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Technology Evolution and Tax Compliance: Evidence from Rwanda

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Summary

Information technology (IT) has great potential to help increase taxpayer compliance and revenue collection. Despite the increasing use of IT solutions by African tax administrations, evidence on its effectiveness remains limited. In Rwanda, the Revenue Authority introduced a more advanced version of its electronic billing machines (EBM) to enhance its ability to track business transactions remotely and to improve taxpayers' experience of using the machines. Using a wealth of administrative data collected by the Revenue Authority, this paper evaluates the impact of the adoption of EBM2 on the ways in which firms file their tax returns. In particular, we are able to compare first-time users of EBM2, who are mostly new taxpayers, with 'shifters', who moved from the old EBM1 to EBM2. We looked first at value added tax (VAT). Overall, the adoption of EBM2 resulted in significant increases in reported business turnover, non-taxable sales, taxable sales, VAT inputs and VAT due. There was also a reduction in the proportion of completed VAT returns that implied zero VAT liabilities. Unsurprisingly, there was no significant overall change in the VAT returns from 'shifters'. They had probably internalised the benefits of electronic billing machines when using the earlier EBM1 version. The effects of the adoption of EBM2 on income tax returns are less positive. Overall, no increase in income tax liability is reported. These results suggest that taxpayers do not believe that the Revenue Authority will attempt to reconcile their (separate) VAT and income tax returns. Taxpayers probably provide more reliable VAT returns because they believe, on the basis of the installation of electronic billing machines, with upgrades, that the Revenue Authority is focusing more on VAT. The main policy implication is that the Revenue Authority should make more effort to reconcile firms' separate VAT and income tax returns, so that the positive effects of the new electronic billing machines on VAT compliance will spillover into income tax compliance.

Keywords: tax compliance, electronic invoicing, electronic billing machines (EBMs).

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Acronyms

CG	Commissioner General
CIS	Certified invoicing system
CIT	Corporate income tax
DID	Difference-in-difference
EBMs	Electronic billing machines
EBM1	Electronic billing machines version 1
EBM2	Electronic billing machines version 2
GDP	Gross domestic product
IC	Information and computer
ICT	Information communication and technology
ICTD	International Centre for Tax and Development
PIP	Personal income tax
RRA	Rwanda Revenue Authority
SDC	Sales data controller
SRM	Sales registration machines
TIN	Tax identification number
VAT	Value added tax

Introduction

In the last decade, African tax administrations have increasingly digitised themselves (Okunogbe and Santoro 2023). For example, governments, as in Rwanda – the country under study – have been introducing electronic billing machines (EBMs) for traders to digitise their transactions and automatically transfer billing information to the revenue authority. EBMs belong to a broader digitalisation development in which a range of technologies are implemented, from integrated and automated tax administration systems for revenue authorities' core functions, to tax e-services, such as electronic filing and payment of taxes (Okunogbe and Santoro 2022). Often, a given technology is rapidly replaced by a more advanced solution, as for the case of EBM2, a software-based e-invoicing system introduced in Rwanda to substitute a more basic earlier version (EBM1). However, in a context such as Rwanda, where limited fiscal capacity and informality are often accompanied by weak familiarity with and trust in technology, how effective are EBMs in improving tax compliance? Relatedly, how would taxpayers react to newer technological solutions, such as EBM2?

In the case of Rwanda, but true for other African tax administrations moving to IT, the implementation of EBMs holds big promises. Potential benefits are expected to arise for both firms and revenue authorities. For firms, these benefits could include, at least in theory, lower administrative and compliance costs, better integration of billing and payment systems, stronger capacity and, especially for small businesses, being able to attract clients and engage in trade through improved accuracy and information security (Okunogbe and Santoro 2023). It is also true that such benefits could vary depending on the business size, with smaller entities struggling more to adopt and correctly use often complex machines (Mascagni, Dom, Santoro and Mukama 2022). Particularly for tax administrations, EBMs could arguably help them to fight tax fraud as they can perform more or less sophisticated checks on incoming data to uncover discrepancies (Bellon, Chang, Dabla-Norris, Khalid, Lima, Rojas, and Villena 2019). In sum, EBMs are crucial for addressing the 'information problem', or the crucial need for data on transactions in the economy, on which to act and enforce compliance, which remains a core challenge for tax administration (Alm 2021). In the case of Rwanda, such promises are even larger for EBM2, a computer-based software installed in commercial computers for VAT registered firms, launched in 2017 to replace the previous EBM1.

Against this context, we attempt to measure the causal impacts of the adoption of EBM2 on tax compliance in Rwanda. Thanks to close collaboration with the Rwanda Revenue Authority (RRA), we have access to a wealth of administrative data which we use to perform our analysis. We have information on the adoption status for each taxpayer and know when exactly they start using EBM2. Importantly, we can distinguish between first-time users, mostly newer firms, and shifters from EBM1, usually more established firms who started with the earlier version and then moved to version 2. We deploy a standard difference-in-difference (DID) design with staggered treatment, and also run a triple DID to address concerns on imbalances in pre-adoption months. We measure impacts on both VAT and income tax returns, as the EBM2 is likely to shape filing of income tax as well. Also, we measure impacts on reporting accuracy, by looking at discrepancies in reported amounts between the two tax heads.

We present three sets of results. First, on VAT reporting, EBM2 produces positive impacts – but on new users only. Shifters from EBM1 are mostly unaffected by the new technology, while new users report increased turnover, VAT on sales and final VAT due. Also, they slightly reduce the probability of zero filing. Second, when it comes to income tax, the evidence is more inconclusive. EBM2 produces negative impacts on the probability of filing on time. Also, while new users report more expenses, probably due to a higher accuracy in reporting enabled by the machines, shifters report significantly fewer expenses, and less

turnover. Final income tax liability is unaffected. Third, we show how discrepancies between VAT and tax returns widen – mostly because users report higher turnover in VAT returns, which does not correspond to a parallel increase in turnover in income tax returns. We speculate that users do not simultaneously consider the two tax heads when filing, and focus on better reporting in their VAT returns, probably perceiving that they are more likely to be observed by the authority – a perception that could have been made more salient by the EBM upgrade.

With this study, we contribute to the limited knowledge around the effectiveness of EBMs in low-income countries. Despite the increasing adoption of such technology in low-income countries, evidence on its impact is still scant. In Rwanda, the earlier version of EBMs has been evaluated by Eissa and Zeitlin (2014), to which our study naturally connects. The authors find that EBM1 leads to an increase in VAT payments by an average of 8 per cent – an effect highly variable by sector and firm size, with smaller firms as well as firms in computing/printing, construction, and restaurant sectors experiencing larger impacts (Eissa and Zeitlin 2014). Our work significantly updates those findings, which relied on a now outdated dataset: VAT returns in 2012–2014. In a more qualitative study, Mascagni, Dom, Santoro and Mukama (2022) document that medium and large taxpayers considerably value EBMs as a tool for facilitating their compliance. EBM2 in particular is much appreciated by this group as it improves record-keeping, monitoring of transactions on a daily basis and business reputation, thus attracting new IT-savvy customers. Also in Africa, Mascagni, Mengistu and Woldeyes (2021) evaluate the impacts of EBMs in Ethiopia. They find a positive impact on tax revenue, which increases by at least 12 per cent for income taxes and 48 per cent for VAT. Interestingly, taxpayers respond by simultaneously adjusting both reported sales and costs, thus yielding net revenue gains that are proportionally lower than the increase in sales (Mascagni, Mengistu and Woldeyes 2021). Our findings on income tax returns resonate with such evidence. More generally, we refer to Mascagni, Mengistu and Woldeyes (2021) in the choice of the empirical strategy, thus making our results directly comparable to those from Ethiopia. Among the few other studies on EBMs, more positive evidence on impacts comes from countries that are further along the technology journey, such as China, studied in Fan, Liu, Qian and Wen (2018).[1]

Lastly, the findings from this paper speak to policy as well. We distil insights on the different reactions between taxpayers, based on their earlier exposure to technology. We show how shifters to EBM2, even if only weakly significantly so, react by reporting lower VAT sales and VAT due, hence suggesting a closer inspection by the RRA of their tax affairs. More careful understanding of this could enlighten the RRA about their behaviours. On the one hand, it is quite expected to see limited impacts from shifters on most filing indicators, as this may hint at correct compliance behaviour already incorporated with the usage of EBM1. On the other, it is somehow concerning to capture negative impacts on VAT sales and liability, as this could be due to more strategic and entrenched tax evasion techniques, well established during the experience with the earlier version. New users, instead, remit more VAT, indicating a big revenue raising potential. Also, we suggest that the authority adopts a more holistic approach in monitoring compliance across tax heads – since the positive impact on VAT does not reverberate on income tax. As a result, discrepancies between the two tax types widen, and call for a prompt response from the authority.

[1] Fan *et al*. (2018) evaluate the impact of computerised invoices, or digital invoice encryption, as launched in 2001, on Chinese manufacturing firms for the period 1998–2007. Such technology implied that invoices became more difficult to falsify or forge. It also improved the quality and speed of data flows to the tax administration, as opposed to a manual system in which invoices were paper-based and lacked a rigorous anti-counterfeit technology. The authors find that e-invoicing explains 27 per cent of cumulative VAT revenues in 2002–2007, a remarkable increase due to improved technology for recording VAT transactions. They explain this finding by a reduction in deductible inputs, which resonates with the fact that e-invoicing made it significantly more difficult to falsify deductible claims.

The remainder of the paper is organised as follows. Section 1 describes the context, while section 2 presents the research design. Section 3 discusses the main results while the last section concludes.

1 Rwandan context

Rwanda is among the fastest growing and most technology-oriented countries in Africa. According to the latest World Bank GovTech Maturity Index (GMTI), which assigns a 0-1 score and a grouping across four categories (A, B, C, D) as an indicator for the state of a country's public sector digital transformation,[2] as of 2022 Rwanda scores 0.53, and is in group B – a group of economies with a high GMTI and a significant focus on GovTech. It also shows that the country performs much better than the low-income countries (LICs) (0.27) and low- and middle-income countries (LMICs) (0.46) averages. When it comes to domestic revenue mobilisation, Rwanda's tax-to-GDP ratio has steadily grow, rising to 16.7 per cent in 2019, in line with the average of 16.3 per cent for sub-Saharan African countries, but over 4 percentage points above the average for low-income countries (Appendix Figure A1).[3] Despite that, Rwanda still shares many of the challenges common to tax administrations in LICs, from limited resources to high levels of informality.[4] Also, the recent COVID crisis particularly hit the Rwandan economy and tax performance, as measured in Mascagni and Lees (2021).

In this paper, we focus primarily on VAT taxpayers' filing behaviour, which is meant to be directly affected by the new electronic billing machines. VAT is the largest contributor to domestic revenues, representing a third of total tax revenues in the last five years (Figure A2). In addition, we also consider the spillover effect on filing behaviour regarding income tax, the third largest tax head (PAYE is second). Previous research has highlighted significant compliance gaps with such taxes (see Introduction). For instance, zero filers represent a sizeable portion of filing taxpayers every year – especially individual businesses,[5] both for VAT and income tax (Mascagni, Mukama and Santoro 2019). Zero filers are taxpayers that file their returns, but report zero on all fields (zero income, zero tax due), thus providing no information, and no tax revenue, to the revenue authority.

In this context, the Rwandan Revenue Authority (RRA) has implemented a number of digital reforms in recent years – from digitising customs and domestic tax management, to introducing technological solutions for taxpayers, including electronic fiscal devices and e-filing and e-payment systems (Santoro, Amine and Magongo 2022). Table 1 below summarises the key IT innovations introduced in the last decades.[6] Among them, a first version of the EBMs, EBM1, was first introduced in 2013 as a way to curb VAT evasion. Compelled by new legislation, VAT registered taxpayers had to adopt the machine, provided at a cost by the RRA, and use it in all sales to their clients. As described in Eissa and Zeitlin (2014), EBM1 consisted of a certified invoicing system (CIS) and sales data controller (SDC)

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2 The GTMI is a composite index based on 48 key indicators in 198 economies based on four indexes: the Core Government Systems Index (CGSI), with 15 indicators; the Public Service Delivery Index (PSDI), with six composite indicators; the Citizen Engagement Index (CEI), with 12 indicators; and the GovTech Enablers Index (GTEI), with 15 indicators. The GTMI is the simple average of the four components measuring the maturity of GovTech focus areas, which are computed as the normalised weighted averages of relevant indicator scores.

3 ICTD/UNU-WIDER (2022). Figures refer to total tax revenues, excluding non-tax revenue.

4 According to Schneider and Medina (2018), informality amounts to 36 per cent of national income over the period 2008–2017, compared to 42 per cent in East Africa.

5 About 52 per cent of filing CIT payers report nil returns, compared to 19 per cent of PIT ones. This behaviour may suggest that CIT businesses engage in strategic filing decisions, aiming to avoid severe fines for non-filing, but limiting their tax liability through nil-filing, a pattern documented elsewhere in Africa (Santoro and Mdluli 2019; Santoro 2022).

6 Recently, Santoro *et al*. (2022) studied the adoption and impact of e-Tax and M-declaration services.

working together. In their first design, EBMs recorded and transmitted sale transactions data to the RRA's system in real time, boosting the monitoring of firms' transactions.

Table 1 Digital reforms undertaken by the RRA, 2004–2021

Year	IT solution
2004	Introduced an Automated System for Customs Data (*ASYCUDA*). *ASYCUDA* is a computerised system which covers foreign trade procedures
2005	Introduced the Standard Integrated Government Tax Administration System (*SIGTAS*)
2011	Introduced e-filing and e-payment
2012	Issued the Electronic Single Window, a system that allows firms to provide import and export information online
2013	Created a mobile application for filing and payment with feature phones
2013	Mandated the use of EBM1 for formal businesses with revenues above a minimum threshold (RWF 20 million (approximately US$30,500) annually)
2014	*E-Tax* enhancement replaced previous e-filling and e-payment systems
2017	Launched EBM2 through a staggered implementation
2019	Launched *e-suggestion*, a web-based chat function to support taxpayers
2021	Launched the 'EBM for all' policy, mandating the use of EBMs for taxpayers of any size

The EBM1 rollout was implemented in a staggered fashion, starting with big businesses and firms in specific sectors. Only at a later stage were all other taxpayers encouraged to adopt the machine, often through the imposition of large fines for non-adopters. Despite the progress from a manual based system, in the implementation process it became apparent that EBM1 still presented challenges. As already explored in Mascagni, Dom, Santoro and Mukama (2022), these challenges consisted of a number of practical barriers and inconveniences that taxpayers experienced, often with negative repercussions on their tax morale, perceptions and attitudes. A first barrier was the high cost of EBMs, especially for small firms, who have to purchase and maintain the machines at their own expense, and the cost of the SIM card through which EBM1 functions. Second, the machines come with issues in the quality of fiscal receipts, which easily deteriorate with time and pose challenges with record-keeping and verification in an audit. Third, it is worth stressing the limitations in the information that EBM1 machines can store – for instance, data on taxpayers' inventory and specific details of the items sold, all arguably valuable information for the RRA. A fourth challenge was the inability of the RRA to provide remote, online, support to taxpayers and monitor the status of the machines.

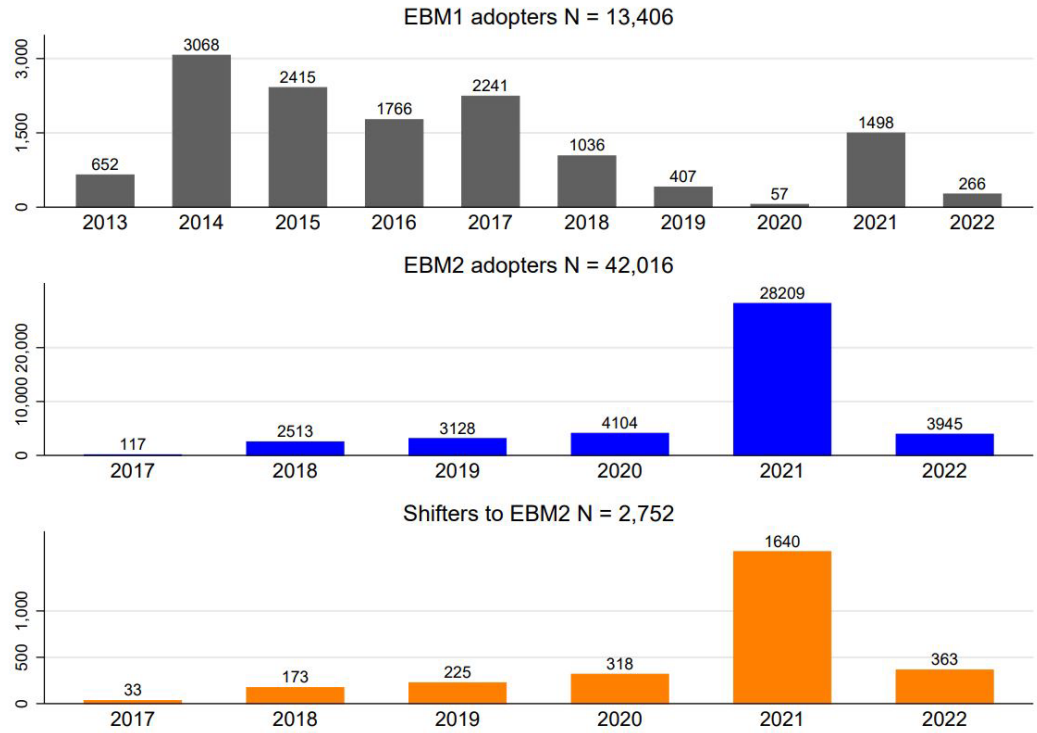
To overcome the limitations above, in March 2017 the RRA introduced a new EBM version known as EBM2. Version 2 consists of software installed in the commercial computers of VAT registered firms. The software is relatively sophisticated and attempts to address the key challenges described above: it is free and does not need a SIM card but functions both online (thus requiring airtime) and offline; all receipts are digitised, stored electronically, and printable if needed; it captures a wealth of extra information on business activity (inventory, item type, etc.); it includes more direct online assistance from the RRA. The differences to the earlier version are significant: the EBM now is no longer a physical machine, as in version 1, but software, which does not depend on a SIM card to operate. In contrast to version 1, however, it works through the internet thus requiring an adequate connection. The online solutions that version 2 offers largely outnumber those of its predecessor. Namely, the storage of crucial information for both the business and the tax administration, as well as the possibility of seeking assistance directly through the software. With EBM1, assistance was mostly received through burdensome and time-consuming in-person interactions (Mascagni, Dom, Santoro and Mukama 2022).

Always following a staggered approach, a sample of large businesses were first requested to switch from EBM1 to EBM2. Sometime later in 2020, all VAT registered businesses were requested to switch to EBM2, and since October 2022 EBM1 is no longer in use. As

described more in detail in section 2, a portion of taxpayers moved from EBM1 to EBM2 (shifters) while a larger portion directly adopted EBM2 (first-time users). No particular enforcement action or tight deadlines were put in place by the RRA to move taxpayers to EBM2, as no specific legal requirement was introduced. Rather, the tax authority would encourage taxpayers to adopt through targeted communication and appeals. In sum, EBM2 represents a remarkable IT-enabled improvement in the electronic billing mechanism and in the capacity of the revenue authority to access the digital paper trail of traders in real time to foster compliance. The IT solution got the attention of neighbouring countries as well, like Kenya, which eventually acquired the system from Rwanda to be applied in its own tax system.[7]

Figure 1 below displays the patterns of adoption of the two technologies. For EBM1, the number of adopters increased dramatically in 2014, one year after launch, while slowly falling in the following years. In 2018, there is a marked fall for EBM1 adoption, coinciding with the parallel introduction of EBM2. EBM1 continued to be adopted up to October 2022, in parallel with the EBM2 rollout, even if at a much lower rate. Also, since 2017, a portion of taxpayers started shifting from EBM1 to EBM2, and increasingly so over time.

Figure 1 Adoption of EBMs



Appendix Figures A3–A5 compare adoption patterns by subcategories of taxpayers. For sectors, the highest rate of EBM2 adoption is found in the transport sector followed by professionals, manufacturing, wholesale and trade and construction. The accommodation and food sector has the lowest rate of adoption. In line with shifts from EBM1 to EBM2, the shifting rate is still low, averaging 5.6 per cent. The highest rate in shifting is in the construction sector, followed by manufacturing and trade (Figure A3). When disaggregating EBM adoption by size of taxpayer, results show that shifters are mostly among large firms, as they most likely started with EBM1. First-time users are mostly found in small and medium firms, since they are probably mostly new and less compliant with EBM1 adoption to begin

[7] Other African countries – including Nigeria, Ethiopia, Zambia, and Liberia – are seeking to acquire the system from Rwanda – see Ruto seeks Rwanda's VAT collection model to boost revenues – The East African.

with. The same pattern applies in Figures A5–A6, when comparing CIT and PIT taxpayers and taxpayers from in and out of Kigali, respectively. The former (companies and urban taxpayers), more likely to be large, are the majority of the shifters. The latter (individual and rural taxpayers) constitute a large part of first-time users.

2 Research design

2.1 Data and sample

To estimate the impact of EBM2 on tax revenue and compliance, the study makes use of rich administrative data from the RRA, as accessed in February 2022. First, we have access to the taxpayer registry, which provides useful background information around the full population of taxpayers – around 300,000 registered entities. Second, we look at the subset of around 60,000 EBM users. They are organised in a similar registry where the status of each user is defined. This registry includes: (i) users of EBM1 only (18 per cent), (ii) users of EBM2 only (66 per cent), (iii) shifters (5 per cent), (iv) users of both versions (10 per cent).[8] As described in the following section, we will restrict the analysis to groups (ii) and (iii) only. Importantly, the dataset includes the exact date of adoption of EBM2, for both first-time users and shifters, which we will exploit in our estimation strategy. Third, our outcome variables are derived from a panel of monthly/quarterly VAT and annual income tax returns in 2013–2020. Pre-adoption information from tax returns is also used to understand the correlates with adoption of any EBM version, as well as of shifting from version 1 to 2 (section 2.2).

Table 2 below presents the differences between the two groups – unsurprisingly, shifters are larger, older and more incorporated businesses. These descriptive findings will be confirmed in our regression setting in section 2.2. Interestingly, the same pattern arises when comparing shifters and taxpayers still using EBM1, as shown in Table A1a. Comparing the group averages in Table A1a with the ones below, we can gather that new users of EBM2 are actually smaller, less incorporated and more rural than, following an increasing order, EBM1 users and shifters.

[8] Usage of both versions refers to those cases in which an EBM1 user also adopted v2 when launching new branches or shops; it also indicates that shifters to v2 might have forgotten to bring the v1 machine back to the RRA so that it could be deactivated. In this latter case, this instance does not necessarily mean that the taxpayer is actively using both versions. To be conservative, we just drop these cases for our analysis, even if they could be considered as EBM2 shifters.

Table 2 T-tests difference between new users and shifters to EBM2

	New users		Shifters		
	Mean	Obs	Mean	Obs	Difference
CIT	0.62	28270	0.84	2738	-0.22***
Kigali	0.56	28255	0.86	2738	-0.30***
Reg. year	2013.37	28270	2008.55	2738	4.81***
Trade	0.42	26916	0.51	2737	-0.09***
Manufacturing	0.09	26916	0.10	2737	-0.01*
Professional	0.07	26916	0.07	2737	0.01
Construction	0.06	26916	0.07	2737	-0.02***
Accom. Food	0.05	26916	0.04	2737	0.00
Transport	0.06	26916	0.05	2737	0.01**
IC	0.03	26916	0.03	2737	0.00
Administrative	0.03	26916	0.04	2737	-0.01*
Other services	0.07	26916	0.02	2737	0.05***
2013-17 Turnover	9.83	11195	17.03	1841	-7.20***
2013-17 VAT sales	4.78	1070	15.00	1854	-10.22***
N	31167				

Notes: * p < 0.10, ** p < 0.05, *** p < 0.01. Standard errors in parentheses. Results derive from t-tests for mean equality, based on administrative data from RRA, updated as of February 2022.

2.2 Estimation strategy

We employ a difference-in-difference strategy estimating the impact of EBM2 adoption on VAT and income tax outcomes. In much the same vein as Mascagni, Mengistu and Woldeyes (2021), we take into account the fact that implementation was not randomised and attempt to build a suitable control group by testing whether the parallel trend assumption holds.

We test such assumptions in multiple ways. First, we carefully restrict the sample of analysis, as explained in the previous subsection – and in line with Mascagni, Mengistu and Woldeyes (2021). As a first step, we drop never adopters and include in the analysis only those firms who eventually adopt the technology by 2021. Because of the way that the difference-in-difference is constructed, we cannot run our estimation strategy on never adopters, as the key time indicator is given by the date of adoption of EBM2. Strikingly enough, the vast majority of taxpayers in the RRA registry, 86 per cent, or more than 250,000 units, had not adopted an EBM of any kind as of February 2022, and are thus dropped. Such evidence hints once again at the practical difficulties in implementing a technology adoption policy on the ground. As summarised in Table A1b, never adopters are mostly individual taxpayers, more likely to be based outside of Kigali, and more recently registered. They are quite active in the transport sector and report smaller turnover and VAT sales. Relatedly, very few of them filed for VAT, thus indicating that they might be micro taxpayers for which VAT registration is not required. In sum, the analysis includes those firms which had EBM1 and then switched to EBM2, which we call switchers, and firms who directly started using EBM2, which we call new users or first-time users.

Second, and in line with Mascagni, Mengistu and Woldeyes (2021), we exclude very early adopters of EBM2 (in 2017 and before) which, despite amounting to 125 entities only, are considerably different to later adopters, as the rollout first involved large firms in selected

sectors (section 1). This is confirmed by t-tests comparing early and late adopters in Table A1c – early adopters are almost all incorporated entities based in Kigali, on average seven years older than later adopters and much more likely to be working in trade and construction. Importantly, as Table A1c shows, early adopters have an income tax turnover which is twice as large as late adopters' and much larger VAT sales. Third and consistently, we drop as many as 4,277 late adopters, i.e. those who adopt the machine in early 2022 (January and February), as for them very little filing period after adoption is available. Appendix Table A1d indicates that such late adopters are less likely to be incorporated and more active in the trade sector. Unsurprisingly, late adopters registered more recently. No significant difference is found for location and turnover or VAT sales reported before adoption.

Lastly, and partly related to the third point, we keep users who adopted the machine for at least three months to run a more conservative month-level fixed-effect analysis on VAT returns – while adding a more conservative condition when using the annual income tax returns (section 2.2). The final panel dataset amounts to about 3,000 firms for which VAT returns are found.[9] Of these, about 1,600 are shifters and 1,400 are new users.

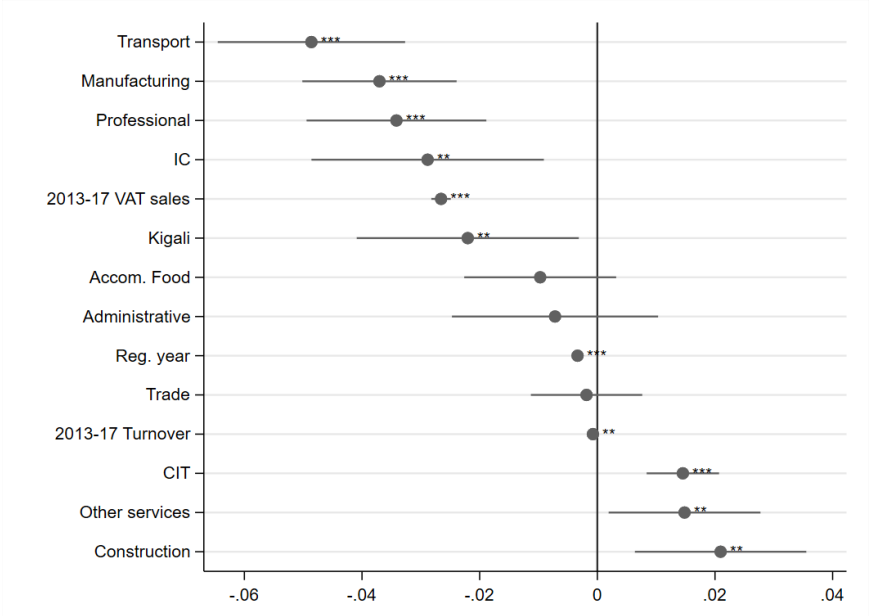
All these excluded categories are arguably different from the group of users we study, thus dropping them enhances the homogeneity of the sample. More specifically, we end up discarding the extreme tails in the taxpayer distribution, and so we drop very small, micro, taxpayers, mostly active in transport, who never adopted the technology, as well as very large entities who adopted it early. While it is true that such conditions restrict the validity of our evidence to the broader and varied population of taxpayers, it is also fair to believe that such extreme categories deserve different considerations. The impacts we present below can be seen as pertaining to the middle ground of small and medium taxpayers, regularly registered for VAT and income tax.

Second, as a mere descriptive exercise, we explore the correlates of EBM2 adoption, regressing it over a set of taxpayer features, as derived from the registry and returns data. When running such descriptive regressions, we drop never adopters, early and late adopters as discussed above. Figure 2 and Figure 3 below show how the features correlating with adoption are somehow fixed in time, such as size, proxied by pre-adoption VAT sales and turnover, and sector.[10] Especially for size, proxied by VAT sales in 2013–2017, we document a clear distinction between new users of EBM2 and shifters from EBM1. Appendix Figure A7 displays the sales distribution of such groups, also comparing them with that of EBM1 users who never adopted the improved technology. New users of EBM2 are quite small compared to shifters, and even compared to EBM1 users – thus probably indicating more recently registered entities, still in their first years of operations. Combining this evidence with Table 2, we also understand that new users are more rural, hence explaining again their smaller size.

[9] EBM2 users for which VAT returns are not available – non-filers – are dropped as well, as the outcome cannot be observed.

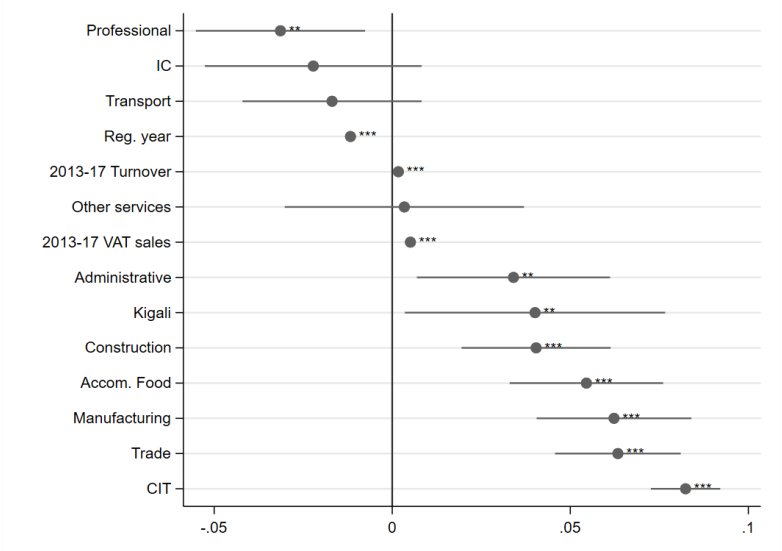
[10] More specifically, the statistically significant factors that are positively correlated with starting using EBM2 are being registered for CIT, and being in the construction, trade and other services sectors. The negative correlates with starting using EBM2 include being in the transport, professional, or ICT sectors, being in Kigali, and being registered for VAT between 2013 and 2017. On the other hand, being registered for CIT, being in the trade, manufacturing, accommodation, construction, or administrative sectors, and the amount of sales reported for income tax and VAT between 2013 and 2017 are positively correlated with shifting from EBM1 to EBM2. Being in transport, professional activities and registration year are negatively correlated with shifting to EBM2.

Figure 2 Correlates with starting to use EBM2



Note: coefficients result from a Probit model where the outcome is an indicator variable for whether the taxpayer started using EBM2, and taking the value 0 if they are still a EBM1 user. All data is extracted from RRA administrative data, updated as of February 2022. Tax centre fixed effects are included. In line with our approach, we drop never, early and late adopters. More details in section 2.1.

Figure 3 Coefficients plot for correlates with shifting to EBM2



Note: coefficients result from a Probit model where the outcome is an indicator variable for whether the taxpayer shifted from EBM1 to EBM2, taking the value 0 if they are still a EBM1 user. All data is extracted from RRA administrative data, updated as of February 2022. Tax centre fixed effects are included. In line with our approach, we drop never, early and late adopters. More details in section 2.1.

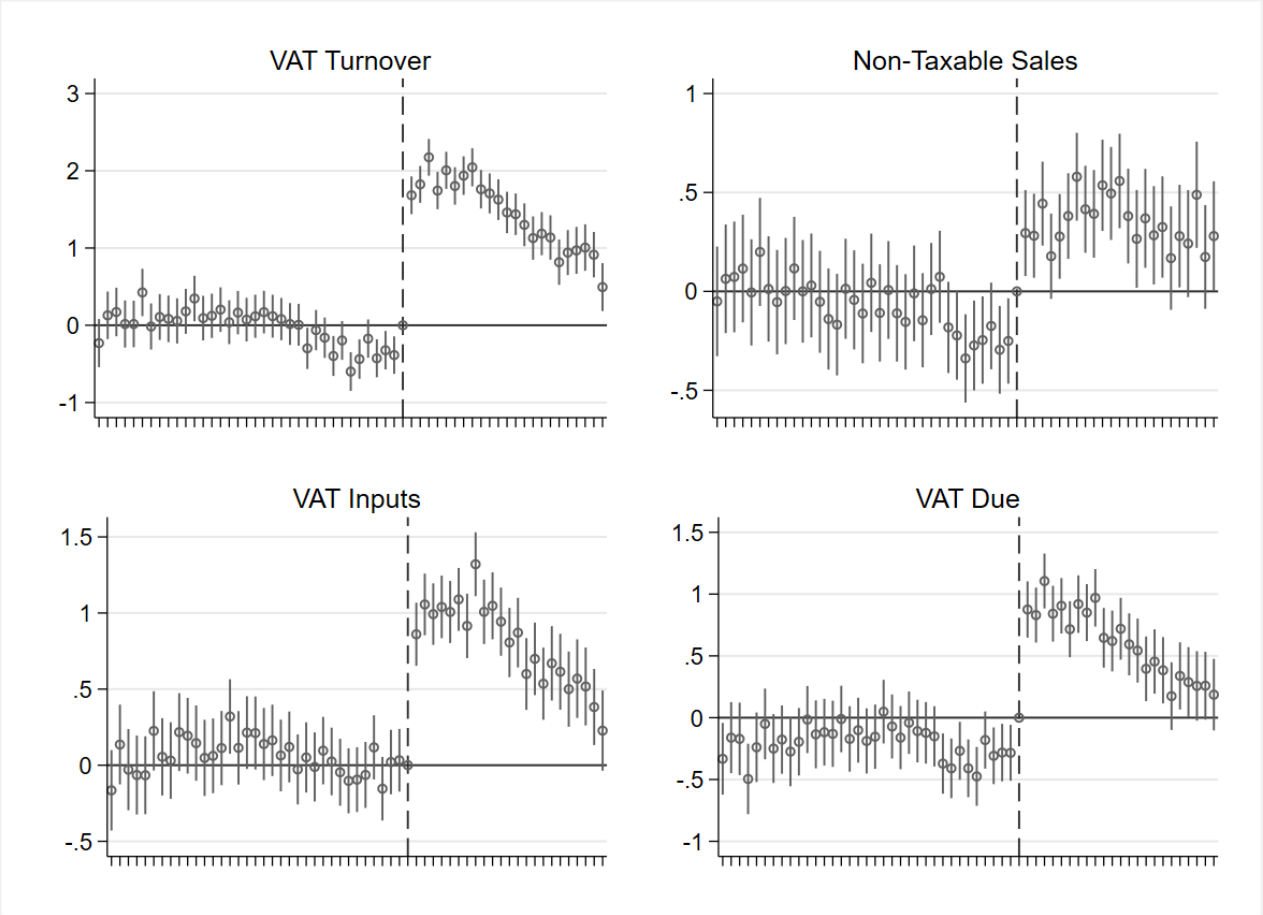
Third, we directly test for the parallel trend assumptions through the equation below, including as many as 36 months before adoption and 24 after adoption:

$$Y_{iy} = \alpha + \sum_{-36}^{24} \beta_t EBM2_{it+k} + Y_i + T_t + \varepsilon_{it} \qquad \text{Equation 1}$$

where, the Y_{it} stands for VAT returns outcomes reported by taxpayer i at a given year period t. The indicator variable $EBM2_{it+k}$ takes value 1 if the firm is *k* periods before (after) adoption in period *t*. Y_i and T_t are firms and month fixed effects respectively. Figure 4 reports

the coefficients for pre and post adoption dummies, where the excluded category is last period before adoption, over a range of four outcomes. While the sizeable jump after adoption (the vertical line) already suggests that the machines have a positive effect, there is no clear imbalance between users and non-users before adoption. Some imbalance emerges for VAT turnover and non-taxable sales just before adoption, which we take into account by running a more conservative triple DID design, as discussed below. Likewise, where outcomes from income tax returns are concerned, the coefficients pre and post adoption are reported in Figure A8. Some imbalance arises, especially in the years closest to adoption, which justifies again the adoption of a more conservative triple DID approach.

Figure 4 Dynamic responses for VAT declarations to EBM2 adoption



Notes: The figures report coefficients on dummies capturing periods before and after EBM2 adoption, estimated in a diff-in-diff setting. The excluded category is the last period before adoption (pre_1). All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

Our main specification follows a standard DID approach with staggered treatment and is described in equation 2 below. We include month and taxpayer fixed effect, while EBM2 switches to one in the month of adoption.

$$Y_{it} = \alpha + \beta_t EBM2_t + Y_i + T_t + \varepsilon_{it} \qquad \text{Equation 2}$$

We measure a range of outcomes. From VAT returns, we consider not only final VAT due, but also VAT sales, non-taxable sales, VAT on inputs and on outputs, nil-filing probability[11] and the probability of being in a refund position. From income tax returns, we consider not just the final income tax liability, but also turnover, expenses and filing on time. As in Mascagni, Mengistu and Woldeyes (2021), we consider a taxpayer as a user of EBM2 if they adopted the machine for at least six months in a given fiscal year – and run a DID at the year

[11] For a detailed discussion around nil-filing, see Mascagni, Santoro, Mukama, Karangwa and Hakizimana 2020.

level for annual income tax returns. We also originally compare the turnover from VAT returns to the same line from the income tax returns, as a measure of accuracy of reporting – another key outcome likely to be shaped by technology.

As a last note, we recur to a triple DID approach, in line with Eissa and Zeitlin (2014) and Mascagni, Mengistu and Woldeyes (2021). This solution largely addresses the concerns on imbalances in pre-adoption months we document in Figure 2 above. We first differentiate our data before running our main DID equation, so to consider taxpayer-specific trends in addition to taxpayer-specific time-invariant factors. Our triple DID estimation builds on equation 2, differentiating it, and reads as follow:

$$\Delta Y_{it} = \beta_t \Delta EBM2_t + \Delta T_t + \theta_i + \Delta \varepsilon_{it} \qquad \text{Equation 3}$$

where θ_i indicates taxpayer-specific time-variant fixed effects, so to control for any potential bias related to the possibility of significant differences in trends before adoption, which might threaten the validity of diff-in-diff estimation (Mascagni, Mengistu and Woldeyes 2021).

3 Results

3.1 VAT outcomes

In Table 3, we report the difference-in-difference results on the effects of EBM2 adoption on VAT declarations for both new users and shifters – with panel A showing our standard DID results and panel B reporting the more conservative triple DID estimates. All amount variables are transformed in logs, to control for skewed distributions. Column 1 reports the impact on turnover, column 2 on non-taxable sales, column 3 on the VAT paid on inputs, column 4 on the VAT on sales, column 5 on the final VAT due, as derived from VAT on sales minus VAT on inputs. Column 6 shows results on the probability of having a VAT nil return, while column 7 refers to the probability of being in a refund position. Panel A indicates that EBM2 adoption causes a significant increase in all key VAT return items (col. 1–5). Interestingly, also the probability of nil-filing is also reduced, while being in a refund position is untouched. However, when a triple DID is introduced in panel B, results become insignificant. Overall, it seems that EBM2 is not producing any effect on VAT reporting.

Table 3 Impact estimates of EBM2 adoption – both shifters and new users

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Turnover	Non-taxable sales	VAT input	VAT on sales	Final VAT due	Nil VAT Yes	Refund Yes
Panel A – Standard DID							
EBM2 treatment	2.20***	0.64***	1.08***	1.93***	1.18***	-0.14***	0.01
	(0.12)	(0.12)	(0.11)	(0.11)	(0.10)	(0.01)	(0.01)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	129928	129928	129928	129928	129928	129928	129928
N of firms	2933	2933	2933	2933	2933	2933	2933
Adj R^2	0.04	0.02	0.03	0.04	0.01	0.04	0.02
Panel B – Triple DID							
EBM2 treatment	0.02	0.02	-0.01	0.00	-0.03	0.00	-0.00
	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	93398	93398	93398	93398	93398	93398	93398
N of firms	1610	1610	1610	1610	1610	1610	1610
Adj R^2	0.02	0.01	0.02	0.02	0.01	0.01	0.00

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

In Table 4, instead, we restrict to new users of the technology. From panel A, the same positive and significant pattern emerges, with larger coefficients, indicating a more sizeable effect on this category. Importantly, nil-filing is curbed by 33 percentage points while now being in a refund position is positively impacted by EBM2 as well. When considering our more conservative approach, the triple DID, it is worth mentioning that EBM2 remains impactful, albeit not on all outcomes. Turnover, for instance, significantly increases by 0.29 log points, and, in parallel, the VAT on sales rises as well. As a result, final VAT due increases too, as the rise in VAT on output is larger than the non-significant increase in VAT on input. Remarkably, nil-filing falls too, even if by just 1 percentage point. This more robust methodology is reassuring in indicating that EBM2 is particularly effective for new users, as they probably benefitted more from adopting the machines for the first-time.

On the other hand, impacts on shifters from EBM1 are more muted. It is true that EBM2 has some significant impacts on turnover, VAT on output and nil-filing when a standard DID is adopted, as shown in Table 5 panel A. However, when our preferred strategy is used in panel B, these estimates lose significance. Remarkably, a negative impact is measured on VAT on output and final VAT due, even if marginally significant only. In sum, it seems that shifters are not particularly shaped by the new technology, in line with the assumption that they were probably quite used to the machines, given their previous experience with EBM1. These findings also indicate that the incremental benefit of EBM2 as compared to EBM1 is probably negligible. While weakly significant, the negative impact on VAT on sales and final VAT due are also concerning as they might indicate tax avoidance responses from shifters, which may deserve closer attention from the tax administration.

Table 4 Impact estimates of EBM2 adoption – new users

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Turnover	Non-taxable sales	VAT input	VAT on sales	Final VAT due	Nil VAT Yes	Refund Yes
Panel A – Standard DID							
EBM2 treatment	5.28***	0.99***	2.57***	4.53***	2.76***	-0.33***	0.05***
	(0.21)	(0.16)	(0.14)	(0.17)	(0.14)	(0.01)	(0.01)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	40254	40254	40254	40254	40254	40254	40254
N of firms	1592	1592	1592	1592	1592	1592	1592
Adj R^2	0.16	0.04	0.10	0.16	0.08	0.15	0.01
Panel B – Triple DID							
EBM2 treatment	0.29***	0.06	0.07	0.25***	0.12**	-0.01**	0.00
	(0.07)	(0.05)	(0.06)	(0.05)	(0.05)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	18282	18282	18282	18282	18282	18282	18282
N of firms	495	495	495	495	495	495	495
Adj R^2	0.01	0.01	0.01	0.01	0.01	0.01	0.00

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

Table 5 Impact estimates of EBM2 adoption – shifters only

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Turnover	Non-taxable sales	VAT input	VAT on sales	Final VAT due	Nil VAT Yes	Refund Yes
Panel A – Standard DID							
EBM2 treatment	0.33**	0.30*	0.18	0.37***	0.19	-0.02**	-0.01*
	(0.14)	(0.16)	(0.14)	(0.14)	(0.13)	(0.01)	(0.01)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	89674	89674	89674	89674	89674	89674	89674
N of firms	1341	1341	1341	1341	1341	1341	1341
Adj R^2	0.02	0.02	0.02	0.02	0.01	0.01	0.02
Panel B – Triple DID							
EBM2 treatment	-0.03	0.01	-0.02	-0.04*	-0.06*	0.00	-0.00
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	75116	75116	75116	75116	75116	75116	75116
N of firms	1115	1115	1115	1115	1115	1115	1115
Adj R^2	0.02	0.01	0.02	0.03	0.01	0.02	0.00

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

We are also able to capture the heterogeneity of impacts across different taxpayer dimensions. First, considering the business sector, we find that firms in manufacturing significantly increase their turnover after adoption (Appendix Table A2, panel A). Among new users, firms in trade and construction are particularly responsive (panel B). Once again, among shifters, no heterogeneity is found across sectors (panel C). When looking at final VAT due, the same pattern is observed overall (Appendix Table A3, panel A). For new users, again those in construction are quite responsive (panel B). Quite concerningly, final VAT due decreases for shifters in trade, albeit only weakly significantly (panel C). No meaningful impact is found, across sectors, on the probability of being in a refund position.[12]

[12] Table omitted for brevity and available on request.

In addition to sector, we also consider the location of taxpayers. Evidence indicates that most of the impact takes place in Kigali (Appendix Table A4, panel A). More specifically, new users in Kigali significantly increase their turnover and final VAT due, while those in provinces slightly increase the probability of being in a refund position (panel B). For shifters, those in Kigali backfire, consistently with the main findings, reducing their final VAT due (panel C).

As a last dimension of interest, we look at taxpayer size. When considering both new users and shifters, we notice a backfiring effect from medium and large taxpayers, especially on VAT paid on inputs and final VAT liability (Appendix Table A5, panel A). However, when restricting to new users, small taxpayers report higher turnover and final VAT due (panel B). Lastly, large and medium shifters are those driving the negative effect on final VAT due (panel C).

Income tax. When it comes to outcomes related to income tax returns, only mixed evidence emerges. Table 6, pooling both new users and shifters, reports the DID estimates at the year level. Overall, the standard approach in panel A indicates that EBM2 negatively impacts on-time filing, but seems to increase turnover and, at a lower degree, expenses – thus resulting in a rise in income tax payable. From panel B, instead, the results show that on-time filing probability is still hampered, while turnover and final income tax payable is reduced. As discussed in section 2 and represented in Figure A8, the main reason behind the different results between standard and triple DID seems to lie in the imbalance in pre-trends, mostly in the two years before adoption. This implies that triple DID coefficients are more robust by design, and hence to be preferred. In sum, adoption of EBM2 brings negative spillover effects on income tax compliance.

Table 6 Impact estimates of EBM2 adoption – income tax – both shifters and new users

	(1)	(2)	(3)	(4)
	On-time	Turnover	Expenses	Tax payable
Panel A – Standard DID				
EBM2 treatment	-0.02*	2.05***	1.15***	1.21***
	(0.01)	(0.18)	(0.14)	(0.16)
Year FE	Yes	Yes	Yes	Yes
N	19368	19368	19368	19358
N of firms	3438	3438	3438	3438
Adj R^2	0.03	0.21	0.13	0.10
Panel B – Triple DID				
EBM2 treatment	-0.05***	-1.11***	-0.06	-0.66***
	(0.02)	(0.26)	(0.20)	(0.23)
Year FE	Yes	Yes	Yes	Yes
N	15880	15880	15880	15864
N of firms	3436	3436	3436	3436
Adj R^2	0.01	0.08	0.01	0.05

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

When we attempt to consider the heterogeneity across subgroups, Table 7, showing only the more conservative and thus preferred triple DID estimates for brevity, shows quite different results between first-time users (panel A) and shifters (panel B). On the one hand, it seems that new users are negatively impacted in terms of their capacity to file by the deadline. This could probably be explained by the fact that they might face technical difficulties in operating the machines, which would add to their compliance costs and make it hard for them to file their income tax returns on time. Qualitative evidence around such technical issues relating to EBMs is largely documented in Mascagni, Dom, Santoro and Mukama (2022). On the other hand, shifters do not show such negative effects.

Another key item which is impacted by EBM2 adoption is expenses, which significantly rise for first-time users, while they fall for shifters. In attempting to explain such results, it could be argued that first-time users, mostly being newly registered and less experienced taxpayers, might benefit from the more accurate record-keeping practices that EBM2 brings (section 1). This could help them fully report their expenses and not leave money on the table, likewise a common practice documented in the literature (Benzarti 2021). In contrast, the negative impact on shifters, usually larger and more sophisticated companies well equipped with tax accountants and advisors, might be explained by the fact that EBM2 might increase the perceived feeling of being under the authority's radar. Thanks to the more accurate data sharing with RRA, EBM2 might be curbing the possibility of tax avoidance through expense over reporting, a common practice among more sophisticated taxpayers both in Africa (Mascagni, Mengistu and Woldeyes 2021) and beyond (Carrillo, Pomeranz and Singhal; Slemrod, Collins, Hoopes, Reck and Sebastiani 2021).

Table 7 Impact estimates of EBM2 adoption – income tax – triple DID

	(1)	(2)	(3)	(4)
	On-time	Turnover	Expenses	Tax payable
Panel A – New users				
EBM2 treatment	-0.12***	0.33	0.83***	-0.04
	(0.02)	(0.39)	(0.28)	(0.30)
Year FE	Yes	Yes	Yes	Yes
N	10431	10431	10431	10425
N of firms	2565	2565	2565	2565
Adj R^2	0.01	0.11	0.03	0.08
Panel B – Shifters				
EBM2 treatment	-0.01	-0.28	-0.63**	-0.17
	(0.03)	(0.29)	(0.28)	(0.37)
Year FE	Yes	Yes	Yes	Yes
N	6324	6324	6324	6324
N of firms	871	871	871	871
Adj R^2	0.02	0.09	0.10	0.03

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

3.2 Potential mechanisms

As a last set of results, we now estimate the impact of EBM2 on the accuracy of reporting. We do that through a number of outcomes, as displayed in Table 8. Column 1 refers to the probability of taxpayers filing for both income tax and VAT. This outcome is measured as the likelihood of filing for the annual income tax return, conditional on having filed at least one (monthly or quarterly) VAT return in the same year. Column 2 refers to accurate reporting for those cases in which there is no discrepancy between the turnover from income tax and VAT returns. Column 3, instead, restricts to those cases in which the VAT return is not nil – since a nil-filer filing zero for both tax types would appear as accurately reporting in column 2. We decided to apply such restrictions to consider only those cases in which a positive VAT turnover is reported in the year, and is thus more liable to create discrepancies with the income tax return. Columns 4 and 5, respectively, look at the probability of having an income tax return's turnover larger or smaller than the corresponding entry from the VAT return. Lastly, column 6 quantifies the size of the discrepancy, in logs, again built as the turnover from VAT minus the turnover from income tax filings.

The key result emerging from such analysis, with both our standard and our triple DID approach, is that EBM2 increases the discrepancies between returns. First, it reduces the probability of filing both returns, albeit only marginally (col. 1). Second, it reduces the probability of reporting the same turnover across returns (col. 2). As shown in cols. 4 and 5,

such a discrepancy is largely due to a significant increase in the turnover from VAT, which does not correspond to a similar increase in income tax returns. This means that the probability of having a larger VAT turnover rises dramatically (col. 5). Consequently, the gap between return items expands (col. 6).

In Appendix tables A6 and A7, we test whether this pattern differs across categories. It is worth noting that this impact is totally driven by new users (Table A7). On the one hand, shifters are not touched by EBM2 in their accurate reporting (Table A6). This might be due to the fact that they are probably already equipped with sophisticated accounting tools, thus do not gain much from the new technology. On the other hand, new users show the same overall pattern from Table 8. Their VAT turnover considerably increases with no corresponding rise in income tax returns, thus enlarging reporting gaps. This could be due to the fact that such taxpayers are probably focusing their reporting efforts on the more frequent VAT-related obligations, somehow disregarding income taxes. It could also be that lack of experience or confusion around the tax system play a role, as new users might not know that the turnover entry should refer to the same amount across the two tax heads.

Table 8 Impact of EBM2 adoption on accuracy – both shifters and new users

	(1)	(2)	(3)	(4)	(5)	(6)
	Filed both	Accurate reporting	Accurate reporting no nil	IT turnover larger	VAT turnover larger	Log discr. amount
Panel A – Standard DID						
EBM2 treatment	-0.01***	-0.15***	-0.04***	-0.05***	0.20***	9.22***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(1.62)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	10870	10870	8134	10870	10870	10870
N of firms	1941	1941	1777	1941	1941	1941
Adj R^2	0.03	0.06	0.01	0.02	0.09	0.13
Panel B – Triple DD						
EBM2 treatment	-0.01**	-0.08***	-0.04***	-0.07***	0.14***	8.54***
	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)	(1.57)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	8892	8892	6997	8892	8892	8892
N of firms	1928	1928	1741	1928	1928	1928
Adj R^2	0.03	0.01	0.03	0.01	0.02	0.03

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

4 Summary and conclusions

The aim of this paper is to present rigorous evidence on the effect of EBM2 adoption on tax revenue and compliance. Our findings contribute to existing knowledge by showing that even if a more sophisticated IT solution for taxpayers, such as EBM2, is effective in increasing tax revenue and compliance, that is not the case for all taxpayers and that, in some cases, such technology is ineffective.

First, the disaggregation of firms into categories of shifters and new users revealed that the EBM2 adoption led to different impacts across the two categories. While shifters from EBM1 are largely unresponsive and, if anything, reporting lower VAT on sales and final VAT due, first-time users significantly increase turnover, VAT on sales and final VAT due, and are also less likely to zero file. On income tax, results are more mixed, with first-time users increasing

their expenses but struggling to file on time. On the expense reporting side, we find that new users report more expenses, probably assisted by the enhanced record-keeping functionalities of EBM2, while shifters cut on expenses, probably signalling a deterrent effect of the EBM data limiting possibilities for tax avoidance through expense overreporting. Second, we found that accuracy in reporting is negatively affected as a result of EBM2 adoption. New users in particular experience a fall in accurate reporting. One reason for this seems to be that taxpayers are now filing correctly for VAT – helped by the machines – but that does not translate into a parallel improvement in income tax filings. This may be due to the fact that some taxpayers perceive that the RRA monitors their transactions and detects misreporting, especially for VAT. This can give them room to evade income tax due by reducing their business income.

The evidence produced in this paper suggests some policy recommendations for the RRA – and African tax administrations in general. While the efforts made to boost the EBM system and foster the adoption of a more elaborated version are impressive, we also acknowledge that there is a need to improve on several aspects.

First, EBM2 adoption effects are mostly found in new users of the technology, which are mostly small firms. Since these firms are typically not the main target of audit activities, as they generate a low share of VAT, strengthening e-invoicing would be a better strategy to improve voluntary compliance rather than investing in an expensive audit strategy for a large number of small taxpayers. In this case, the EBM for all policy currently implemented by the RRA, mostly affecting small taxpayers with a requirement to adopt the machines, could be effective in improving the compliance of such a category, compared to a situation in which the technology is not there.

Second, shifters to EBM2 are largely unresponsive, as expected by taxpayers already familiar with the technology. However, the negative impact on VAT on sales and final VAT due, even if weakly significant, could be problematic and call for closer scrutiny from the tax administration. As documented here, shifters are larger, more equipped taxpayers – entities who are usually very intelligent in responding to increased enforcement measures.

In terms of future research, it would be interesting to study the effectiveness of the EBM for all policy currently ongoing. Likewise, this same analysis could be repeated in about one year, when a large number of taxpayers, who started using EBM2 *en masse* in 2022 and have been removed from this study, will have filed for VAT. In the same fashion, such impact evaluation could be run on taxpayers who only use the machine for income taxes. Relatedly, it would be worth collecting survey data on EBM2 users to gain better knowledge on the mechanisms at play, on which we could only speculate. As an additional avenue for research, it would be useful to explore how the new e-invoicing technology helps the tax administration in performing its functions. EBM2 produces a huge amount of real time data, flowing into the RRA's systems – a significant improvement on top of the previous version. It is unclear then how the RRA is unlocking the potential of this new data, whether its analytical systems are fully exploiting the new information received, and whether monitoring capacity has improved as a result. We leave these open questions for future research.

Appendix

Tables

Table A1a T-tests difference between users of EBM1 and shifters to EBM2

	EBM v1 users		Shifters to EBM v2		
	Mean	Obs	Mean	Obs	Difference
CIT	0.72	9448	0.85	2375	-0.13***
Kigali	0.72	9440	0.87	2375	-0.14***
Reg. year	2013.14	9448	2008.47	2375	4.67***
Trade	0.47	9378	0.49	2375	-0.03**
Manufacturing	0.09	9378	0.10	2375	-0.01**
Professional	0.08	9378	0.07	2375	0.00
Construction	0.08	9378	0.08	2375	0.00
Accom. Food	0.07	9378	0.04	2375	0.03***
Transport	0.05	9378	0.06	2375	-0.01
IC	0.03	9378	0.03	2375	0.00
Administrative	0.04	9378	0.04	2375	-0.00
Other services	0.03	9378	0.02	2375	0.01**
2013-17 Turnover	13.91	8489	17.20	1746	-3.29***
2013-17 VAT sales	13.28	7886	15.10	1783	-1.82***
N	12319				

Notes: * p < 0.10, ** p < 0.05, *** p < 0.01. Standard errors in parentheses. Results derive from t-tests for mean equality, based on administrative data from the RRA, updated as of February 2022.

Table A1b T-tests difference between never adopters and adopters of EBM2

	Never adopters		Sample TPs		
	Mean	Obs	Mean	Obs	Difference
CIT	0.35	253136	0.64	30645	-0.28***
Kigali	0.48	252464	0.58	30630	-0.10***
Reg. year	2017.03	253136	2012.99	30645	4.04***
Trade	0.24	223129	0.43	29291	-0.19***
Manufacturing	0.05	223129	0.09	29291	-0.04***
Professional	0.04	223129	0.07	29291	-0.03***
Construction	0.03	223129	0.06	29291	-0.03***
Accom. Food	0.04	223129	0.05	29291	-0.00**
Transport	0.28	223129	0.06	29291	0.22***
IC	0.02	223129	0.03	29291	-0.01***
Administrative	0.02	223129	0.03	29291	-0.01***
Other services	0.07	223129	0.06	29291	0.01***
2013-17 Turnover	5.44	77057	10.82	12941	-5.38***
2013-17 VAT sales	5.61	5607	11.23	2853	-5.62***
N	283940				

Notes: * p < 0.10, ** p < 0.05, *** p < 0.01. Standard errors in parentheses. Results derive from t-tests for mean equality, based on administrative data from the RRA, updated as of February 2022.

Table A1c T-tests difference between early and sample EBM2 adopters

	Sample TPs		Early (<=2017)		
	Mean	Obs	Mean	Obs	Difference
CIT	0.64	30885	0.92	123	-0.28***
Kigali	0.58	30870	0.91	123	-0.33***
Reg. year	2012.97	30885	2006.07	123	6.90***
Trade	0.43	29530	0.52	123	-0.09**
Manufacturing	0.09	29530	0.25	123	-0.16***
Professional	0.07	29530	0.03	123	0.04*
Construction	0.06	29530	0.01	123	0.05**
Accom. Food	0.05	29530	0.02	123	0.02
Transport	0.06	29530	0.03	123	0.03
IC	0.03	29530	0.02	123	0.01
Administrative	0.03	29530	0.02	123	0.01
Other services	0.06	29530	0.01	123	0.06**
2013-17 Turnover	10.76	12920	20.24	116	-9.48***
2013-17 VAT sales	11.03	2809	17.08	115	-6.05***
N	31167				

Notes: * p < 0.10, ** p < 0.05, *** p < 0.01. Standard errors in parentheses. Results derive from t-tests for mean equality, based on administrative data from the RRA, updated as of February 2022.

Table A1d T-tests difference between late and sample EBM2 adopters

	Sample TPs		Reg. in Jan-Feb 2022		
	Mean	Obs	Mean	Obs	Difference
CIT	0.65	28824	0.51	2061	0.13***
Kigali	0.58	28809	0.59	2061	-0.01
Reg. year	2012.92	28824	2013.72	2061	-0.80***
Trade	0.42	27605	0.51	1925	-0.09***
Manufacturing	0.09	27605	0.08	1925	0.02***
Professional	0.08	27605	0.05	1925	0.03***
Construction	0.06	27605	0.03	1925	0.03***
Accom. Food	0.05	27605	0.06	1925	-0.01**
Transport	0.06	27605	0.06	1925	-0.00
IC	0.03	27605	0.02	1925	0.01**
Administrative	0.03	27605	0.02	1925	0.01*
Other services	0.06	27605	0.08	1925	-0.02***
2013-17 Turnover	10.75	12155	10.88	765	-0.13
2013-17 VAT sales	11.03	2717	10.93	92	0.10
N	31042				

Notes: * p < 0.10, ** p < 0.05, *** p < 0.01. Standard errors in parentheses. Results derive from t-tests for mean equality, based on administrative data from the RRA, updated as of February 2022.

Table A2 Impact estimates of EBM2 adoption on turnover

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Trade	Construction	Manufacturing	Transport	Administrative	Accommodation	Professional
Panel A – All							
EBM2 treatment	0.00	0.02	0.23**	-0.02	-0.11	-0.06	0.14
	(0.04)	(0.12)	(0.10)	(0.08)	(0.14)	(0.08)	(0.11)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	37481	10718	8539	7681	3597	4022	6743
N of firms	642	191	161	102	69	63	120
Adj. R^2	0.03	0.02	0.03	0.03	0.05	0.14	0.03
Panel B – New users							
EBM2 treatment	0.33**	0.42**	0.55	0.10	0.42	-0.06	0.48
	(0.16)	(0.19)	(.)	(0.19)	(0.42)	(0.26)	(0.33)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4540	3073	1795	1218	662	716	1220
N of firms	139	84	56	22	26	14	43
Adj. R^2	0.03	0.05	0.03	0.08	0.11	0.14	0.11
Panel C – Shifters							
EBM2 treatment	-0.04	-0.04	0.13	-0.02	-0.21	-0.02	0.07
	(0.03)	(0.15)	(0.11)	(0.09)	(0.17)	(0.08)	(0.12)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	32941	7645	6744	6463	2935	3306	5523
N of firms	503	107	105	80	43	49	77
Adj. R^2	0.04	0.03	0.05	0.04	0.05	0.17	0.04

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

Table A3 Impact estimates of EBM2 adoption on final VAT due

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Trade	Construction	Manufacturing	Transport	Administrative	Accommodation	Professional
Panel A - All							
EBM2 treatment	-0.08	-0.05	0.15*	0.08	0.01	-0.16	-0.01
	(0.05)	(0.10)	(0.09)	(0.08)	(0.13)	(0.12)	(0.10)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	37481	10718	8539	7681	3597	4022	6743
N of firms	642	191	161	102	69	63	120
Adj. R^2	0.01	0.01	0.02	0.02	0.03	0.07	0.02
Panel B – New users							
EBM2 treatment	0.03	0.26***	0.32	0.11	0.53	0.02	0.12
	(0.09)	(0.09)	(.)	(0.19)	(.)	(.)	(0.27)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4540	3073	1795	1218	662	716	1220
N of firms	139	84	56	22	26	14	43
Adj. R^2	0.02	0.04	0.02	0.08	0.12	0.13	0.06
Panel C - Shifters							
EBM2 treatment	-0.09*	-0.14	0.11	0.10	-0.11	-0.18	-0.07
	(0.05)	(0.13)	(0.11)	(0.10)	(0.16)	(0.15)	(0.11)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	32941	7645	6744	6463	2935	3306	5523
N of firms	503	107	105	80	43	49	77
Adj. R^2	0.01	0.02	0.03	0.02	0.04	0.08	0.03

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

Table A4 Impact estimates of EBM2 adoption by location

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Turnover KGL	Turnover Provinces	VAT input KGL	VAT input Provinces	Final VAT due KGL	Final VAT due Provinces	Refund KGL	Refund Provinces
Panel A – All								
EBM2 treatment	0.01	0.06	-0.02	0.02	-0.03	-0.06	-0.00	0.01*
	(0.03)	(0.08)	(0.02)	(0.06)	(0.03)	(0.06)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	78954	13876	78954	13876	78954	13876	78954	13876
N of firms	1327	272	1327	272	1327	272	1327	272
Adj. R^2	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.01
Panel B – Shifters								
EBM2 treatment	0.39***	0.13	0.10	0.05	0.22***	-0.05	-0.00	0.01**
	(0.08)	(0.13)	(0.08)	(0.09)	(0.05)	(0.08)	(0.00)	(0.01)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	12411	5807	12411	5807	12411	5807	12411	5807
N of firms	344	148	344	148	344	148	344	148
Adj. R^2	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01
Panel C – Shifters								
EBM2 treatment	-0.04	0.02	-0.03	0.03	-0.06*	-0.04	-0.00	0.00
	(0.03)	(0.09)	(0.03)	(0.08)	(0.04)	(0.10)	(0.00)	(0.01)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	66543	8069	66543	8069	66543	8069	66543	8069
N of firms	983	124	983	124	983	124	983	124
Adj. R^2	0.03	0.02	0.02	0.02	0.01	0.02	0.00	0.01

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

Table A5 Impact estimates of EBM2 adoption by size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Turnover S	Turnover ML	VAT input S	VAT input ML	Final VAT due S	Final VAT due ML	Refund S	Refund ML
Panel A – All								
EBM2 treatment	0.02	0.02	0.01	-0.07**	-0.01	-0.10*	0.00	-0.00
	(0.03)	(0.05)	(0.03)	(0.03)	(0.03)	(0.06)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	68142	25256	68142	25256	68142	25256	68142	25256
N of firms	1347	263	1347	263	1347	263	1347	263
Adj. R^2	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.00
Panel B – New users								
EBM2 treatment	0.30***	0.19	0.09	-0.03	0.12**	0.11	0.00	-0.01*
	(0.08)	(0.15)	(0.06)	(0.13)	(0.05)	(0.13)	(0.00)	(0.01)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15815	2467	15815	2467	15815	2467	15815	2467
N of firms	467	28	467	28	467	28	467	28
Adj. R^2	0.01	0.04	0.01	0.05	0.01	0.03	0.01	0.04
Panel C – Shifters								
EBM2 treatment	-0.05	0.01	-0.00	-0.08**	-0.04	-0.12*	0.00	-0.00
	(0.04)	(0.05)	(0.03)	(0.04)	(0.04)	(0.07)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	52327	22789	52327	22789	52327	22789	52327	22789
N of firms	880	235	880	235	880	235	880	235
Adj, R^2	0.03	0.01	0.02	0.02	0.01	0.01	0.00	0.01

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

Table A6 Impact of EBM2 adoption on accuracy – shifters only

	(1)	(2)	(3)	(4)	(5)	(6)
	Filed both	Accurate reporting	Accurate reporting no nil	IT turnover larger	VAT turnover larger	Log disc amt
Panel A – Standard DID						
EBM2 treatment	0.00	-0.01	-0.01	-0.01	0.01	-0.41
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(2.69)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	6435	6435	6162	6435	6435	6435
N of firms	949	949	949	949	949	949
Adj R^2	0.01	0.02	0.01	0.02	0.04	0.16
Panel B – Triple DID						
EBM2 treatment	-0.00	-0.01	-0.00	-0.00	0.01	1.63
	(0.00)	(0.01)	(0.01)	(0.01)	(0.02)	(2.28)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	5482	5482	5322	5482	5482	5482
N of firms	949	949	949	949	949	949
Adj R^2	0.01	0.01	0.02	0.01	0.03	0.06

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

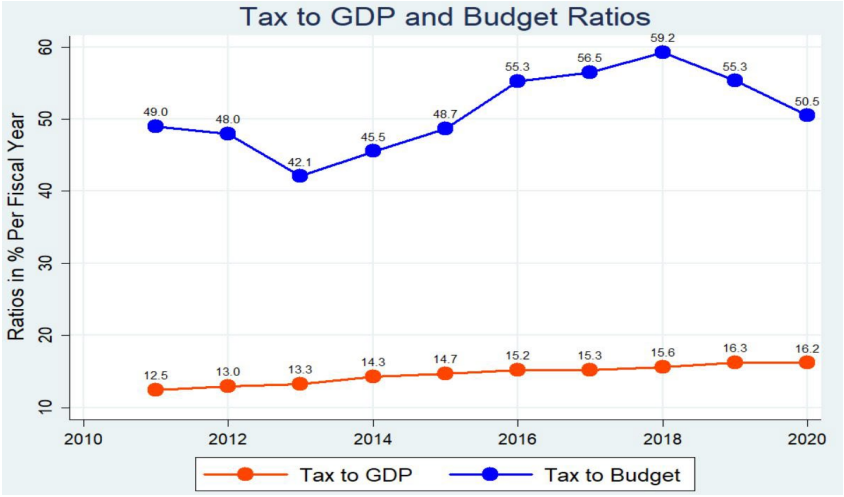
Table A7 Impact of EBM2 adoption on accuracy – new users

	(1)	(2)	(3)	(4)	(5)	(6)
	Filed both	Accurate reporting	Accurate reporting no nil	IT turnover larger	VAT turnover larger	Log disc amt
Panel A – Standard DID						
EBM2 treatment	-0.01	-0.29***	-0.12***	-0.08***	0.37***	14.19***
	(0.01)	(0.03)	(0.03)	(0.02)	(0.03)	(1.65)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	4435	4435	1972	4435	4435	4435
N of firms	992	992	828	992	992	992
Adj R^2	0.07	0.16	0.05	0.02	0.22	0.14
Panel B – Triple DID						
EBM2 treatment	-0.01	-0.26***	-0.25***	-0.15***	0.41***	15.88***
	(0.01)	(0.04)	(0.06)	(0.04)	(0.04)	(2.05)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	3410	3410	1675	3410	3410	3410
N of firms	979	979	792	979	979	979
Adj R^2	0.08	0.05	0.11	0.02	0.07	0.05

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimation strategy is explained in section 2.2 and the outcomes are described in section 3. All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

Figures

Figure A1 Tax to GDP with local government taxes included and tax to budget ratios



Source: authors' computation on RRA data.

Figure A2 Revenue share in total tax revenue by tax type

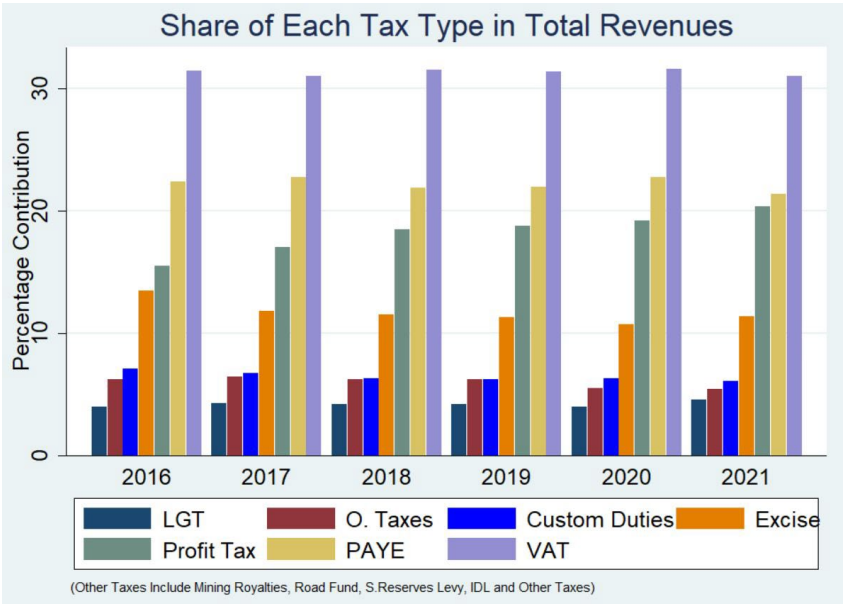


Figure A3 Adoption of EBMs by sector of activity

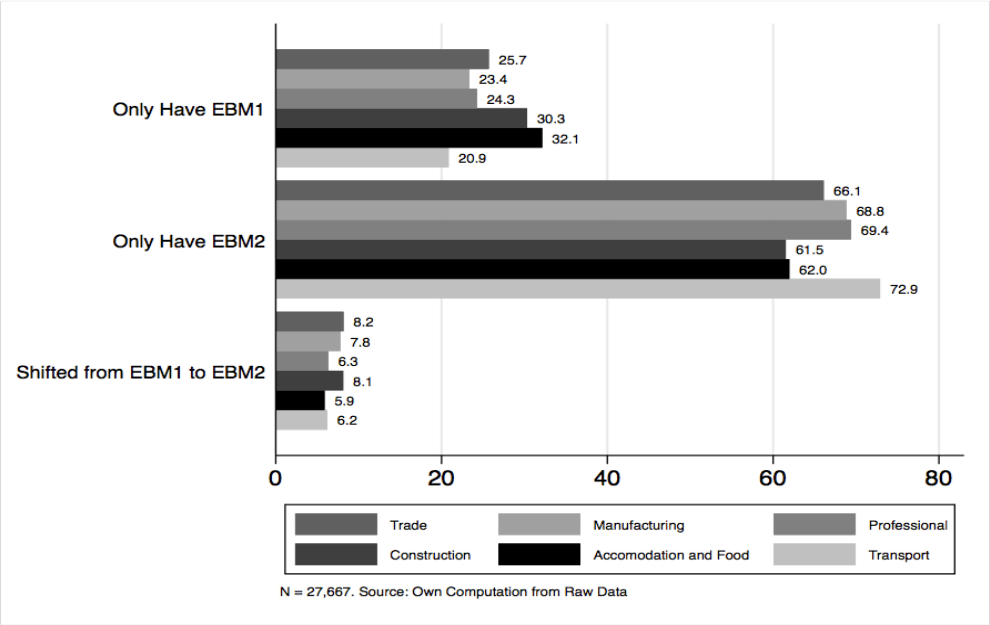


Figure A4 EBM usage by taxpayer size

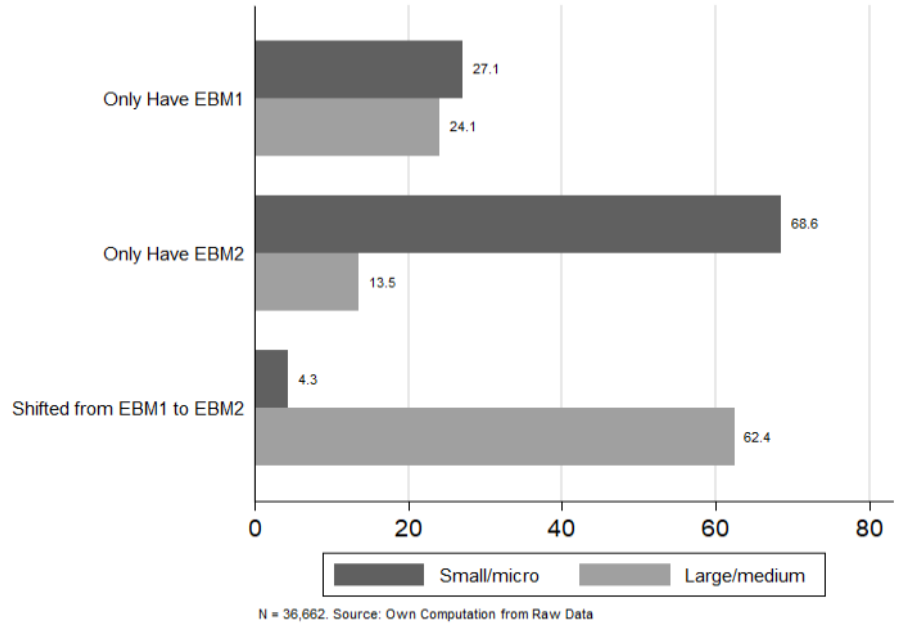


Figure A5 EBM usage for CIT-PIT taxpayers

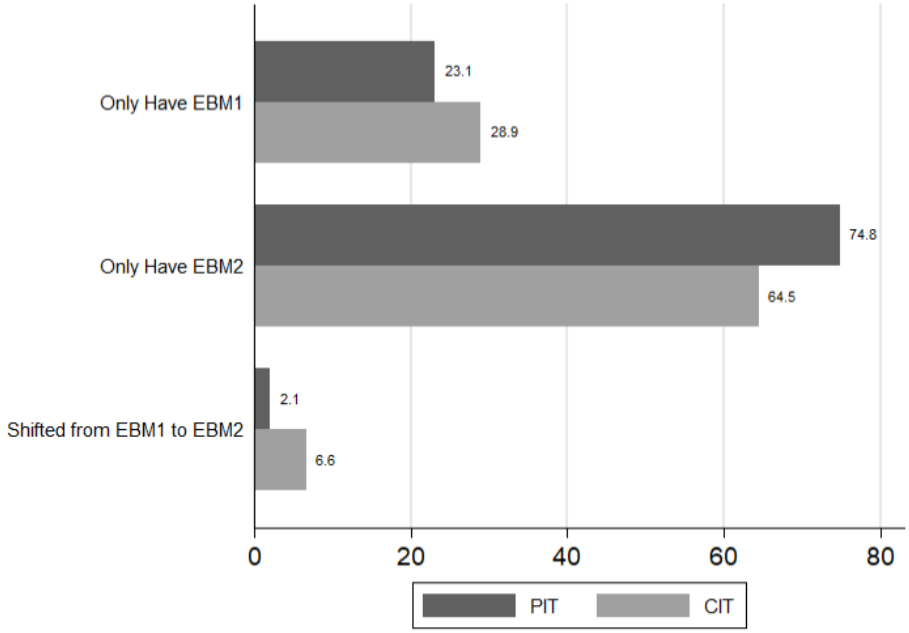


Figure A6 EBM usage by location

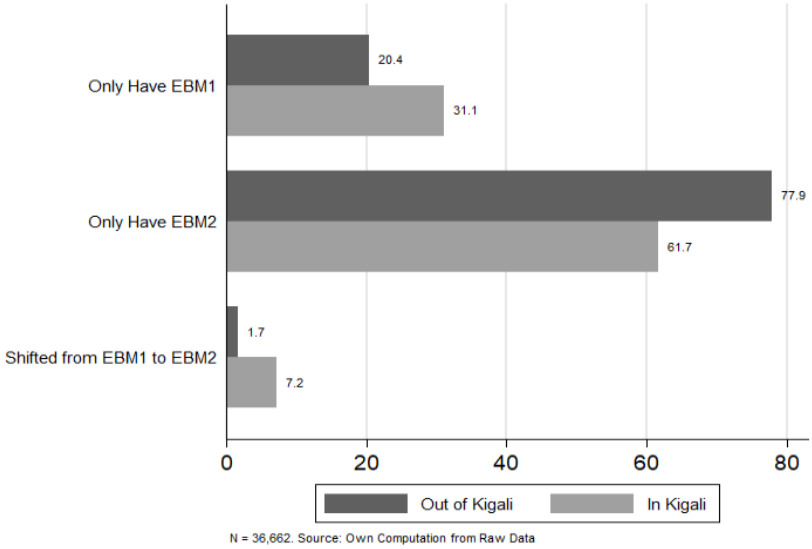
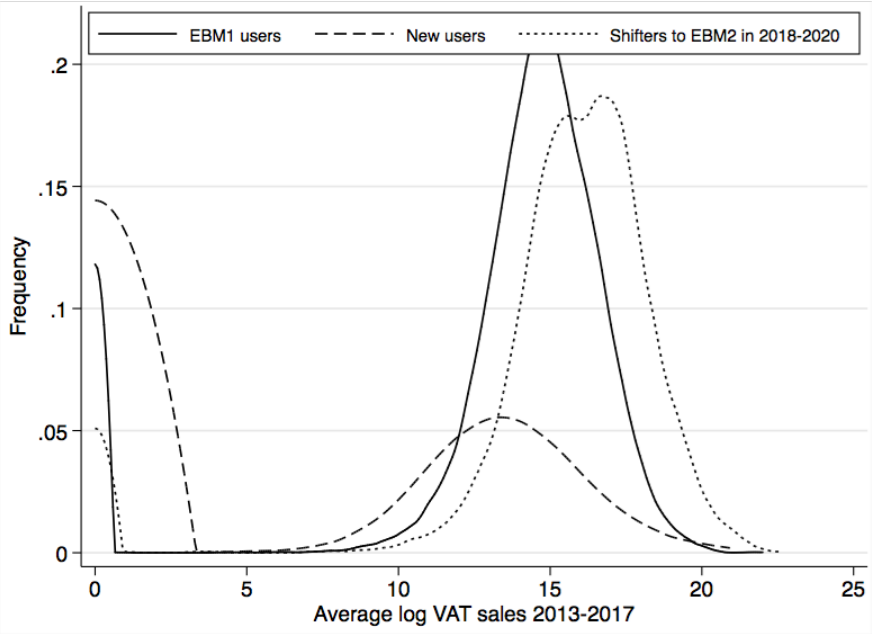
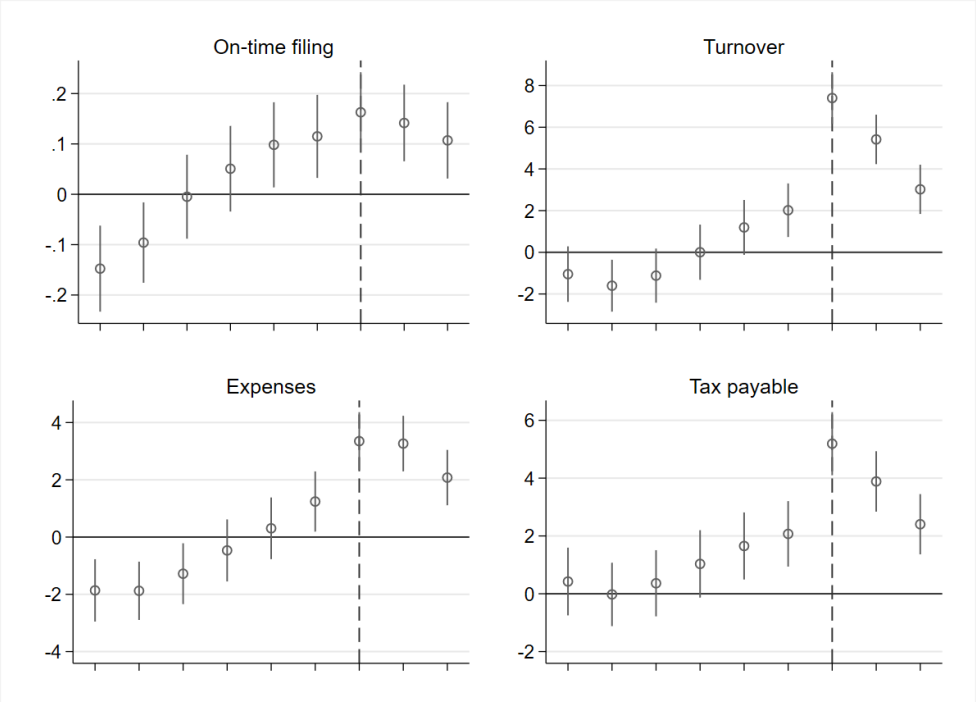


Figure A7 VAT sales in 2013–2017 and EBM adoption



Source: Own computation from raw data.

Figure A8 Dynamic responses for income tax declarations to EBM2 adoption



Notes: The figures report coefficients on dummies capturing periods before and after EBM2 adoption, estimated in a diff-in-diff setting. The excluded category is the last period before adoption (pre_1). All data is extracted from RRA administrative data, updated as of February 2022. More details in section 2.1.

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