E-invoicing, Tax Audits and Tax Compliance

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Abstract: Making use of a unique administrative data set that spans the period 2012-2019 and covers the universe of administrative tax filings in Rwanda, this paper investigates both the *direct* and (through tax audits) the *indirect* impact of the introduction of e-invoicing on firms' reporting behaviour across all business tax bases. The evidence suggests that while e-invoicing adoption yields an increase in firms' net VAT payments (direct effect), the compliance impact of the e-invoicing is significantly improved when account is taken of the audits (indirect effect). The evidence also shows that e-invoicing adopters react by over-reporting on margins that reduce their final liability, a pattern that is also nuanced by tax audits. Interestingly, the results show that audits involving firms that adopt the e-invoicing system lead to a significant compliance improvement on VAT; for corporate income taxes e-invoicing adoption and tax audits improve compliance, but this is purely driven by their direct impact. Personal income taxes are unresponsive to the introduction of e-invoicing or audits.

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1 Introduction

To strengthen the capacity of tax collection, enhance the overall performance and quality of services provided to individuals and enterprises, and ultimately make taxation more growth-friendly, African tax administrations have begun embracing the digital technology.[1] Perhaps not surprisingly, the integration of digital innovations has been more prominent in Value Added Tax (VAT); VAT accounts for a significant share of tax revenues in Africa, representing on average over 35 percent of tax revenue collected (ATAF, 2021b).[2]

A central element in the digitilization transformation has been the move towards electronic tax systems[3] which are based on digitised tax records that can be extracted for electronic and automated processing. A component of these electronic tax systems is e-invoicing through which every sales transaction, both to other businesses and to final consumers, is recorded thereby a digital audit trail is created that allows tax authorities to trace transactions and verify the authenticity of invoices.[4] The implementation of such technology is enabling tax administrations to strengthen the integrity of their processes and facilitate efficient audits.

Past experience with technology adoption however shows that there is no shortage of warnings to be drawn from examples of tax administrations failing to reap the potential benefits of technology innovations,[5] in particular in economies where a significant portion of economic activity operates in the informal sector and businesses conduct cash transactions, or may not have the necessary technological infrastructure to take advantage of the capability offered by an e-invoicing system. In sectors, for example, with inadequate technological infrastructure, such as poor internet connectivity or limited access to digital devices, implementing e-invoicing systems may face significant barriers, hindering the widespread adoption of e-invoicing and limiting its impact on tax compliance.[6] The difficulties associated with the adoption of e-invoicing may also be exacerbated by instances where businesses intentionally engage in non-compliant practices, such as issuing false

[1] Technology and the innovations offered, reflecting the challenges of adopting technology in the public sector, has been however absorbed at different paces, (ATAF, 2021a).

[2] VAT adoption has been one of the most significant recent development in tax policy. While only 47 countries adopted VAT in 1990, 170 countries embraced this tax in 2020 (OECD et al., 2020).

[3] And broader use of information computer technology (ATAF, 2021a).

[4] There are other benefit from e-invoices implementation, including the elimination of physical paper invoices as well as the reduction of the administrative burdens related to invoice processing for both taxpayers and tax authorities.

[5] Some examples are presented in USAID (2008).

[6] In addition, complex tax regulations (numerous exemptions, special schemes, or varying tax rates) may also constraint the efficient implementation of e-invoicing systems, resulting in potential gaps or inaccuracies in tax compliance despite e-invoicing implementation.

invoices, manipulating transaction data, or colluding with other entities to evade taxes.[7] E-invoicing is therefore unlikely to address all tax compliance challenges,[8] even when implemented alongside supportive measures and enforcement mechanisms. The objective of this paper is to shed light on the role of e-invoicing (or to adopt the more commonly usage of the term, *Electronic Billing Machines*—EBMs) in enhancing compliance directly, through broadening the tax base, but also indirectly through their impact on enhancing compliance through making tax audits more efficient.[9]

More specifically, using Rwandan administrative tax data on filings and audits, as well as information on the adoption of the EBMs by firms over the period spanning the years 2012-2019, this paper investigates the impact of EBMs on enhancing compliance across all business tax bases: VAT, Corporate Income Tax (CIT), and Personal Income Tax (PIT).[10] Importantly, the analysis seeks to quantify the *direct* impact of the EMBs on compliance (and through broadening the tax base) and its *indirect* effect, through making audits more efficient. Despite the importance of these issues for revenue mobilization, the evidence of such policy innovations is relatively unexplored.[11]

Interestingly, the evidence of the impact of EBMs on compliance is mixed. Evidence for Ethiopia and Rwanda on the earlier period of EBM introduction suggests that EBM adoption led to significant increase in VAT revenues in these countries (Ali et al., 2021; Eissa and Zeitlin, 2014). Casey and Castro (2011), making use of cross-country data, presents some evidence that indeed the introduction of EBMs alone is not generally associated with a significant increase in VAT revenue collection or permanent compliance

[7]Digitalization may also foster stronger tax avoidance and evasion raising also the behavioural responses to taxation, such as through more aggressive tax planning if the information collected in not accurate and timely (an issue discussed in Chapter 5, IMF, 2017).

[8]An important point in the discussion of electronic tax systems (and one that is also emphasized in Eissa and Zeitlin, 2014) is that, as enforcement devices, they require additional enforcement instruments in order to be effective. The reason for this is that (almost) all electronic tax systems are not part of an end-to-end digitization process and so there are other margins that taxpayers can exploit to evade their tax liabilities. In VAT, for example, electronic invoicing systems that are not designed to cross-match input suppliers and purchasers will be subject to misreporting. For some recent evidence on Uganda and Rwanda, respectively, see Almunia et al. (2022) and Mascagni et al. (2019).

[9]There are various electronic tax systems distinguished by the form of information transmitted to the tax authority and how this information is embedded in the authority's ecosystem. Some systems involve a platform that provides digital accounting and tax application, displaying all purchases and sales in the digital documents sent by licensed electronic invoicing providers, OECD (2022). A detailed description of the system evaluated here is provided later on.

[10]In Rwanda, business income is subject to either CIT or PIT depending on the firm's statutory structure (incorporated vs. non-incorporated businesses).

[11]Country specific recommendations that have been put forward by the Tax Administration Diagnostic Assessment Tool (TADAT) for Rwanda highlight the importance of improving compliance and include as high priority the digital transformation of taxpayer services, the improvement of digital skills and competencies, and the wider deployment of e-services (RRA, 2021). Rwanda ranks low in the uptake of information technologies and on the e-government scoreboard as well as on the Digital Economy Society Index (DESI).

improvements. The reason for this is that the introduction of the EBMs requires sufficient interoperability with the system that supports tax audits and, more broadly, the tax compliance function.

More recently, Mascagni et al. (2021) show that the introduction of EBMs in Ethiopia increased VAT revenues by 48 percent and income tax revenues by 12 percent. They also provide evidence that EBM users tend to increase their expenses reported in order to try to mitigate their tax liability. Taken together, the evidence so far points to the fact that while EBMs might be conducive to tax compliance behaviour, fully effective compliance improvements require the combination of technological innovations together with other enforcement mechanisms and, in particular, tax auditing. This paper contributes to this literature by quantifying the impact of EBMs on tax compliance, focusing in particular on how much of this impact is due to broadening of the base and how much is due to improving tax audits. Digital (and accurate) records are important for tax auditing and therefore the use of an EBM system should facilitate the effectiveness of tax audits, as the necessary information during (or before) an audit is made available to the tax auditors.[12] This, the argument goes, will be internalised by firms thereby increasing their tax compliance.

Things of course might be different in countries with weak institutions.[13] In two recent contributions—focusing on Uganda and Rwanda, respectively—Almunia et al. (2022) and Mascagni et al. (2019)[14] show that electronic submission of information to tax authorities does not necessarily lead to more compliance. The reason for this is that, despite the fact that transaction are digitalized, there are internal and external discrepancies in transactions recorded, driven by the view that the tax authority does not have the capacity in cross-checking (and possibly, if it does, there are no real consequences from being non-compliant).[15] The use of technology, such the EBMs, but also more broadly the use of digitised administrative data, make it possible for tax administrators to systematically verify the accuracy of taxpayers' records and perform cross-checks between trading partners, but this mechanism is not always fully exploited (Okunogbe and Pouliquen, 2022). And thus, in this light, audits can serve as an instrument to maximize the potential com-

[12]It also reduces the cost of compliance for both the tax authority and the taxpayers by decreasing the possibility of committing errors when reporting their liabilities. Tax authorities work towards an operating model in which taxation reduces the administrative work required for tax-related obligations. This is achieved by utilizing the information that is generated through the digitised process.

[13]A point emphasized in, among others, Acemoglu et al. (2001), Besley and Persson (2009), and Besley et al. (2013).

[14]See also the discussion in Section 2.2.

[15]An internal inconsistency represents the gap between different data sources for the same taxpayer (for example, VAT returns and VAT annexes) while an external discrepancy refers to the gap, for the same transaction, between buyer's and seller's reported amounts.

pliance effect of technological innovations, such as the EBMs, when employed to enforce and eventually correct the flagged discrepancies.

This paper shows that in Rwanda[16] while EBM adoption yields an increase in firms' net VAT payments of about 12 log points (direct effect) its impact is significantly improved by 8.9 log points through enhancing the quality of the tax audits (indirect effect). But the indirect effect is only present for tax audits associated with VAT. The results also suggest that EBM adopters do react to the adoption of the EBM by over-reporting other margins of their VAT returns: the purpose of doing so is to reduce their final liability, a pattern that is sometimes nuanced by tax audits (see more details in Section 4). Interestingly, the results also show that audits involving firms adopting the EBM system are the only ones that yield a significant compliance improvement in net VAT payments (7 log points), highlighting the importance of the EBMs for compliance. Finally, when it comes to business income taxes (CIT and PIT), the results suggest that there is an increase in compliance for CIT only. These effects originate from the direct impact of the policies: EBM (3.6 log points) and tax audits (9.3 log points). Interestingly, there is no indirect effect of EBMs on the CIT tax audits. No significant impact is obtained for PIT in our preferred specification.

This paper contributes to two important and growing areas of literature. First, it contributes to the literature investigating the impact of technological innovations and the reporting behaviour of firms. Prior work highlights the introduction of an e-invoicing system in emerging economies and developing countries finding relatively large increases in tax revenues (direct effect). This is the case for China (Fan et al., 2018), Peru (Bellon et al., 2022), Argentina (Templado and Artana, 2018), Uruguay (Bérgolo et al., 2018), and Ecuador (Ramírez and Oliva, 2018). The widespread adoption of technological innovations in tax administration have also brought radical changes to the revenue collection process in the developing world. In a recent study for Tajikistan, Okunogbe and Pouliquen (2022) examine the impact of electronic tax filing on reporting behaviour as well as on bribing, providing evidence of significant reduction in taxpayers' compliance costs and an increase in tax payments among firms previously more likely to evade. Conversely, firms which are a-priori less likely to evade tend to reduce their tax payments but also pay fewer bribes, as e-filing reduces extortion opportunities. The role played by the digitization of transactions in enhancing compliance is studied in two recent contributions. Das et al.

[16]Rwanda has undertaken major reforms in recent years aiming to improve tax collection and compliance. These reforms have increased the efficiency of tax administration and have significantly contributed to the attainment of better revenue mobilization and fiscal performance. However, challenges remain in several areas related to the streamlining of the legal framework, the modernization of the tax administration, the reduction of administrative burden and the increase in the fairness of the tax system, RRA (2021).

(2022) show that India's demonetization campaign led firms to significantly increase in their reported taxable sales and tax liabilities. Conversely, by exploiting administrative data and a policy reform, Brockmeyer and Saenz Somarriba (2023) provide evidence that digitization of transactions did not lead to increased tax compliance in Uruguay. These authors suggest that card machine adoption and a low share of card sales in total reported sales can rationalize their findings.

This paper also contributes to the literature investigating the compliance impact of operational audits. Despite the extensive evidence on the deterrence impact of audits in the developed world (see, for example, among others, Kleven et al., 2011; Gemmell and Ratto, 2012; DeBacker et al., 2015, 2018; Advani et al., 2021) the issue of evaluating tax audits in developing countries is somewhat neglected. Notable exceptions are the recent contributions by Best et al. (2021) and Kotsogiannis et al. (2022). Best et al. (2021) focus on Pakistan and find that although VAT audits uncover a substantial amount of evasion, they do not deter future noncompliance. These authors suggest that, given that these inspections tend to focus on checking mechanical violations, they are unlikely to move firm priors on the detection probability upwards. Kotsogiannis et al. (2022) analyse CIT audits in Rwanda and provide evidence of an aggregate positive impact in terms of future compliance, an effect that is completely driven by comprehensive audits, with audits that are narrower in their scope (desk and issue audits) delivering a counter-deterrence effect.

The evidence therefore tends to suggest that, depending on the context, technological innovations and tax audits may not be fully exploited in terms of their potential as tax enforcement instruments. These are issues which—despite being recognised as a theoretical possibility (in the discussion of the paper trail perspective of digitilization)—have attracted, to the best of our knowledge, limited empirical attention in the literature. The reminder of the paper is organized as follows. Section 2 provides some institutional background, discusses the mechanisms originating the synergies between tax audits and EBMs, and describes the data the analysis is based on. Section 3 describes the methodological approach followed, and Section 4 presents the results, while Section 5 provides some concluding remarks.

2 Institutional Setting, Mechanisms and Data

2.1 Institutional Setting: The EBM System

Rwanda is a representative low-income country both in terms of fiscal capacity and tax structure (ATAF, 2021b). As with many other countries in the cluster of countries Rwanda belong to, the VAT is the main source of revenue: in 2017/2018 the VAT contributed 33

percent of total domestic revenue, followed by the employment income tax under the Pay as You Earn (PAYE) scheme (23 percent), business income taxes (CIT and PIT, 19 percent), excise tax (12 percent), and import duty (8 percent) (RRA, 2019). As noted earlier, Rwanda has recently introduced important reforms part of which focus on compliance, including the introduction of ICTs to improve service delivery and enhance tax compliance.[17] To improve efficiency in VAT collection and strengthen compliance, Rwanda made it mandatory for VAT registered taxpayers[18] to use EBMs and issue certified VAT electronic invoices recording every sales transaction, both to other businesses and to final consumers, and submitting them electronically directly to the Rwanda Revenue Authority (RRA). This was backed by provisions for significant administrative penalties for non-compliance depending on the size of the firm.

EBMs were first used by VAT registered businesses in 2013 and they consisted of two main components working together as one system: the Sales Data Controller (SDC) and Certified Invoicing System (CIS), designed to record and transmit transaction data to the RRA system in real time. The EBM was also expected to enhance the RRA capacity to monitor business transactions and according to a report by the International Growth Centre (IGC), the use of EBM in this inception phase had a positive impact, increasing VAT payments by 6.5 percent between March 2013 and September 2014 (Eissa and Zeitlin, 2014). During this period the adoption of EBM expanded rapidly and, by September 2014, they were over 3,943 taxpaying firms who had acquired active EBMs, which corresponds to 77.8 percent of all VAT-registered firms at that time.

The implementation of the first EBM rollout (labeled EBM1 after the type of machines being installed in this phase) in 2013 was in a staggered fashion, first enrolling large businesses and firms in specific sectors, and later all other taxpayers. In January 2014, RRA announced the deadline for the adoption of EBMs by all VAT registered taxpayers (by end of March of the same year). Owing to the increased enforcement that was mounted by the authority, the number of EBM adoption increased dramatically in the same year, one year after the launch. However, the rate of adoption slightly dropped in the following two years (see Figure 1, Panel A). Despite announcing the deadline for the adoption of EBMs, some taxpayers did not adopt the use of EBMs, while others started adopting them in later years.[19] Exemption from EBM reporting can be awarded to

[17]For further details on the Rwandan tax system see, for example, Tourek (2022), Mascagni et al. (2022), Kotsogiannis et al. (2022), and Mascagni et al. (2023).

[18]With the VAT law No. 37/2012 of 09/11/2012, article 24. In Rwanda, the VAT law requires any business that carries out taxable activities exceeding a turnover of Rwf 20 million in the previous fiscal year or Rwf 5 million in the last quarter to register for VAT. However, any other business below this turnover may register for VAT due to the nature of business or for voluntary reasons.

[19]Several reasons contributed to this, including the fact that some firm categories were allowed exemption from using EBMs if they applied for it and met certain conditions in both the ministerial order No.

firms if they can demonstrate that the vast majority of their sales are VAT exempt, and VAT-qualifying sales are minimal (if up to 75 percent of sales are VAT exempt); their VAT-qualifying sales only take place at very limited periods during the year (less frequent and less than 30 invoices in a calendar year); or their current installed VAT system is sufficient and using EBMs causes unfair technical difficulty. Nevertheless, the implementation of EBMs was generally successful and the cumulative figures on EBM adoption and VAT registration follows an increasing path over time (Figure 1, Panel B).

The inception phase in the deployment of the EBM system (EBM1), presented a number of challenges mainly consisting in practical barriers and inconveniences that taxpayers experienced, often with negative repercussions on their tax morale, perceptions and attitudes (Mascagni et al., 2023). These challenges comprised of the high cost of EBMs for small firms, which had to cover the purchase cost themselves and maintenance costs over time, as well as the cost of the SIM card through which EBMs1 function.[20] There were also issue with the quality of receipts that used to easily deteriorate posed challenges to RRA with record-keeping and verification in audits, as well as limitations in the information that such machines could store,[21] which prompted the need for an upgrade to the system, which resulted in the introduction of upgraded EBMs, known as EBM2, in March 2017. The new system aimed at increasing the adoption and use of EBMs and it was designed to be more accessible to all eligible taxpayers since it is supplied in the form of a software, it is trained and installed free of charge by RRA, as opposed to the previous requirement for the firms to purchase the device. The implementation of the phase 2 in EBM deployment, followed a similar staggered approach to that of EBM1, in which a sample of large businesses were first requested to switch from EBM1 to EBM2. Later in 2020 all VAT registered businesses were requested to switch to EBM2 and, as of today, EBM1 is no longer given to taxpayers.[22]

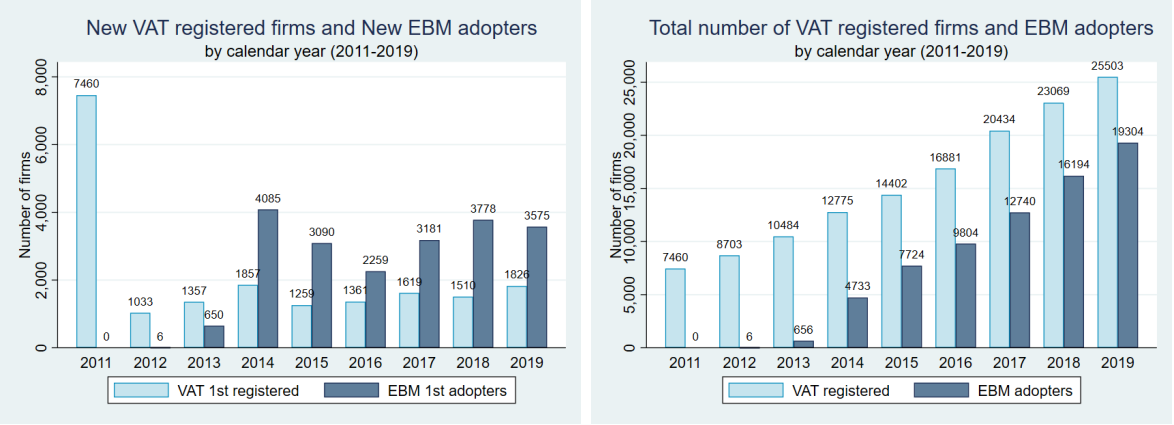
002/13/10/TC of 31/07/2013 and commissioner general rules No. 002/2013 of 12/09/2013. Another, but anecdotal, reason for the low uptake of EBM was the spike in VAT registration mainly driven by former government employees that were laid off in big numbers during a major reform in public intuitions in 2014. Most of these former government employees sought to open up businesses mainly targeting public tenders, a process that usually require to be registered for VAT, which led to more VAT registrations without corresponding need to acquire and use EBM hence lowering the relative rate of adoption of EBMs. Nevertheless, this phenomenon has not played a major role in this process compared to EBM exemptions.

[20]The EMB upfront cost in installation was high both for the firms and the government as it required four full years of VAT payments to be recovered (Eissa and Zeitlin, 2014).

[21]It was also not possible, for example, for RRA to track taxpayers' inventory and specific details of the items sold. In addition the RRA could not provide remote, online, support to taxpayers and monitor the status of the machines.

[22]In 2019, the *EBM for all* policy was launched to expand the use of EBMs to non-VAT firms, requiring an invoice to be generated by an electronic invoicing system for any taxable activity.

Figure 1: VAT registered firms and *EBM* adopters (2011 - 2019).



Note: The graph on the left (Panel A) reports the number of new VAT registered firms and the number of new EBM adopters by year while the graph on the right (Panel B) reports the correspondent cumulative figures.

2.2 Mechanisms: EBM and Tax Audits Synergy

As with almost all VAT systems, Rwanda follows the credit-invoice system, which allows for the deduction of VAT already paid at each stage of production.[23] This sequence of transactions creates a paper trail of records that show the flow of goods and services together with the associated cost of VAT transactions. This auditable paper trail along the production chain serves as a self-enforcement mechanism (Pomeranz, 2015; Naritomi, 2019). Since VAT is levied on sales, it is linked to the PIT and CIT tax bases and therefore even a marginal improvement in VAT compliance is likely to have a significant impact on the revenues accrued from those tax bases.

An e-invoicing system strengthens compliance through several channels.[24] First, through providing revenue agencies with real-time transaction information from firms, EBMs can play a crucial role in better defining tax liabilities. Through collecting and processing large amounts of data provided through electronic invoicing and tax declarations, revenue authorities can also automatically detect inconsistencies, such as mismatches between self-reported and third party–reported tax liability. Second, EBMs could also play a major role in terms of reducing firms' compliance costs. Finally, by providing reliable information flows on firms' transactions to the revenue authority, an EBM system is expected to reinforce its enforcement capacity both on VAT and indirectly on income tax bases. Nevertheless, African tax administrations are not fully exploiting

[23]The idea of the credit-invoice system is that firms issue invoices for any sale. When business to business transactions occur, firms can claim the VAT charged on input purchases as taxes already paid and are only required to remit the "value added" on goods sold (sales - business to business purchases).

[24]For a more thorough discussion on this see Okunogbe and Santoro (2023).

the paper trail mechanisms through e-invoicing systems unlocking the potential of VAT cross-checks. Recent evidence, for example, suggests that, despite the adoption of EBMs, there are widespread discrepancies in data reported by buyers and sellers for the same transactions, both in Rwanda (Mascagni et al., 2019) and Uganda (Almunia et al., 2022).

While firms are expected to mechanically increase the amount of total sales reported after the adoption of the EBM, in the absence of automatic pre-filling of taxpayer information, they also have an incentive to overreport other margins so to minimize the VAT paid. Firstly, this behavioural effect may materialize in inflated VAT paid on inputs—as documented by Mascagni et al. (2021) for Ethiopia—but there are additional margins that can be subject to manipulation, including the mis-classification of goods to exempted and zero-rated. Similarly, firms may claim inflated VAT refund with the same aim. One contribution of this paper is to shed some light on these margins too (see Sections 3 and 4). Finally, firms may underreport sales by understating prices, through mis-classifying goods and applying reduced tax rates to them. All these mechanisms may lead to significant reduction in EBM-enhanced compliance if not tackled through appropriate additional enforcement policies paired with the EBM adoption. In particular, the aim of this paper is to evaluate the role played by e-invoicing in indirectly enhancing compliance by improving the quality and performance of risk-based tax audits.

The flow of information generated through electronic invoicing together with further data sources, can be used by tax authorities to implement data-driven risk-based audit selection procedures. This involves scoring the universe of taxpayers based on their likelihood of noncompliance and selecting for audits those with higher estimated riskiness under the authority's tax enforcement capability constraints. Recently, many African countries, including Rwanda, have started to explore these policies but little is known whether they enhance compliance. In this light, a notable exception is Kotsogiannis et al. (2022) that analyse the Rwandan CIT providing evidence of positive aggregate impact of audits on deterrence but also pointing out that narrow-scope audits deliver a counter-deterrence effect, thus suggesting that there are margins of these policies that can be improved. Thus, in our context, audits can benefit from EBMs enhancing their effectiveness in selecting taxpayers based on their likelihood of noncompliance and providing an improved deterrence effect. But, at the same time, the impact of EBM on compliance can be improved by the additional enforcement checks provided by audits on the accuracy of information transmitted in matching tax records and third parties reporting. The main contribution of our paper is therefore to try to understand whether tax audits are adequate enforcement instruments that can help the EBM system enhancing its full potential compliance impact through these synergies. Finally, as in Mascagni et al. (2021),

we will also investigate the impact of these enforcement instruments on income taxes but separating the estimation for CIT and PIT since, given the different nature of the firms reporting these taxes, different impact might arise.

2.3 Data

All data employed in this paper is at the taxpayer (business) level. They include mostly financial variables used to calculate taxes (for example, total sales, taxable income, VAT refunds), as well as some taxpayer characteristics, such as size as defined by RRA,[25] geographical location (at tax centre level), and the information on the date in which firms adopted the EBM system. VAT declarations have been annualised and merged with the data from the correspondent firms' income tax declarations (CIT or PIT) using the anonymized tax identification number. This dataset is finally merged with the detailed records of audits undertaken by the RRA during the years 2013 through 2017.

In general, the RRA tends to audit two tax periods but taxpayers are required to keep their records for a longer period. Tax enforcement examinations involve three types of audits:[26] desk audits, issue audits and comprehensive audits. Comprehensive audits are in-depth and time-intensive examinations and usually are conducted through RRA staff visiting the taxpayer's business premises in order to review all relevant documents. Desk and issue audits are narrower in their scope, generally focusing on a single aspect and single tax period and are conducted by RRA staff using information already submitted to RRA through various sources including from the tax declarations.[27] We have also been given access to the detailed confidential information on the criteria for audit selection which includes the risk rules employed to assign risk scores to the world of tax declarations. The risk criteria utilise information that spans across tax bases.[28] The administrative data is retrieved from RRA systems which collect and store tax data from tax procedures followed by taxpayers. The resulting dataset consists of a panel of firms over the period 2012-2019. Before performing our analysis we apply some restrictions to this data in order

[25] RRA classifies businesses as follows: *Micro*-businesses declare a turnover of less than 12 million Rwf (USD 13,380 as of February 2019 exchange rate) in a tax period; *Small*-businesses have a turnover between Rwf 12 million and Rwf 50 million (USD 55,750) in a tax period; *Medium*-businesses have a turnover higher than Rwf 50 million in a tax period; and *Large*-business above that threshold.

[26] Following an administrative procedure RRA may also amend submitted tax liability which is initiated when the tax administration discovers a miscalculation or omission, an understatement or any other error in which case the tax administration rectifies the submitted tax liability. These amendments are not considered audits and therefore they do not appear in the analysis.

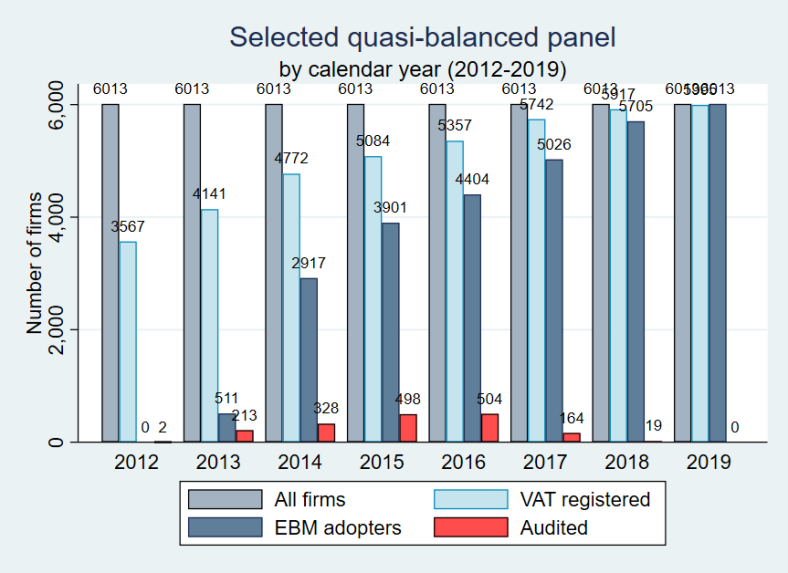
[27] For more details on the audit process, see Kotsogiannis et al. (2022).

[28] After each return has been filed, audit flags are generated based on the characteristics of the returns in a deterministic way. In conducting the audits, tax auditors follow the audit procedures described in the manual of audits which provides a systematic approach to the tax audit process ensuring consistency in auditing. The integrity of the tax and audit data has been assured by the RRA.

to select a sample of relatively more homogeneous firms. First, we select firms filing a tax declaration for all years for at least a tax base (VAT, CIT or PIT) during the observed period. In doing so we end up with a quasi-balanced panel of 6,013 firms.

The choice of a quasi-balanced panel instead of a perfectly balanced panel across all relevant tax bases is driven by the intention to keep a reasonable sample size while capturing the impact of EBMs and audits on the behaviour of firms usually reporting taxes. This is a reasonable compromise under the assumption that a firm may have been exempted from reporting a specific tax base during some year in the observed period. Furthermore, and in order to have a comparable control group for the EBM adopters, we restrict the analysis to firms eventually adopting EBM at some point between 2013 and 2019. By doing this, we avoid comparing EBM adopters with businesses that will never adopt, which are likely to have a substantially different reporting behaviour. This also ensures having at least one pre-treatment period for any adopter in any observable period to formally test the parallel trend condition (see also Section 3 and in particular Figure 3). Figure 2 presents a graphical representation of the composition of our selected sample in which we include also the firms audited in the waves we have been granted access to.[29]

Figure 2: Composition of selected sample



Note: The graph presents the composition of our quasi-balanced panel.

Table 1 presents the summary statistics for our outcome variables in levels, and for the selected sample spanning the period 2012-2019. Namely, these are the annual aggregations of the correspondent fields of VAT declarations and the income tax liabilities

[29] As noted above in the text, we have been granted access to 5 waves of audits, 2013-2017, but they are recorded into a specific tax period depending on the month in which the taxpayers have been notified, this is why few of them are coded as starting in 2012 and 2018.

(CIT and PIT). More precisely, *VAT payable* represents the total output VAT, that is, the sum of VAT charged on Taxable Sales and VAT Reverse charge. *VAT paid on inputs* is the sum of all input components of VAT (VAT paid on imports and VAT paid on local purchases); *Total non-taxable sales* aggregates exempted sales, zero-rated sales and exports, while *VAT refund claimed* is the total amount of VAT refunds claimed by firms. Our main margin of interest is the net VAT liability annually paid by firms, that is *VAT due*, which is obtained by subtracting *VAT paid on inputs* from *VAT payable*. *CIT payable* and *PIT payable* represent the relevant income tax liability paid by taxpayers net of any tax discounts claimed and depending on their statutory structure (incorporated vs. non-incorporated businesses). All variables are expressed in thousands of US$.

Table 1: Summary statistics - outcome variables (2012-2019)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
VAT Due	1,000 US $	40,575	29.73	438.77
VAT Payable	1,000 US $	40,575	77.03	629.09
VAT Paid on Inputs	1,000 US $	40,575	68.69	409.13
Total Non-Taxable Sales	1,000 US $	40,575	279.45	3265.87
VAT Refund Claimed	1,000 US $	40,575	1.95	109.56
CIT Payable	1,000 US $	26,393	13.89	236.91
PIT Payable	1,000 US $	10,293	2.29	18.78

Note: Authors' calculations based on data provided by RRA.

For our selected sample, we also report in Table 2 some descriptive statistics for the main outcome variables associated with the tax audits performed by RRA for all tax periods audited, across all relevant tax bases and available audit waves. In particular, *audit outcome* represents the amount of tax base underreported uncovered with a mean of just over US$ 40,000 and the standard deviation of about US$ 512,000. *Audit outcome* is also reported as a share of the *potential tax base* (defined as the sum of tax base declared by the taxpayer and the *audit outcome*). *Total fines*, which gives the sum of all fines and penalties applied to those businesses found underreporting tax bases has a mean of just over US$ 23,000 and standard deviation of just over US$ 317,000. *Total audit outcome* gives the sum of *audit outcome* and *total fines*. Finally, *total audit outcome (%)* is calculated as the percentage of *total audit outcome* over the *potential tax base including fines* (defined as the sum of taxable income declared by the taxpayer and *total audit outcome* as to include tax fines). Thus, Table 2 reveals that audits contribute a substantial amount of tax revenues in terms of uncovered tax bases underreported which amounts to about 30 percent of the potential tax base audited (about 33 percent including fines).

Tables 3 and 4 present the same information splitting the sample of audited firms

Table 2: Audits descriptive statistics (2013-2017)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
Audit outcome	1,000 US $	1,728	40.66	511.95
Audit Outcome (%)	% Potential Tax Base	1,728	29.58	42.35
Total Fines	1,000 US $	1,728	23.16	317.36
Total Audit Outcome	1,000 US $	1,728	63.91	825.48
Total Audit Outcome (%)	% Potential tax base (Including Fines)	1,728	32.72	43.67

Note: Authors' calculations based on data provided by RRA.

between EBM adopters and non-adopters. In terms of their performance evaluated in levels, audits involving firms employing EBMs uncover a higher amount of underreporting and levy a larger amount of fines, leading to a greater total audit outcome when compared to the others. Nevertheless, when evaluated in relative terms, as a percentage of the potential tax base, audits involving EBM non-adopters tend to slightly outperform audits targeting EBM users. This means that the use of EBM leads to an increase of the declared tax bases—the main component of the denominator of this ratio—that is more than proportional to the increase in underreporting detected plus fines levied. This is also true when comparing firms of the same size (see Apprendix A, in particular Tables A.1-A.4). Read in this way, EBM adoption seem to improve compliance by widening the declared tax base and by enhancing the detection power of audits.

Table 3: Audits descriptive statistics EBM adopters (2013-2017)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
Audit outcome	1,000 US $	1,106	44.02	621.41
Audit Outcome (%)	% Potential Tax Base	1,106	28.37	42.46
Total Fines	1000 US $	1,106	25.44	384.31
Total Audit Outcome	1,000 US $	1,106	69.47	1,002.38
Total Audit Outcome (%)	% Potential Tax Base (Including Fines)	1,106	31.17	43.78

Note: Authors' calculations based on data provided by RRA.

The next section presents the methodology employed to estimate the joint effect of EBMs and audits on the future reporting behaviour of taxpayers, that is the deterrence impact of these two enforcement instruments which is at the heart of the contribution of this paper.

Table 4: Audits descriptive statistics EBM non-adopters (2013-2017)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
Audit outcome	1,000 US $	622	34.68	204.27
Audit Outcome (%)	% Potential Tax Base	622	31.72	42.10
Total fines	1,000 US $	622	19.11	131.37
Total Audit Outcome	1,000 US $	622	54.01	327.11
Total Audit Outcome (%)	% Potential Tax Base (Including Fines)	622	35.48	43.38

Note: Authors' calculations based on data provided by RRA.

3 Estimation Strategy

To estimate the direct and indirect—through tax audits—effects of EMBs on promoting compliance in future tax payments, the analysis relies on a DID setting. Equations (1)-(2) check separately the parallel trend assumption through dynamic fixed effects models for the EBM adoption treatment

$$Y_{it} = \alpha + \sum_{k=-3}^{2} \beta_k EBM_{it+k} + \theta_i + \tau_t + \varepsilon_{it}, \tag{1}$$

and the audit treatment

$$Y_{it} = \alpha + \sum_{k=-3}^{2} \beta_k AUDIT_{it+k} + \theta_i + \tau_t + \varepsilon_{it}, \tag{2}$$

where Y_{it} is the annual net VAT due expressed in natural logarithm (ln henceforth),[30] EBM_{it+k} in equation (1) is a dummy equal to 1 if the taxpayer is k periods before (after) the EBM adoption in period t, while $AUDIT_{it+k}$ in equation (2) accounts for the audit treatment, In both models β_k represents the period specific pre- and post-treatment effects while the terms τ_t and θ_i account respectively for time effects and firms fixed effects and ε_{it} is the error term,

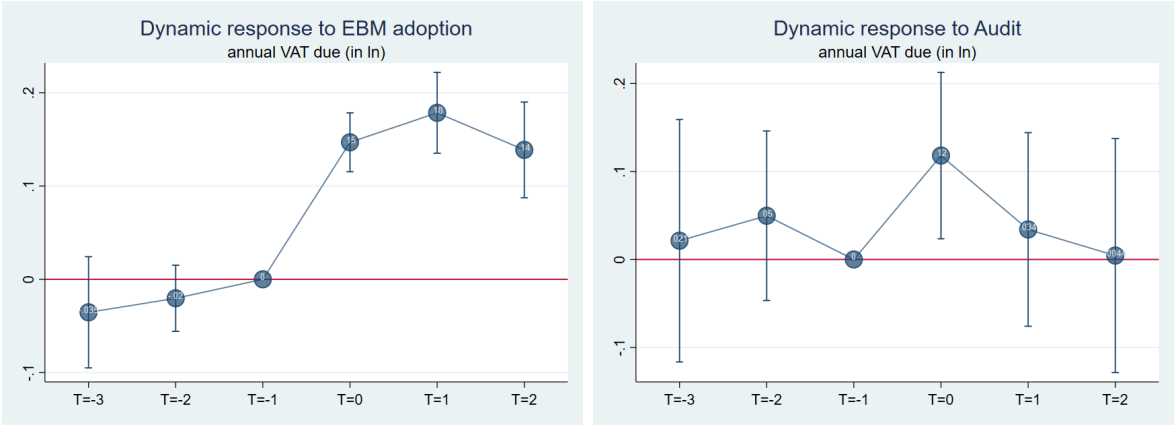
Since RRA audit selection is risk-based, equation 2 combines DID with matching employing Coarsened Exact Matching (CEM, see Iacus et al., 2011, 2012) to stratify taxpayers based on their risk scores, the index used by RRA for audit selection[31] and employs a weighted fixed effects model with weights resulting from that stratification providing balancing across the two cohorts of treatment.[32]

In both models, the absence of significance in pre-treatment differences between treated taxpayers and the control group tend to confirm that the pre-treatment parallel

[30]To be more precise, we use the transformation $ln(Y_{it} + 1)$ so to account for null values.
[31]More details on this can be found in Kotsogiannis et al., 2022; Hebous et al., 2023.
[32]See Appendix B that deepens this method.

trend is achieved and significance in post-treatment estimated coefficients provides a first evidence of the pro-deterrence impact of EBMs and audits on firms' VAT reporting behaviour (see Figure 3). In particular, while the impact of EBM adoption persists over time, the positive impact of audits on future compliance seems to be present for the sole first year of treatment.[33]

Figure 3: Event Study: Dynamic response to *EBM* adoption and *Audits* treated separately.



Note: These figures report the estimates of the period-specific treatment effects on net VAT liability for EBM adoption (through a Fixed Effects model) and for audits (through a CEM-Weighted Fixed Effects model). Firms and year fixed effects are controlled for. The excluded category is the last period before treatment (T=-1); 95 percent confidence intervals are shown.

As discussed in Section 2.2, the contribution of this paper is twofold. First, its objective is to estimate the direct and indirect impact—through tax audits enhancement—of EBM adoption on promoting VAT compliance while trying to understand the mechanisms behind the aggregate treatment effect on net VAT liability. To shed light on this, the strategy is to analyse the joint impact of these two enforcement instruments on different margins of VAT registered firms' reporting behaviour with the aim of decomposing their estimated net effect on the annual *VAT due* and disentangle the treatment effect on the underlying parts of the VAT return. As discussed in Sections 2.2 and 2.3, these are the annual aggregations of *VAT payable*, or in other words total output VAT — *total non taxable sales*, *VAT paid on inputs* and *VAT refund claimed* reported by firms in their VAT returns. Secondly, the analysis also focuses on other margins across income taxes, specifically the *CIT payable* and *PIT payable*. Our baseline framework is a standard DID model with fixed effects and time effects as presented in equation 3 where the dependent variable Y_{it} represents alternatively each of the margins described above expressed in ln, EBM_{it} is a dummy indicator that switches on the year of adoption while τ_t and

[33]This is consistent with the findings in Kotsogiannis et al. (2022) for CIT and the 2015 audit wave in Rwanda.

θ_i account respectively for time effects and firm fixed effects and ε_{it} is the error term. Since the equation is estimated through a fixed effect panel data model, the data is first differentiated in the estimation and as a result the coefficient β in equation 3 estimates the overall DID effect between adopters and non-adopters.

$$Y_{it} = \alpha + \beta EBM_{it} + \theta_i + \tau_t + \varepsilon_{it}. \tag{3}$$

We then introduce a dummy variable $Audit_{it}$, which is equal to 1 if the firm has been audited in tax period t, which is also interacted with the EBM adoption indicator. Given the risk-based selection in audit assignment, we also control, through matrix R_{it}, for a set of dummy variables each accounting for one of the risk rules used by RRA in their audit selection process. The resulting fully fledged model is represented in equation 4 where the parameters of interest are β_1, β_2—that collect respectively the treatment effects of EBM adoption and tax audits employed in isolation—and in particular β_3 estimating their joint effect on compliance, i.e. the indirect effect of EBMs on deterrence through enhanced audit effectiveness. Finally, and in order to better account for risk-driven audit selection, we also combine matching with DID as in Kotsogiannis et al. (2022) and Hebous et al. (2023). Namely, we estimate a CEM-weighted version of Equation 4, CEM-stratifying taxpayers based on their aggregate likelihood of being noncompliant as synthesized by their total risk score. In this way, we achieve an improved balance across treatment cohorts.[34]

$$Y_{it} = \alpha + \beta_1 EBM_{it} + \beta_2 Audit_{it} + \beta_3 Audit_{it} * EBM_{it} + \gamma R_{it} + \theta_i + \tau_t + \varepsilon_{it}. \tag{4}$$

The next section presents the results of the empirical analysis.

4 Results

Tables 5-11 present the results on each of the margins described in Section 3. Each table focuses on a single outcome variable, and it is organized in the same way, presenting the results for our baseline model (equation 3) in Column 1 and progressively refining the model by including the $Audit_{it}$ treatment (Column 2) and its interaction with the EBM adoption (Column 3). Models 2 and 3 are then enhanced by controlling for the set of dummies identifying the risk rules (Columns 4 and 5). Finally, column 6 presents the results of the estimation of the CEM-weighted fixed effects version of Equation 4 which represents our preferred model.

Table 5 shows the results of the estimated impact of EBM adoption and tax audits on the annual net VAT due that is, the net VAT liability yearly paid by firms. In absence

[34]See also Appendix B for more details on this method, and in particular Table A.5 and Figure A.1.

Table 5: Impact of EMB adoption and Audits on future compliance - outcome: VAT due (in ln)

	(1)	(2)	(3)	(4)	(5)	(6)
EBM_adopted	0.147***	0.147***	0.141***	0.115***	0.109***	0.120***
	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.011)
Audit		0.040	-0.018	0.035	-0.022	-0.019
		(0.024)	(0.030)	(0.028)	(0.032)	(0.028)
Audit*EBM_adopted			0.090***		0.087**	0.089**
			(0.030)		(0.034)	(0.034)
N	40,502	40,502	40,502	40502	40502	39046
AIC	82,000.63	81,998.60	81,995.39	80,254.66	80,251.57	79,997.14
BIC	82,009.24	82,015.82	82,021.22	80,375.184	80,380.71	80,125.73
Adjusted Within R^2	0.003	0.003	0.003	0.045	0.045	0.053
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Audit Risk Rules	No	No	No	Yes	Yes	Yes
CEM on risk score	No	No	No	No	No	Yes

Note: Robust standard errors (clustered by tax centre) are reported in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

of additional enforcement, our CEM matched-DID estimation shows that EBM adoption yields an increase in VAT net payments of 12 log points (direct effect), which is incremented by additional 8.9 log points when the use of EBMs is paired with tax audits (indirect effect). Interestingly, and further highlighting the importance of the indirect impact of EBM adoption on the deterrence effect of audits, our results show that the only audits leading to a significant improvement in VAT compliance are those involving firms employing EBMs which yield a net combined effect on future VAT payments of about 7 log points (s.e.=3.4 log points) compared to a (negative but) not significant effect of the other audits. All this suggests that the information flow provided to RRA by EBMs improves the audit performance in terms of deterrence power, conveying to the taxpayer the message that RRA has relevant information that has been used in the audit process which is internalized in taxpayer's future decision-making process.

In order to understand what drives these results, we explore next the treatment effects of EBM usage and tax audits on several additional margins of firms' VAT reporting behaviour. First, as explained in Sections 2.2 and 3, we decompose the effect on the net VAT due into its output and input components. Table 6 presents the results on VAT payable, for example, the output component of VAT. Our preferred model (Column 6) provides evidence of a significant and positive direct impact of both EBM adoption and tax audits on the aggregation of annual VAT on Taxable Sales and VAT Reverse charge with a significant role played by these two instruments when employed in synergy (indirect effect). In particular, EBM adoption considered in isolation leads to an increase of 28.2

Table 6: Impact of EMB adoption and Audits on future compliance - outcome: VAT payable (in ln)

	(1)	(2)	(3)	(4)	(5)	(6)
EBM_adopted	0.380***	0.381***	0.377***	0.281***	0.275***	0.282***
	(0.014)	(0.014)	(0.015)	(0.011)	(0.012)	(0.019)
Audit		0.141***	0.110***	0.113***	0.063***	0.063***
		(0.018)	(0.015)	(0.025)	(0.014)	(0.017)
Audit*EBM_adopted			0.049***		0.077**	0.075**
			(0.017)		(0.032)	(0.028)
N	40,502	40,502	40,502	40,502	40,502	39,046
AIC	106,884.37	106,859.06	106,860.22	100,662.15	100,661.73	100,404.04
BIC	106,892.98	106,876.28	106,886.05	100,782.67	100,790.86	100,532.63
Adjusted Within R^2	0.010	0.011	0.011	0.152	0.152	0.170
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Audit Risk Rules	No	No	No	Yes	Yes	Yes
CEM on risk score	No	No	No	No	No	Yes

Note: Robust standard errors (clustered by tax centre) are reported in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

log points in VAT payable which are incremented by additional 7.5 log points when EBM users are audited. Tax audits have a significant impact on this margin too. Their effect has the magnitude of 6.3 log points of VAT payable for non-users of EBM and gets more than doubled if the firm adopted EBMs leading to a log point effect of 13.8 (s.e. = 3.9 log points).

A consequence of these results, taken together with the progressive expansion of the e-invoicing system, is an expected mechanical increase in adopters' reported VAT paid on inputs. Indeed, as a result of the increase in EBM usage along the VAT chain, providers are expected to increase the VAT levied (Table 6) in business-to-business transactions (see also Section 2.2). But on top of this effect, there might also be a behavioural one affecting this margin in the same direction. Indeed, firms might decide (in the absence of automatic pre-filling) to over-report VAT paid on inputs as a strategic measure to partially reduce their final VAT liability (VAT due). This behaviour is possible (and not uncommon), but relates in particular to audited firms. Indeed, when it comes to tax audits, there might be two opposite effects on this margin. On the one hand, audits may deliver a pro-deterrence effect through lower VAT paid on inputs following the audit.[35] On the other, audited taxpayers may also decide to increase their gross VAT liability (as documented in Table 6) but try to partially counter this effect over-reporting VAT paid on inputs and ending up with a milder increase in their net VAT liability. Thus, the net effect of audits would depend on which of these two components tends to prevail on the

[35]This is likely in particular if this was a detected source of noncompliance, something we cannot identify due to lack of this information.

Table 7: Impact of EMB adoption and Audits on future compliance - outcome: VAT paid on Inputs (in ln)

	(1)	(2)	(3)	(4)	(5)	(6)
EBM_adopted	0.068**	0.067**	0.054**	0.088***	0.078***	0.078***
	(0.029)	(0.028)	(0.025)	(0.029)	(0.027)	(0.021)
Audit		-0.187***	-0.302***	-0.185***	-0.275***	-0.279***
		(0.062)	(0.075)	(0.054)	(0.064)	(0.067)
Audit*EBM_adopted			0.178***		0.138***	0.132***
			(0.026)		(0.020)	(0.019)
N	40,502	40,502	40,502	40,502	40,502	39,046
AIC	73,734.13	73,627.60	73,604.57	71,458.203	71,444.37	68,352.15
BIC	73,742.74	73644.82	73,630.40	71,578.731	71,573.51	68,480.738
Adjusted Within R^2	0.001	0.003	0.004	0.056	0.056	0.055
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Audit Risk Rules	No	No	No	Yes	Yes	Yes
CEM on risk score	No	No	No	No	No	Yes

Note: Robust standard errors (clustered by tax centre) are reported in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

other on the average estimated effect. Table 7 reports the results on this margin providing evidence for these effects. Specifically, EBM adopters increase their VAT paid on inputs by 7.8 log points in absence of audits and by 20.1 log points (s.e.=3.3 log points) when audited, suggesting the presence of both a mechanical and a behavioural adjustment at least for audited taxpayers. Indeed, while the net impact of audits on this margin is promoting compliance, we find evidence of both components of the effect. Namely, EBM non-adopters audited firms reduce their input VAT reported by 27.9 log points while audited adopters reduce them less–by 14.7 log points (s.e.=3.3 log points)—as a result of the combination of the two above-mentioned effects of audits.

A similar strategic margin of action VAT payers may utilize to contain their net VAT payments, and one that has been not explored by the literature, regards non-taxable sales. Indeed, after adopting EBM or experiencing an audit, firms might try to compensate the increase in gross VAT liability reported (Table 6), by inflating their non-taxable sales. This can be done by misreporting within this category some of their taxable sales in the vein of reducing their net VAT liability. Table 8 confirms this hypothesis, showing log point effects of 8.6 and 17.9 on this margin due to EBM adoption and tax audits, respectively. While the negative sign of the interaction term (-8.8 log points) tend to suggest that when EBM and audits are simultaneously used, these effects may be nuanced, our data cannot identify the magnitude or sign of the coefficient with sufficient precision (s.e.=9.7 log points) to determine whether the indirect effect of these instruments lead to a different

Table 8: Impact of EMB adoption and Audits on future compliance - outcome: Total non taxable sales (in ln)

	(1)	(2)	(3)	(4)	(5)	(6)
EBM_adopted	0.103***	0.103***	0.112***	0.072***	0.079***	0.086***
	(0.013)	(0.012)	(0.018)	(0.014)	(0.020)	(0.021)
Audit		0.115***	0.196***	0.105***	0.166***	0.179***
		(0.036)	(0.048)	(0.028)	(0.043)	(0.047)
Audit*EBM_adopted			-0.126		-0.094	-0.088
			(0.084)		(0.083)	(0.097)
N	40502	40502	40502	40,502	40,502	39,046
AIC	114,257.48	114,244.42	114,241.79	112,492.36	112,491.72	110,816.89
BIC	114,266.09	114,261.64	114,267.61	112,612.89	112,620.86	110,945.48
Adjusted Within R^2	0.001	0.001	0.001	0.043	0.044	0.050
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Audit Risk Rules	No	No	No	Yes	Yes	Yes
CEM on risk score	No	No	No	No	No	Yes

Note: Robust standard errors (clustered by tax centre) are reported in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

net impact or not.[36]

Table 9: Impact of EMB adoption and Audits on future compliance - outcome: VAT refund claimed (in ln)

	(1)	(2)	(3)	(4)	(5)	(6)
EBM_adopted	0.069***	0.069***	0.078***	0.066***	0.074***	0.080***
	(0.016)	(0.016)	(0.015)	(0.017)	(0.016)	(0.019)
Audit		-0.085***	-0.002	-0.094***	-0.026	-0.026
		(0.019)	(0.041)	(0.017)	(0.039)	(0.042)
Audit*EBM_adopted			-0.128***		-0.104***	-0.108***
			(0.034)		(0.035)	(0.037)
N	40,502	40,502	40,502	40,502	40,502	39,046
AIC	44,230.90	44,186.15	44,161.02	43,804.56	43,788.99	44,350.84
BIC	44239.51	44203.36	44,186.85	43,925.09	43,918.12	44,479.43
Adjusted Within R^2	0.002	0.003	0.003	0.012	0.013	0.012
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Audit Risk Rules	No	No	No	Yes	Yes	Yes
CEM on risk score	No	No	No	No	No	Yes

Note: Robust standard errors (clustered by tax centre) are reported in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Another previously unexplored margin concerns how EBM adopters and audited firms adjust their VAT refund claimed. Table 9 suggests that in absence of audits, firms increase their claims by about 8 log points after adopting EBMs, but this effect is com-

[36]The net effect of EBM adoption for audited taxpayers is -0.2 log points with s.e.=8 log points, while the net effect of audits for EBM adopters is 9.1 log points with s.e.=5.7 log points.

pletely and significantly neutralized when audits are involved, as suggested by the interaction term (-10.8 log points) and leading to a not significant net effect of -2.8 log points (s.e.=5.2 log points). Also, the information collected by RRA through EBMs plays a crucial role in terms of audit effectiveness as proven by the fact that the sole audits reducing VAT refund claimed significantly (by 13.5 lo points, s.e.=0.8 log points) are those performed on EBM adopters while the others have a (negative but) non-significant impact. Taken together, all these results suggest that the introduction of an e-invoicing system provides direct and indirect benefits on net VAT compliance (Table 5), by broadening the reported tax base (direct effect) and by enhancing the audit process (indirect effect). This impact on net VAT liability originates from improved VAT gross compliance which is significantly higher for audited EBM adopters (Table 6) and it persists despite taxpayers tend to adjust simultaneously different components of their VAT declarations to try to reduce the increase in their net payments, a pattern that is in some instances nuanced by the combined effect of audits and EBM.

Table 10: Impact of EMB adoption and Audits on future compliance - outcome: CIT payable (in ln)

	(1)	(2)	(3)	(4)	(5)	(6)
EBM_adopted	0.027**	0.048**	0.049**	0.042***	0.046***	0.036***
	(0.012)	(0.020)	(0.018)	(0.014)	(0.013)	(0.012)
L.Audit		0.084***	0.104**	0.066***	0.102***	0.093***
		(0.021)	(0.041)	(0.010)	(0.028)	(0.031)
L.Audit*EBM_adopted			-0.027		-0.051	-0.048
			(0.034)		(0.034)	(0.033)
N	26,365	23,472	23,472	23,472	23,472	22,690
AIC	49,891.34	41,800.91	41,802.57	40,418.760	40,419.49	40,382.08
BIC	49,899.52	41,817.04	41,826.77	40,531.65	40,540.45	40,502.52
Adjusted Within R^2	0.000	0.001	0.001	0.059	0.059	0.056
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Audit Risk Rules	No	No	No	Yes	Yes	Yes
CEM on risk score	No	No	No	No	No	Yes

Note: Robust standard errors (clustered by tax centre) are reported in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

When it comes to income taxes, EBMs and tax audits tend to provide compliance improvements when used in isolation and for the sole CIT, although their synergies seem not to materialize. In particular, as it is shown in Table 10, CIT declared by EBM adopters in Rwanda increases by about 3.6 log points but while audits in isolation produce an increase of 9.3 log points (coherent with the findings of Kotsogiannis et al. (2022) for the 2015 audit wave), there is not a significant difference between audits performed on EBM adopters and non-adopters. The results for PIT (Table 11) seems to suggest that there is a

Table 11: Impact of EMB adoption and Audits on future compliance - outcome: PIT payable (in ln)

	(1)	(2)	(3)	(4)	(5)	(6)
EBM_adopted	0.033**	0.065***	0.063***	0.047***	0.045***	0.021
	(0.015)	(0.016)	(0.015)	(0.017)	(0.016)	(0.020)
L.Audit		-0.054	-0.103	-0.033	-0.096	-0.097
		(0.041)	(0.091)	(0.045)	(0.090)	(0.111)
L.Audit*EBM_adopted			0.058		0.075	0.073
			(0.063)		(0.058)	(0.078)
N	10,221	9,381	9,381	9,381	9,381	9,053
AIC	9,971.47	7,771.57	7,773.01	7540.735	7,541.79	7,782.98
BIC	9,978.70	7,785.86	7,794.45	7,633.64	7,641.84	7,882.53
Adjusted Within R^2	0.000	0.002	0.002	0.027	0.027	0.027
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Audit Risk Rules	No	No	No	Yes	Yes	Yes
CEM on risk score	No	No	No	No	No	Yes

Note: Robust standard errors (clustered by tax centre) are reported in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

similar deterrence impact provided by EBM although this is not statistically significant in our preferred model (Column 6). Tax audits instead do not appear to enhance compliance in this case.

5 Concluding Remarks

Improving VAT compliance is undoubtedly a major challenge for tax administrations across the world, and in particular so for developing countries (IMF, 2015), which tend to rely on this tax base as a source of revenues (ATAF, 2021b). The digitalization of billing payments can enable governments to reduce bureaucracy and administrative costs and enhance revenue mobilization. But it is important to understand the impact of such technological innovations and the mechanism underlying such impact. This is an important issue and one that is directly related to the design and effectiveness of tax auditing and capacity building in tax administrations.

By using available data on VAT, CIT and PIT as well as information on firms' EBM adoption and tax audits performed by the RRA, this paper has investigated the role played by the joint use of e-invoicing and tax audits in promoting VAT compliance in Rwanda, a representative developing country. The analysis has identified both a direct—through tax bases broadening—and an indirect—via tax audit enhancement — impact of the introduction of the e-invoicing system on net VAT compliance. Specifically, while EBM adoption provides per-se an increase in firms' net VAT payments of about 12 log points (direct effect), this impact is significantly improved when paired with audits (20.9 log points) thanks to the indirect enhancement of the enforcement policy provided by EBMs. Furthermore, and perhaps more importantly, the results have shown that the only tax audits leading to a significant pro-deterrence effect on VAT compliance are those involving firms employing EBMs yielding a 7 log points net impact. The paper has also provided evidence that EBM adopters simultaneously react by over-reporting other margins of their VAT returns with the aim of reducing their final liability, a pattern that is sometimes nuanced by tax audits. Finally, when it comes to business income taxes (CIT and PIT), the results provide evidence of compliance improvements also for CIT, but the synergy for this tax base is absent. These effects originate from EBM (3.6 log points) and tax audits (9.3 log points) when used in isolation, although their synergies seem not to materialize in this case. Interestingly, we find no evidence of impact for PIT.

We hope to have shown that the results obtained are instructive and the issues identified merit further investigation.

Appendix A: Additional Descriptive Statistics

Tables A.1-A.4 present the descriptive statistics of the main audit outcome variables, clustering our sample of firms by size as defined by the RRA (see also footnote 25) and by EBM adoption status. The aim of this exercise is to compare the average performance of audits involving EBM adopters with those implicating non-adopters but maintaining a comparable size across these cohorts. With the aim of maintaining the subsamples as comparable as possible in terms of their sample size across EBM adoption cohorts, we group together medium and large firms in the first cluster, and small and micro firms in the second cluster. For medium-large firms, both the average underreporting uncovered through the inspection, the audit outcome, the total fines charged, and the total audit outcome are about the double for EBM adopters compared to non-adopters (Tables A.1-A.2). Regarding micro-small firms, we record a similar ratio in terms of audit outcome, but fines tend to be similar across cohorts, with those applied to EBM adopters being just above those charged to non-adopters. The resulting total audit outcome is about 1.5 times higher for EBM adopters. All this suggests that by providing accurate information on firms' transactions, the use of EBMs can boost the monitoring ability of the revenue authority, enhancing its capacity to detect tax evasion through audits. Interestingly, when we compare audits across these cohorts but in terms of their relative performance—that is considering the outcomes as share of the potential tax base—audits involving EBM non-adopters tend to slightly outperform audits targeting EBM users. Given that the potential tax base is defined as the sum of the tax base declared by the taxpayer and the audit outcome, this means that within the same size category, firms using EBMs declare higher tax bases than non-adopters and do so more than proportionally compared to the difference in the outcome of the audits.

All this, read together with the main results of the paper on deterrence effects, seems to confirm that the improved compliance channelled through EBM is obtained by widening the declared tax base and by enhancing the detection and deterrence power of audits.

Table A.1: Audits descriptive statisics EBM adopters – Medium & Large firms (2013-2017)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
Audit outcome	1,000 US $	363	115.27	1078.76
Audit outcome (%)	% Potential tax base	363	19.03	34.77
Total fines	1,000 US $	363	67.54	667.21
Total audit outcome	1,000 US $	363	182.82	1,740.20
Total audit outcome (%)	% Potential tax base (including fines)	363	21.6	36.57

Note: Authors' calculations based on data provided by RRA.

Table A.2: Audits descriptive statisics EBM non-adopters – Medium & Large firms (2013-2017)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
Audit outcome	1,000 US $	356	56.94	267.72
Audit outcome (%)	% Potential tax base	356	28.11	38.43
Total fines	1,000 US $	356	30.28	171.34
Total audit outcome	1,000 US $	356	87.54	428.56
Total audit outcome (%)	% Potential tax base (including fines)	356	32.36	40.36

Note: Authors' calculations based on data provided by RRA.

Table A.3: Audits descriptive statisics EBM adopters – Small & Micro firms (2013-2017)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
Audit outcome	1,000 US $	743	9.22	60.10
Audit outcome (%)	% Potential tax base	743	32.93	45.07
Total fines	1,000 US $	743	4.87	38.42
Total audit outcome	1,000 US $	743	14.09	97.73
Total audit outcome (%)	% Potential tax base (including fines)	743	35.84	46.21

Note: Authors' calculations based on data provided by RRA.

Table A.4: Audits descriptive statisics EBM non-adopters – Small & Micro firms (2013-2017)

Variable	Measurement Unit	Observations	Mean	Std. Dev.
Audit outcome	1,000 US $	266	4.89	14.29
Audit outcome (%)	% Potential tax base	266	36.56	46.20
Total fines	1,000 US $	266	4.17	26.94
Total audit outcome	1,000 US $	266	9.13	34.13
Total audit outcome (%)	% Potential tax base (including fines)	266	39.66	46.88

Note: Authors' calculations based on data provided by RRA.

Appendix B: Outcomes of the CEM Procedure

Several matching techniques are discussed in the literature (see, among others, Stuart, 2010; King et al., 2011; Imbens and Rubin, 2015; Guo and Fraser, 2015). In general, all matching methods for causal inference seek a trade-off between maximizing balance on the relevant pre-treatment covariates between the treated and control units while keeping a reasonable matched sample size (King et al., 2011). Among the available methods we employ CEM, which has been proven to possess a set of powerful statistical properties. In particular, CEM has been shown to perform better than commonly used matching methods (like e.g. Propensity Score Matching and Mahalanobis Distance Matching) in reducing the initial imbalance across treatment cohorts.[37] Moreover, CEM algorithm is extremely intuitive. First, CEM temporarily coarsens each relevant pre-treatment variable into meaningful groups through a threshold assigned by the user based on intuitive substantive information, where it is possible, or through alternative standard binning algorithms.[38] Subsequently, units with the same 'bin signature' (that is, with the same values) for all the coarsened variables are placed in a single stratum. And, finally, the control units within each stratum are weighted to equal the number of treated units in that stratum. Strata without at least one treated and one control unit are pruned from the data set. Each treated unit is weighted with 1 while the weights for each control unit equals the number of treated units in its stratum divided by the number of control units in the same stratum, normalized so that the sum of the weights equals the total matched sample size. By employing these weights we analyse the unpruned units through a DID approach to finally estimate equation (4).

Specifically, we employ CEM to stratify the sample based on the sole risk score, which is the relevant index used by RRA to prioritize audits. In the interest of mantaining a reasonable sample size, we decide to focus on a single variable, also given that our main DID setting is a Twoway Fixed Effects (TWFE) model in which firms fixed effects as well as time fixed effects are already controlling for most of potential heterogeneity across cohorts. Thus, focusing on the risk scores allows us to reduce the remaining imbalance across treatment cohorts that is due to potential differences in the likelihood of noncompliance—the main source of sample selection—not already accounted for in our standard TWFE baseline.

Table A.5, Panel A reports the summary of the matching procedure in terms of Matched and Unmatched observations. By focusing on the risk score we can match most of the observations we have in our selected sample. Specifically, we can match 94.7 % of audited taxpayers and about 97 % of unaudited firms. Table A.5, Panel B provides a measure of imbalance reduction through L_1 statistics introduced by Iacus et al. (2011). Specifically, in our case this imbalance measure is based on the L_1 difference between the histogram of risk scores across treatment cohorts (see Iacus et al., 2011 for a formal definition). In short, L_1 is bounded between 0 and 1—with higher values indicating higher imbalance—and it is an index that should be evaluated in relative rather than absolute terms by comparing the values before and after the stratification process. After CEM

[37] CEM also reduces model dependence, estimation error, bias, variance, mean square error, and other criteria while seeking a trade-off between sample size and balance (see Iacus et al., 2011, 2012; Blackwell et al., 2009; King et al., 2011; King and Nielsen, 2019 for more details and formal proofs, and Iacus et al., 2019 for a discussion on the inference theory).

[38] In this case, we use the Freedman-Diaconis rule

imbalance in the risk scores reduces to 3.73 percent of the initial imbalance, indicating that homogeneity in the likelihood of being noncompliant across treatment cohorts increases significantly as a result of the CEM process while keeping almost all observations matched-in. This is visually confirmed in Figure A.1 that plots the distribution of the risk scores before and after the CEM procedure.

Table A.5: Summary of the CEM matching procedure

Panel A: Matching summary

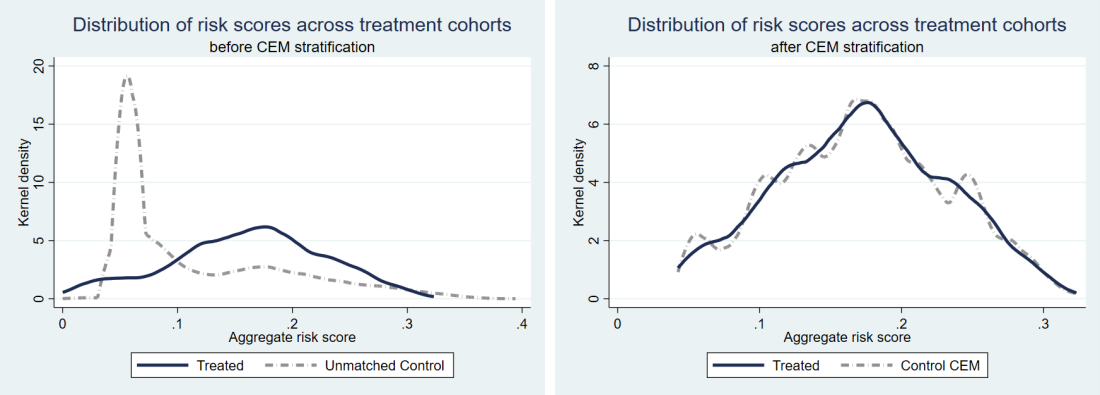
	Non-audited	Audited
Available observations	42,016	6,088
Matched	40,840	5,768
Unmatched	1,176	320

Panel B: Difference across treatment cohorts

Before CEM							
	L1	mean	min	25%	50%	75%	max
Risk score	0.2818	-0.0004	-0.0456	0.0249	0.0128	-0.0088	-0.071
After CEM							
	L1	mean	min	25%	50%	75%	max
Risk score	0.0105	0.0001	-0.0032	-0.0001	0.0001	0	-0.0005

Note: The table depicts the matching summary of the CEM procedure, L_1 statistics for imbalance as defined in Iacus et al. (2011), and differences across treatment cohorts in the distribution of the risk scores before and after CEM.

Figure A.1: Risk score imbalance reduction (CEM)



(a) (b)

Note: Authors' calculations based on data provided by RRA.

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