

The Promise and Limitations of Information Technology for Tax Mobilization

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Abstract

Tax revenue in many low- and middle-income countries is inadequate for funding investments in public goods and human capital. With high levels of informality and limited state capacity, many tax authorities have difficulty determining the true tax base and collecting taxes efficiently and equitably. Tax authorities are increasingly adopting new technologies to improve administrative processes, reduce taxpayer compliance costs, and enhance their overall effectiveness. This paper reviews the recent literature on the

use of technology for tax administration. It highlights the potential of technology to improve tax collection by helping to identify the tax base, monitor compliance and facilitate compliance. It also identifies possible limitations to the use of technology arising from inadequate infrastructure and connectivity, lack of adoption or resistance by taxpayers and tax collectors, lack of institutional mainstreaming, and an unsupportive regulatory environment.

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The Promise and Limitations of Information Technology for Tax Mobilization*

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Increasing tax revenue is an important policy goal in many low- and middle-income countries (LMICs). On average, low-income countries collect 11 percent of GDP as taxes compared to 22 percent in high-income countries (UNU-WIDER Government Revenue Dataset, 2021). Beyond funding public investments such as infrastructure, health and education, taxation is also important for providing redistribution, and reducing reliance on foreign aid and natural resource revenues. However, with high levels of informality and limited state capacity in LMICs (Besley and Persson, 2009), many tax authorities have difficulty determining the true tax base and collecting taxes efficiently and equitably.

Over the last few decades, tax systems around the world have increasingly adopted new technologies to improve administrative processes, reduce taxpayer compliance costs, and enhance their overall effectiveness at collecting tax revenue. These developments come in the context of digital transformation across all facets of life: from government to business to interpersonal relationships and much more, an increasing number of interactions are conducted virtually given the rapid development and expansion of digital infrastructure. For example, in 2020, 51 percent of the global population was connected to the internet. This figure was 7 percent only 20 years earlier (Our World in Data/ World Bank indicators).

Given the rapid expansion in the use of information technology by tax authorities, this paper provides a review of the recent evidence from LMICs. We draw on a burgeoning literature on the role of technology in tax administration to highlight key lessons on maximizing the potential of technology. We also discuss complementary reforms that must be undertaken to ensure that investments in technology yield the desired results for tax mobilization. While we include papers that provide descriptive evidence from many contexts, we emphasize papers that use rigorous methods to establish a causal impact of the introduction of technology and highlight the methods used when describing these papers.

In the first part of the paper, we consider how technology may transform three core functions of tax administration. First, technology may be used to *define compliance*, that is, to strengthen the capacity of tax administration to identify the tax base, or the pool

of subjects liable to remit a given tax amount. This could happen, for instance, when technology enables the creation of a new database of taxable subjects (such as individuals or properties). Similarly, technology could help define the actual amount to be remitted more transparently by relying on the automatic capture of transactions as they occur, through electronic fiscal devices (EFDs) or electronic payments.

Second and relatedly, technology may be used to *monitor compliance*. Modern data analytic tools could significantly boost the capacity of the tax administration to monitor and enforce compliance, through the automation of crosschecks of self-reported tax liability with other data sources. Technology-based tools also allow for analyzing large amounts of data to support risk-based audits which would result in more targeted and transparent audit selection.

Third, technology may be used to *facilitate compliance*, that is, to simplify processes and improve taxpayer experience. Technology could significantly reduce tax compliance costs, which are often disproportionately borne by smaller taxpayers. For example, e-filing (often accompanied by e-payment) of taxes can make the taxpaying experience less time consuming and more consistent across taxpayers. As we would see, certain technologies may address more than one of these three uses.

While technology may also be used to improve other core functions of tax administration, such as the capacity to perform more timely data-driven decision-making, and to run more elaborate statistical analysis and forecasting, these internal functions are beyond the scope of this paper. Instead, we focus on those IT solutions directly affecting taxpayers' interactions with the tax administration, potentially shaping their compliance.

In the second part of the paper, we consider factors that may prevent the realization of the potential of technology to improve tax mobilization. First, lack of appropriate infrastructure and internet connectivity will hinder effective deployment of the technologies. Second, users (taxpayers and tax officials) may avoid or actively resist the introduction of a new technology due to lack of awareness and training, high adoption costs or loss of opportunity for unofficial

behaviors. Third, the absence of a clear organizational strategy that involves high-level change management and a proper sequencing of the digitization of different functions and processes can hamper the effectiveness of technologies that are introduced. Fourth, without a functional legal system to enforce tax laws, the revenue authority may be unable to collect tax liabilities that have been uncovered with the use of technology. Relatedly, there needs to be an appropriate regulatory framework that allows a balance between data privacy and security and the use of new data and technology for tax purposes.

While there are many applications of technology in tax administration, this paper focuses on foundational technological innovations which are usually adopted at the core of the digital journey of a tax administration, such as e-filing and e-payment, electronic fiscal devices (including electronic sales registers and electronic billing machines), IT solutions used for taxpayer registration and communication, as well as tax data crosschecks and third-party data analytics. We highlight these types of technology as they communicate with each other and are likely to perform best when included in the same technological transformation package – usually supported by an integrated (and automated) tax administration system (ITAS). For example, the huge amount of data produced by EFDs is unlikely to be fully tapped without an automated and integrated data management system on the receiving end. Likewise, without a flexible, adaptive, timely response from the authority (which is often enabled by ITAS), e-filing is unlikely to be successful (Santoro et al., forthcoming).

Focusing on these foundational technologies also enables us to draw on an increasing, robust body of evidence that has been produced on them in the last few years. We expect that the lessons from reviewing the existing evidence on the effectiveness of technologies that are more widely used in LMICs will help in understanding the potential impact and constraints in the adoption of more sophisticated technologies that have been introduced in some other contexts, such as the automatic withholding of taxes from sales payments made via credit card (Brockmeyer and Hernandez, 2016), automatic pre-filing of tax returns using

third-party information, and the use of blockchain to verify transactions and tax records.¹

This paper contributes to both the academic literature as well as policy conversations in LMICs. It provides a review of the booming literature on the use of technology in tax administration (Bird and Zolt, 2008; OECD, 2021; World Bank, 2016; Kochanova, Hasnain and Larson, 2020; Bellon et al., 2019; Santoro et al., forthcoming) and identifies outstanding gaps in the literature for future research. It therefore complements other reviews on taxation in developing countries (e.g. Mascagni (2018), Slemrod et al. (2017), Pomeranz and Vila-Belda (2019)).

More broadly, the paper adds to the literature on the use of technology in governance. The evidence on the effectiveness of investment in e-government on strengthening government capacity to deliver services, reduce corruption, and expand citizen participation is still rather mixed (World Bank, 2016). On the one hand, there is evidence of effective deployment of digital public service provision in procurement (Lewis-Faupel et al., 2016), education (Aker and Ksoll, 2019; Escueta et al., 2017), voting (Callen and Long, 2015; Fujiwara, 2015; Callen et al., 2016; Aker, Collier and Vicente, 2017) and social protection (Aker et al., 2016; Banerjee et al., 2020; Muralidharan, Niehaus and Sukhtankar, 2016). On the other hand, better information technology does not necessarily translate into improved behaviors and welfare, especially in health (Nglazi et al., 2013, provides a review) and agriculture (Aker, Ghosh and Burrell, 2016; Courtois and Subervie, 2015; Hildebrandt et al., 2014; Nakasone, Torero and Minten, 2014; Mitra et al., 2013; Camacho and Conover, 2010; Fafchamps and Minten, 2012; Casaburi et al., 2014). This paper examines several studies where technology has led to improvements in government service delivery but also describes conditions that may preclude successful outcomes. Relatedly, the paper also addresses basic questions of digital technology access and usability (Aker and Cariolle, 2020; Santoro et al., forthcoming).

For policy, the paper provides guidance to policy makers as tax authorities increasingly

¹Blockchain technology would enable a variety of services (such as e-registration with government entities, e-filing of taxes, and sharing of data among government agencies) under a strong security model where all information is digitally signed and encrypted and all incoming data are authenticated and logged (Martinovic, Kello and Sluganovic, 2017).

adopt electronic systems in interacting with taxpayers in a post-COVID world where remote interactions are more prevalent. It distills lessons from the academic literature on the vast potential of technology as well as highlights the necessary technical, institutional and political factors for a successful shift to technology. In particular, it emphasizes how technology adoption must be contextualized within the current administrative capacity of the country. Lastly, by highlighting the potential policy impact of rigorous and timely policy research, in many cases made possible by the rich data produced from the use of technology, this paper also seeks to encourage further collaboration between policymakers and researchers.

1 Potential of Technology in Taxation

1.1 Define Compliance

Information technology is crucial for addressing the “information problem,” a core challenge for tax administration (Alm, 2021). In order to tax, the government must be able to identify the tax base. Prior research has shown that for taxes that are subject to third-party reporting, such as wages paid to employees and capital income paid to clients, tax evasion is limited. However, evasion is substantially higher for taxes not subject to third party reporting, where taxpayers self-declare their tax liability (Kleven et al., 2011).

Tax authorities can deploy appropriate technology systems to obtain information on taxpayer liabilities that may otherwise be hidden or manipulated by taxpayers. For third-party information, technology can enable the efficient submission of large amounts of data from a reporting entity (such as an employer or financial company). Technology may also facilitate linking databases that provide information on the different sources of taxable income or assets of a taxpayer. The examples below will highlight the use of technology in defining the tax base in different settings. First, in addressing the challenge of information on transactions that may otherwise go unreported, we examine the use of electronic fiscal devices that report information on sales as they occur as well as electronic payments that provide a

paper trail of a firm’s income. In addition, we examine the use of technology in improving taxpayer registration, with a specific focus on how IT is used in real estate tax administration to systematically capture information on tax liabilities that are observable but not codified.

1.1.1 Obtaining Real-time Transaction Information with Electronic Fiscal Devices

Electronic fiscal devices (EFDs) are machines that automatically record transactions as they are performed and communicate this information to the tax administration through either a mobile network or the internet. In some cases, these machines also print out receipts. Such unprecedented flow of information holds the potential of assisting the tax administration in knowing more about the taxpayer population.

Ali et al. (2021) exploits the staggered rollout of EFDs across VAT-registered firms over 12 years in Ethiopia to evaluate the impact of such technology on both VAT tax payments and proxies of the tax base. They show that EFDs significantly increase reported sales and tax payments, while also leading to positive impacts on actual output – proxied by employment rates. Importantly, the tax base does not appear to be negatively affected as the paper does not find any significant relationship between EFD adoption and net entry rate of firms.

Mascagni, Mengistu and Woldeyes (2021) provides further evidence from the adoption of EFDs in Ethiopia. Using a difference-in-differences approach, the paper considers the fact that EFDs may have compliance effects across other tax types beyond VAT, following the recent shift towards studying compliance spillovers across taxes for a complete evaluation of any policy intervention (López-Luzuriaga and Scartascini, 2019). Like Ali et al. (2021), the paper finds a significant increase in VAT payments but also in income tax payments. In addition, the paper documents that the EFDs significantly improve the accuracy of firms’ reporting, measured by the discrepancies in reported sales between VAT and income tax returns. On average from 2010 to 2014, 60 percent of firms reported discrepancies in turnover

in their declarations. Such discrepancies more than halve after the introduction of EFDs as a result of the combination of improved record-keeping practices and increased perception of detection of misreporting.

In addition to the positive evidence above, there are some more nuanced considerations. First, while technology could help better identify transaction volumes and tax payable, as shown in Ethiopia, behavioral and strategic responses from taxpayers could produce perverse effects. Mascagni, Mengistu and Woldeyes (2021) show that the increase in VAT sales as a result of EFD adoption is offset by simultaneous and proportionally larger increase in deductible costs thus substantially reducing the potential revenue gains. Similar offsetting responses are found in the broader tax literature on firms (Ariel (2012); Carrillo, Pomeranz and Singhal (2017); Slemrod et al. (2017); Mascagni and Nell (2022)). Second, while technology could be an effective tool to identify the tax base and the tax due more accurately, it proves to be ineffective in those contexts lacking robust traditional enforcement. While new technology could generate new data, it is only effective if it spurs adequate deterrence actions from the authority, which in turn depend on the resources available for traditional enforcement.

1.1.2 Electronic Payments for Transactions

While electronic payments such as credit cards, debit cards and mobile money are not technologies developed specifically for taxation, they play an important role in providing a paper trail for revenues received by firms, thereby providing information on tax liabilities.² Unlocking the full potential of such data, however, relies on formal data sharing agreements between revenue authorities and commercial banks and credit cards companies. Section 2.4 discusses the need for a supportive regulatory framework to facilitate such data sharing.

In West Bengal, India, Das et al. (2022) finds that the 2016 demonetization policy resulted in a higher reliance on electronic payments which in turn increased the amount of sales

²As an extreme application with potential negative economic and equity implications, some countries have introduced legislation to impose taxes on all mobile money transactions.

firms reported for tax purposes. By using administrative data on firms' VAT tax returns and exploiting the variation in the intensity of the demonetization shock across local areas, the authors find that a 10 percent increase in electronic payments in an area increases average reported sales by 0.3 percent. The paper finds tentative evidence regarding the effect on total tax liabilities: the effects are of similar magnitude as the effect on sales but are not precisely estimated. The authors argue, albeit cautiously, that the higher visibility of electronic transactions reduces scope for evasion, as traders have less room for sales underreporting.

Along the same lines, Brockmeyer and Sáenz Somarriba (2022) use both regression discontinuity and difference-in-difference estimations to evaluate the impact of VAT rebates for consumers using electronic payments instead of cash in Uruguay. Using transaction-level data on all electronic transactions and monthly firm-level VAT declarations, they examine the impact of the rebates on credit and debit card transactions and on tax compliance. The VAT rebate was preceded by other incentives such as lowering commissions for POS usage, reducing the tax withholding rates applied by card companies, and providing subsidies to firms for POS rental, which were all part of Uruguay's Financial Inclusion Reform, a government-wide effort to foster electronic payments in trade and move away from cash.

First, the paper shows that the incentives translate into an immediate 50 percent increase in the number of debit and credit card transactions, and a 30 percent increase in the volume of card transactions – mostly spurred by customers' responses. On the other hand, firms are largely unresponsive to the incentive: only a small fraction of eligible firms took up the subsidy, 80 percent of whom already had a POS machine when taking up the subsidy. This means that the revenue authority did not gain significant additional information on firms previously out of their radar (extensive margin), as the vast majority of the adopters were already visible. In terms of impact on compliance, the policy effect on reported output VAT and net VAT liability is very small and statistically indistinguishable from zero.

1.1.3 Using Technology for Taxpayer Registration

Technology could also significantly assist tax administration in registering taxpayers and, more importantly, uniquely identifying them. In this sense, integrated tax administration systems (ITAS) are crucial in streamlining the registration process. Unsurprisingly, one of the first modules usually implemented when an ITAS is launched is the registration module, enabling e-registrations. In the absence of a well-functioning, automated system, revenue authorities often implement suboptimal practices which translate into the existence of parallel registries, often kept on Excel spreadsheets, and, ultimately lead to administrative confusion, duplication of work and difficulty in monitoring the taxpayer base (Ligomeka, 2019; Stewart-Wilson, 2020). In light of the recent wave of automation in tax administration, more research is needed to explore impacts on internal efficiency.

Despite these positive considerations that can be made in support of technology in registration, technology-enabled registrations could take place over-aggressively in LMICs, along with the increasing drive towards formalizing as much as possible, often to reach given annual targets (Moore, 2020). However, it is still unclear whether mass registration would translate into higher compliance. If anything, abundant evidence is being produced on the poor impacts on revenues due to widespread non-filing and nil-filing. Across a variety of contexts, such as Costa Rica (Brockmeyer et al., 2019); Eswatini (Santoro and Mdluli, 2019), Ethiopia (Mascagni and Mengistu, 2019), Guatemala (Kettle et al., 2016), Rwanda (Mascagni, Mukama and Santoro (2019), Uganda (Almunia et al., 2021), and Venezuela (Ortega and Scartascini, 2015), about 20 – 50 percent of registered taxpayers either do not file taxes or file zero taxes. New entrants also have higher compliance costs on average (Mascagni, Santoro and Mukama, 2019).

1.1.4 Using Technology for Property Registration

Technology may also improve administration of real estate tax and the registration of properties. Knebelmann (2022) documents experiences from over 15 property tax digitalization

projects in countries in Africa, Latin America, the Caribbean, and Asia and highlights how satellite imagery tools and geo-referenced data systems can help in detecting, registering, characterizing and valuing properties.

Okunogbe (2021) provides an example of a low-cost technology investment for strengthening real estate tax registration and payment in Monrovia, Liberia. Only about 5 percent of residential property owners were estimated to be on the tax register (Okunogbe, 2013). To address the absence of a comprehensive property cadastral, the Liberia Revenue Authority (LRA) recruited and trained young people to use open-source software on tablets to capture the location, ownership, photograph and observable features of properties.

Using the newly created property database, the LRA sent out four types of notices to request payment of real estate taxes in a randomized experiment: i) a “Plain Notice” that provided information on the property tax requirement and the procedures to pay; ii) a “Detection Notice” that included identifying information from the new database, namely the property owner’s name and a photograph of the property; iii) a “Penalty Notice” that provided information on the legal consequences of not complying; and iv) a “Detection and Penalty Notice” that combined the features of these two notices. The Detection and Penalty notice tripled the property registration and tax payment rate among recipients, relative to Plain notice registration rate of 4 percent and payment rate of 2 percent. The Detection notice and the Penalty notice alone did not have a statistically significant impact on registration or payment, indicative of the complementarities between technology-enabled detection and traditional penalties and enforcement.

Another illustrative example of the role of technology in identifying properties comes from Dzansi et al. (2022) in Ghana. A municipal government in the Greater Accra region adopted a new technology that included a geospatial database of properties and a revenue management software. The property database was created by combining high-resolution aerial photographs with digital registry maps. The revenue management software produced bills and recorded payments for each property. The study implements a randomized ex-

periment whereby a randomly selected group of tax collectors who deliver bills and collect payments were given tablets that provided navigational directions to help the collector locate designated properties. Tax collectors using the tablets delivered 27 percent more bills and collected 103 percent more tax revenues than collectors in the control group.

There are also more sophisticated tools that may help the tax authority go beyond identifying properties to also determining their valuation. For example, with machine learning, local authorities may use satellite imagery to identify and measure properties and then deploy teams to ground truth the data and collect additional data on observable characteristics such as the quality of walls, roofs, and windows. Combining this property information with market data on rental values may then be used to calculate the taxable value of properties using a simplified “points based” system (Fish, 2018). Grieco et al. (2019) document how, using this approach, the Freetown City Council in Sierra Leone almost doubled the number on the tax register from 57,000 to about 110,000 properties and produced much higher tax bills for the most valuable properties, owned by the wealthiest taxpayers, which have been historically under-taxed. Given the importance of complementary automation to strengthen tax administration, this reform also introduced technology to improve other aspects of the real estate tax administration process beyond data collection to valuation, such as billing, payments, appeals and enforcement.

1.2 Monitor Compliance

With the increased use of technology in defining the tax base as described in the previous section, troves of data are constantly being generated and may be used by tax authorities to monitor taxpayers’ compliance and detect evasion when it occurs. However, many tax authorities in LMICs do not do routinely use this information for automated large-scale analyses but only access third-party information on a case-by-case basis. Modern technology provides cutting-edge data analytics tools to analyze these data and detect non-compliance. This section describes two applications: automated cross-checks of third-party reports such

as the VAT and, more broadly, using taxpayer characteristics to predict non-compliance and allocate audits.

1.2.1 Automated Cross-checks of Third-Party Information

Third-party information refers to when the tax authority receives information about a taxable transaction from multiple sources. For example, VAT is supposed to be self-enforcing because government receives a report of a transaction from both buyer and seller who have opposite incentives.

Numerous studies document large discrepancies between figures reported by buyers and sellers for the same VAT transactions as well as within-firm discrepancies where figures reported through different channels by the same firm differ. In Uganda, Almunia et al. (2021) show that sellers and buyers report different amounts in 79 percent of trading pair-month observations. Interestingly, for about a fourth of firms, their overall reporting behavior is “disadvantageous,” due to reporting errors in VAT returns that increase the firm’s overall liability and potentially leave money on the table. The paper estimates that VAT misreporting cost Uganda USD 446 million in revenue from 2013-2016.

Similarly, in Ecuador, Carrillo, Pomeranz and Singhal (2017) show that self-reported revenue on corporate income tax returns is lower than third-party reports in 24 percent of filings. In Rwanda, Mascagni, Mukama and Santoro (2019) find that 43 percent of VAT payers either over- (18 percent) or under-report (25 percent) their VAT sales compared to what is automatically recorded in the Electronic Billing Machines (EBMs). In Ethiopia, Mascagni, Dom and Santoro (2021) document that in 60 percent of cases, total sales from VAT returns are different from the same figure from the profit tax returns.

Given these large discrepancies, systematically identifying them through crosschecks of data sources seem to be a low-hanging fruit that could help recover, at least partially, the foregone revenues. However, administrative complexity, low technical capacity, and low enforcement capacity for following up on uncovered discrepancies often result in these potential

gains not being materialized (Steenbergen, 2017; Carrillo, Pomeranz and Singhal, 2017).

More promising evidence on the use of technology in monitoring compliance by effectively using third-party information come from countries that are further along the technology journey. Fan et al. (2018) evaluate the impact of computerized invoices, or digital invoice encryption, as launched in 2001, on Chinese manufacturing firms for the period 1998-2007. Such technology implied that invoices became more difficult to falsify or forge. It also improved the quality and speed of data flows to the tax administration, as opposed to a manual system in which invoices were paper-based and lacked a rigorous anti-counterfeit technology. The authors make use of a difference-in-differences design comparing outcomes before and after the 2001 reform for firms more or less affected by the policy, as proxied by the ratio of non-deductible inputs over outputs – with a higher ratio implying a more intense exposure to the policy. They find that e-invoicing explains 14- 23 percent of cumulative VAT revenues in 2002-2007, a remarkable increase due to improved technology in recording VAT transactions. They explain such finding by a reduction in deductible inputs, which resonates with the fact that e-invoicing significantly made it more difficult to falsify deductible claims.

Another positive example of how technology may help monitor compliance comes from Delhi in India where Mittal and Mahajan (2017) study the impact of a policy improving the quality of VAT-related information available to the revenue authority. They consider a policy reform mandating VAT filers to report firm-level transaction details with tax-identification numbers for all transacting partners. This intervention, against a previous context in which only aggregate VAT returns were submitted and evasion was uncovered only through costly audits, enabled the revenue authority (in principle) to easily perform computerized cross-checks between buyer and seller reports and automatically flag discrepancies.

Using data on the universe of VAT returns over five years, the authors adopt a difference-in-differences strategy exploiting the timing of the policy and comparing wholesalers, who are more likely to be affected by the policy since they are more likely to sell to other registered firms, and retailers, for which the third-party verification mechanism is more likely to break

down as final customers do not have to report their purchases. The authors find that the reform led to a 29 percent increase in average tax collections from wholesalers relative to retailers. Importantly, the impact is largely driven by the largest wholesalers, who are in turn monitored by a special unit dedicated to large taxpayers. This result suggests that targeted tax enforcement can be successful when accompanied by third-party information, with potential benefits to the overall equity of the tax system.

In Pakistan as well, Shah (2020) examines the effectiveness of exploiting third-party information to uncover VAT evasion and documents how the revenue authority curbed fake VAT input claims by a computerized VAT invoice validation mechanism. More specifically, it evaluates the impact of the introduction of a software-based system to accept or reject VAT input tax credits. Such intervention can be considered as a proxy for the increase in the capacity of tax administration to process the VAT information flow or paper trail, enabled by investment in IT and replacing traditional, tax officials based, enforcement mechanisms. The paper relies on administrative tax data for the universe of VAT returns filed in Pakistan over 8 years and uses a difference-in-differences strategy, in which non-exporting firms, the treated group, are compared over time to exporting firms, the control group, for which a virtually identical level of scrutiny existed prior to the reform.

Results indicate a 50 percent decline for treated firms subject to the VAT input automatic checks. Importantly, success has been possible only after a decade-long period of transition towards a fully computerized infrastructure, funded by donors. Also, the reform received wide institutional and political support from both the government and the constitution, an aspect that is often missing in low-capacity countries.³

Besides information from trade partners, payments records from credit card companies also present a source of third party information that tax authorities can use to cross-check tax declarations and detect non-compliance. Dogan (2011) describes the introduction of a data warehouse in Turkey that enabled access to credit card information from commercial

³In Pakistan, there were constitutional provisions which restricted judiciary from staying the recovery of evaded tax.

banks. After the introduction of the data warehouse, the revenue authority more heavily relied on systematic data matching, mostly between VAT returns and credit card sales data, and data-driven risk management to uncover large evasion. Although the paper does not have a rigorous impact evaluation methodology, the change in patterns is remarkable. In June 2008, just before the launch of the new technology, up to 140,000 registered taxpayers did not report credit card sales information in their VAT returns, with 60,000 (100,000) taxpayers showing discrepancies in more than 20 (5) percent of transactions. One year after the introduction of the data warehouse, fewer than 20,000 taxpayers had a discrepancy rate of greater than 20 percent. This example illustrates how technology – a well-functioning integrated and automated data warehouse – supported by political will, can also foster inter-institutional data sharing agreements, and create a data-oriented cross-agency administrative ecosystem.

1.2.2 Risk-based Audits

Many tax authorities compile data from several dimensions of a taxpayer’s behavior to generate a risk profile, that reflects the likelihood that a taxpayer is evading (Khwaja, Awasthi and Loeprick, 2011). Selecting audit cases using this data-driven approach leads to more targeted and efficient audits as risk-based audits allocate the limited resources of the tax authority to cases with higher likelihood of recovering significant tax revenue. As a result, compliant firms also face a lower monitoring burden as they are less likely to be audited.

Discrepancies from third-party reports discussed in 1.2.1 are a key indicator that may be included in the algorithm that is used to predict firm risk. Other risk criteria commonly incorporated into risk models are the sector(s) of activity and business structure, quality of record keeping, past compliance behavior, cost ratios and deductions from gross revenue, and comparisons with industry and sector averages (Loeprick and Engelschalk, 2011). In some cases, tax authorities use machine learning methods such as a random forest algorithm to predict firm future risk of evasion while in other cases, a more explicit formula with

different weights given to each indicator is used. Bachas et al. (2021) report that both methods predicted historical evasion with similar levels of accuracy for audits in Senegal. However, the method with explicit indicators was simpler and more transparent to use by tax inspectors compared to machine learning methods.

1.3 Facilitate Compliance

An important application of technology in taxation is to improve taxpayers' experience by making it easy for them to obtain information and fulfill their tax obligations. Many tax authorities are increasingly adopting a customer service orientation towards taxpayers (OECD, 2021). One initial step taken by tax authorities is to provide detailed instructions, forms and guidance on their website on the compliance steps and requirements for each type of tax. A further step is to make it possible for taxpayers to complete transactions online, such as the ability to file and pay taxes online. Tax authorities may then also have individual taxpayer accounts that contain the taxpayer's transaction history with the tax authority. The tax authority may also use electronic means of communicating with taxpayers such as SMS and email reminders, payment confirmation and announcements.

A major consequence of these technology-driven tools is that they allow taxpayers to interact with the tax system in an impersonal way. In their absence, taxpayers would likely be subject to the discretion of tax officials responsible for providing information, conducting transactions and monitoring them in person. We consider three specific technologies: e-filing and e-payment, electronic billing machines, and online communication.

1.3.1 E-Filing and E-Payment Tax Services

Electronic filing and payment refers to digital services that allow taxpayers to (i) file their taxes electronically – together with a range of other tax-related activities (attach annexures, claim refunds, make appeals, update their personal details, get assistance online, check their filing history, etc.), usually through a web portal to which they have access or through sim-

ilar phone applications, and (ii) to pay tax liabilities online, by means of digital platforms (mobile money, credit card or similar electronic transfers) which efficiently connect the revenue authority, private banks or digital financial service providers, and the central bank. The main promise that e-filing and e-payment hold is that they allow taxpayers to perform such activities in a less burdensome and more transparent way – saving travel and queuing costs, error-prone manual inputting, and avoid physical interactions with tax officials who may ask for bribes.

To examine to what extent these expected benefits are realized in practice, Okunogbe and Pouliquen (2022) study the introduction of e-filing in Tajikistan. Small business owners faced high compliance costs as they had to submit monthly tax declarations in person at the tax office. These frequent meetings with tax officials also provided opportunity for unofficial payments and 32 percent of taxpayers said they expect to give gifts in a meeting with tax officials (World Bank Enterprise Surveys, 2013). The study examines the impact of e-filing using a randomized trial in which a randomly selected group of firms were encouraged to e-file by providing them with training on e-filing as well as logistical help to complete the cumbersome e-filing registration process.

The treated group e-filed at a higher rate than the comparison group. Firms that were more likely to be evading at baseline (measured by a risk profile score used by the tax authority) were less likely to adopt e-filing and also more likely to stop e-filing after a few months. Tax payments doubled among these high-risk score firms. While there was no average effect on bribes, e-filing led to an 18 percentage point reduction in bribes among firms less likely to have been evading. More broadly, e-filing resulted in a large reduction in compliance cost across firms, with 5 hours saved each month (about 40 percent of the time spent on fulfilling tax obligations).

This intervention highlights the role of technology in not only reducing compliance costs for taxpayers, but also affecting tax payments and unofficial payments by changing the interactions between taxpayers and tax officials. It also underscores the importance of thinking

about distribution effects in the impact of technology as certain taxpayers may be more affected than others. Lastly, it provides lessons on the take-up of technology solutions as taxpayers may be strategic in deciding to take up and those for whom the technology may have greatest impact may be least likely to adopt.

In Uganda, Jousté, Nalukwago and Waiswa (2021) finds that a new e-filing system doubled the number of presumptive taxpayers and increased revenues, especially when coupled with the parallel Taxpayer Register Expansion Project that provided a one-stop shop where tax officials offered assistance and further lower taxpayers' compliance costs. On a similar note, in Belarus, e-filing was part of a broader reform to lower compliance costs for citizens, including simplifying the tax code, setting up taxpayer facilitation services, and reaching out to the business community (World Bank, 2016).

Non-traditional technology solutions besides ITAS-based e-filing and e-payment systems may also be very effective in facilitating compliance and reducing opportunities for corruption in low-resource settings. During door-to-door property tax campaigns in Kananga, Democratic Republic of Congo (Weigel, 2020; Balán et al., 2022), tax agents used handheld printers to issue receipts to taxpayers who made cash payments to them instead of traveling to the tax office. Each transaction was recorded in the device's memory and downloaded to the government database on a regular basis. Program supervisors confirmed that the revenue deposited were equal to the amounts on the receipts that were issued, ensuring agents were accountable for the cash payments received.

The potential of e-filing in reducing compliance costs depends on the policy design itself, as shown by Yilmaz and Coolidge (2013) who critically compare the different policy experiences of South Africa, Nepal and Ukraine. Important aspects in the design of IT solutions could have unintended consequences on taxpayers' compliance costs, especially when solutions are not customer-centric, reliable and trustworthy. E-filing is impactful in those cases, like South Africa, in which it completely replaces paper-based filing with no additional work required from firms. In Nepal, where e-filing was mandatory and particularly cumbersome,

it actually increased compliance costs. In Ukraine, where businesses kept filing on paper in parallel to e-filing due to lack of trust on the online system, compliance costs increased as well. Similarly, Kenyan Revenue Authority (KRA) continued to maintain two concurrent tax filing systems - manual and i-tax - even after the introduction of the latter. As these two systems were not integrated with one another, they likely generated confusion among taxpayers and the KRA detected discrepancies in taxpayers' records (Maisiba and Atambo, 2016).

Along the same lines, Kochanova, Hasnain and Larson (2020) suggest that the policy implementation of complementary online tools such as e-payments plays a crucial role – whereas a simpler e-filing system that does not enable online payment of taxes may not affect compliance costs and interactions with tax officials. Likewise, the existence of an ITAS on the tax administration side could considerably improve the e-filing experience – as taxpayers would be able to monitor their tax obligations on their web-profile, provide feedback and receive timely assistance. A highly policy-relevant message that can be derived from the literature is that the success of a given technology does not only depend on the effectiveness and design of that specific solution, but most importantly hinges on the comprehensive implementation of a coherent set of IT measures which together address interlinked taxpayer needs (such as file and pay online), communicate smoothly and, thus, combined have an impact.

1.3.2 Electronic Fiscal Devices

Electronic fiscal devices, already discussed in section 1.1.1 for their potential in better defining tax liabilities, could also play a major role in terms of reducing compliance costs. The evidence available is rather mixed. On the one hand, current research indicates that EFDs are impactful in making the taxpayer experience less burdensome, more predictable and less frustrating. Ethiopian firms highlighted the following benefits from EFD adoption: ‘less opportunity for theft’ (mentioned by 20 percent of respondents), ‘updated and easily available

sales information’ (22 percent), ‘easy to comply with tax requirements’ (17 percent) and ‘better sales and inventory control’ (16 percent) (World Bank, 2015, p. 26).

Similarly, evidence from a mixed methods approach - based on administrative data, focus group discussions (FGDs) and a nationally representative survey - from Mascagni, Dom and Santoro (2021) shows that medium and large taxpayers considerably value EBMs as a tool for facilitating their compliance. A more sophisticated version, EBM2, which is software-based and works on computers, is also quite appreciated by this group as it improves record-keeping, monitoring of transactions on a daily basis and business reputation, thus attracting new IT-savvy costumers.

While EFDs may improve the tax paying process for many taxpayers, there is also the risk that disadvantaged taxpayers may be left behind or may face even higher compliance costs. Section 3.1 discusses this consideration. These technologies should therefore be coupled with sustained taxpayer education and assistance and provide timely communication and feedback mechanisms for taxpayers.

1.3.3 Online Communication

Linked to its role in facilitating compliance, technology also holds a great potential in terms of communicating information around the tax system and easing the burden with complying. By accessing e-portals, for instance, taxpayers could seek for tax-related assistance online or browse through tax laws and similar official documents. In the large literature on tax nudges featuring communication experiments that manipulate the message content and test different motivations behind compliance, most projects use traditional delivery methods, such as letters. However, increasing attention is being devoted to more modern and cheaper solutions, such as SMSs and e-mails (Mascagni, 2018). More research is needed in this direction, given the huge potential that IT-based communication retains in potentially reshaping the way in which revenue authorities assist, educate, train their taxpayers (World Bank, 2016; OECD, 2021).

An illustrative example comes from Rwanda, where in early 2016 the Rwanda Revenue Authority sent messages to 9,000 taxpayers, aimed to encourage compliance. Mascagni and Nell (2022) use a randomized experiment to compare the efficacy of different delivery methods, from more traditional (physical letters) to more digitized (SMS, email). They show that non-traditional delivery methods, specifically SMS, are highly effective and significantly increase tax due of nudged taxpayers, in contrast to physical letters. This exercise is particularly relevant from a policy perspective, as governments in developing countries are constantly looking for cost-effective ways to achieve policy goals, in the context of very limited capacity. In this setting, it would be difficult to scale up the delivery of physical letters beyond a relatively small group considering the often poor quality of taxpayer addresses in tax registries (Ortega and Scartascini, 2015; Mayega et al., 2019).

2 Limitations of Technology

While the evidence discussed above highlights the unprecedented potential of technology in improving tax administration and revenue mobilization, it is also true that technology alone is unlikely to be effective in a context in which pre-existing, complementary factors are not yet in place (Bird and Zolt, 2008). This is also true in high income countries as failure to get these preconditions right explains the poor take-up of e-government services there as well (Gauld, Goldfinch and Horsburgh, 2010; Reddick and Turner, 2012). The relevance of these preconditions, and the evidence produced on them, is summarized below.

2.1 Hard Infrastructure and Connectivity

Even the most user-friendly technology will hardly function if basic infrastructure such as electricity and, for those technologies based on the Internet, stable connectivity are lacking. Immediate implications concern the take-up and usage – neither taxpayers/users nor tax officials can smoothly take-up and use a technology that halts in peak periods or functions

only intermittently.

In addition, inadequate infrastructure and connectivity could also pose important equity repercussions, as those taxpayers most likely to be disconnected from the internet are likely to be smaller, rural, and less-educated. In turn, their broad taxpaying experiences could be frustrating, and their tax attitudes and perceptions could deteriorate. Particular attention should be devoted to these unintended consequences, especially in light of the increasing shift to e-filing and e-payment as a response to the COVID-19 pandemic - as in certain cases such as Eswatini Santoro, Amine and Magongo (2022) and Cameroon, revenue authorities imposed the adoption of e-tools to avoid physical interactions. However, it is unclear whether making adoption compulsory would prove to be effective for compliance if large portions of the taxpayer population are simply not covered by connectivity or stable electricity.

Some descriptive evidence describes the challenges taxpayers face in adopting technology in less IT-friendly contexts. In Zimbabwe, Obert et al. (2018) study the underutilization of the e-filing tax system and conclude that connectivity is indeed a major challenge to most taxpayers, with around 33 percent of respondents reporting absolutely no access to any form of network connection. For instance, one challenge unearthed by this study was that the server used to operate the e-filing system frequently faltered during peak periods, with negative repercussions on taxpayers' filing experience. Likewise, in Eilu (2018) review of six studies on EFDs adoption in Kenya and Tanzania, poor internet connection is cited in three of the studies, while power outages come just next.

To address these challenges, tax authorities can proactively roll out less sophisticated technologies with the clear policy intent of reaching less connected taxpayers and facilitating their compliance. This is the case of Rwanda, where the revenue authority launched the M-declaration tool as an offline declaration and payment solution for rural taxpayers, working on simple feature phones. M-declaration has been introduced as a simpler complement to the more IT-heavy E-tax platform, which instead works on computers and through the internet. Solutions like M-declaration could easily address connectivity issues and enable

digital payments through the widespread mobile money system. The survey study of Santoro et al. (forthcoming) shows how user profiles of M-declaration and E-Tax are different by policy design and how the two technologies get adopted by those who need them most. The Malawi Revenue Authority also introduced a similar M-mobile application. In Tajikistan, electronic kiosks were built and equipped in remote locations around the country for use by taxpayers who wish to e-file but do not have access to computers (World Bank, 2018). As these technologies are extremely new, no robust impact evaluation has yet been conducted and future research should examine whether they alleviate the compliance costs of smaller taxpayers.

2.2 The Human Factor

Technology is a tool, which does not live by itself but is meant to be used by people. If people refrain from, resist, or manipulate technology, it is unlikely to produce any positive impact. This human factor is crucial to understanding the potential of technology more realistically. In this context, users of IT can be divided into two broad categories: taxpayers and tax officials.

2.2.1 Taxpayers

Besides the infrastructure limitations mentioned above, taxpayers may fail to adopt a technology for several reasons. First, taxpayers may have little understanding and practical knowledge of sophisticated innovations. Lack of awareness was a major barrier to e-filing adoption in different contexts such as Nigeria and Tajikistan (Obert et al., 2018; Eilu, 2018; Efobi et al., 2019; Mas' ud, 2019). In Rwanda, focus group discussions by Mascagni, Dom and Santoro (2021) reveal that that taxpayer confusion, complexity and practical difficulties with the EFDs are particularly severe for smaller taxpayers. Eilu (2018) reviews the evidence from seven studies based on the adoption experiences of firms in Kenya and Tanzania, to conclude that the most-cited challenge with the use of electronic fiscal devices (EFD) was

lack of training.

Second, users may fail to adopt a new technology if sunk costs for its implementation are too high. This was the second most-cited challenge in the Eilu (2018) review. There could be resistance in adoption from taxpayers within certain categories having to cover significant costs for accessing the service (Yilmaz and Coolidge, 2013). Qualitative evidence from Rwanda (Mascagni, Dom and Santoro, 2021) documents high levels of frustration, as taxpayers have to buy the EFDs with their own funds and also have to cover all ancillary costs on the equipment needed for using the machines (airtime, internet connection, computers, printers, etc.). In this sense, digital technologies can reinforce socioeconomic disparities already present in the taxpayer population.

Limited evidence exists on the impacts of subsidies for technology uptake, with rather inconclusive results. Despite considering a different technology (Point of Sale (POS) terminals for electronic payments for transactions), Brockmeyer and Sáenz Somarriba (2022) provides some evidence on the impact of incentives, which could inform the design of incentive schemes for other technology, such as EFDs. It finds that only 2 percent of eligible firms took up the subsidy, and of these, 80 percent already had a POS. This suggests that firms consider other factors beyond costs, such as the compliance impact of the new technology, when deciding whether to adopt technology.

Third, different individual taxpayer characteristics are also associated with technology adoption. Efobi et al. (2019) finds from a survey that internal firm characteristics like owner's education, age of the company and use of an external auditor and computerized accounting system are most strongly correlated with the use of e-filing and e-payment. These characteristics may be proxies of taxpayer knowledge and ability to bear adoption costs. They may also reflect trust in tax administration, as taxpayers could be reluctant to adopt a new technology due to mistrust towards the tax administration, especially for concerns around data security and confidentiality issues.

Besides these factors affecting adoption, more IT-sophisticated taxpayers could blatantly

manipulate the technology in order to avoid paying taxes. A tax administration whose internal systems are not integrated and automated is open to manipulation attacks from taxpayers. In Malawi, among many other countries, the revenue authority makes use of several disconnected systems running in parallel, making registration, tracking and monitoring quite challenging. Being aware of these weaknesses, taxpayers seem to use multiple TINs for the same business to cut tax liabilities, while not being automatically detected (Ligomeka, 2019). This strategic behavior is observed in Uganda as well, despite even though the tax authority maintains a uniform registry (Mayega et al., 2019). This highlights the fact that even a sound integrated system, which could in theory easily identify fraud, would prove inefficient if not used to its full potential by the tax administration.

2.2.2 Tax Officials

Tax officials as well are adopters of technology and could sub-optimally use it due to a number of constraints. First, tax officials could resist change and prefer keeping up the usual, often manual-based, practices. Tax officials can have a disincentive to reorganize their work to take full advantage of digital technologies, often due to the possibility of losing the discretionary benefits they have been accumulating with a manual, discretionary system. However, very little causal evidence has been produced on how technology could shape the interactions between taxpayers and tax collectors – with the exception of Okunogbe and Pouliquen (2022) - as well as on incentive schemes for motivating tax officials in taking-up a new technology.⁴

Regarding the latter, Chalendard et al. (2020) argue that the effectiveness of technology-enabled third-party valuation advice in Madagascar is undermined by the limited incentives to tax officials to optimally make use of this new information. The authors find that even though better information on import values from a third party significantly enhanced performance of the customs department by enabling a more exact determination of tax liabilities,

⁴Outside technology, notable exceptions are Khan, Khwaja and Olken (2016) and Amodio et al. (2021), who study the impact of performance pay for tax collectors on revenue and bribe payments.

its impact on revenue appeared compromised by misaligned incentives of custom officials. Thus, the absence of strict sanctions against opportunistic behavior and the prevalence of rampant corrupt practices in Madagascar customs, as in customs of other low- and middle-income countries, could explain why the provision of information to inspectors have not yielded stronger impacts.

Mayega et al. (2019) provides some interesting qualitative evidence on staffs' resistance to technology in Uganda. It documents the negligence of under-incentivized registration staff, who do not respond to TIN duplicates warning triggered by the system, hence clogging up the registry with duplicates. In Malawi as well, preferences for manual practices imply that a specific, separate registry exists for large taxpayers, stored and managed on separate Excel files, not integrated on a uniform platform and controlled by the LTU staff (Ligomeka, 2019). Anecdotal evidence suggests that these discretionary practices are commonplace in other countries as well.

A second major impediment for tax officials is a lack of adequate skills and training. Many revenue authorities in LMICs routinely assign their staff to intense training periods, often incentivized, as well as make completion of certain learning modules compulsory for promotion. Notwithstanding, it seems that more could be done in terms of building more specific, tailored skills on how to use technology and, correspondingly, how to manage tax data. Observational evidence indicates that revenue authorities in low-income countries often do not cross-check their tax records, even if it would be relatively straightforward to do so (Kangave et al., 2016; Almunia et al., 2021; Mascagni, Mukama and Santoro, 2019). This, for instance, is documented in Rwanda, where easily identifiable discrepancies across VAT returns are not closed likely due to limited know-how from tax officials. Robust evidence is lacking on this aspect but most existing studies point to the lack of IT skills as one of the concurring causes for limited usage of different technologies, such as systematic cross-checks (Pirttilä, 2017).

2.3 Institutional Strategy and Change Management

In some cases, technology adoption by a tax authority is not successful because different components are not properly sequenced. In other cases, the new IT systems are not properly integrated into the organizational structure. While there is less evidence from causally identified studies on these internal processes of tax administration, this section describes key features of successful roll out of technology and provides illustrative examples from different tax authorities.

The adoption and implementation of technology should not happen in a single step, motivated by a political frenzy or competitive imitation of peers, but rather within a clearly defined, long-term transformational journey. As a first consideration, the sequencing of technology adoption, as delineated in a strategy of structural reform, is crucial. Digitization of functions and processes is usually pioneered by customs departments, as they tend to use internationally standard information systems. After piloting a new automated and integrated platform in customs (such as ASYCUDA+++ and ASYCUDA World), revenue authorities turn to digitizing their internal functions by automating all internal processes. In this phase, it is preferred that clear sequential actions are taken. For instance, a new integrated and automated tax administration system is unlikely to succeed if the existing data within the tax administration are not properly cleaned first, so as to be adequately analyzed by the new system.

Likewise, retraining and reengineering tax officials should come before introducing the technology, as well as repeatedly over time. Also, there seems to be a clear sequencing in how the different functions get automated. After customs, usually e-registration modules are introduced next, to improve the quality of taxpayer registries. Then, the most relevant taxes are digitalized first, with VAT and income taxes being the priority. All the remaining taxes and fees usually get digitized at a later stage.

Once all internal functions are integrated successfully, the next step entails providing e-services to taxpayers. E-filing and e-payment systems could develop naturally and directly

feed into a well-running automated tax administration system. Often, e-services are rolled out sequentially, first imposed as a pilot on large taxpayers, and only later to the taxpayer population at scale. More and more sophisticated modules could be added as the opportunity arises. For instance, the M-declaration phone application introduced in Rwanda was meant to represent an additional service building on the already existing e-filing system.

As a second related point, technology provides the opportunity for an unparalleled cultural change within the tax administration, where obsolete analog practices are abandoned and a new mindset, based on efficiency and transparency, is embraced. Descriptive evidence from different contexts shows that it is difficult to change the silos mentality with which different departments within a revenue authority tend to operate. It is commonplace to see different IT systems operating in parallel to manage taxpayer data. This simultaneous use of distinct systems creates a host of structural challenges for the tax administration. One major challenge is the duplication of work. Given that different units manage the systems, another challenge pertains to the authorization required by officials in a unit to access the data from a different unit within the same institution. As a result, officers often concentrate solely on recording information on taxes under their mandate and ignore any other tax-relevant data (Ligomeka, 2019).

For example, in Ethiopia, as many as four institutions collect data on employment income (the revenue authority, the Ministry of Finance and two institutions for social security provision, each for the public and private sectors). Despite having common challenges and aligned interests, such institutions do not communicate for both political and technical reasons (Mascagni, Santoro and Mukama, 2019). More broadly, customs and domestic tax departments still appear not to communicate systematically. To properly address this challenge when introducing new technology, it is acutely important to have a rigorous procurement process that carefully gathers system/ business requirements, understands user needs, and reviews business processes to ensure that the procured technology systems are fit-for-purpose and avoid needless duplication.

At a higher level, the implementation of technology requires strong buy-in from key leaders and a long-term strategy at the national level. The Rwandan case is very much emblematic of how technological transformation has been enabled by the strong political support from the very top government through the Vision 2020 development plan (Schreiber, 2018). A number of concurring strategic actions have been taken in order to unleash the full potential of technology in Rwanda. First, government and donors massively invested in high-speed fiber-optic network, serving the whole country. This directly enabled the RRA to make use of more advanced online technologies and to eventually launch its automated data management system. Second, a target-oriented and performance-based staff management culture has been crucial to build higher professionalism within the tax authority – often coupled with intense trainings on IT tools. Third, the government eliminated import taxes on computers, cell phones, and telecommunications equipment, facilitating digital inclusion. Lastly, to facilitate compliance of micro-entrepreneurs through digital means, the Finance Ministry’s policy committee moved quickly to create a simple, new presumptive tax for them, easily payable through mobile phones (Schreiber, 2018). More research is needed to understand how the political vision of a country could spur successful technological transformation.

2.4 Regulatory Framework

A broader key consideration is the regulatory and legal framework in which technology exists. As technological innovations develop at a faster and faster pace and tax administrations keep updating themselves, the same should be true for the legal system. However, the latter is typically much slower to respond and adapt to change. On the one hand, revenue authorities could strengthen themselves through the use of technology. On the other hand, the ultimate ability to enforce, prosecute, impose sanctions and collect taxes often lies outside the authority itself. Hence, countries need a functional, modern legal system enabling the technology-enhanced tax administration to fully benefit from this transformation.

There are many ways in which the legal system could hamper the potential of technology

in tax administration. For instance, technology could empower revenue authorities in their enforcement capacity, helping them with assessing the underlining true liability, tracking defaulters, and identifying blatant evaders. All these efforts are however likely to be unfruitful if actual prosecution does not materialize due to long delays in courts. Likewise, technology could spur mass registration and formalization, which however would not deliver better compliance outcomes if the tax code is silent about tax obligations of new entrants (Mascagni, Mengistu and Woldeyes, 2021). Furthermore, confusion could arise about the legal requirements to use a given technology, such as e-filing. In a situation where e-filing is made compulsory by decision of the revenue authority but where the national laws are still ambiguous on whether the adoption of a digital practice is mandatory or voluntary, or for whom, navigating the regulations could lead to higher compliance costs of taxpayers, alongside greater mistrust and frustration.

On top of that, gaps in regulation could arise when it comes to co-using a given technology across different public institutions. As mentioned above, data sharing between revenue authorities and a range of public and private actors does not happen systematically, often due to privacy and confidentiality concerns. One possible approach is for policy makers in a country to work towards setting up a central automated platform which would be accessible from a variety of government institutions and banks for identification of taxpayers and cross-checking of information. Robust evidence on the effectiveness of such mechanisms is needed to determine how effective this approach may be. Along the same lines, in order to boost tax compliance, higher income countries have enacted specific legislation whereby processors of debit or credit cards and electronic payment systems are mandated to report to the tax authorities the gross receipts of the enterprises accepting these forms of payments. Legislation in lower income countries is still mostly undefined.

Lastly, a crucial consideration is that as technology evolves, adjustments in the regulatory framework are needed in order to protect citizens from unintended consequences in terms of privacy, confidentiality, data leakages and cybersecurity. Accessing third-party data

from, say, digital financial services providers comes with risks of breaching confidentiality agreement with the clients of those services. Likewise, the institution of national ID systems or other electronic systems at scale in contexts which are not fully democratic poses new risk in terms of the government ability to surveil and restrict citizens' rights. In these cases, a conducive regulatory framework needs to be in place, allowing keeping a balance between data protection and security and the use of new data and technology for tax purposes. In sum, technology needs to be thought of as a unique catalyst for broader regulatory reforms within public institutions and an opportunity to modernize tax codes, eventually promoting the country to a higher development trajectory.

3 Conclusion

This paper describes the potential that information technology provides for tax mobilization, as well as the challenges that still exist in low- and middle-income countries in order to tap into it. First, technology could be a powerful tool for understanding the tax base: tax authorities can use technology-based tools to collect information to identify taxable entities (such as individuals or property during registration drives) as well as to collect information on the tax liability, for example, through the use of electronic billing machines that record sales transactions, or from third-party sources like employers, vendors, customers or financial institutions.

Second, technology also contributes to strengthening the capacity for tax monitoring. It provides data analytic tools such as machine learning for collecting and analyzing large amounts of data to detect inconsistencies, such as mismatches between sales reported for income tax to those recorded for VAT, or between VAT sales and purchases reported by sellers and buyers. By using different electronic sources of information on taxpayers' behavior, tax authorities can systematically assign risk of tax evasion to different firms to prioritize audits to maximize revenue recovery.

Third, technology is also valuable for improving service delivery to taxpayers. Technology solutions like electronic filing and payment can reduce the time and other compliance costs borne by taxpayers. Electronic billing machines reduce the costs of compiling and submitting information. Electronic communication tools (such as email and SMS) provide a timely and cost-effective way of keeping taxpayers informed of their tax requirements and account status. These technologies also reduce the level of in-person interactions between taxpayers and tax officials, thus reducing opportunities for extortion and collusion.

A common theme to these uses of technology is that they move the tax system towards becoming more standardized and delivering a consistent experience across taxpayers and away from the use of tax official discretion in the treatment of taxpayers. At the same time, several country examples highlight a range of challenges associated with the adoption of technology in taxation. First, given the infrastructure deficit in many low- and middle-income countries, access to internet and electricity may hinder the effective adoption of technology by taxpayers, especially the disadvantaged, raising equity concerns.

Second, no matter how sophisticated an IT system is, it is only as effective as its users can employ it. On the one hand, taxpayers may be hesitant to use technology tools due to lack of information and trust, security concerns or high costs of adoption. Taxpayers could also deliberately respond to technology in perverse ways, by adjusting multiple margins in their tax returns and thus muting the impacts on revenue mobilization. Tax authorities have responded by conducting regular trainings for taxpayers and in some cases subsidizing the costs of technology adoption or rolling out less sophisticated alternatives to serve disadvantaged taxpayers.

On the other hand, tax officials may not maximize the use of IT tools due to lack of skills and training or may actively resist to avoid losing the private benefits they received from the influence they had under a manual system. Tax authorities must ensure that their IT agenda focuses on empowering staff members with the skills and training they need, while also being as manipulation-proof as possible. Related to that, tax administrations should

be equipped with sufficient resources to conduct traditional strategies in enforcement and monitoring, to which IT-enabled audit solutions could contribute.

Third, technology reform must not be a stand-alone project but should be part of a broad institutional strategy, where complementary reforms are designed. It requires a clear sequencing of reforms to avoid redundancies and disorder. For example, it is important to coordinate human resource needs (recruitment and training) with hardware and infrastructure needs (e.g. internet, electricity, computers) alongside investment in different software and complementary e-solutions. Different tax modules should be sequenced so they build on one another. Importantly, adequate investments in traditional tools for monitoring and enforcement should be planned for as well.

Fourth, the success of technology reforms in taxation is dependent on the broader regulatory environment. In many countries, the legal authority to enforce, prosecute, impose sanctions to recover delinquent taxes does not lie within the tax authority but with the judiciary, which may be slow and inefficient. Also, the regulatory framework needs to be updated on data sharing between institutions and private actors, and provisions to protect citizens' rights. As such, technology-based reforms in tax administration must be backed by a functional, modern legal system to realize the full revenue gains and ensure a fair and equitable tax system.

The recent upsurge in the literature on taxation in low and middle-income countries is, in large part, due to the availability of administrative tax data in electronic format. As countries continue on their technology transformation journey, there are two key opportunities for collaborating with researchers. First, tax authorities can work with researchers in real-time to understand the impact of different technology interventions they adopt to guide expansion or modifications to the technology. Second, tax authorities can collaborate with researchers more broadly to understand the implications of different tax policy choices for efficiency and equity through the analysis of tax data in electronic format. Beyond providing rigorous evidence on government policies to advance both research and policy, these partnerships

may also have beneficial spillover effects. Academic researchers typically have state of the art data analytic tools that may not only be used on the specific collaborative project but can also translate into upgrading the capacity of officials in the tax agency. Pomeranz and Vila-Belda (2019) provide examples of successful collaborations and tips for mutually beneficial engagements.

Avenues for future research include better understanding the role of tax officials in the effective deployment of technology, the effectiveness of “low-tech” technologies such as mobile taxation, and further applications of machine learning and artificial intelligence in monitoring and facilitating compliance. In the long run, it will be interesting to observe how technology goes beyond changing tax administration to change tax policy: with better tools for identifying the tax base and monitoring compliance, low- and middle- income countries may change the mix of tax instruments and rely more on payroll and personal income taxes as in high-income countries.

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