



## Short communication

## E-invoicing, tax audits and VAT compliance

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## ABSTRACT

Difficult to find another policy shift that has promised as much for tax compliance in developing countries as digitalization. Yet the evidence on its impact is scant. Using the universe of tax filings in Rwanda over the period 2012–2019, this paper investigates the extent to which digitalization (in the form of e-invoicing) has impacted on VAT compliance and in particular the effectiveness of tax audits. The evidence suggests that on the aggregate e-invoicing adoption has increased firms' net VAT payments and has improved the efficiency of VAT audits. It is also shown that e-invoicing has a sizeable impact on VAT liabilities reported by audited firms, with this impact being attributed to tax audits being more efficient rather than to VAT registered firms becoming more compliant following their adoption of e-invoicing.

## 1. Introduction

To strengthen the capacity of tax collection,<sup>1</sup> enhance the overall performance and quality of services provided to individuals and firms, and ultimately make taxation more growth-friendly, African tax administrations have begun embracing digitalization (ATAF, 2021a). The use of modern technology enables more accurate (and formal) linkages between sellers and purchasers – typically taking the form of electronic invoicing (e-invoicing)<sup>2</sup> – and can benefit businesses significantly, through making record keeping more efficient and accurate. It can benefit tax administrations too. The use of technology, such as e-invoicing, makes it possible for tax administrators to systematically

verify the accuracy of taxpayers' records and perform cross-checks between trading partners. Perhaps not surprisingly – given the importance in total revenues of the Value Added Tax (VAT) – the integration of digital innovations, and e-invoicing in particular, has been more prominent in VAT.<sup>3</sup>

Despite the importance of this issue for revenue mobilization in developing countries, the evidence of the impact of such policy innovation on firms' compliance (reviewed shortly below) is relatively unexplored and mixed. The paper contributes to this literature by seeking to provide an answer to the policy relevant question of whether the introduction of e-invoicing in Rwanda – which allowed for the automated transfer of billing information between firms and the tax

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<sup>1</sup> At an average of around 15 percent, tax ratios in developing countries remain low. In about half of those countries, the tax ratio is below the 15 percent widely considered as the minimal level for which there is some prospect of them meeting their needs. Achieving the Sustainable Development Goals has been estimated to require, on average, additional revenue of around 15 percent of GDP, with this calculation being made before the revenue setback imposed by COVID-19. Since the onset of the pandemic general government debt in developing countries has risen by about 5 points of GDP.

<sup>2</sup> More than fifty countries around the world have already adopted e-invoicing (Barreix et al., 2018), and the number is growing, OECD (2022).

<sup>3</sup> VAT contributes a substantial portion of tax revenues in Africa, accounting for, on average, over 35 percent of the total tax revenue collected, ATAF (2021b). 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). Despite its significant rise as a tax innovation, it is universally recognized that VAT has both weaknesses and vulnerabilities; see, for example, Ebrill et al. (2001) and Keen and Smith (2006) for a detailed discussion.

authority and the creation of a digital trail – improved the effectiveness of VAT audits.

Making use of the universe of administrative tax data on VAT filings and tax audit records in Rwanda, as well as information on the adoption of the e-invoicing by firms over the period spanning the years 2012–2019, this paper shows that e-invoicing<sup>4</sup> adoption yields an increase in firms' net VAT payments. The bulk of this positive impact on compliance, however, stems from tax audits becoming more effective in deterring tax evasion in the post-audit period. The results also show that audits involving firms adopting the e-invoicing system are the only ones that yield a significant compliance improvement in net VAT payments, highlighting the importance of e-invoicing for VAT audit enhancement. In particular, e-invoicing enhances the accuracy of tax audits in determining correct tax liabilities, leading firms to declare less input VAT after an audit.

The remainder of the paper is organized as follows. Section 2 briefly reviews the literature. Section 3 provides some institutional background and describes the data the analysis is based on. Section 4 describes the methodological approach followed. Section 5 presents the results, while Section 6 provides some concluding remarks.

## 2. Literature review

The evidence of the introduction of e-invoicing on compliance is mixed. Using cross-country data, [Casey and Castro \(2011\)](#) find that the introduction of e-invoicing alone is generally not associated with significant increases in VAT revenue collection or permanent compliance improvements. The reason for this is lack of capacity in supporting effective implementation and insufficient interoperability with systems that support tax audits and, more broadly, the tax compliance function.

E-invoicing might change firms' reporting behavior. [Mascagni et al. \(2021\)](#) show that while the introduction of e-invoicing in Ethiopia increased both VAT revenues and income tax revenues, firms operating within the e-invoicing ecosystem tend to increase their reported expenses in order to reduce their tax liability. The lack of effective cross-checking of sales and purchases across traders as a source of inefficiency in promoting compliance is also emphasized in [Mascagni et al. \(2019\)](#) (for Rwanda) and [Almunia et al. \(2022\)](#) (for Uganda).<sup>5</sup>

Earlier work on the initial adoption of e-invoicing, which used data from Ethiopia and Rwanda, suggests that the pilot implementation of e-invoicing led to a significant increase in VAT revenues after the first year of adoption in these countries ([Ali et al., 2021](#); [Eissa and Zeitlin, 2014](#)). More recently, [Bellon et al. \(2022\)](#) examine the impact of switching from paper to electronic invoicing on firm tax compliance and performance using quasi-experimental variation in the roll-out of VAT e-invoicing in Peru. They find that e-invoicing increases reported firm sales, purchases and VAT liabilities by over 5 percent in the first year after adoption. Related to this evidence, [Hakizimana and Santoro \(2023\)](#) analyze the impact of an innovation in the Rwandan e-invoicing system suggesting that it is the initial adoption of e-invoicing – whether in the first or second phase – rather than switching between technologies, that enhances compliance.<sup>6</sup> This paper relates to all these

contributions, but its emphasis is also distinctively different, as it focuses on the channel of the impact of e-invoicing on tax compliance through tax audits, a key operational function of a tax authority.

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. \(2024\)](#). [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. \(2024\)](#) analyze Corporate Income Tax (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 (in-depth and broad in scope) audits, with audits that are narrower in their scope (desk and issue audits) delivering a net counter-deterrence effect.

The evidence across these two strands of the literature briefly discussed in the preceding paragraphs, suggests that, depending on the context, technological innovations and tax audits may not be fully exploited as tax enforcement instruments. Despite being recognized as a theoretical possibility (in the discussion of the paper trail perspective of digitalization), these issues have attracted, to the best of our knowledge, limited empirical attention in the literature.

## 3. The E-invoicing system, mechanisms and data

Rwanda is a representative low-income country both in terms of fiscal capacity and tax structure ([ATAF, 2021b](#)).<sup>7</sup> To improve efficiency in VAT collection and strengthen compliance, Rwanda made e-invoicing mandatory for VAT registered taxpayers in 2013 (see [RRA, 2024](#)). E-invoicing meant that a firm could 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).

### 3.1. Timing of the reform

It was early recognized that switching to e-invoicing would create significant costs for firms and the tax administration,<sup>8</sup> including updating IT capacity and staff training. This has led to a gradual and

<sup>4</sup> E-invoicing (formally called Electronic Invoicing System) refers to both the initial and the updated version of the ecosystem designed by the Rwanda Revenue Authority (RRA). What matters for (and what is utilized in) the analysis is that both versions share the common feature that they both record and transit information on all transactions to the tax authority, [RRA \(2024\)](#).

<sup>5</sup> A point we return to in Section 3.2. One reason for the poor revenue performance of many developing countries is that their tax administrations lack effectiveness in administering their core functions which in turn reflects weaknesses not only in processes and procedures, including in the use of available technologies, but also in governance arrangements and in quality and quantity of the resources available. A point emphasized in, among others, [Acemoglu et al. \(2001\)](#), [Besley and Persson \(2009\)](#), and [Besley et al. \(2013\)](#).

<sup>6</sup> There is a broader literature evaluating the impact of different aspects of digital technologies on tax compliance; see, for example, [Ramírez and Oliva \(2018\)](#), [Bérgolo et al. \(2018\)](#), [Templado and Artana \(2018\)](#), [Castro et al. \(2016\)](#), [Lee \(2016\)](#). A digital innovation that has gained significant momentum is e-filing of tax returns; for evidence of this on compliance see [Yilmaz and Coolidge \(2013\)](#), [Kochanova et al. \(2016\)](#), [Okunogbe and Pouliquen \(2022\)](#). A comprehensive discussion of this literature is offered by [Okunogbe and Santoro \(2022\)](#).

<sup>7</sup> 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](#)). Further details on the Rwandan tax system can be found in, for example, [Tourek \(2022\)](#), [Mascagni et al. \(2022\)](#), [Mascagni et al. \(2023\)](#), and [Kotsogiannis et al. \(2024\)](#).

<sup>8</sup> During the transition phase e-invoicing 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](#)). It was also significantly costly, especially for small firms, which had to cover the purchase and maintenance costs over time. The upfront cost in installation required four full years of VAT payments to be recovered ([Eissa and Zeitlin, 2014](#)). 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.

staggered introduction of e-invoicing, with large firms and firms in specific sectors required to adopt e-invoicing first. During the first period of adoption e-invoicing expanded rapidly and, by September 2014, there were over 3,943 taxpaying firms actively using e-invoices, which corresponds to 77.8 percent of all VAT-registered firms at that time.<sup>9</sup>

In January 2014, RRA announced the deadline for the adoption of e-invoicing by all VAT registered firms (by end of March of the same year). During this phase there was increased monitoring effort by RRA and the number of e-invoicing adoptions increased significantly in the same year, one year after the launch. Despite announcing the deadline for the adoption of e-invoicing, some firms did not participate, while others started adopting it in later years.

There were also issues with the quality of receipts that used to easily deteriorate, which posed challenges to RRA with record-keeping and verification in audits, as well as limitations in the information that the e-invoicing machines could store. These challenges prompted the need for an upgrade to the system, which resulted in the introduction of an upgraded e-invoicing system in March 2017, which aimed at increasing the adoption and use of e-invoices by making it more accessible to all eligible firms. Indeed, unlike the previous requirement for firms to purchase a device, this system was provided as software, which the RRA installed free of charge.

The implementation of the second phase in e-invoicing followed a similar staggered approach to that of the initial transition, in which a sample of large businesses were first requested to switch from the initial phase to the second phase. Later in 2020 all VAT registered businesses were requested to switch to the latest e-invoicing system (for further details, see [Hakizimana and Santoro, 2023](#)).

### 3.2. E-invoicing and tax audits

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.<sup>10</sup> This sequence of transactions creates a paper trail of records that shows the flow of goods and services together with the associated cost of VAT transactions, and serves as a self-enforcement mechanism ([Pomeranz, 2015](#); [Naritomi, 2019](#)).

As alluded to in the introductory section, an e-invoicing system strengthens compliance through two main channels.<sup>11</sup> Through collecting and processing large amounts of data provided through electronic invoicing and tax declarations, revenue authorities can automatically detect (both intentional and unintentional) inconsistencies, such as mismatches across the VAT chain (for example, between input VAT paid by firm  $i$  to  $j$  and the output VAT received by  $j$  from  $i$ ) as well as between self-reported and third party—reported tax liabilities. Through more accurate storage of transactional information, e-invoicing can also reduce compliance costs for the firms and mitigate the possibility of unintentional errors, which can be significant. Both of those channels reinforce the VAT enforcement capacity of a revenue authority, enhancing its VAT audit effectiveness.

But the success of e-invoicing depends on the design of the ecosystem (for example, pre-filling of VAT returns) and its effectiveness in cross-checking information. No system is of course perfect, and particularly so in developing countries. As such it can be exploited

by (non-compliant) businesses. Without automatic pre-filling of information, firms may have an incentive to over-report VAT paid so to minimize their tax liabilities. In this regard, the e-invoicing system in Rwanda has limitations. Indeed, while it allows for the information to be transmitted in real time to the revenue authority, the system is not designed to be used for automatic pre-filling of VAT returns, allowing firms to manipulate their purchases by inflating the VAT paid on inputs. This is a behavior that has also been documented for Ethiopia (see [Mascagni et al., 2021](#)). Of course, there are other margins that can be subject to manipulation, including the misclassification of goods to exempted and zero-rated, [Keen and Smith \(2006\)](#).

This paper contributes to this issue shedding some light on these margins too, highlighting the role of tax audits in mitigating this behavior (see Sections 4 and 5).

What this all points to is that the operational significance of e-invoicing might diminish if not tackled through appropriate additional enforcement policies. It is the subtle relationship between the two instruments, e-invoicing and tax audits, that is the focus of the paper and, in particular, whether tax audits are adequate enforcement instruments that can support e-invoicing in achieving its full compliance potential.

Attention now is turned to the data used in the analysis.

### 3.3. Data: VAT and tax audits

All data employed in this paper is at the firm level and include mostly financial variables used to calculate taxes (for example, total taxable sales, exempt items, VAT paid on inputs), as well as some firm characteristics, such as size (as defined by RRA),<sup>12</sup> geographical location (at Tax Center level), and the information on the date in which firms adopted e-invoicing. VAT declarations have been annualized and merged with the detailed records of audits undertaken by the RRA during the years 2013 through 2017.<sup>13</sup>

The RRA tends to audit two tax periods but firms are required to keep their records for a longer period. Tax enforcement examinations involve three types of audits<sup>14</sup>: 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 firm's 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 tax declarations.<sup>15</sup> 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 universe of tax declarations.

The risk criteria utilize information that spans across tax bases.<sup>16</sup> The administrative data is retrieved from RRA systems which collect

<sup>9</sup> E-invoicing was also expected to enhance the RRA capacity to monitor firms' transactions. The evidence for the first stage of the introduction of e-invoicing is that is increased VAT payments by 6.5 percent between March 2013 and September 2014, [Eissa and Zeitlin \(2014\)](#).

<sup>10</sup> 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).

<sup>11</sup> For a detailed discussion on this see [Okunogbe and Santoro \(2023\)](#).

<sup>12</sup> RRA classifies firms as follows: *Micro*-firms declare a turnover of less than 12 million Rwf (US\$13,380 as of February 2019 exchange rate) in a tax period; *Small*-firms have a turnover between Rwf 12 million and Rwf 50 million (US\$55,750) in a tax period; *Medium* and *Large*-firms have a turnover above that threshold.

<sup>13</sup> VAT declarations have been annualized to address two key issues that may play a role in periodical VAT reportings: seasonality in firm activity and strategic reporting compensations across months or quarters during the same year aimed at reducing the final liability.

<sup>14</sup> 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.

<sup>15</sup> More details on the audit process can be found in [Kotsogiannis et al. \(2024\)](#).

<sup>16</sup> After each return is filed, audit flags are deterministically generated based on the characteristics of the returns. Tax auditors conduct audits by following the procedures outlined in the audit manual, ensuring a systematic and consistent approach to the tax audit process. The integrity of the tax and audit data is assured by the RRA.

**Table 1**  
Summary statistics—outcome variables (2012–2019).

Variable	Observations	Mean	Std. Dev.
VAT Liability	39,176	31.71	447.11
VAT Payable	39,176	81.33	646.55
VAT Paid on Inputs	39,176	70.94	405.36
Non-Taxable Sales	39,176	359.50	3,850.74

Note: Authors' calculations based on data provided by RRA. All units are expressed in US\$1,000.

and store tax data submitted by the firms. The resulting dataset consists of a panel of firms over the period 2012–2019. Before performing the analysis we select a sample of relatively homogeneous firms. Concretely, we select firms filing a VAT declaration for all years during the observed period and, in doing so, we end up with a perfectly balanced panel of 4,897 firms. These firms are typically operationally active and in better financial health, making them more representative of the treated population.<sup>17</sup>

For this sample, Table 1 presents the summary statistics for our outcome variables, which are the annual aggregations of the correspondent fields of VAT declarations. 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); while *Non-Taxable Sales* aggregates Exempted Sales, Zero-rated Sales and Exports. The main margin of interest is the net *VAT Liability* annually paid by firms, that is *VAT Due* in VAT forms, which is obtained by subtracting *VAT Paid on Inputs* from *VAT Payable*. All variables are expressed in thousands of US\$.

For our selected sample, Table 2 (Panel A) reports descriptive statistics for the detection performance of the tax audits conducted by RRA for all tax periods and available audit waves. In particular, *Audit Outcome* represents the amount of tax base (taxable sales) underreported uncovered with a mean of just over US\$40,000 and the standard deviation of about US\$503,000. *Audit Outcome* is also reported as a share of the *Potential Tax Base* (defined as the sum of taxable sales declared by the taxpayer and the *Audit Outcome*). *Total Fines*, which gives the sum of all fines and penalties applied to those firms found underreporting tax bases, has a mean of almost US\$23,000 and standard deviation of approximately US\$312,000. *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)*. Thus, Panel A of Table 2 reveals that in terms of detection, audits uncover substantial amounts of underreported tax bases which amounts to about 28 percent of the potential tax base audited (about 31 percent including fines).

Panels B and C of Table 2 present the same information by splitting the sample of audited firms between adopters and non-adopters of e-invoicing, respectively. The probability of being audited within the two clusters in our sample is comparable, with 3.94% for e-invoicing non-adopters and 5.29% for e-invoicing adopters. In terms of their performance evaluated in levels, audits involving firms who have adopted e-invoicing uncover a higher amount of underreporting and levy a larger amount of fines, leading to a greater total audit outcome, relative

to those who have not adopted e-invoicing. Nevertheless, when evaluated in relative terms, as a percentage of the potential tax base, audits involving non-adopters of e-invoicing tend to slightly outperform audits targeting users of e-invoicing. This suggests that the use of e-invoicing may contribute to an increase in declared tax bases. This seems to apply also when comparing firms of the same size (see Appendix A).<sup>18</sup> Read in this way, adoption of e-invoicing tends to improve compliance by increasing the declared tax base and by enhancing the detection power of audits.

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

#### 4. Estimation strategy

As already discussed in Section 3.2, the primary aim of this paper is to estimate the impact of e-invoicing on promoting VAT compliance through tax audits enhancement. We analyze this impact on the net *VAT Liability* reported by firms as well as on other margins of VAT registered firms' reporting behavior with the aim of decomposing their estimated net effect on the annual VAT payments and disentangle the treatment effect on the underlying parts of the VAT return. As discussed in Sections 3.2 and 3.3, these are the annual aggregations of *VAT Payable*, or in other words total output VAT; *Non-taxable Sales*, and *VAT Paid on Inputs* reported by firms in their VAT returns in a given year.

Considering that we are leveraging data from multiple audit waves and that the adoption of e-invoicing has been staggered, our identification strategy employs a Stacked Difference-in-Differences (DID) approach. This means that for any wave of treatment, we compare taxpayers who were treated – that is, audited or adopters of e-invoicing – to those who were never treated during the entire sample period (see Cengiz et al., 2019; Cunningham, 2021 and Appendix B.1).<sup>19</sup> Furthermore, we combine this approach with Coarsened Exact Matching (CEM, see Iacus et al., 2011, 2012 and Appendix B.2 that elaborates further on this method) matching treated and untreated firms based on their aggregate likelihood of being noncompliant as synthesized by their total risk score, the index used by RRA for audit selection.<sup>20</sup>

The probability of being audited is highly predicted by the risk score. Indeed, as shown in Appendix A, Figure A.2, the probability of receiving an audit increases in the decile of risk score and there is a high correlation (0.937) between these two variables, confirming the importance of the risk score in audit selection. Therefore, it is reasonable to assume that when matching on this variable we are accounting for most of the selection bias embedded in the RRA's risk-based audit selection. However, potential endogeneity issues may also affect the staggered e-invoicing adoption as all firms were given a common deadline by which to adopt the e-invoicing system. Differences in adoption timings might therefore be associated to some extent with some observable and unobservable firm characteristics. Arguably, one

<sup>18</sup> It would certainly be desirable to look at firms' industry as an additional source of heterogeneity but, unfortunately, data limitations do not allow us to do so. For more discussion on this see Kotsogiannis et al. (2024).

<sup>19</sup> As a robustness, we replicate the analysis employing the approach by Callaway and Sant'Anna (2021) and Sant'Anna and Zhao (2020) including the not yet treated in the control group. The results, reported in Appendix C.3 and C.4, corroborate our main findings on the aggregate impact. Nevertheless, the limitation in using this latter approach is that it does not allow for the introduction of interaction terms thereby preventing us from identifying any synergy that might exist between e-invoicing and audits, which is the core contribution of the paper. For this, we have chose not to use this approach as our main estimation strategy.

<sup>20</sup> In particular, we use the risk score corresponding to the first audit wave we have in the data, 2013, that is before any treatment is applied, including e-invoicing.

<sup>17</sup> Audited firms and adopters of the e-invoicing system tend to be larger or more operationally active (see also Section 4). We focus on this sample, representing 15% of unique firms, to ensure homogeneity between treated and control units. The full panel is highly unbalanced, with many firms present for only a few fiscal years, often due to bankruptcy. These firms are not representative of the treated population. However, Appendix C.4 replicates the analysis for the unbalanced sample also using Callaway and Sant'Anna (2021) and Sant'Anna and Zhao (2020), with results consistent with our main analysis, supporting the generalizability of our conclusions.



**Table 2**  
Audits (2013–2017): Descriptive statistics.

Variable	Measurement Unit	Observations	Mean	Std. Dev.
<i>Panel A: Total</i>				
Audit Outcome	US\$1,000	1,788	40.59	503.66
Audit Outcome (%)	% Potential Tax Base	1,788	28.48	41.61
Total Fines	US\$1,000	1,788	22.64	311.97
Total Audit Outcome	US\$1,000	1,788	63.32	811.95
Total Audit Outcome (%)	% Potential Tax Base (Including Fines)	1,788	31.56	43.01
<i>Panel B: E-invoicing Adopters</i>				
Audit Outcome	US\$1,000	960	48.45	665.91
Audit Outcome (%)	% Potential Tax Base	960	28.15	42.20
Total Fines	US\$1,000	960	28.10	411.85
Total Audit Outcome	US\$1,000	960	76.56	1,074.18
Total Audit Outcome (%)	% Potential Tax Base (Including Fines)	960	30.99	43.56
<i>Panel C: E-invoicing Non-Adopters</i>				
Audit Outcome	US\$1,000	828	31.47	183.78
Audit Outcome (%)	% Potential Tax Base	828	28.87	40.93
Total Fines	US\$1,000	828	16.31	116.37
Total Audit Outcome	US\$1,000	828	47.96	293.38
Total Audit Outcome (%)	% Potential Tax Base (Including Fines)	828	32.21	42.37

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

would expect less compliant firms to take longer to adopt a technology that makes non-compliance more difficult. Therefore, also for e-invoicing adoption, matching firms based on their risk score (thereby proxying their likelihood of being noncompliant) provides a reasonable approach to address potential selection bias issues. Nevertheless, and for both treatments, further observable firm characteristics may play a role in the selection bias.

More precisely, as discussed more in detail in Kotsogiannis et al. (2024), audit selection in the RRA is driven by the product of the likelihood of underreporting and conditional on underreporting (and found noncompliant) the likelihood that the audit will yield some revenue. The synthetic risk score used here for matching relates to the former likelihood. The impact-on-revenues likelihood that is not observed relates to size (in terms of sales in a given year). Indeed, with a correlation of 0.824, the probability of being audited for VAT registered increases in the size of the firm (Figure A.3). Similarly, as discussed in Section 3, size plays an important role also in the adoption of e-invoicing and potentially other observable characteristics may correlate with this. For this reason, and for both treatments, we employ a sequential selection process in order to identify a set of observable characteristics that are associated with treatment assignment based on their predictive power. These include, on top of the risk score, the decile of total sales in year 2013 as a measure of firm size, a categorical variable for the type of income tax reported by VAT payers (CIT or PIT), a dummy for nil-filers, a categorical variable identifying the type of firm,<sup>21</sup> and a categorical variable identifying the type of VAT regime the taxpayer is subject to.<sup>22</sup>

With these covariates, we perform a battery of robustness tests to our main estimation strategy. First, we implement a more comprehensive CEM stratification and matching. By exact matching on these covariates (in addition to using CEM on the risk score), we believe that we are accounting for most of the residual selection bias that risk-based audits and e-invoicing adoption might entail. Second, we perform a robustness analysis based on Propensity Score Matching (PSM) estimated with the same set of covariates.<sup>23</sup> Finally, with the limitations

already discussed (see footnote 19), we employ the Sant'Anna and Zhao (2020) estimator using this comprehensive set of covariates both for the outcome model and the estimation of the propensity score. The results of all these sensitivity analyses, including parallel trend tests, are reported in Appendix C (Sections C.1 to C.4) and corroborate those presented in the main text both qualitatively and quantitatively, suggesting that most of the selection bias is already accounted for by applying CEM on the risk score. As discussed in Section 3.3, this is partly achieved by initially selecting a sample of taxpayers who consistently filed VAT returns during the period, as these tend to be operationally active firms in healthier financial condition, making them more representative of the treated population.

Formally, we estimate CEM-weighted versions of Eq. (1) on the stacked dataset. The dependent variable  $Y_{it}$  represents each of the margins described above expressed in levels (thousands of US\$), and  $Audit_{it}$  and  $E-INV_{it}$  are dummy indicators that switch on when the taxpayer is first audited and on the year of adoption of e-invoicing, respectively, while  $\tau_t$  and  $\theta_t$  account, respectively, for time-by-stack fixed effects and taxpayer-by-stack fixed effects and  $\varepsilon_{it}$  is the error term. The parameters of interest are  $\beta_1$ ,  $\beta_2$  – that collect respectively the treatment effects of tax audits and e-invoicing adoption employed in isolation – and, in particular,  $\beta_3$  which estimates their joint effect on compliance that is, the impact of e-invoicing on deterrence through enhanced audit effectiveness.

$$Y_{it} = \alpha + \beta_1 Audit_{it} + \beta_2 E-INV_{it} + \beta_3 Audit_{it} \times E-INV_{it} + \theta_t + \tau_t + \varepsilon_{it}. \quad (1)$$

The next section presents the results of the empirical analysis.

## 5. Results

This section reports the results of the analysis obtained with our main specification. Appendix C provides additional robustness checks validating the results presented in the main text, including the parallel trend test, and the methodology used.<sup>24</sup>

<sup>21</sup> The types of legal entities, in order of their relative share in the total number of legal entities, are: private corporation, individual, partnership, local NGOs, cooperative, government body, others, joint venture, association, public corporation, trust, international NGOs, and other NGOs.

<sup>22</sup> A standard regime based on monthly installments and a simplified one based on quarterly installments.

<sup>23</sup> To be more specific we employ a Kernel estimator that provides an efficient weighted average counterfactual based on all control group units (see Heckman et al., 1997, 1998).

<sup>24</sup> As already discussed, Sections C.1 and C.2 of the Appendix estimate the model employing a comprehensive set of matching covariates and employing CEM and PSM respectively; Sections C.3 and C.4 estimates the impact through the Sant'Anna and Zhao (2020) estimator with a balanced and unbalanced panel respectively.

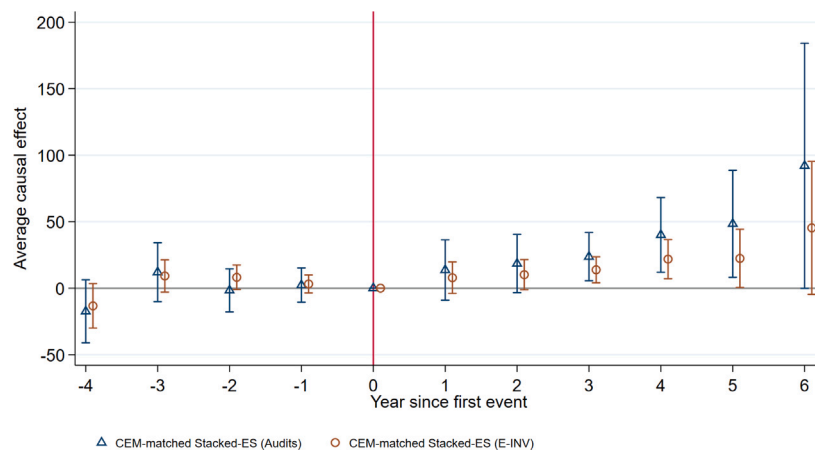


Fig. 1. Event Study: Aggregate dynamic response to VAT audits and e-invoicing.

Note: This figure reports the estimates of the period-specific treatment effects on net VAT Liability for audits and e-invoicing separately. Estimates are obtained through CEM-Weighted Stacked-ES models. Taxpayer-by-stack and year-by-stack fixed effects are controlled for; 95 percent confidence intervals (based on robust standard errors clustered at taxpayer-by-stack level) are shown.

### 5.1. Parallel trend

As a first step, we test the parallel trend assumption through a CEM-Weighted Stacked Event Study (ES) model applied to our main outcome variable, firms' net VAT Liability. This entails estimating dynamic fixed-effects models applied to the audit treatment and e-invoicing adoption separately using the CEM-matched stacked dataset. The absence of significance in pre-treatment differences between treated taxpayers and control units tends to confirm that the pre-treatment parallel trend is achieved and significance in post-treatment estimated coefficients provides a first evidence of the pro-deterrence impact of audits and e-invoicing adoption on firms' net VAT Liability reported (see Fig. 1).

The analysis turns now to the estimation of Eq. (1) for the net VAT Liability.

### 5.2. Net VAT liability

Table 3 focuses on the net VAT Liability. Columns (1) and (2) report the aggregate post-treatment impact of audits and e-invoicing adoption, respectively, when estimated in isolation. The results provide evidence of an aggregate post-treatment increase in the net VAT Liability declared of about US\$27,000 for audits and about US\$11,000 for e-invoicing adopters. These effects tend to persist when included jointly (Column 3).

The results of the estimation of the fully fledged model described in Eq. (1) – that includes the joint deterrence effect of the two instruments through the interaction term of *Audit* and *E-INV* – are reported in Column (4), indicating that the impact on compliance is mostly driven by tax audits performed on firms adopting the e-invoicing system. The only audits leading to a significant improvement in VAT compliance are those involving firms employing e-invoicing, which yield a net combined effect on future VAT payments of about US\$33,400. Regarding the impact of the adoption of e-invoicing on compliance, the analysis suggests that it is mostly achieved when combined with audits. Indeed, the estimated coefficient of the adoption of invoicing per se is relatively small in absolute value, while the effect of e-invoicing when paired with audits corresponds to an increase of about US\$32,000. All this suggests that the information flow provided to RRA through e-invoicing improves audit performance in terms of deterrence power. One way to rationalize this impact is that firms realize that the RRA has relevant information that has been used in the audit process and internalize this information in their decision-making process for VAT declaration. Additionally, the analysis also indicates that the adoption of e-invoicing per se provides a limited improvement

Table 3

Impact of audits and e-invoicing adoption on net VAT liability.

	(1)	(2)	(3)	(4)
Audit	26.843*** (9.404)		24.889*** (9.248)	6.677 (9.746)
E-INV		10.913*** (3.475)	8.501*** (3.205)	5.678* (2.933)
Audit*E-INV				26.695* (13.630)
<i>Linear combinations</i>				
Audit+Audit*E-INV				33.372*** (11.853)
E-INV+Audit*E-INV				32.372** (13.784)
Observations – Unstacked	39,176	39,176	39,176	39,176
Observations – Stacked	112,472	112,472	112,472	112,472

Note: CEM-Stacked DID models. Taxpayer-by-stack and year-by-stack fixed effects are controlled for. Robust standard errors (clustered at taxpayer-by-stack level) are reported in parentheses; \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

in compliance, and it needs to be paired with further enforcement measures to be fully effective.

To shed some light on what drives the results, we next explore the impact of tax audits and e-invoicing adoption on three additional margins of firms' VAT reporting behavior, which determine the net VAT liability: VAT Payable, VAT Paid on Inputs and Non-Taxable Sales.

### 5.3. Other margins of non-compliance

Table 4 reports the results of this analysis. Column (1) reproduces, for convenience, Column (4) of Table 3. Column (2) presents the results on VAT Payable (the gross amount VAT payable before crediting any VAT paid on inputs purchased), while Column (3) reports the results on VAT Paid on Inputs. Concerning VAT Payable, the results provide evidence of a significant and positive direct impact of both tax audits and e-invoicing on the total output component of VAT. E-invoicing, however, does not make audits more efficient (in a statistical sense) in terms of them enhancing compliance on this margin.

Turning attention to VAT Paid on Inputs, Column (3) suggests that firms do not report more (again in a statistical sense) VAT paid on the purchase of inputs, following an audit or having adopted e-invoicing. Instead, e-invoicing affects the impact of audits on firms' reported input VAT by reducing it, and is therefore conducive to additional tax compliance. An explanation for this is that with e-invoicing – and even in the absence of cross-checking VAT declarations across the

**Table 4**  
Impact of e-invoicing adoption and audits on the components of net VAT liability.

Outcome	(1)	(2)	(3)	(4)
	VAT Liability	VAT Payable	VAT Paid on Inputs	Non-Taxable Sales
Audit	6.677 (9.746)	43.953*** (15.383)	29.031 (26.772)	58.754 (201.189)
E-INV	5.678* (2.933)	17.738*** (3.741)	6.143 (4.211)	20.975 (22.957)
Audit*E-INV	26.695* (13.630)	-6.968 (20.531)	-62.920*** (23.522)	-99.559 (192.013)
<i>Linear combinations</i>				
Audit+Audit*E-INV	33.372*** (11.853)	36.985** (17.988)	-33.890* (18.644)	-40.805 (151.051)
E-INV+Audit*E-INV	32.372** (13.784)	10.770 (21.425)	-56.777** (22.649)	-78.584 (195.774)
Observations	39,176	39,176	39,176	39,176
Observations – Stacked	112,472	112,472	112,472	112,472

Note: CEM-Stacked DID models. Taxpayer-by-stack and year-by-stack fixed effects are controlled for. Robust standard errors (clustered at taxpayer-by-stack level) are reported in parentheses; \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

production chain – the paper trail of transactions makes on average tax audits more accurate in identifying the correct tax liability thereby inducing a positive behavior response of firms in declaring less input VAT following an audit.

A similar strategic margin of action firms may utilize to reduce their net VAT payments, and one that has been unexplored in the literature, regards the classification of VATable goods to the category of Non-Taxable Sales. Intuitively, one would expect a similar response to VAT Paid on Input, since the information provided to RRA through e-invoicing does make the identification of misclassified goods somewhat easier. Column (4) analyzes this margin showing that, indeed, the signs are identical to the signs of VAT Paid on Inputs, but, unfortunately, there is not enough statistical power in the data to identify the impact with sufficient precision.

## 6. 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). One reason for the poor revenue performance of many developing countries is that their tax administrations commonly lack effectiveness in their core functions – registration of taxpayers, assessment of their liability, and collection of taxes – and so compliance. Digitalization offers potentially transformative opportunities for improving tax compliance and revenue mobilization. The limited ability of administration in low income countries to implement basic reforms suggest that digitalization is not a panacea. For tax administrations operating under weak capacity the implementation of technological solutions should be carefully assessed. 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.

Using available data on the universe of anonymized VAT records as well as information on firms' e-invoicing 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 provided evidence that the introduction of the e-invoicing system in Rwanda delivered a pro-deterrence impact on VAT liabilities reported mainly through tax audit enhancement. E-invoicing adoption has provided a limited increase in firms' net VAT payments, while its impact is significantly higher when paired with audits thanks to the (indirect) enhancement of the enforcement policy provided by e-invoicing. 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 e-invoicing yielding a net impact of about US\$33,400 in the post-treatment period. The paper has also

provided some evidence that e-invoicing does affect the impact of audits on reported input VAT by firms in a way that is conducive to tax compliance.

The results suggest that digitalization is a good strategy for enhancing compliance. To harness its full potential, however, e-invoicing needs to be designed and implemented effectively within an ecosystem that records all information through the business-to-business and business-to-consumers transactions. This journey for developing countries is a long, and expensive, one: for this, every step taken needs to be thoroughly evaluated.

We hope to have shown that the results obtained are instructive and the issues regarding the evaluation of digital solutions for tax compliance merit further investigation.

## CRedit authorship contribution statement

**Christos Kotsogiannis:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Luca Salvadori:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **John Karangwa:** Data curation, Investigation, Resources, Validation, Writing – review & editing. **Innocente Murasi:** Data curation, Investigation, Resources, Validation.

## Declaration of competing interest

The authors certify that they have no relevant or material financial interests that relate to the research described in this paper. The authors declare that there is no conflict of interest regarding the publication of this article.

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## Appendix. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.jdevco.2024.103403>.

## Data availability

The data that has been used is confidential.

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