1 and 2 with the districts in phase 3 (never-treated group)

Dependent variables:	IHS Tax collection	
	(1)	(2)
Digitization of land records (Phase 1 vs. Phase 3)	-2.008**	
	(0.905)	
	[0.032]	
Digitization of land records (Phase 2 vs. Phase 3)		-1.766***
		(0.588)
		[0.0030]
Dep. var. mean (in 000 PKR)	16278.9	16278.9
District fixed effects	Yes	Yes
Fiscal year fixed effects	Yes	Yes
Observations	126	156

Notes: Data is at the district-fiscal year level. IHS tax collection is the inverse hyperbolic sine of the amount of taxes in thousand PKR collected by the government in a district-fiscal year. Phase 1 is a dummy that takes the value one for all the districts that were planned to be digitized in phase 1 in any years after FY2012, and remains zero otherwise. Phase 2 is a dummy that takes the value one for all the districts that were planned to be digitized in phase 2 in any years after FY2013, and remains zero otherwise. Phase 3 are those districts that are never treated in the sample period 2006-2013. Standard errors clustered at district level in parentheses. *Wild* clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table B.6: Did the digitization reform affect district-level tax collection? (placebo test based on different years of start of digitization)

Dependent variable:	IHS Tax collection	
Placebo:	Phase 1 2006 Phase 2 2007	Phase 1 2009 Phase 2 2010
	(1)	(2)
Digitization of land records	-0.475	-0.394
	(1.827)	(0.790)
	[0.78]	[0.59]
Dep. var. mean (in 000 PKR)	16800.8	16682.9
District fixed effects	Yes	Yes
Fiscal year fixed effects	Yes	Yes
Observations	212	212

Notes: The unit of observation is a district-fiscal year. The placebo is based on defining the 'digitization of land records' variable as a dummy that takes value 1 for phase 1 and 2 districts from years FY2006 (FY2009) and FY2007 (FY2010) respectively (instead of FY2012 and FY2013 in the main specification). IHS tax collection is the inverse hyperbolic sine of the amount of taxes in thousand PKR collected by the government in a district-fiscal year. Standard errors clustered at district level in parentheses. *Wild* clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

Table B.7: Did the digitization reform affect district-level tax collection? (Randomization inference p-value)

Dependent variable:	IHS Tax collection
	(1)
Digitization$_d$ × post$_t$	-1.628***
	(0.591)
	[0.004]
Randomization inference p-val	0.021
Control mean of outcome	16278.9
District fixed effects	Yes
Fiscal year fixed effects	Yes
Observations	212

Notes: The unit of observation is a district-fiscal year. 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts, and remains zero otherwise. Post is a dummy variable that takes the value 1 in years after FY2012, and remains zero otherwise. IHS tax collection is the inverse hyperbolic sine of the amount of taxes in thousand PKR collected by the government in a district-fiscal year. Randomization inference p-values (at the bottom of the table) are from permutation test similar to the randomization based inference test (Athey and Imbens, 2017; Young, 2019). We re-assign digitization over districts 10,000 times and compute the estimates under the null hypothesis that the treatment has no effect. Owing to this reassignment over just districts, we create separate dummy variables "Digitization of land records" and "post". Standard errors clustered at district level in parentheses. *Wild* clustered bootstrapped (with 10,000 replications) p-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

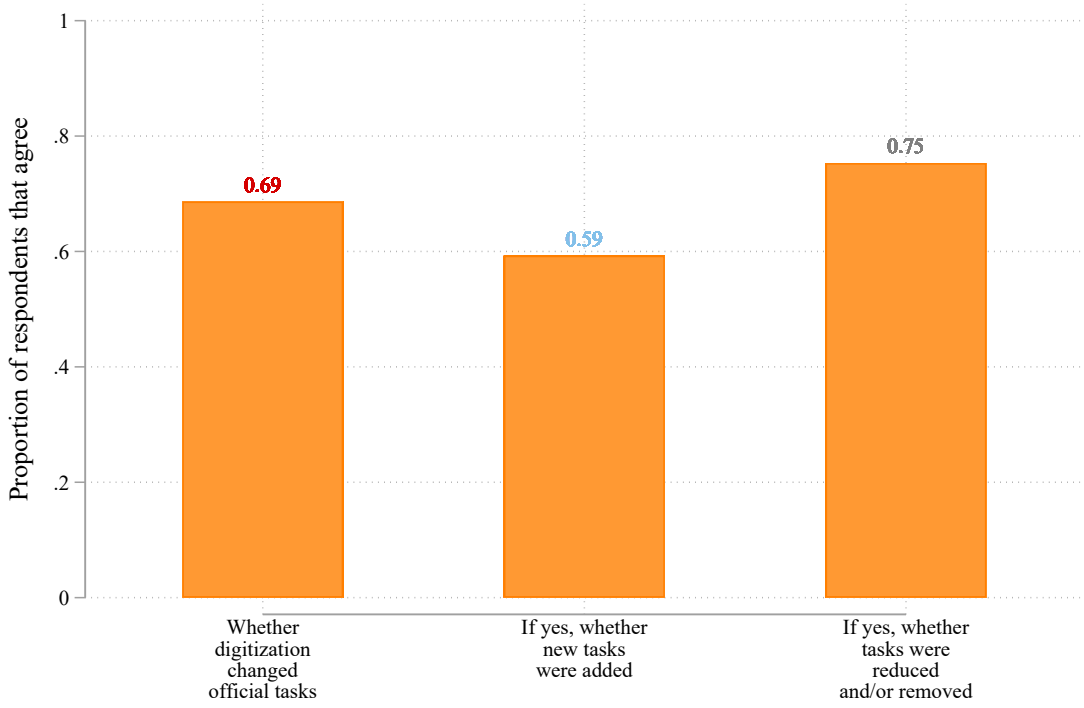
Table B.8: Did the digitization reform affect district-level tax collection? (robustness to controlling for the ability of bureaucrats' managers)

	District level tax		Performance of bureaucrats			
Dependent Variables:	IHS Tax collection	Tax collection (000 PKR)	$\frac{Tax\ collected}{Tax\ demand}$(%)	Whether atleast 50% tax demand was collected	Whether atleast 75% tax demand was collected	Share of months with zero collection
	(1)	(2)	(3)	(4)	(5)	(6)
Digitization of land records	-1.831***	-7934.3*	-30.42**	-0.347**	-0.404***	0.238*
	(0.623)	(4133.5)	(12.81)	(0.145)	(0.144)	(0.128)
	[0.005]	[0.028]	[0.029]	[0.019]	[0.008]	[0.075]
Avg. ability of managers	0.826	1440.9	33.87**	0.324	0.331	-0.342*
	(0.953)	(9303.7)	(15.63)	(0.199)	(0.208)	(0.179)
	[0.330]	[0.913]	[0.011]	[0.110]	[0.085]	[0.060]
Dep. var. mean	16278.9	16278.9	53.9	0.53	0.43	0.19
District fixed effects	Yes	Yes	No	No	No	No
Bureaucrat fixed effects	No	No	Yes	Yes	Yes	Yes
Fiscal year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	210	210	301	301	301	301

Notes: In Columns (1) and (2), the unit of observation is a district-fiscal year, while in Columns (3) and (4) it is a bureaucrat-revenue circles-fiscal year. 'Digitization of land records' is a dummy variable that takes value 1 for phase 1 and 2 districts in years after FY2012 and FY2013 respectively, and remains zero otherwise. IHS tax collection is the inverse hyperbolic sine of the amount of taxes in thousand PKR collected by the government in a district-fiscal year. Tax collection is the amount of taxes in thousand PKR collected by the government in a district-fiscal year. The outcome variable in Column (3) is the ratio of tax collected to tax demand issued. The outcome variables in Columns (4) and (5) are dummy variables that take values 1 if at least 50% (75%) of the annual tax demand was collected, and remains zero otherwise. The outcome variable in column (6) is the share of months in the fiscal year in which no tax was collected by bureaucrats. While the dependent variable in Columns (1) is in IHS, the mean presented at the bottom of the table is in levels (000 PKR). Standard errors clustered at district level in parentheses. *Wild* clustered bootstrapped (with 10,000 replications) *p*-values in square brackets. Significance levels are denoted as: * p<0.1, ** p<0.05, *** p<0.01.

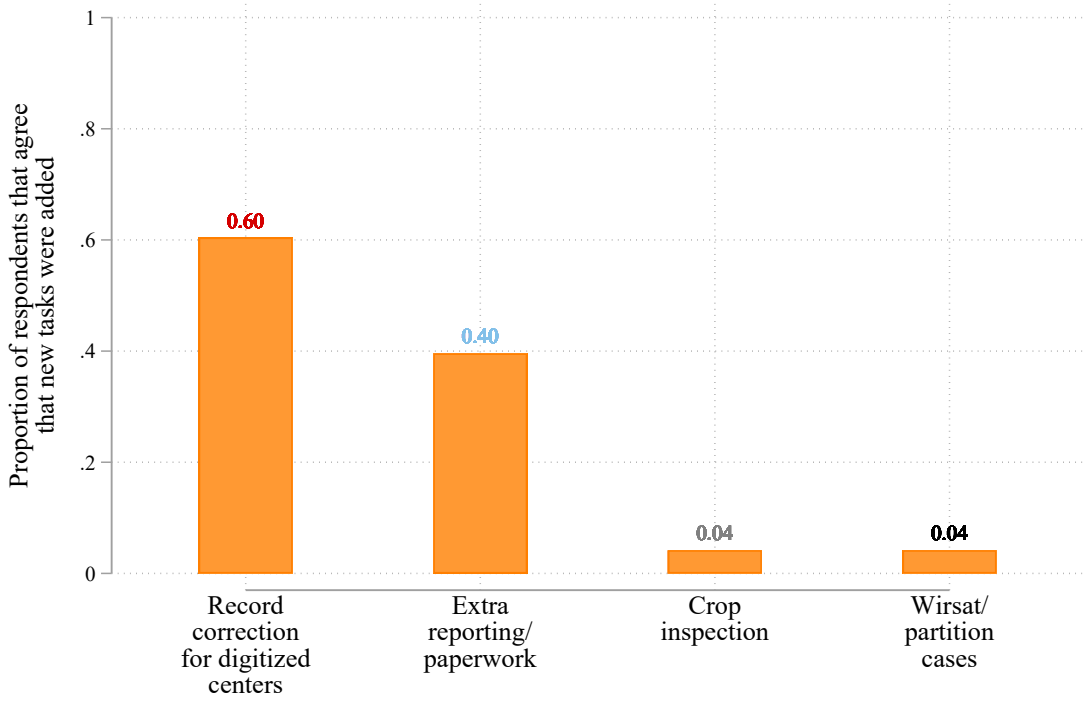
C Appendix: Figures

Figure C.1: Changes in the tasks of the bureaucrats after the digitization reform



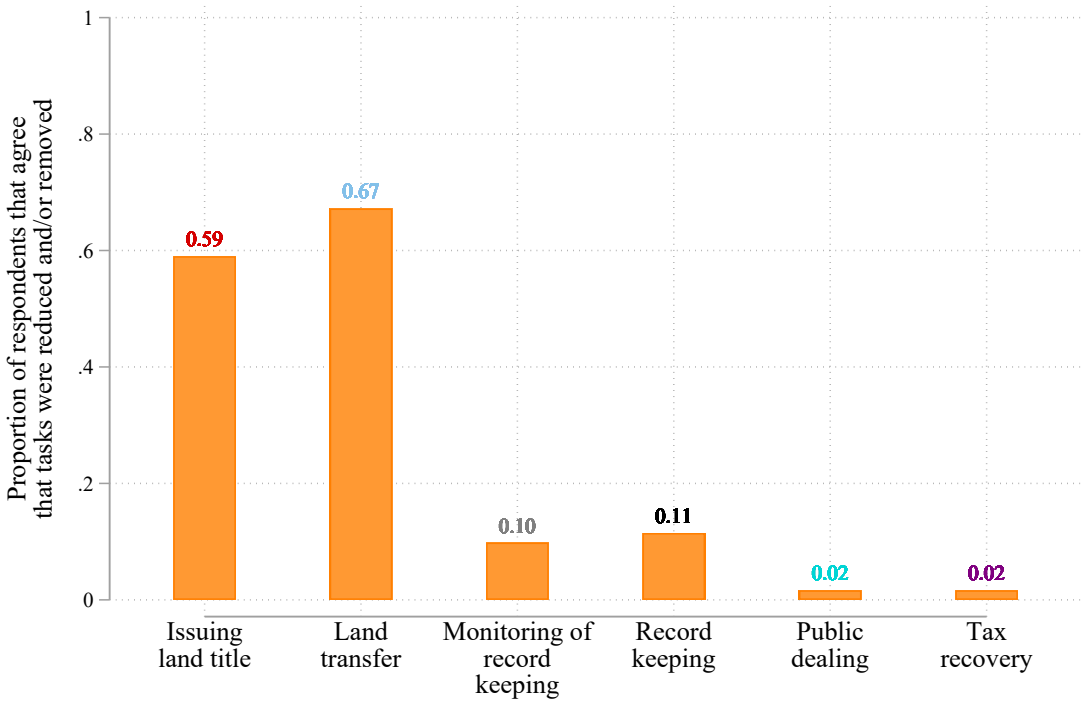
Notes: The figure is based on the bureaucrat survey restricted to the 118 bureaucrats who served as *Qanungo* between 2006-2013. The first bar plots the proportion of bureaucrats that agreed in the question "Do you think LRMIS (the digitization reform) changed the official tasks that you are supposed to do?"

Figure C.2: Bureaucrats' tasks added after the digitization reform



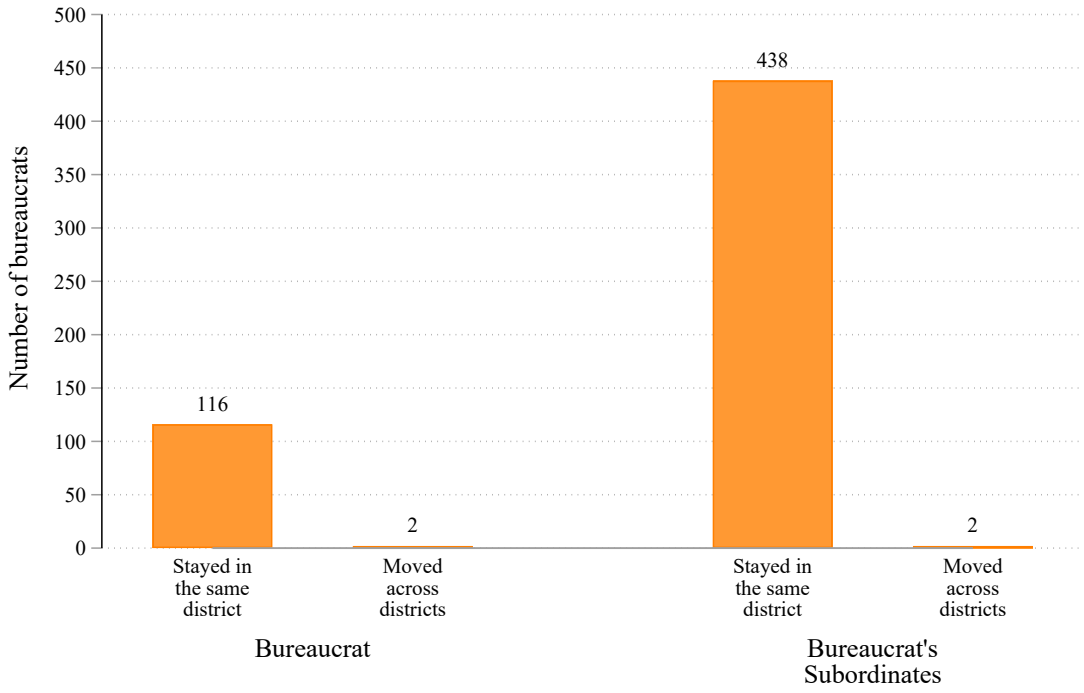
Notes: The figure is based on the bureaucrat survey restricted to the 81 bureaucrats who served as *Qanungo* between 2006-2013 and who agreed with the question "Do you think LRMIS (the digitization reform) changed the official tasks that you are supposed to do?"

Figure C.3: Bureaucrats' tasks reduced after the digitization reform



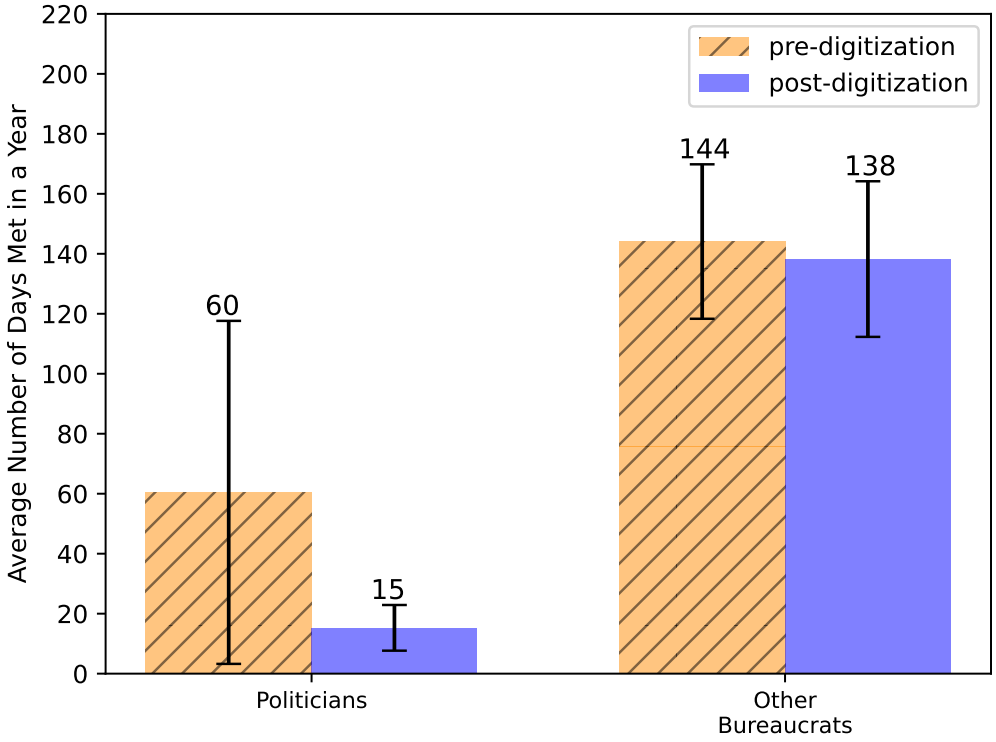
Notes: The figure is based on the bureaucrat survey restricted to the 81 bureaucrats who served as *Qanungo* between 2006-2013 and who agreed with the question "Do you think LRMIS (the digitization reform) changed the official tasks that you are supposed to do?"

Figure C.4: Movement of bureaucrats across districts



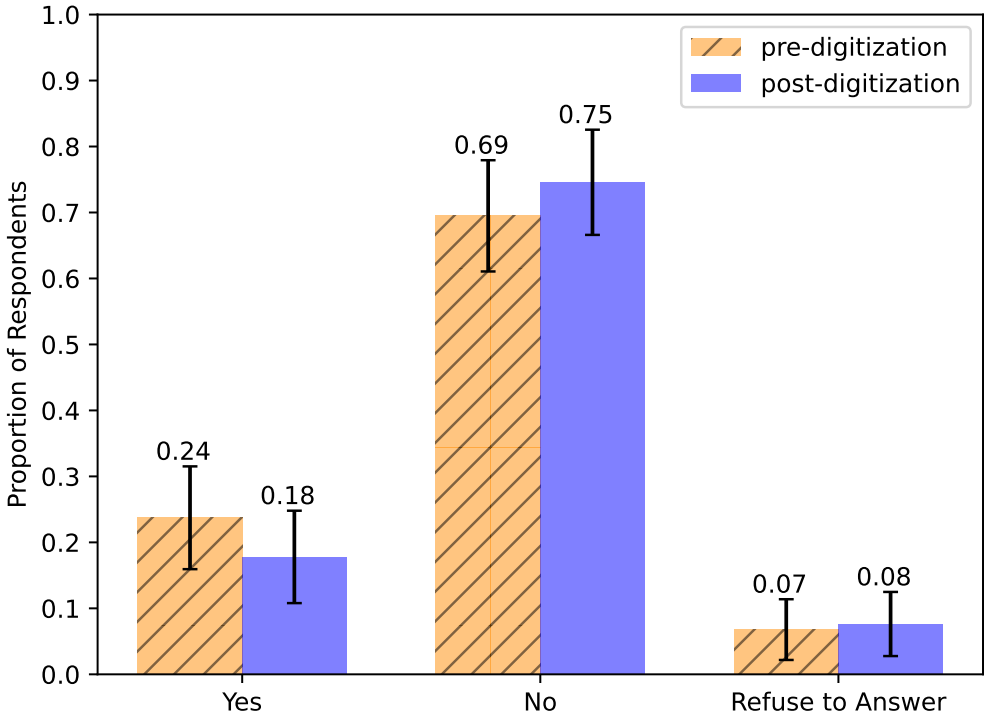
Notes: The figure is based on the bureaucrat survey. The left-hand side shows transfers among the bureaucrats that are the focus of this paper (Qanungos). The right-hand side shows transfers among their subordinates (Patwaris).

Figure C.5: Bureaucrats' social interactions with politicians and other bureaucrats before and after the digitization reform



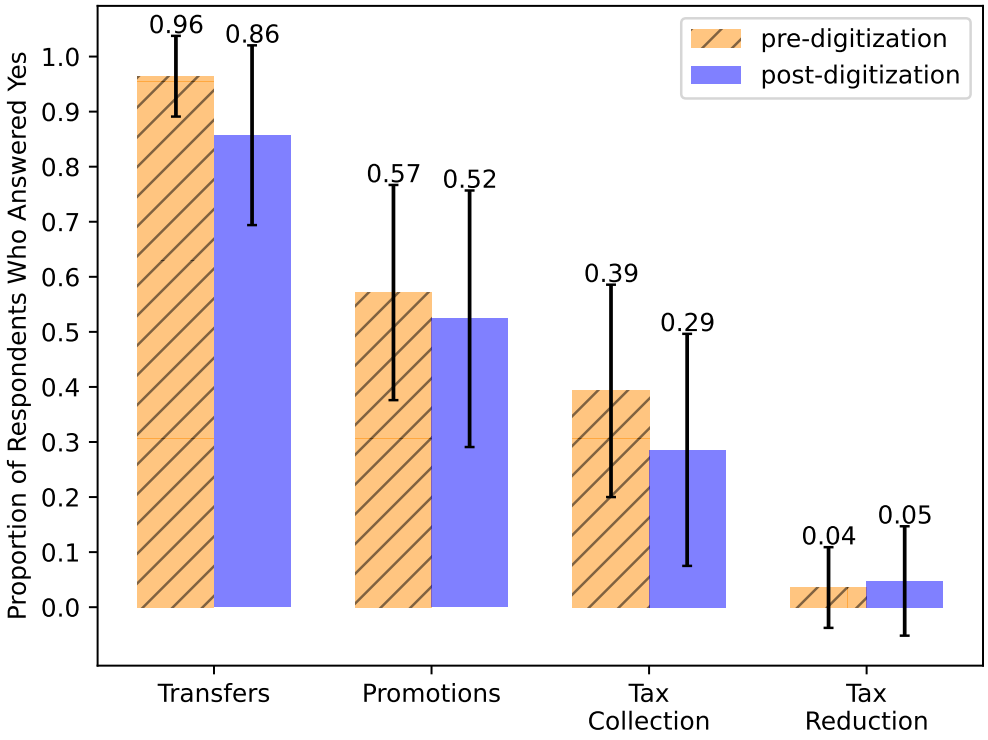
Notes: The figure is based on the bureaucrat survey restricted to the 118 bureaucrats who served as *Qanungo* between 2006-2013. We used a Likert scale to ask about the frequency of interactions between the respondent and politicians or other bureaucrats, before, and after, the reform. The Likert scale options were as follows: daily, twice a week, weekly, bi-monthly, monthly, quarterly, bi-annually, annually, less than once per year and never. We calculated the average number of days of interactions in a year for each bureaucrat based on these responses.

Figure C.6: Political interference in the work of bureaucrats



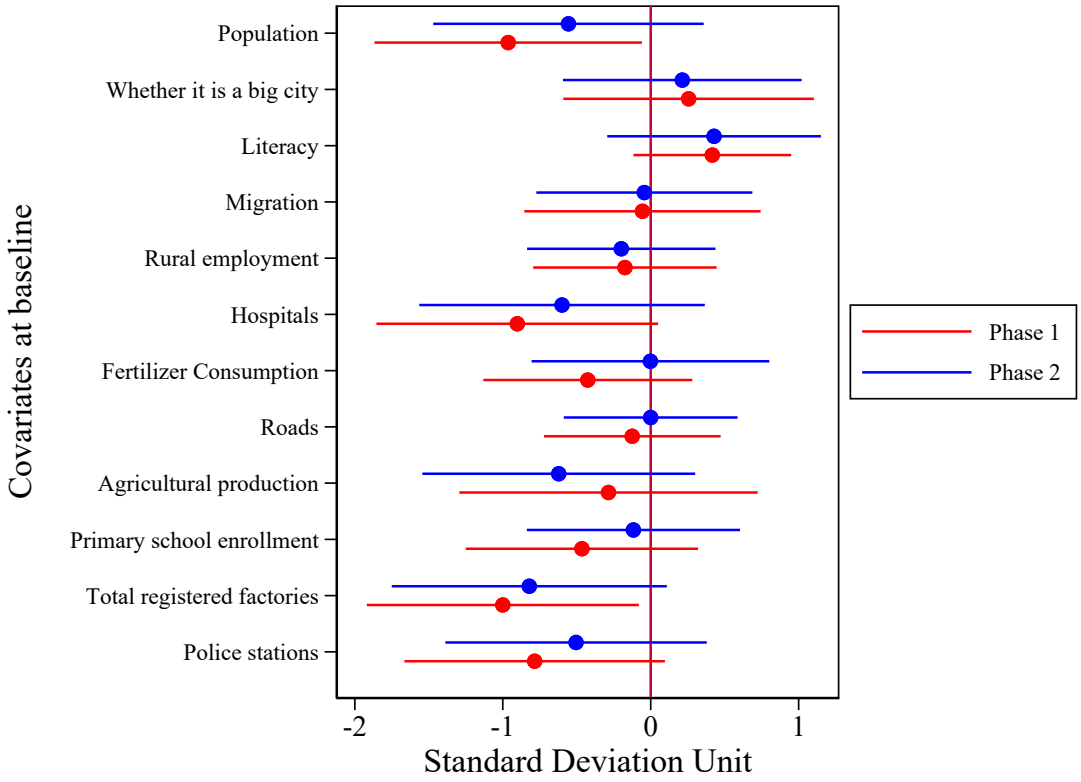
Notes: The figure is based on the bureaucrat survey restricted to the 118 bureaucrats who served as *Qanungo* between 2006-2013. The question was: "In general, would you say that politicians interfere with the work of revenue officials in this revenue circle?"

Figure C.7: Matters in which politicians interfere



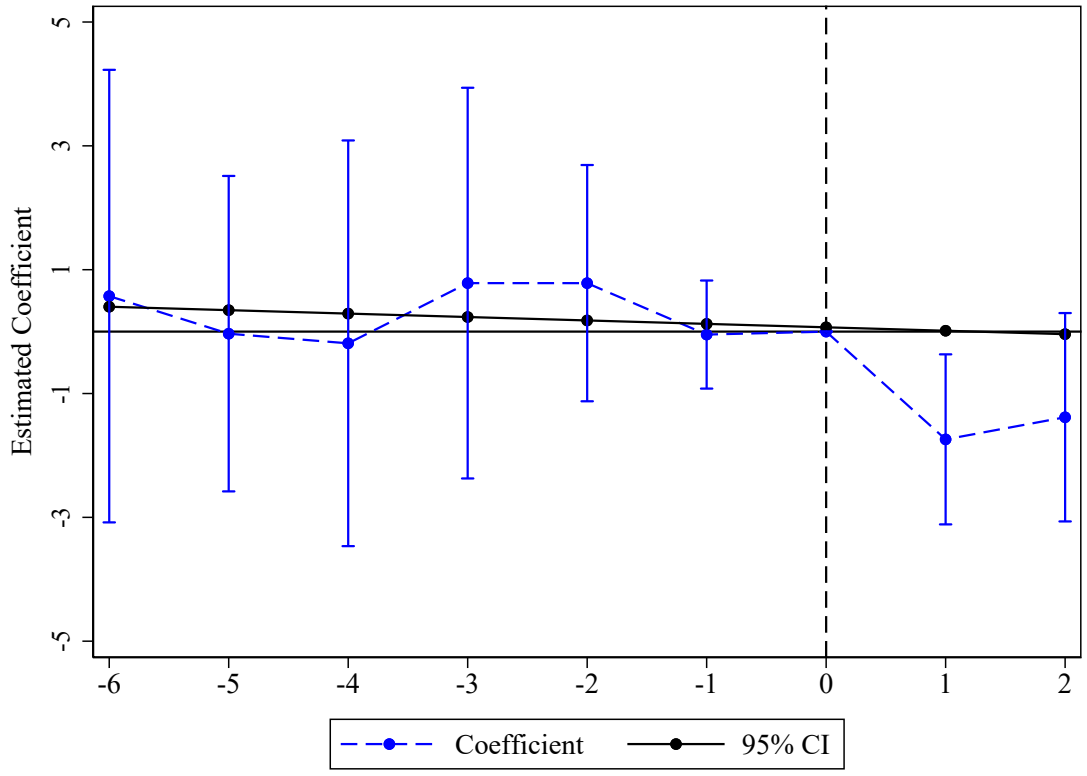
Notes: The figure is based on the bureaucrat survey restricted to the 118 bureaucrats who served as *Qanungo* between 2006-2013. Bureaucrats who responded 'yes' to the question: "In general, would you say that politicians interfere with the work of revenue officials in this revenue circle?" were further asked "On which matters politicians usually interfere with work?" The matters listed above were suggested by the research team along with the category of "others".

Figure C.8: Balance test of baseline characteristics of districts in phase 1 and 2 of the digitization reform



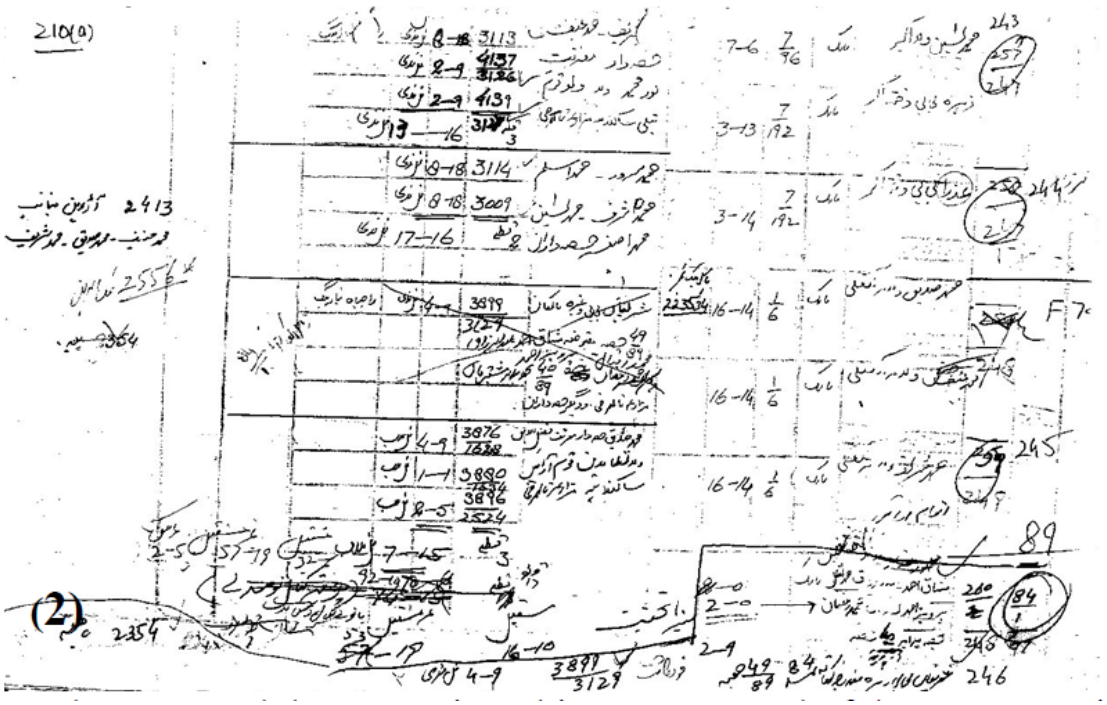
Note: Data on baseline characteristics from the Development Statistics of the Pakistan Bureau of Statistics 1997-2010. The point estimates are from a regression of the respective covariates on a dummy that takes the value of one if the district lies in phase 1 or 2 of the digitization reform, and remains zero otherwise. The reference category are phase 3 districts. Intervals are 95% confidence intervals.

Figure C.9: Event study plot for the district level IHS tax collection with a trend line based on pre-digitization data (TWFE estimator)



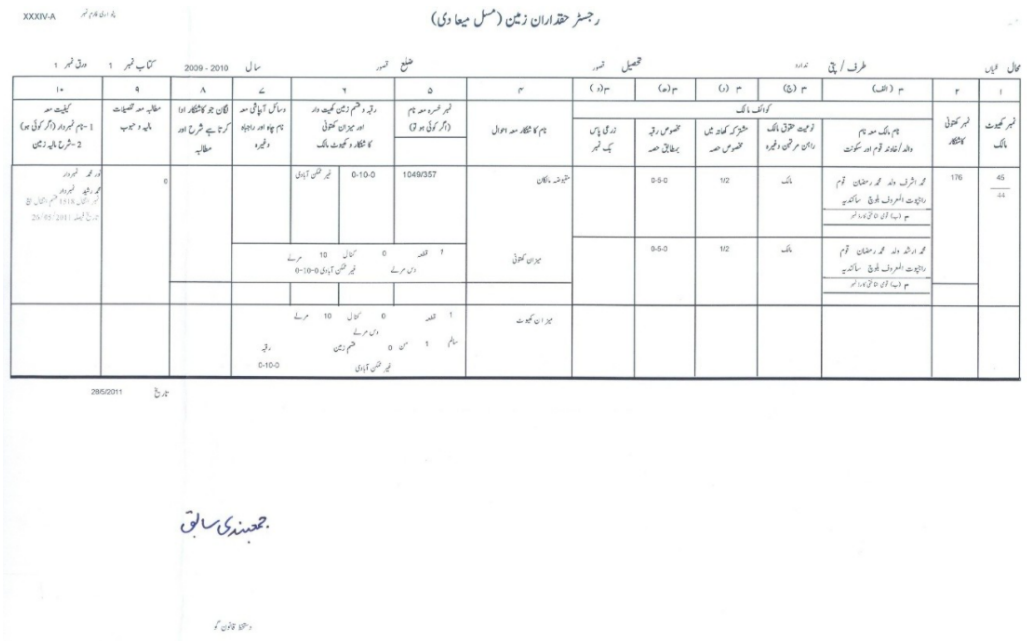
Notes: Data is at the district-fiscal year level. Each coefficient is obtained from a set of indicator variables that take values one if, in a given fiscal year, phase 1 or phase 2 districts were k years away from the introduction of digitized land records, as described in Equation 1. The reference year is FY2011 for phase 1 and FY2012 for phase 2. District and year fixed effects are included. Standard errors were clustered at the district level. The trend line is based on pre-digitization data (2006-2011). It is generated by regressing the pre-treatment coefficients (from Equation 1) on fiscal years 2006-2011.

Figure C.10: An example of a manual land record



Notes: The source of the figure is *Figure 2* in Adeel (2010). Before the digitization reform such land records were maintained by the bureaucrats we study.

Figure C.11: An example of a digitized land record



Notes: The source of the figure is: http://cadastraltemplate.org/pakistan.php

Figure C.12: A new bureaucracy set up to handle digitized land records

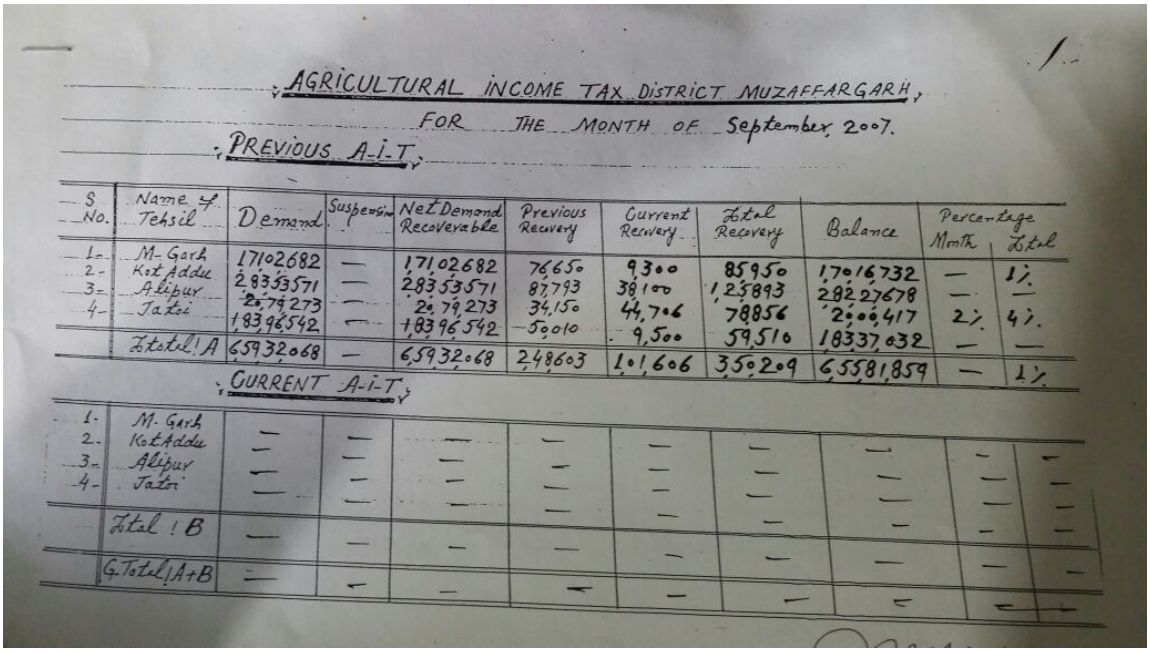


Notes: The source of the image is the World Bank (2017). New centers were set up across Punjab to deliver computerized land record services.

D Data Sources



Figure D.13: The Board Of Revenues (BOR) record room



AGRICULTURAL INCOME TAX DISTRICT MUZAFFARGARH

FOR THE MONTH OF September 2007.

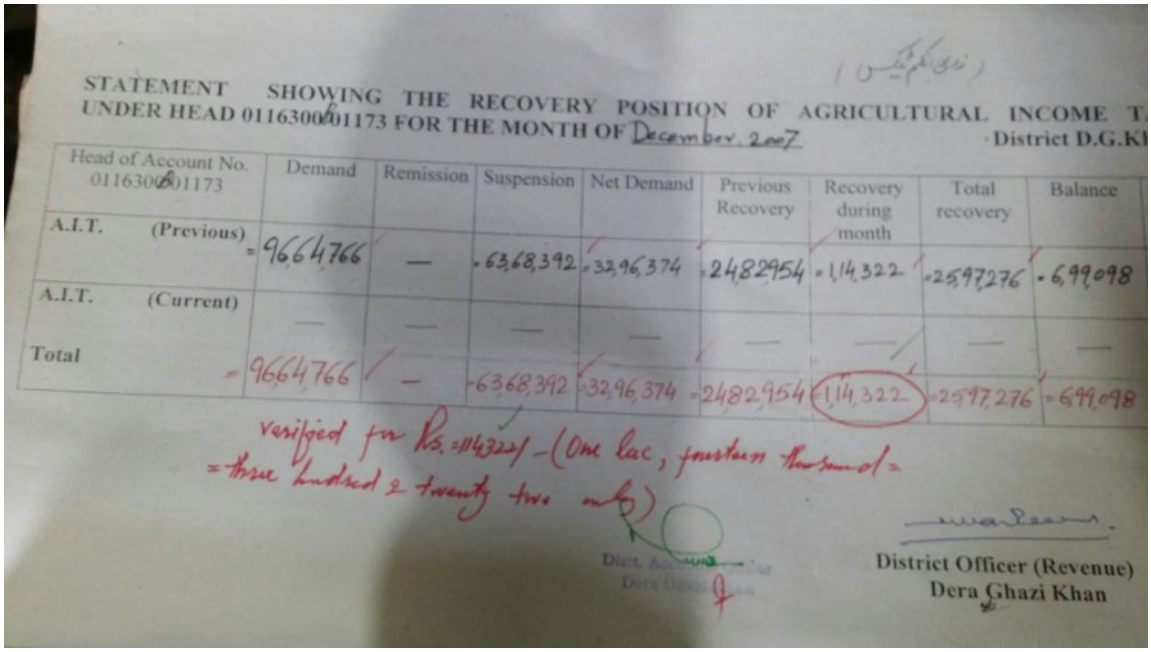
PREVIOUS A.I.T.

S No.	Name of Tehsil	Demand	Suspension	Net Demand Recoverable	Previous Recovery	Current Recovery	Total Recovery	Balance	Percentage Month	Percentage Total
1-	M. Garh	17102682	—	17102682	76650	9300	85950	17016732	—	1%
2-	Kot Addu	28353571	—	28353571	87793	38100	125893	28227678	—	—
3-	Alipur	2679273	—	2679273	34150	44706	78856	2600417	2%	4%
4-	Jatoi	18396542	—	18396542	50010	9500	59510	18337032	—	—
	Total A	65932068	—	65932068	248603	101606	350209	65581859	—	1%

CURRENT A.I.T.

1.	M. Garh	—	—	—	—	—	—	—	—	—
2.	Kot Addu	—	—	—	—	—	—	—	—	—
3.	Alipur	—	—	—	—	—	—	—	—	—
4-	Jatoi	—	—	—	—	—	—	—	—	—
	Total B	—	—	—	—	—	—	—	—	—
	G.Total (A+B)	—	—	—	—	—	—	—	—	—

Figure D.14: The BOR tax collection pro forma



STATEMENT SHOWING THE RECOVERY POSITION OF AGRICULTURAL INCOME T.
UNDER HEAD 01163001173 FOR THE MONTH OF December 2007
District D.G.K

Head of Account No. 01163001173	Demand	Remission	Suspension	Net Demand	Previous Recovery	Recovery during month	Total recovery	Balance
A.I.T. (Previous)	9664766	—	6368392	3296374	2482954	114322	2597276	699098
A.I.T. (Current)	—	—	—	—	—	—	—	—
Total	9664766	—	6368392	3296374	2482954	114322	2597276	699098

verified for Rs. 114322/- (One lac, fourteen thousand three hundred & twenty two only)

District Officer (Revenue)
Dera Ghazi Khan

Figure D.15: The BOR tax collection pro forma verified by District Accounts Officer

E Sampling for the bureaucrat survey

The retrospective survey was carried out in 2020, with the main aim to rebuild career trajectories of bureaucrats between 2006-2013 (the years when the tax data is available). Our sampling frame therefore, included people who were in-charge of revenue circles (*Qanungo*) as well as people who in the recent past had worked as a *Qanungo*. These included bureaucrats that had risen through the ranks via promotions and were in-charge of the tehsils: (*Tehsildars* and *Naib-tehsildars*).

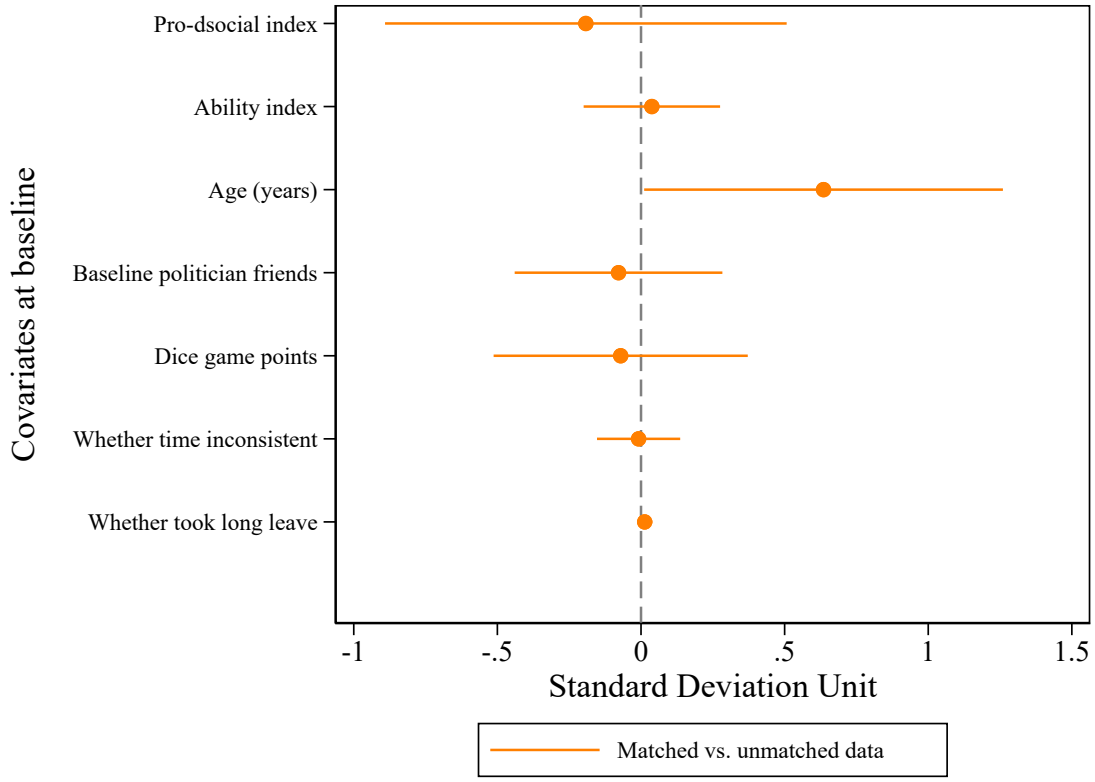
We stratified on districts and randomly sampled tehsils within each district.[42] We next created a sampling frame by contacting the local offices. Using that sampling frame we selected the universe of *Tehsildars* and *Naib-Tehsildars* working in the selected tehsils in Punjab. One *Qanungo* working with each of the *Naib-tehsildars* was randomly selected for the survey. We found 118 respondents who worked as Qanungos between 2006-2013.[43]

We could string-match the revenue circle name for 105 of those 118 respondents to match the survey data with the tax collection data. Of those the tax performance was missing for 27, so our final data set includes 78 respondents whose tax performance is observed between 2006-2013. In Figure E.16 below, we examine the potential systematic differences between these bureaucrats and the broader sample across various characteristics, utilizing data gathered from the bureaucrat survey. The only covariate showing marginal statistical significance is age. The p-value resulting from a joint significance test of all covariates in the figure is 0.5027, providing evidence that the sample is not systematically selected based on characteristic of the bureaucrats.

[42]Out of 141 tehsils in Punjab, we were able to survey bureaucrats from 138 tehsils. We were unable to survey the bureaucrats from the following three tehsils: Nishtar Town (Lahore districts), Shahkot (Nankana Sahib district), Ahmed Pur (Sheikhupura district).

[43]To find these, we started by surveying a total of 610 bureaucrats across different levels of hierarchy. Of those, 488 responded to the second round of telephonic survey about their career trajectory. The telephonic survey was used to recap the career paths of the bureaucrats, while their perceptions of digitization as well as their traits were measured in-person. In the pilot this was suggested by the field team as the best way to get maximum response rate, since the length of the two together were running to above 1 hour 30 min.

Figure E.16: Characteristics of the bureaucrats in the sample that were matched with the tax data



Note: Data on bureaucrats' characteristics is from the bureaucrat survey. The point estimates are from a regression of the respective covariates on a dummy that takes the value of one if the bureaucrats in the survey data were matched with the tax data, and remains zero otherwise. Pro-sociality index is created from five measures: Inclusion of Others in Self scale (Aron et al., 2004; Ashraf et al., 2020), whether they have donated blood, money donated in public good game, whether they do volunteer work and whether they give charity. Ability index is created from four measures: an incentivized matrix game and a memory game as in Hanna and Wang (2017), response to questions on general knowledge and revenue rules and regulations, respectively. Politician friends are the number of friends of the bureaucrats that are either federal or provincial politicians. Dice game points is a proxy for dishonesty and it is the total in an incentivized dice game as in Hanna and Wang (2017). Intervals are 95% confidence intervals.

F Details on string matching revenue circles

We carried out an extensive string matching exercise to merge the tax, digitization and bureaucrats' careers datasets. We took the following steps to merge the three sets of data:

- As a first step we manually checked each revenue circle, tehsil and district in the tax data against their counterparts recorded in the digitization data from the Punjab Land Records Authority (PLRA) and allocated a unique ID to each.[44] There were 1125 revenue circles in total, out of which 838 were given IDs using this process.
- The district, tehsil and revenue circle names in the bureaucrat survey data was manually cleaned. There were 690 unique revenue circles-tehsil-districts in this data, out of these we were able to give IDs to 458.
- Finally, we merged all the three data on revenue circle, tehsil and district names.

We next checked the veracity of these data using further records from the government on details of revenue circle, tehsil and district names across Punjab. These were personally obtained from the government in 2020.

[44] Digitization data from PLRA contained details of names of most of the tehsils and revenue circles except the following 19 (out of 141 in total) tehsils: Gujranwala Sadar, Kabirwala, Kharian, Shorkot, Khushab, Quaidabad, Jauharabad Lahore city, Nishtar Town, Muzaffargarh, Depalpur, Renala khurd, Arifwala, Khanpur, Murree, Rawalpindi city, Rawalpindi Sadar, Rawalpindi Cantt and Daska.

G Satellite vegetation cover data

We used NASA's MODIS land products to observe a satellite based vegetation cover index. MODIS vegetation indices provide consistent spatial and temporal comparisons of vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structure. The normalized difference vegetation index (NDVI) are derived from atmospherically-corrected reflectance in the red, near-infrared, and blue wavebands. NDVI ranges from -1 to +1. If the NDVI values are negative it is highly likely that it's water. On the other hand, values close to +1 suggest that there is a high possibility that there are dense green leaves.[45]

NASA's MODIS land products rely on the Sinusoidal Tile Grid System, which divides earth into 36 x 18 sinusoidal grids to locate a particular area on earth.[46]. Since we are only interested in the Punjab province of Pakistan, our first step was to locate the tiles where Punjab is located. Given the shapefile of districts of Punjab, we uniformly sample 10,000 points within each district and calculated their locations on the sinusoidal tile.[47] We find that all 36 $\times$ 10,000 points lie within three tiles, namely (horizontal 24, vertical 5), (horizontal 24, vertical 6), and (horizontal 23, vertical 5). There are a total of 4800 $\times$ 4800 pixels within each of the three tiles mentioned above, with each pixel having a 250 m $\times$ 250 m size. Moreover, data for each year is divided into time intervals of 16 days. This results in 23 different time intervals in a given year. For each 16-day time interval in a year, and for each of the 36 districts of Punjab, we obtained the NDVI values of all pixels belonging to that particular district and take the average to get the NDVI value for that particular district in that particular 16-day interval. Since each year has 23, 16-day intervals, we end up having a list of 23 different NDVI values for a particular district in a particular year. Following the method used in Beg (2020), we use the maximum value of that list as the NDVI value for that district for that year.

[45] Details accessed at https://gisgeography.com/ndvi-normalized-difference-vegetation-index/

[46] Accessed at: https://modis-land.gsfc.nasa.gov/MODLAND_grid.html

[47] We decided to rely on this method rather than just consider the district's center and calculate their locations on the sinusoidal tile. This allows us a more holistic view of the vegetation cover of the district.