International Tax and Public Finance (2025) 32:195–237
https://doi.org/10.1007/s10797-023-09820-x

Digitalization and cross-border tax fraud: evidence from e-invoicing in Italy

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Accepted: 27 November 2023 / Published online: 28 February 2024

Abstract

The digitalization of transaction processes through tools such as electronic invoicing (e-invoicing) aims to improve tax compliance and reduce administrative costs. Another important aspect of digitalization is its potential to reduce tax fraud. We exploit the comprehensive introduction of e-invoicing in Italy in 2019 and examine the effect of increased domestic tax enforcement capabilities on cross-border value-added tax (VAT) fraud. As a proxy for this fraud, we make use of the discrepancy in trade data that are double-reported in both the importing and exporting country (trade data gap, TDG). We calculate the TDG for imports to Italy from all other EU countries at the most detailed product level. Our results suggest a significant decline in cross-border fraud in response to the introduction of mandatory e-invoicing, providing an important rationale for the application of this measure by other countries. Furthermore, we estimate that e-invoicing decreased the Italian VAT loss in 2019 by about € 2.2 billion to € 2.6 billion compared to 2018. In this context, we underpin the suitability of the TDG as an approach for the study of anti-fraud measures.

Keywords E-Invoicing · Digitalization · International trade · VAT fraud · Trade data gap · Tax enforcement · Reverse charge

JEL Classification F14 · H21 · H26 · K34 · K4

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1 Introduction

Digitalization promises to improve tax enforcement due to the acceleration of data collection that enables tax administrations to monitor transactions in real time (Jacobs, 2017). As a result, digitizing tax collection is gaining noticeable popularity in tax policy debates and is attracting increasing interest among academics. In this study, we examine the effect of the transition from paper-based to electronic invoicing (e-invoicing) on cross-border value-added tax (VAT) fraud. For this purpose, we use the Italian e-invoicing system, which became mandatory for almost all transactions between resident entities as of January 1, 2019.

Many non-European countries, especially within Latin America and Asia, implemented digitized transaction processes, i.e. through mandatory business-to-business (B2B) e-invoicing to monitor economic processes. In the European Union (EU), Italy is the first country to have introduced such a system on a mandatory basis for B2B and B2C (business-to-customer) transactions.[1] Italy has undertaken the introduction of e-invoicing on its own, i.e. without specific coordination with other EU Member States. Hence, the scope is limited to the national level. Therefore, we ask the question whether enhanced domestic tax enforcement capabilities have a significant deterrent effect on cross-border VAT fraud that accounts for a bulk of overall VAT gaps[2] within the EU (European Commission, 2016; Frunza, 2016; Braml & Felbermayr, 2021).[3]

VAT[4] as the main form of consumption tax is implemented in about 170 countries. In the countries of the Organisation for Economic Co-operation and Development (OECD), it generates approximately one-third of all tax revenue (OECD, 2020). This type of consumption tax has the potential to create high revenue at relatively low administrative and economic costs.[5] However, it is also prone to fraud as firms

[1] In many EU countries, e-invoicing is mandatory only for business-to-government (B2G) transactions (Giannotti et al., 2019). Other EU countries are planning to adopt or have already adopted e-invoicing on B2B and B2C supplies. An overview of the current legislative status can be found in country-specific factsheets provided by the European Commission: https://ec.europa.eu/digital-building-blocks/sites/display/DIGITAL/eInvoicing+Country+Factsheets+for+each+Member+State+and+other+countries. Accessed 19 January 2024.

[2] VAT (compliance) gap is the difference between the VAT revenue that would be collected in the case of full compliance and the actual VAT revenue.

[3] Estimations range from € 50 billion (European Commission, 2016; Frunza, 2016) to € 64 billion (Braml and Felbermayr, 2021) annually.

[4] Some countries implemented a "Goods and Services Tax (GST)," for example, Australia, India or Canada. The GST is very similar to VAT because both tax the value added to the sale of products or services (OECD, 2020).

[5] The design of the VAT makes it neutral with regard to business decisions. By principle, VAT does not affect the choice of the legal form, financing structure and investment projects. This applies not only to domestic activities but also to cross-border transactions. Taxation in the importing country (destination principle) links VAT to the place of consumption, making the location decision of companies irrelevant for this tax and considerably reducing the scope for tax planning (Cnossen, 1998; McLure, 1993).

themselves collect the tax on behalf of the state. The tax is payable by the acquirer to the supplier, while the latter is obliged to forward the received VAT to the tax authorities after deducting input tax paid on own purchases. The damage resulting from organized VAT fraud, under which the supplier does not remit the received tax from the acquirer, is partially reduced if the right to deduct the input VAT for the supplier is refused and is thus limited to the tax amount on his or her profit margin ("value added"). However, the fraudster's plunder and thus the VAT loss increase significantly if the fraudster is able to avoid paying the input VAT. Zero-rated cross-border transactions open up this possibility. The fraudster imports goods from another EU Member State without VAT, sells them with VAT on the domestic market and disappears with the gross amount received.[6] Due to the disappearance, the fraudster is called "missing trader" and the straightforward name of this scheme is 'missing trader intra-Community' (MTIC) fraud.[7] Based on the cross-border element, recent studies have shown that the product-specific gap between the export reported by the exporting country and the corresponding import reported by the importing country (trade data gap, TDG), serves as an indicator of cross-border VAT fraud (Braml & Felbermayr, 2021; Bussy, 2020; Stiller & Heinemann, 2019, 2023).[8]

With e-invoicing, the risk of fraud detection increases since the invoice has to be sent electronically via a system of the tax administration that enables quicker cross-checks between VAT claimed and paid. The penalties imposed for not using the e-invoicing system, as well as the refusal to deduct VAT when the purchaser knew or ought to have been aware of the existence of VAT fraud, provide an incentive for honest businesses to avoid suspicious transactions. If e-invoicing prevents the fraudster's domestic supplies, the fraudster imports less or no more. As a result, declared exports and undeclared imports decrease or honest importers replace the fraudster, increasing declared imports. In both cases, the TDG declines.

Therefore, we exploit a difference-in-differences model accounting for potential omitted variable bias including unit and time fixed effects. We obtain data on Italy's trade with the remaining EU countries for all products at the level of the 8-digit code of the Combined Nomenclature (CN), 12 months before and after the introduction of e-invoicing on January 1, 2019. As the control group, we use products that fall under the previously introduced reverse charge mechanism (RCM) and therefore should not be subject to VAT fraud. RCM applies to B2B transactions and is a VAT blocking mechanism under which the buyer is obliged to pay the VAT to the tax

[6] The buyer must declare the import VAT (while the same amount can be deducted as input VAT). This reporting obligation is delayed because the import VAT is not collected at the border when the supply is made, but must be declared in the next regular VAT return. This creates a time lag during which fraudsters can intensively carry out EU imports and domestic supplies before the tax authority can detect the fraud (Sergiou, 2012).

[7] MTIC fraud can be divided further into "acquisition fraud" and "carousel fraud." The latter differs from the former in that the goods imported by the missing trader circulate, so that they are imported several times, allowing VAT to be evaded at each "turn" of the carousel.

[8] Trade data gaps are extensively used in tariff evasion research; see e.g. Fisman and Wei (2004). However, there is inconsistency in terminology as some authors refer to the same measure as e.g. "Bilateral Discrepancy" (Braml and Felbermayr, 2021), "Trade Gap" (Javorcik and Narciso, 2008), "Evasion Gap" (Fisman and Wei, 2004) or "Reporting Gap" (Bussy, 2020) or other notations.

authorities instead of paying it to the supplier. Thus, the VAT does not come under control of the fraudster. Recent empirical studies confirm the fraud-reducing effect of the RCM (Buettner & Tassi, 2023; Bussy, 2020; Stiller & Heinemann, 2019, 2023). However, we provide additional empirical evidence for the effect of the RCM with regard to the Italian implementation.

We identify the difference in the TDG before and after the reform between products potentially not affected by e-invoicing (RCM products) as the control group and all remaining products (non-RCM products) as the treatment group.[9] We find that the introduction of e-invoicing is associated with a significant decrease in cross-border VAT fraud expressed by the TDG. The results hold when we replace the control group (RCM products in Italy) with non-RCM products in EU countries that did not adopt e-invoicing and had the highest VAT gaps in 2018 according to Poniatowski et al. (2020), i.e. Greece, Lithuania, Romania and Slovakia. Furthermore, we find a significant decrease in the TDG if we narrow down the treatment group to make treated products more similar to RCM products.

Using a simple back-of-the-envelope calculation, we estimate that e-invoicing tackled cross-border VAT fraud in a range from € 2.2 billion to € 2.6 billion from 2018 to 2019. Our results are close to the Italian estimates of an increase in VAT revenue in 2019 of about € 1.7 billion to € 2.1 billion euros (Italian Ministry of Economy & Finance, 2020). However, our model is able to isolate the effect of cross-border VAT fraud. Given that Italy detected around € 1 billion in cross-border fraud in 2019 and 2020 (European Commission, 2021a), e-invoicing has not completely extinguished fraud.

Our findings contribute to a better assessment of the impact of e-invoicing on cross-border VAT fraud, confirm the significant share of this fraud in total revenue losses and underpin the suitability of the TDG as an indicator for cross-border VAT fraud. Since administrative costs in relation to the system are low (running cost of up to € 20 million a year) a domestic e-invoicing system provides a promising way to tackle cross-border VAT fraud in other countries.

Tax research on digital tools, including e-invoicing systems, focuses on the potential to improve tax compliance and collection in developing countries (Alonso et al., 2021; Bellon et al., 2022; Bérgolo et al., 2018; Fan et al., 2020; Hernandez & Robalino, 2018; Lee, 2016; Mascagni et al., 2021; Ramirez et al., 2018; Templado & Artana, 2018) as well as cost implications for both tax administrations and firms (Giannotti et al., 2019). Although theoretical considerations on the use of digital tools against VAT fraud in Europe go back a long time (see e.g. Ainsworth, 2006), empirical studies on the tax fraud-reducing effect of digitalization are scarce. Most recently, Kitsios et al. (2022) conducted an empirical study that examines the impact of digitalization efforts on cross-border VAT fraud using aggregated trade data. They confirm that digitalization correlates with lower tax fraud. However, their analysis focus on the relationship between aggregated trade data within the EU and the Online Service Index conducted by the

[9] We exclude fuels from the sample since e-invoicing became mandatory during 2018 already. See Table 19 in Appendix for a detailed explanation of each product group.

United Nations as proxy for digitalization efforts. Such a highly generalized index cannot disentangle single digital measures. Moreover, cross-border tax fraud is a product-specific phenomenon that can be studied only to a limited extent with aggregated data.

As part of the annual VAT gap study for all EU Member States, Poniatowski et al. (2022) find a statistically significant negative correlation between the VAT gap and (digital) reporting obligations, including VAT listing, Standard Audit File-Tax, real time and e-invoicing. However, this estimation aims to identify the overall impact of digital reporting obligations in the EU rather than single measures. Nevertheless, it shows the importance of improved tax reporting.

Against this background, the implication of certain digitalization measures with regard to cross-border tax fraud has been insufficiently examined. Such empirical evidence is essential to evaluate ongoing implementation efforts and to support tax policy in future debates as the digitalization of tax administrations become increasingly important. This demonstrates the example of the current debate on a harmonized e-invoicing system in Europe (European Commission, 2020). While especially in Latin America, e-invoicing is attested to have considerable anti-fraud potential (Barreix & Zambrano, 2018), the question remains how it affects the case of cross-border VAT fraud in Europe. We address this research gap by examining the introduction of e-invoicing in Italy in 2019 on B2B and B2C transactions using gaps in double-reported trade data between Italy and the remaining EU countries at the most detailed product code level of the CN.

With this paper, we contribute to the ongoing empirical research on the examination of measures against VAT fraud and its impact on tax revenues using trade data gaps as fraud proxy (Braml & Felbermayr, 2021; Bussy, 2020; Stiller & Heinemann, 2019, 2023). In this sense, we also contribute more broadly to the overall literature on the analysis of the TDG as a cross-border fraud indicator (Fisman & Wei, 2004; Javorcik & Narciso, 2008, 2017; Mishra et al., 2008; Stoyanov, 2012).

Additionally, our paper contributes to the emerging empirical research on the relationship between digitalization and tax fraud. Kitsios et al. (2022), Strango (2021) and Poniatowski et al. (2022) find that higher digitalization of tax reporting obligations is correlated with less (cross-border) tax fraud. All these papers, however, focus on aggregated country-level data and proxies for general digitalization efforts. We extend this literature stream i.e. by using disaggregated product-level data and a single reform, uncovering the impacts of digitalization on tax fraud on a more detailed level.

The rest of this paper is structured as follows. In Sect. 2, we provide the institutional background of the e-invoicing system in Italy and formulate our hypothesis in conjecture with the definition of our proxy for cross-border VAT fraud. In Sect. 3, we present the data and in Sect. 4 the identification strategy. Section 5 is devoted to the presentation and discussion of the main results. Section 6 addresses robustness checks and in Sect. 7, we describe and perform a quantification of the fraud. Section 8 concludes. We provide additional heterogeneity analyses in Section B in Appendix.

2 Hypothesis development

2.1 Reform background and theoretical considerations

In 2019, the obligation to send invoices electronically via the Italian exchange system (*Sistema di Interscambio*; SdI) came into force for the vast majority of Italian firms carrying out B2B and B2C transactions.[10] E-invoices fully replaced paper-based invoices for taxpayers with an annual turnover of more than € 65 thousand. According to the Italian Ministry of Economy and Finance (2018a), this threshold intends to cover 80% of all taxable persons in Italy. The initial start of the system dates back to June 2014, where e-invoicing became mandatory for transactions with ministries, tax agencies and national security agencies. From March 2015, all business-to-government (B2G) supplies were integrated into the system. This was followed by a voluntary adoption of e-invoicing for B2B in 2017. From July 2018, the use of the SdI was mandatory for the sale of fuels and became binding to all B2B and B2C transactions from January 1, 2019 (Italian Revenue Agency, 2021).

Italy enforces the system mainly by the imposition of different penalties when not using the SdI. These include the refusal of the input VAT deduction when no confirmed e-invoice is sent through the system and additional monetary fines.[11] The seller has to send the invoice file (*Fattura PA*) to the SdI, so that the tax authority acquires the information contained in the e-invoices in real time. However, in the first instance, the SdI only checks if the formal requirements are met. In a second step, the e-invoice data are transmitted to the tax authority that stores the e-invoices and uses automated and integrated processes to cross-check the consistency between the VAT declared and paid and also with other cross-border anti-fraud information sources (European Council, 2018; European Commission, 2021).[12] If the system accepts the formal validity, the seller obtains a receipt, while the buyer receives the invoice. Only through this procedure, the invoice is regarded as such for purposes of VAT and the acquirer can deduct the input VAT. Therefore, the taxable buyer should be sensitive to require an e-invoice before transferring the gross amount to the seller.[13]

Moreover, fines are imposed when the SdI is not applied. The fines range between 90% and 180% of the VAT. As an exception, the regulations allowed taxpayers to

[10] According to the official EU website on the Italian e-invoicing system (https://ec.europa.eu/digital-building-blocks/wikis/display/DIGITAL/eInvoicing+in+Italy), the taxable person must be resident or have a permanent establishment in Italy.

[11] Official FAQ of the Italian Revenue Agency. https://www.agenziaentrate.gov.it/portale/web/guest/schede/comunicazioni/fatture-e-corrispettivi/faq-fe/risposte-alle-domande-piu-frequenti-categoria/sanzioni. Accessed 27 July 2023.

[12] See e.g. https://ec.europa.eu/digital-building-blocks/wikis/display/EINVCOMMUNITY/Italy+-+2019+eInvoicing+Country+Sheet or https://www.mef.gov.it/en/focus/From-January-2019-the-electronic-invoicing-is-mandatory/. Both accessed 5 July 2023.

[13] As an exception, the Italian VAT law enables the buyer to send a self-e-invoice to the SdI to obtain the input VAT deduction in case the seller does not comply with the e-invoicing regulations. However, the tax authority can make the buyer liable of the VAT of the supplier and can pose a penalty up to a hundred percent of the tax, with a minimum of € 250.

avoid these fines if the e-invoice was uploaded to the SdI until the 15th of the following month during the first half of 2019.[14] Since then, an e-invoice has to be sent directly to the SdI to avoid the penalties.

In order to theoretically assess the compliance effects of e-invoicing, we distinguish between two broad types of non-compliance. On the one hand, non-compliant firms, in particular those under-reporting sales or over-reporting costs, and on the other hand the organized MTIC fraud. We focus on the latter, but presenting a short theoretical framework for both to justify how our model is able to isolate the effects on cross-border VAT fraud conceptually.

When an invoice has been sent through the SdI, the tax authority receives the transaction-based information shortly after and can perform cross-checks between taxpayers. This limits non-compliant firms to adjust their accounting records afterward. Therefore, keeping a certain level of tax evasion is thus very likely to be costlier after the reform, as these practices can potentially be exposed more quickly. In addition to increased costs of evasion, several benefits result from the system. Namely, the automation of invoice retention obligations, lower cost per invoice compared to paper invoices, streamlining of accounting processes and the availability of real-time accounting data (Italian Revenue Agency, 2021). Shedding light on the effect of switching from paper-based to electronic invoicing, Bellon et al. (2022) find for Peru that firms indeed increase reported sales, purchases and VAT liabilities on average. These results are stronger among small firms since they tend to be less compliant. For the introduction of e-reporting[15] of sales in Ethiopia, Mascagni et al. (2021) find that reported sales increase; however, firms also adjust reported cost upward. Therefore, curbing the positive tax collection effect by the reform, which nevertheless showed a net positive effect. Moreover, Fan et al. (2020) find a significant increase in VAT revenues after the introduction of digitally encrypted invoices in China.

In contrast to the non-compliance behaviour described above, organized cross-border fraud is likely to react differently to increasing digitalization. VAT fraudsters might hardly profit from any of the structural benefits resulting from the process digitalization. The reform confronts them with increased costs of fraud that can jeopardize their activities. Note that MTIC fraud differs from cases in which seller and buyer have an incentive to under- or over-report sales and costs, or even consensually carry out transactions without invoicing. Fraudsters make profits from the VAT collected that is not remitted to the tax authority. Regardless of whether the buyer is involved in the fraud, the invoice sent to the buyer determines the success. If the buyer is involved, the right to deduct the input VAT is essential to keep an overall profit from the scheme for the criminal organization.[16] In the event that the buyer

[14] See e.g. the explanations on the official website of the Italian Revenue Agency, https://www.agenziaentrate.gov.it/portale/web/guest/schede/comunicazioni/fatture-e-corrispettivi/faq-fe/risposte-alle-domande-piu-frequenti-categoria/sanzioni. Accessed 5 July 2023.

[15] A reform that made the use of sales registration machines (SRMs) mandatory in a staggered roll-out. These SRMs communicate sales electronically to the tax authority.

[16] If a missing trader A sells a good for 100 plus 20 VAT domestically to the involved firm B and B pays the gross amount of 120 to A, the scheme can only lead to a profit if A does not remit the 20 to the tax authority, while B gets a refund of 20.

is unaware, the fraudster has to pretend to be a compliant firm, as an invoice and inconspicuous transaction circumstances are central for the buyer to obtain an input tax deduction. The imposed penalties arising from not applying the electronic system should increase the incentive of taxpayers even further to take care not making business with fraudsters. Thus, the use of the SdI should increase the costs of fraudsters in each case (selling to involved or uninvolved firms) since the fraudster has to provide an unsuspicious e-invoice through the SdI for that a registration has to take place. Compared to paper invoices, electronic invoicing additionally poses a higher risk of detection for fraudsters, as the tax authority can cross-check the invoice data in real time.

2.2 E-invoicing and trade data gap

A growing literature that examines the effectiveness of measures against VAT fraud exploits discrepancies in double-reported trade data (Bussy, 2020; Kitsios et al., 2022; Stiller & Heinemann, 2019, 2023). Fisman and Wei (2004) first used these discrepancies to study tariff evasion on the product level between China and Hong Kong. This approach has found wide use in other studies related to tariff evasion (Javorcik & Narciso, 2008, 2017; Mishra et al., 2008; Stoyanov, 2012). In accordance to the vast literature, we define the ratio of exports to corresponding imports of product p at the 8-digit CN product level at time t from exporting country e to importing country i reported by country e and i, respectively, as the trade data gap (TDG). Taking the natural logarithm on both sides leads to

$$\ln \mathrm{TDG}_{\mathrm{eipt}} = \ln \mathrm{Export}_{\mathrm{eipt}} - \ln \mathrm{Import}_{\mathrm{eipt}} = \ln \left(\frac{\mathrm{Export}_{\mathrm{eipt}}}{\mathrm{Import}_{\mathrm{eipt}}} \right) \tag{1}$$

Equation (1) implies positive ln TDG values for $\frac{\mathrm{Export}_{\mathrm{eipt}}}{\mathrm{Import}_{\mathrm{eipt}}} > 1$ (case with prevalent fraud) and negative values for $\frac{\mathrm{Export}_{\mathrm{eipt}}}{\mathrm{Import}_{\mathrm{eipt}}} < 1$, as well as the value zero for $\frac{\mathrm{Export}_{\mathrm{eipt}}}{\mathrm{Import}_{\mathrm{eipt}}} = 1$. Besides fraud, ln TDG can occur due to different valuations of exports and imports. Since exports are valued as free-on-board, while imports include also cost of insurance and freight, the latter should be slightly higher by default resulting in a slightly negative value (Eurostat, 2020).

European taxpayers operating across borders are generally obliged to report imports and exports not only in the domestic periodic VAT return but also in the Intrastat system. The application of the TDG as proxy for cross-border VAT fraud is based on the theoretical argument that the fraudster does not report imports in the Intrastat system, while the exporter does. Since the fraudsters import goods on a zero-VAT basis, i.e. without payable input VAT, there is no incentive to comply with the obligations to file tax returns and Intrastat declarations.[17] However, we

[17] The import is subject to an intra-Community acquisition in which the importer has to self-declare the import and the respective output VAT for the exporter in the other Member State. However, this VAT can be deducted immediately as input VAT and therefore has only importance for reporting. Thus, the VAT liability is transferred to the buyer regarding intra-Community transaction. Later, we will define the reverse charge mechanism (RCM) as the *domestic* transfer of tax payment liability from the supplier to the buyer. However, the mechanism behind intra-Community acquisitions is similar as the supplier does

only observe respective gaps if exporters report trade within the Intrastat systems, while fraudulent importers fail to do so. We rely on the assumption that exporters fulfill their reporting obligations. This assumption can be justified by the fact that the exporter does not have to be aware of the fraud. Even if involved, compliance with the declaration requirements could be used as an argument by the exporter to be unknowingly involved in the fraud in case of detection. Therefore, the exporter can claim the refund of the input tax. Such a line of reasoning does not help the fraudulent importer, as the tax due is not paid to the tax authority. The declaration of imports could possibly help the fraudster not to be detected immediately by the tax office. However, this strategy in the absence of tax payment can only work for a short time until the tax authority finds out that domestic VAT is not remitted.

Even though the implementation of Italy's e-invoicing in 2019 targets domestic supplies and therefore has no direct impact on cross-border transactions. We expect a significant impact on TDG since e-invoicing increases the tax enforcement capabilities on domestic supplies and hence increases the costs for cross-border VAT fraud. As outlined above, the cross-border transaction is essential for the fraud scheme. If the fraudsters would acquire goods domestically, they would have to pay the input tax to the supplier and claim its refund from the tax authority. Importing the goods at zero rate from another EU Member State is less risky for the fraudsters. It has a liquidity advantage and allows them to charge a price lower than the net purchase price, as the fraudsters consider VAT as revenue, unlike the compliant taxpayers. Hence, they can undercut market prices for i.e. selling higher quantities (e.g. European Court of Auditors, 2019).

E-invoicing intends to increase compliance by non-compliant firms and to tackle cross-border fraud. We formulate the assumption that the TDG mainly reacts to the effect of e-invoicing on fraud instead of compliance changes by non-compliant firms. We argue that these firms are still incentivized to report an EU-import. Failure to declare the imports would preclude the deduction of the purchasing costs for income tax purposes. Against this background, we hypothesize:

Hypothesis The introduction of mandatory e-invoicing in Italy significantly reduces the trade data gap and thus cross-border VAT fraud.

3 Data

We use Eurostat's freely accessible database,[18] which contains detailed information on exports and imports between EU Member States (intra-EU) for all goods distinguished by the 8-digit CN code, the most detailed level available. Data on intra-EU

Footnote 17 (continued)
not charge VAT (it is zero-rated) and the buyer declares the VAT for the supplier and deducts this VAT as input tax in the same reporting period.

[18] We use the dataset '*EU trade since 1988 by HS2-4-6 and CN8*' with the code '*DS-045409*' freely available at https://ec.europa.eu/eurostat/web/main/data/database.

trade are based on Intrastat declarations by taxpayers exceeding the country-specific threshold (see Table 12 in Appendix) (Eurostat, 2020). To construct the TDG, we collect monthly data on traded products using the 8-digit CN code for intra-EU-imports to Italy from the 27 remaining EU countries reported by Italy and the corresponding intra-EU-exports reported by the remaining EU countries. For a robustness check, we extend this by analogous data for Greece, Lithuania, Romania and Slovakia as importing countries. The observation period ranges from January 2018 to December 2019, resulting in 12 months before and 12 months with mandatory e-invoicing in Italy (introduction of e-invoicing on January 1, 2019). Observations including the value of zero for exports and imports were omitted from the sample since our dependent variable requires nonzero values. We further exclude fuels from our baseline sample since these products were already subject to mandatory e-invoicing six months prior to the general introduction. Table 7 in Appendix presents the distribution of products across the product codes of our sample.

Table 1 presents the descriptive statistics for ln TDG by treatment and control group. We use products falling under the reverse charge mechanism (RCM) as control group. These products should be unaffected by the fraud-reducing effect of the reform. We discuss the selection of this control group when we present the identification strategy below. We expect the mean ln TDG to be (if at all slightly below) zero in case without fraud. The mean ln TDG of the control group consisting of RCM products (TREAT = 0) before and after e-invoicing at 0.0266 and −0.0332, respectively, is relatively stable and close to zero. In contrast, treatment products (TREAT = 1) show about ten times higher mean ln TDG before e-invoicing (0.2624), which indicates potential fraud within this group. The respective mean of 0.0683 for TREAT in the period with e-invoicing is significantly lower and close to zero; however, it is still higher than its counterpart for the control group, indicating that some fraud activity could be left over. Nonetheless, these descriptive results give suggestive evidence that the mandatory e-invoicing system in Italy significantly affected the treatment group.

4 Identification strategy

4.1 Empirical framework

According to our hypothesis, the application of the mandatory e-invoicing in Italy reduces cross-border VAT fraud. Thus, we estimate the following difference-in-differences model:

$$\ln \mathrm{TDG}_{\mathrm{ept}} = \gamma_{\mathrm{ep}} + \lambda_t + \delta\left(\mathrm{POST}_t \times \mathrm{TREAT}_p\right) + \beta X_{\mathrm{ept}} + \varepsilon_{\mathrm{ept}} \tag{2}$$

POST_t is a dummy equal to one from January 2019 on and zero otherwise. TREAT_p is a dummy equal to one if a product p belongs to the treatment group and zero if the product is protected by RCM.[19]

All non-RCM and non-FUELS products form the treatment group. As the control group, we use products that were most likely not affected by fraud in the run-up to the mandatory e-invoicing. Findings by Buettner and Tassi (2023), Bussy (2020), and Stiller and Heinemann (2019, 2023) provide theoretical and empirical support that the introduction of the RCM substantially tackles cross-border VAT fraud in the importing country as it excludes the fraudster from receiving the output tax. This domestic reverse charge procedure, implemented on certain products and services, shifts the liability to pay the VAT from the supplier to the buyer in B2B transactions. Therefore, fraudsters cannot take control over the VAT anymore, eliminating the incentive to trade with these products for fraudulent purposes. To provide additional evidence, we estimate the effect of the Italian RCM following the approach of Stiller and Heinemann (2023). For brevity, we refer to the description of the exercise and the results in Table 8 in Appendix. RCM significantly reduced the ln TDG in the two main implementation events around April 2011 and May 2016 (see Table 8, Panel C, Column 3, Appendix) indicating a substantial decrease in cross-border VAT fraud.

Due to the hypothesized fraud-reducing effect of e-invoicing in Italy, we predict a negative coefficient δ in Eq. (2). Our panel data enables us to include unit and time fixed effects. γ_{ep} reflects unit fixed effects as exporting-country-8-digit CN code combinations and λ_t represents time fixed effects as continuous month-year combinations.

X_{ept} is a vector of control variables that contains the variables $\text{THRESHOLD GAP}_{\text{et}}$, REDUCED A_p, REDUCED B_p, REDUCED C_p and EURO_{e}. $\text{THRESHOLD GAP}_{\text{et}}$ captures differences in reported exports and imports due to different thresholds for reporting obligations for these trade flows that each country is required to set within the Intrastat system (see for thresholds Table 12, Appendix).[20] The variables REDUCED A_p, REDUCED B_p and REDUCED C_p are dummies equal to one if the VAT rate in Italy on the specific product p is reduced to 10%, 5% or 4%, respectively, and zero otherwise. These dummies serve to capture VAT rate effects.[21] If fraudsters take the VAT rate into account, as higher rates should technically increase their profits, reduced rate products should be unattractive for

[19] There is no change in product allocation between both groups within the observation period.

[20] $\text{THRESHOLDGAP}_{\text{et}} = \ln\left(\frac{\text{THRESHOLD}_{\text{et}}}{\text{THRESHOLD}_{\text{t}}}\right)$. EU Member States are obliged to estimate missing trade due to thresholds, fraud and other reasons. However, since we obtain 8-digit CN codes from the bulk download option provided by Eurostat (see https://ec.europa.eu/eurostat/data/bulkdownload), those estimations are excluded as they are indicated by alphanumeric product codes.

[21] The reduced (10%, 5% and 4%) and standard (22%) VAT rates in Italy remain constant within the observation period. Including dummies that indicate reduced VAT rate leaves all other products to the baseline. This group consists of products falling under the standard VAT rate but also that are tax exempted. The list of tax exemptions can be found in Article 10 of the Presidential Decree No. 633/1972. Due to our observation window, we checked Article 10 effective from 3 Aug 2017 to 31 Dec 2019. However, there are no clearly distinguishable products since mostly services are covered or products that are only tax exempted under certain circumstances or with certain characteristics.

Table 1 Descriptive statistics of ln TDG

lnTDG (dependent variable)		Observations	Mean	Standard deviation	Minimum	Maximum
TREAT = 0	if POST = 0	12,200	0.0266	1.8705	− 12.1698	11.9568
	if POST = 1	13,259	− 0.0332	1.9731	− 12.6402	10.8908
TREAT = 1	if POST = 0	617,474	0.2624	1.8838	− 15.1976	14.2156
	if POST = 1	679,090	0.0683	1.9699	− 14.2465	16.7204

Equation (1) shows the calculation for ln TDG. POST is a time dummy that equals zero 12 months before e-invoicing became mandatory for all products in Italy in January 2019 and equals one 12 months after December 2018. TREAT is a dummy equal to one if the product is assigned to the treatment group (non-RCM and non-FUELS) and zero if it is assigned to the control group (RCM)

them. We therefore expect a lower ln TDG for these products. Further, we include EURO_e that serves to absorb differences in trade data that could occur due to currency conversion (Loschky, 2006). The variable drops as soon as unit fixed effects are included. The error term is represented by ε_{ept}. All variables with explanations are displayed in Table 10 (Appendix). See also Table 11 (Appendix) for descriptive statistics on all control variables.

4.2 Event study and parallel trends

Given our difference-in-differences approach, treatment and control groups must share similar pre-trends. We provide graphical and statistical evidence to test this assumption. Graphic A of Fig. 1 displays the simple mean values of ln TDG for treatment and control group by each period. Treatment products show a significantly higher mean ln TDG before the reform compared to control products. It is noteworthy that the control group exhibits stronger fluctuations than the treatment group. However, before the reform, both groups exhibit similar directions in terms of increases and decreases of ln TDG. In period 0 (January 2019) and 1 (February 2019), the treatment group shows a decreasing trend of ln TDG in both months, while the control group increases. Beyond that, the treatment group lingers at a significantly lower level as prior to the reform, close to the level of the control group. A sharp decline of ln TDG can also be seen already in the two months before the event. However, this occurred equally for both groups, potentially caused by reporting issues.

To test the parallel trends assumption more formally and to obtain dynamic effects, we estimate an event study specification of Eq. (2) that reads

$$\ln \text{TDG}_{\text{ept}} = \gamma_{\text{ep}} + \lambda_t + \sum_{k \neq -1; k = -12}^{11} \delta_k \left(D_t^k \times \text{TREAT}_{\text{p}} \right) + \beta X_{\text{ept}} + \varepsilon_{\text{ept}} \tag{3}$$

in which $D_t^k = 1[t = Period_0 + k]$ and thus includes dummies turning one when the reform is k months from the start of the reform in period $k = 0$. The period

immediately prior to introduction ($k = -1$) is not included in the equation and represents the base period, which is set to zero by convention. This dynamic specification includes periods before (pre-trends) and after (dynamic effects) the introduction of e-invoicing. We expect δ_k to be around zero for $k < 0$ and negative for $k \geq 0$. Graphic B of Fig. 1 presents the estimated event study coefficients. The picture reveals that with the exception of the periods close to the ends of the observation window, the coefficients are close to zero directly prior to the reform. In the first period of the event, the coefficient drops visibly and stays negative for the majority of the postreform periods.

We keep the observation window short so that other policy changes aiming at increasing compliance interfere minimally with pre- and post periods. However, we want to discuss briefly the implementation of certain other measures during the sample period.[22,23] Before the SdI was technically ready to process cross-border invoice data in 2022, Italy first demanded so-called *Spesometro* declarations. From 2011 to 2018, Italian taxpayers were obliged to report invoice data including import and export information in a quarterly or bi-annual report. In 2019, the *Esterometro* replaced the system by implementing a mandatory monthly filing of VAT sales and purchases made to or acquired from non-resident businesses since the SdI did not include cross-border invoice data. However, these reports did not release taxpayers from the obligation to file Intrastat declarations.[24] In general, it cannot be ruled out that a shortening of the reporting period has an impact on cross-border VAT fraud. However, the planned introduction of *Esterometro* has been postponed to April 30, 2019. Moreover, the Italian Ministry of Economy and Finance has also extended filing deadlines of the predecessor regulation (*Spesometro*) for 2018.[25]

[22] The official announcement of the adoption of e-invoicing can be traced back to the official Italian Budget Law for 2018 (Law no. 205/2017) made public December 27, 2017. Unfortunately, checking for anticipation is hampered by a significant change in the importing Intrastat threshold, which increased from € 200 thousand in 2017 to € 800 thousand in 2018 (Eurostat, 2017, 2021). This came along with the obligation to declare monthly Intrastat reports instead of quarterly if a taxpayer exceeded € 200 thousand in EU-imports in one of the quarters 2017 (Italian Revenue Agency, 2017). Note that there is no estimation for trade carried out below the threshold. Hence, for pure reporting reasons, a higher import threshold leads to less reported imports and a higher trade gap, holding the export threshold constant. Controlling for THRESHOLD GAP may not capture this difference when treatment and control group products are differently affected, which we can neither confirm nor reject. For the years from 2020 onward, limiting the period to December 2019 rules out confounding effects of additional measures such as the tax receipt lottery for B2C transactions and possible other fraud possibilities due to COVID-19.

[23] Already mid-2017, Italy widened the scope of the split payment mechanism from transactions to the public administration in 2015 to all companies controlled by the public administration and to companies listed in the FTSE-MIB index of the Italian Stock Exchange (Italian Ministry of Economy and Finance, 2018b). Under this mechanism, the buyer pays the VAT to a blocked account, which the supplier cannot access automatically. However, the scope is limited to the specified recipients and we believe that it does not interfere with the observation period.

[24] Institutional information is accessible over the following websites: https://taxbackinternational.com/blog/italy-spesometro-esterometro-reports/ and https://www.avalara.com/vatlive/en/country-guides/europe/italy/italian-spesometro-declaration.html. Both accessed 7 July 2023.

[25] Decree of the president of the council of ministers on 27 Feb 2019: https://www.gazzettaufficiale.it/eli/id/2019/03/05/19A01521/sg.

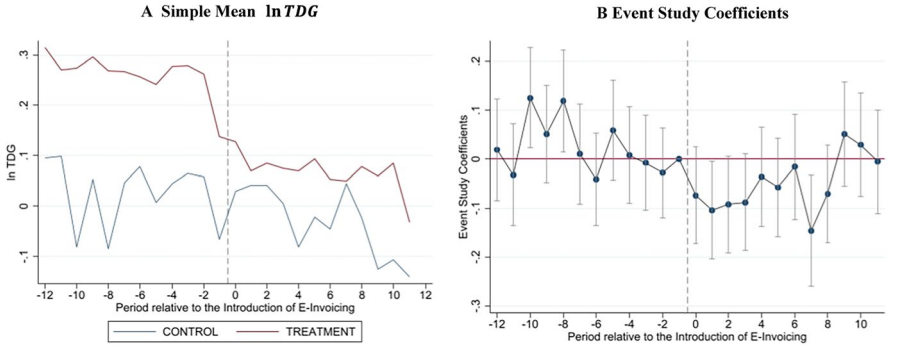

Fig. 1 Development of ln TDG. *Notes* Graphic A shows the mean value of ln TDG as defined in Eq. (1) for treatment (red) and control (blue) by each month within the 24-month observation window. Graphic B shows the event-study coefficients from Eq. (3). Grey lines indicate the 90% confidence interval (Color figure online)

5 Results

Table 2 presents our baseline results for ln TDG displaying all variables included in the model. The coefficient of POST is negative, but statistically significant only when including unit or alternative time fixed effects and suggests a general decreasing trend of ln TDG in Italy. TREAT, on the other side, shows positive coefficients throughout the specifications indicating that the treatment group suffered from higher fraud prior to the reform compared to the control group. This result confirms our rationale for identifying RCM products as a control group.

The main variable of interest is the interaction of both variables. The corresponding coefficient is negative and statistically significant throughout the specifications (see Table 2, Columns 1 to 8). Noteworthy, fixed effects control for a large share of the variation as the adjusted R^2 increases significantly after including unit fixed effects. Simultaneously, the coefficient of the interaction drops from -0.136 in Column 3 to -0.073 in Column 4 (see Table 2). The exclusion of the control variables does not change the results (see Table 2, Column 6).

For robustness, we modify unit and time fixed effects and include them on a higher hierarchy. We use exporter-4-digit HS codes instead of exporter-8-digit CN codes regarding unit fixed effects and quarter-years instead of month-years as time fixed effects. As expected, including the alternative set of fixed effects lowers the adjusted R^2 since these fixed effects capture less variation. The interaction effect increases slightly in magnitude to -0.103 (see Table 2, Columns 7 and 8). Nevertheless, we believe that the specification from Column 5 gives us the best estimate, adequately controlling for omitted variables and lets us observe the preferred within variation of exporter-8-digit CN codes combinations. Finding this robust negative effect throughout the specifications strongly supports our hypothesis that mandatory e-invoicing reduced cross-border VAT fraud in Italy. Regarding Column 5 (Table 2), the application of e-invoicing in Italy is associated with a reduction of the TDG by approximately 7%.

Table 2 Baseline results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
POST	−0.060	−0.059		−0.108***				−0.084**
	(0.037)	(0.037)		(0.033)				(0.035)
TREAT	0.236***	0.261***	0.261***				0.314**	0.314**
	(0.040)	(0.040)	(0.040)				(0.135)	(0.135)
POST×TREAT	−0.134***	−0.136***	−0.136***	−0.073**	−0.073**	−0.073**	−0.103***	−0.103***
	(0.037)	(0.037)	(0.037)	(0.033)	(0.033)	(0.033)	(0.035)	(0.035)
EURO		0.081***	0.080***					
		(0.012)	(0.012)					
THRESHOLD GAP		−0.049***	−0.049***	−0.360***	−0.360***		−0.364***	−0.364***
		(0.009)	(0.009)	(0.043)	(0.043)		(0.045)	(0.045)
REDUCED A		−0.201***	−0.201***	−0.712***	−0.720***		−0.299*	−0.298*
		(0.019)	(0.019)	(0.003)	(0.006)		(0.156)	(0.156)
REDUCED B		0.031	0.031					
		(0.157)	(0.158)					
REDUCED C		−0.243***	−0.243***				−0.417	−0.418
		(0.030)	(0.030)				(0.380)	(0.380)
Observations	1,322,023	1,322,023	1,322,023	1,322,023	1,322,023	1,322,023	1,322,023	1,322,023
Adjusted R^2	0.003	0.004	0.005	0.484	0.484	0.484	0.137	0.137
Unit FE	No	No	No	Yes	Yes	Yes	No	No
Time FE	No	No	Yes	No	Yes	Yes	Yes	No
Exporter-4-digit HS code FE	No	No	No	No	No	No	Yes	Yes
Quarter FE	No	No	No	No	No	No	No	Yes

The dependent variable is ln TDG, defined in Eq. (1). The importing country is Italy. Exporting countries are all other EU Member States. For explanations on variables, see Table 10 in Appendix. The corresponding correlation matrix is displayed in Table 13, Panel A in Appendix. The identifier for unit FE is a combination of exporting country and the 8-digit product code. Regressions are calculated using OLS. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

Our first control variable EURO is positively correlated with the dependent variable (see Table 2, Column 2; due to collinearity with unit fixed effects, the variable drops out from Column 3). This result could be explained by the fact that intra-Eurozone fraud avoids currency exchange risks and is therefore more lucrative. Concerning THRESHOLD GAP, the negative coefficient is plausible as the variable sets the reporting threshold for exports in relation to the reporting threshold for imports. An increase in this variable reflects a relative increase in non-reported exports to imports, which reduces ln TDG. Note that country-specific estimations for non-reportable trade below the thresholds are not included in the trade figures. REDUCED A and (in some cases) REDUCED C show a negative and statistically significant coefficient as well, indicating that reduced VAT rate products are less appealing to fraudsters. This result is reasonable since a lower tax rate reduces their profits. REDUCED B is omitted from all specification including fixed effects due to collinearity. We note that the control variables do not change the results in any way. However, we keep them throughout the regressions and robustness checks later on, as they might capture some specific fraud behavior that is not controlled for by fixed effects.

6 Robustness checks

6.1 Alternative control group

In our first robustness test, we want to address the concern that trade with RCM products could still contain fraud, since e.g. B2C transactions are not fully covered by this mechanism. We are convinced by the empirical evidence and our exercise from Table 8 (Appendix) that the RCM removes fraud to a significant extent. This can be underpinned by the nature of cross-border VAT fraud, which is based on high-value transactions taking place at the B2B rather than the B2C level. Nevertheless, we want to address this concern. Therefore, we additionally make use of an alternative control group to check the robustness of our initial results. We modify our empirical setting and replace the initial control group (RCM products in Italy) with non-RCM products in other importing countries that did not adopt e-invoicing. Considering the 2018 VAT gap study by Poniatowski et al. (2020), Greece, Lithuania, Romania and Slovakia show similar levels of VAT gaps for the year 2018 and are therefore used as an alternative control group.

According to the above-mentioned strategy, we modify Eq. (2) as follows. The dummy variable TREAT takes on the value of one if the importing country is Italy and zero if the importing country is Greece, Lithuania, Romania or Slovakia.[26] Note that the respective equation gets an additional subscript i since the variation now also stems from the fact that we observe different importing countries and country pairs. The correlation matrix (Table 13, Panel B) and the descriptive statistics (Table 14) regarding the alternative control group are displayed in Appendix.

[26] Due to data availability, we restrict the set of control variables to EURO and THRESHOLD GAP.

Referring to the descriptive statistics, we can observe that the mean ln TDG of the control countries is relatively low and increases slightly from 0.0167 to 0.0302 after the introduction of mandatory e-invoicing in Italy. Despite the high VAT gaps, the low TDG indicates less cross-border VAT fraud activity in these countries before the Italian reform. Figure 2, Graphic A displays the differences in the mean ln TDG for treatment (Italy) and control countries (Greece, Lithuania, Romania and Slovakia) regarding non-RCM products. The level of the Italian ln TDG is visibly higher pre-reform and significantly closer to the control units afterward. Graphic B of Fig. 2 presents the event-study coefficients that show a sharp decline from period 0, staying constantly on a negative level.

Table 3 displays the regression table for our alternative control group specification. We can observe a negative and statistically significant interaction throughout the specifications. The coefficient of interest is −0.201 (see Table 3, Column 4) in the main specification. Thus, non-RCM products in Italy show a considerably lower TDG after the introduction of e-invoicing compared to the control country units. Noteworthy, the magnitude is higher compared to the baseline results, reflecting a more severe decrease of the treatment group compared to the control group. This might be due to a spillover effect of the Italian reform on the control countries. In this regard, we observe a positive coefficient for the main effect POST when it is included. This indicates that within our alternative sample, and in the absence of the reform, the TDG would have developed slightly upward. This is contrary to our baseline results (we observed a downward trend in the absence of the reform) and may be indicative for the spillover hypothesis. Finally, the coefficient on TREAT is positive when included. This confirms that treatment products suffered higher fraud activities prior to the reform.

6.2 Alternative dependent variables

In this section, we check if our baseline results hold when we change the dependent variable. First, we use ln TDG calculated analogous to Eq. (1) using quantities instead of values. Second and third, we winsorize and trim the value-based ln TDG at the bottom and top 1% by each exporting country, respectively. Therefore, we try to control for outliers in the data. Fourth and fifth, we examine the effect on the natural logarithm of export and import, respectively. In this case, we include the opposite trade flow (ln Import or ln Export, respectively) into the model as control variables. Therefore, we test our estimation assumptions used in the following section, according to which we expect to observe falling exports and/or rising imports.

Table 4 presents the results for all described alternative dependent variables. The coefficient of −0.063 for ln TDG in quantities (see Table 4, Column 1) is statistically significant and comparable to our initial result (−0.073 in Table 2, Column 5). This strongly confirms our baseline result and indicates that fraudsters underreport values and quantities, which strengthens the assumption that missing traders fail to report imports at all. Winsorizing and trimming ln TDG and therefore excluding outliers hardly affect the quantity of the estimator (see coefficient in Table 4, Columns 2 and 3). That gives us additional confidence regarding our baseline model.

Interestingly, the coefficient on the interaction regarding ln Export is insignificant (see Table 4, Column 4), suggesting that export values did not change after e-invoicing. On the other side, we find a positive and statistically significant coefficient regarding ln Import (see Table 4, Column 5). This result could be indicative that honest traders took over trade from fraudsters that left the market after the reform. Unlike the fraudsters, we expect compliant traders to declare the imports due to business expense deduction, which results in a positive coefficient. To this extent, it seems reasonable that export reporting did not change. However, our model cannot pick up the reason why we observe or not observe certain reactions in specific export and import behavior. Using trade data gaps is more sophisticated in detecting changes in fraudulent trade. Therefore, we leave the interpretation to the reader and assume in the following section that changes in ln TDG can occur due to both decreases in exports and increases in imports.[27]

6.3 Restricted treatment group

In this section, we restrict the group of treated products to those that fall under the same 2-digit and 4-digit HS code as the RCM products, respectively.[28] This procedure modifies the treatment group with the aim to make it more comparable to the control group as the baseline treatment group covers many different products. Note that throughout RCM products form the control group and do not change compared to the baseline approach. Table 5 presents the results. The statistically significant coefficient of the interaction within the 2-digit HS code sample is very close to our main result (−0.074 in Table 5, Column 1 vs. −0.073 in Table 2, Column 5). The corresponding coefficient from the regression based on the 4-digit HS code is with −0.215 almost three times larger (Table 5, Column 2). In this case, the sample size is significantly smaller due to the reduction of the treatment group.[29] However, we find significant effects also by decreasing the number of treatment products and making them theoretically more similar to the control products, which supports the suggestive evidence gained so far.

[27] We estimate boundaries based on both, exports and imports to capture all variations that could lead to a lower TDG.

[28] In this case, we use the first two or four digits from the 8-digit product code. We are aware of further matching procedures like propensity score matching or entropy balancing. However, these procedures rely on the identification of matches (in this case matched treatment and control products) based on a set of characteristics that have an effect on the assignment to treatment or control group and the outcome variable. Those (product specific) characteristics are unobservable which is why we refrain from these procedures and create adequate workarounds.

[29] Next to the assumed higher comparability, the finding could reveal a possible spillover effect that is reversed by e-invoicing. The earlier introduction of RCM on fraud-prone products might have caused fraudsters to use other but comparable products. Fraudsters switched to other products of the same product category rather than to a complete different product group since they may have installed an effective supply chain including exporters, fraudsters and other involved firms. Under the premise that e-invoicing reduces fraud, we consequently observe stronger effects with these fraud-prone products. However, our model cannot detect any previous spillovers on these similar treatment products. Therefore, our hypothesis is mostly opinion based and has to be taken with caution.

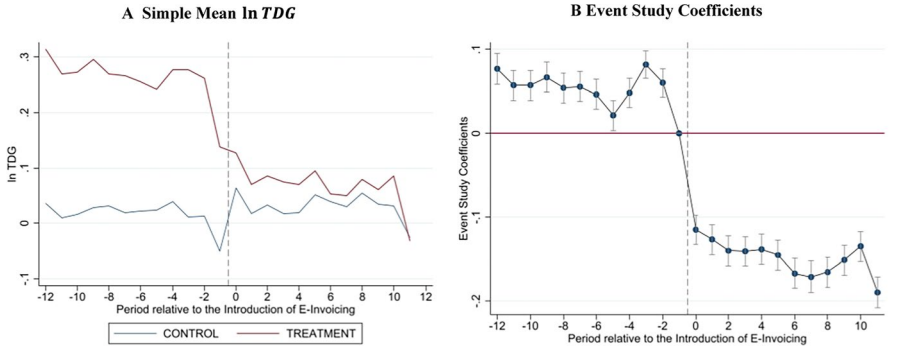

Fig. 2 Development of ln TDG—alternative control group. *Notes* Graphic A shows the mean value of ln TDG as defined in Eq. (1) for treatment (red) and alternative control (blue) group (non-RCM products in Greece, Lithuania, Romania and Slovakia) by each month of the 24 months observation window. Graphic B shows the event-study coefficients from Eq. (3) using the alternative control group. Grey lines indicate the 90% confidence interval (Color figure online)

Table 3 Alternative control group

	(1)	(2)	(3)	(4)
POST	0.013***	0.014***		
	(0.003)	(0.003)		
TREAT	0.246***	0.251***		
	(0.006)	(0.009)		
POST×TREAT	−0.208***	−0.208***	−0.199***	−0.201***
	(0.006)	(0.006)	(0.005)	(0.005)
Observations	4,520,922	4,520,922	4,520,922	4,520,922
Adjusted R^2	0.002	0.002	0.456	0.456
Unit FE	No	No	Yes	Yes
Time FE	No	No	Yes	Yes
Controls	No	Yes	No	Yes

The dependent variable is ln TDG, defined in Eq. (1). The sample consists only of non-RCM products and in case of Italy also non-FUELS products and contains the importing countries Italy, Greece, Lithuania, Romania and Slovakia. Exporting countries are all other EU Member States. For explanations on variables, see Table 10 in Appendix. The corresponding correlation matrix is displayed in Table 13, Panel B in Appendix. Controls include THRESHOLD GAP and EURO. The identifier for unit FE is a combination of country-pair and the 8-digit product code. Regressions are calculated using OLS. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

Table 4 Alternative dependent variables

	ln TDG using quantities (1)	Winsorized ln TDG (2)	Trimmed ln TDG (3)	ln Export (4)	ln Import (5)
POST×TREAT	−0.063*	−0.073**	−0.070**	0.002	0.095***
	(0.034)	(0.031)	(0.028)	(0.026)	(0.029)
Observations	1,299,168	1,322,023	1,295,633	1,322,023	1,322,023
Adjusted R^2	0.494	0.485	0.458	0.863	0.840
Unit FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

In Column 1, the dependent variable is ln TDG using quantities instead of values analogously to Eq. (1). In Columns 2 to 3, the dependent variable is the value-based ln TDG winsorized and trimmed, respectively, at the bottom and top 1% by each exporting country. In Columns 4 and 5, the dependent variable is the natural logarithm of export reported by the exporting country to Italy and the natural logarithm of import from the exporting country reported by Italy, respectively. Exporting countries are all other EU Member States. For explanations on variables, see Table 10 in Appendix. In Columns 4 and 5, the natural logarithm of import and export, respectively, is included as control. Regressions are calculated using OLS. The identifier for unit FE is a combination of exporting country and the 8-digit product code. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively

Table 5 Alternative treatment groups

	Same 2-digit HS code treatment group (1)	Same 4-digit HS code treatment group (2)
POST×TREAT	−0.074**	−0.215***
	(0.034)	(0.069)
Observations	454,661	34,484
Adjusted R^2	0.480	0.504
Unit FE	Yes	Yes
Time FE	Yes	Yes
Controls	Yes	Yes

The dependent variable is ln TDG, defined in Eq. (1). The importing country is Italy. Exporting countries are all other EU Member States. In contrast to our baseline model, TREAT only contains treatment products falling under the same 2-digit HS code (Column 1) or 4-digit HS code (Column 2) in respect of the RCM products. For explanations on variables, see Table 10 in Appendix. Controls include in these specifications only THRESHOLD GAP. Regressions are calculated using OLS. The identifier for unit FE is a combination of exporting country and the 8-digit product code. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

7 Quantification of fraud tackled by e-invoicing

The previous results provide suggestive evidence that e-invoicing tackled cross-border VAT fraud by decreasing the TDG. Throughout, the interaction coefficient δ from Eq. (2) captures the decrease in the level of the TDG for treatment products due to e-invoicing. Therefore, exports (imports) of treatment products in 2018 were abnormally high (low) due to fraudulent activity. Mechanically, the TDG decreases when exports (imports) decrease (increase). Therefore, we use simple back-of-the-envelope calculations to estimate the amount of VAT revenue loss (REVLOSS) in the year prior to the reform using the following formulas, separately based on exports and imports:

$$\text{REVLOSS}_{\tau}^{\text{EXP}_{2018}} = \text{EXPORT}_{\tau}^{2018} \times \left(1 - e^{\delta_{\text{weighted}}}\right) \times \text{VAT}_{\tau} \tag{4}$$

$$\text{REVLOSS}_{\tau}^{\text{IMP}_{2018}} = \text{IMPORT}_{\tau}^{2018} \times \left(e^{-\delta_{\text{weighted}}} - 1\right) \times \text{VAT}_{\tau} \tag{5}$$

In simple terms, Eqs. (4) and (5) calculate the amount of export excess and import deficit resulting from abnormally high exports and abnormally low imports in 2018 backward from the TDG reduction observed with δ.[30] There are four different VAT rates ($\text{VAT}_{\tau};\tau$) for which we calculate REVLOSS in Table 15 in Appendix. We use the sum of exports to Italy reported by the 27 exporting countries (EXPORT^{2018}) and the sum of imports reported by Italy from the 27 exporting countries (IMPORT^{2018}).

In general, the interaction coefficient δ estimates the reduction of the TDG. Therefore, we recalculate the amount of exports or imports that have led to this increased TDG in 2018 compared to 2019. These exports and imports are the base of fraudulent trade assumed to be carried out domestically by fraudsters. Therefore, we multiply each export excess and import deficit with the respective VAT rate to obtain the amount evaded in the year prior to the reform. Table 15 (Appendix) outlines the detailed values used in the calculation steps. Note that in the case where Italy refused to refund input VAT to a taxable buyer, part of REVLOSS was recovered. However, we could not find any statement of how much input VAT deduction was refused by Italy.

In the baseline regression, we estimate an unweighted average effect of the reform that could bias our estimation exercise if e.g. a product with significantly higher trade volume experiences a stronger or weaker decline after e-invoicing. To estimate REVLOSS, we re-run our baseline regression weighting each observation by export or import volume of a product relative to all other products prior to the reform, respectively. Combining this weighted approach with the estimation of export- or import-based values, gives us a range of four alternatives. If previously declared exports to the fraudsters are eliminated through e-invoicing, the TDG reduces (export-based estimation). The other possible outcome is that honest

[30] The dependent variable is the natural logarithm of the trade data gap (ln TDG), defined as the natural logarithm of exports over imports. Hence, we use the reverse operation e^{δ} to calculate the effects in percentage.

Table 6 Results – weighted by export and import share

	weight = export share (1)	weight = export share (2)	weight = export share (3)	weight = import share (4)	weight = import share (5)	weight = import share (6)
POST	0.048			0.043*		
	(0.034)			(0.026)		
TREAT	−0.002			0.048		
	(0.078)			(0.095)		
POST×TREAT	−0.046	−0.064*	−0.056*	−0.059**	−0.054*	−0.048*
	(0.035)	(0.035)	(0.033)	(0.028)	(0.028)	(0.027)
Observations	1,322,023	1,322,023	1,322,023	1,322,023	1,322,023	1,322,023
Adjusted R^2	0.000	0.592	0.593	0.000	0.562	0.562
Unit FE	No	Yes	Yes	No	Yes	Yes
Time FE	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes

The dependent variable is ln TDG, defined in Eq. (1). The weight is based on the export or import volume of each product relative to all other products in 2018 as indicated above each column. The importing country is Italy. Exporting countries are all other EU Member States. For explanations on variables, see Table 10 in Appendix. The identifier for unit FE is a combination of exporting country and the 8-digit product code. Regressions are calculated using OLS. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

importers become more active after the fraudsters are pushed out of the respective market, which increases the declaration of imports, and therefore decreases the TDG (import-based estimation).

The results of the weighted regressions are displayed in Table 6. The coefficients of the interaction are statistically significant and reduced to −0.056 using the export share as weight (Table 6, Column 3) and −0.048 using the import share as weight (Table 6, Column 6) compared to the unweighted baseline result of −0.073 (Table 2, Column 5). If we insert the two new coefficients into Eqs. (4) and (5), we obtain a range for REVLOSS between € 2.2 billion and € 2.6 billion (see Table 15, Appendix, and in particular Columns 12 to 15).[31] Hence, e-invoicing tackled cross-border VAT fraud accounting for about 7% of overall uncollected VAT given the total VAT gap of Italy of € 32.415 billion in 2018.[32]

The Italian Ministry of Economy and Finance (2020) estimates the effect of e-invoicing for 2019 using macro-level data and calculates an unexplained residual between actual VAT revenue and the VAT revenue theoretically paid based on the economic cycle of € 1.7 billion and € 2.1 billion. Note that this approach captures all compliance increases by e-invoicing regardless of the cross-border nature. Comparability to our estimate is limited since Italy estimates a figure for 2019, while we are estimating the amount of fraud that could have been carried out in 2018. However, Italy stated that they identified "companies involved in intra-Community fraud mechanisms carried out between the last months of 2019 and 2020, based on invoicing flows for non-existent transactions amounting to around EUR 1 billion" (European Commission, 2021). Together with our results, this indicates that e-invoicing initially reduced cross-border VAT fraud but did not eliminate the fraud activities entirely.

By nature, we lack of precise proxies with regard to tax fraud, but the estimation underpins the significant extent of cross-border VAT fraud and helps to assess the effects of the reform as precisely as possible. Considering the comparably low investment cost of about € 3.7 million and running cost of the mandatory e-invoicing system, amounting to € 10 to 20 million a year, our results provide a strong argument in favor of this tool for combating VAT fraud (Italian Revenue Agency, 2021; Italian Ministry of Economy and Finance, 2018a).[33]

[31] We estimate Eqs. (4) and (5) using all given decimal places by Stata for the coefficients on the interaction term that is −0.0556129 and −0.0483151 for $\delta_{weighted}$ using export share weights and import share weights, respectively. However, we obtain a quantitatively similar range of REVLOSS between € 2.2 and € 2.6 billion using the 2018 mean of exports (imports) that is an average monthly value of exports (imports) of a certain product from a certain exporting country and multiplying this with the mean value of country pair-product observations (panel ID variable), the mean VAT rate and $\delta_{weighted}$ times 12. Multiplying by 12 months leads to a yearly amount based on the average monthly values. In an earlier version of this paper, we calculated € 0.6 billion to € 1.0 billion as the VAT fraud tackled by the reform. However, this figure was based on country-specific estimates that did not take non-significant results into account (see Table 16 in Appendix).

[32] We use a mid-point estimate between € 2.2 and 2.6 billion and divide this by the VAT gap of € 32.415 billion.

[33] While the Italian Ministry of Economy and Finance (2018a) states that the running costs of the system are about € 10 million a year, a white paper from May 2021 by the Italian Revenue Agency (2021) states an amount of € 20 million. In this document, € 2.5 million is allocated to the initial set-up costs regarding B2G invoicing in 2015 and additional € 1.2 million to extent the system to B2B and B2C invoicing.

The estimation results are subject to some external constraints. Clearly, the observed VAT revenue and fraud-reducing effect is an Italian specific estimate. Since the level of pre-reform cross-border fraud is an important factor regarding the effectiveness of the mandatory e-invoicing, generalizations for other countries from the results need to be made with caution. As we discussed regarding the parallel trends assumption, we cannot rule out some anticipation of increased fraud in 2018.

8 Conclusion

The numerous measures taken against VAT fraud (such as RCM), as well as the ongoing significant revenue losses, make studies on the effectiveness of these countermeasures particularly important. In 2019, Italy introduced a mandatory e-invoicing system for B2B and B2C supplies, taking a pioneering role in the EU in the timely recording and control of transactions. This paper examines the effect of digitalization in form of e-invoicing in Italy on cross-border VAT fraud using discrepancies in double-reported trade data between Italy and the remaining EU Member States on product flows based on the 8-digit product code. As control group, we use products falling under RCM since recent empirical evidence suggests the fraud-eliminating effect of this measure. All other products serve as the treatment group.

We find a significant reduction of cross-border VAT fraud with the introduction of the mandatory e-invoicing system. This result holds for a number of robustness checks. Additionally, we quantify the reform in Italy using a back-of-the-envelope calculation and estimate that cross-border VAT fraud in 2018 led to VAT revenue losses between € 2.2 billion and € 2.6 billion tackled by the reform. Our findings indicate a desirable fraud-reducing effect of a mandatory e-invoicing system easily exceeding the set-up and running costs of such system. Even though the e-invoicing system covered only domestic transactions, it demonstrates a considerable deterrent effect on cross-border VAT fraud activities. The results provide key insights into the benefits of digitalization.

Appendix A

See Table 7, 8, 9, 10, 11, 12, 13, 14, 15.

Table 7 Product descriptions

Panel A: Frequencies in percent (%) and quantity (#) of baseline sample products by the first-digit product code and number of unique products (#Unique) by each first-digit product code

First-digit product code	0	1	2	3	4	5	6	7	8	9	Total
%	7.19	4.37	8.63	9.06	7.78	5.40	13.11	10.64	25.04	8.77	100.00
#	95,006	57,824	114,080	119,840	102,902	71,402	173,369	140,642	330,980	115,978	1,322,023
#Unique	1,112	530	1,369	648	600	667	667	898	1,765	544	8,800

Panel B: Examples of products by each first-digit product code

First-digit product code = 0	Living animals (01), meat (02), fish and crustaceans (03), dairy products, eggs, hones, edible products of animal origin (04 and 05), trees and other plants, bulbs, roots (06), vegetables, plants, roots and tubers used for nutritional purposes (07), edible fruits and nuts (08), coffee, tea, mate and spices (09)
First-digit product code = 1	Grain (10), milling products, malt, wheat gluten (11), oilseeds and oleaginous fruits, various grains, seeds and fruits, plants for industrial or medicinal use (12), shellac, glues, resins and other plant saps and extracts (13), vegetable braiding materials (14), animal and vegetable fats and oils, processed edible fats and waxes (15), preparations of meat, fish or crustaceans (16), sugar (17), cocoa (18), preparations made from cereals, flour starch or milk (19)
First-digit product code = 2	Preparations made from vegetables, fruits, nuts (20), various edible preparations (21), beverages, spirits, and vinegar (22), residues and waste from food industry (23), tobacco and processed substitutes (24), salt, sulfur, earth and stones, plasters, cement (25), ores, slag and ash (26), mineral fuels, mineral oils and products of distillation, bituminous substances, mineral waxes (27), inorganic chemical products, organic and inorganic compounds of precious metals, rare earth metals, radioactive elements (28), organic chemicals (29)
First-digit product code = 3	Pharmaceutical products (30), fertilizer (31), tanning and dye extracts and derivatives (32), essential oils and resinoids, perfumed, toiletry or beauty preparations (33), soaps, organic surfactants, detergent preparations, lubricant preparations, artificial and prepared waxes, shoe polish, scouring powders, candles (34), proteins (35), powder and explosives, pyrotechnic products, matches (36), goods for photographic or cinematographic purposes (37), miscellaneous chemical products (38), plastics and goods made therefrom (39)

Table 7 (continued)

Panel B: Examples of products by each first-digit product code	
First-digit product code = 4	Rubber and goods made therefrom (40), raw hides, skins and leather (41), goods made from leather, saddlery, travel goods, handbags and similar containers (42), furskins and artificial furs (43), wood and wood products (44), cork and goods made from cork (45), goods made of straw, basketry and wickerwork (46), pulp of wood and other fibrous materials (47), paper and cardboard, goods made from paper pulp, paper or cardboard (48), books, newspapers, pictures and other graphic arts products, manuscripts, typescripts and plans (49)
First-digit product code = 5	Silk (50), wool, fine or coarse animal hair, yarn and fabric of horsehair (51), cotton (52), other vegetable textile fibers (53), sewing thread of synthetic or artificial filaments (54), synthetic staple fibers (55), wadding, felt and non-woven fabrics, specialty yarn, twine, ropes and goods made from these materials (56), carpets and other textile floor coverings (57), special fabrics, tufted textile fabrics (58), impregnated, coated, covered or layered fabrics (59)
First-digit product code = 6	Knitted or crocheted fabrics (60), articles for clothing and clothing accessories (61), articles of clothing and clothing accessories not knitted or crocheted (62), other made up textile goods, worn clothing (63), shoes, spats and similar goods (64), headgear and parts thereof (65), umbrellas, parasols, walking sticks, seat sticks, whips, riding crops and parts thereof (66), prepared feathers, artificial flowers, goods made from human hair (67), goods of stone, plaster, cement, asbestos, mica or similar materials (68), ceramic products (69)
First-digit product code = 7	Glass and glassware (70), natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and goods made of these materials, fantasy jewelry, coins (71), iron and steel (72), goods of iron and steel (73), copper and articles thereof (74), nickel and goods made from it (75), aluminum and goods made from it (76), lead and articles mad from it (78), zinc and articles thereof (79)
First-digit product code = 8	Pewter and articles thereof (80), other base metals (81), tools, cutlery, spoons and forks, of common metal (82), miscellaneous goods of base metals (83), nuclear reactors, boilers, machinery and mechanical equipment (84), electric machines, apparatus and devices and parts thereof, sound recorders and reproducers, televisions (85), rail vehicles, stationary track material, mechanical signaling devices for traffic routes of all kinds (86), vehicles, except rolling stock for railways and trams (87), aircraft, spacecraft and parts thereof (88), ships, boats and floating devices (89)

Table 7 (continued)

Panel B: Examples of products by each first-digit product code	
First-digit product code = 9	Optical, photographic, cinematographic, measuring, testing, precision, medical or surgical instruments (90), watchmaking goods (91), musical instruments (92), weapons and ammunition (93), furniture, bedding, mattresses, slatted frames, cushions and similar products (94), toys, games and sports equipment (95), various finished goods (96), works of art, collectibles and antiques (97)

Panel A: The first row shows the frequency in percent based on the sample used in the baseline regressions. The second row displays the number of product-period observations by first-digit product code bin. In the third row, the unique number of products by first-digit product code bin is shown. Panel B: The products falling under each first-digit product code are explained in a general way with the respective 2-digit HS code in parentheses

Table 8 RCM analysis

Panel A: Explanation of estimation procedure

We estimate the effect of RCM using an adopted difference-in-differences model from Stiller and Heinemann (2023) using Italy as the importing country:

$$\ln \mathrm{TDG}_{ept} = \gamma_{epv} + \lambda_{tv} + \delta \mathrm{RCM}_{ipt} + \beta X_{ept} + \varepsilon_{eptv} \quad \text{(A.1)}$$

The sample consists of all traded products (for which RCM was introduced in at least one EU Member State between 2003 and 2019) between Italy as the importing country and all other EU Member States in the event windows April 2010 to March 2012 (introduction on mobile phones and integrated circuits with effect of April 2011) and May 2015 to April 2017 (introduction on game consoles, laptops, and tablet-PCs with effect of May 2016).

RCM_{ipt} is a dummy constructed as an interaction between a post variable turning one in the 12 months after the event and a treatment variable indicating if a product belongs to the treatment group (RCM products, see above). All control products are never-treated products. We estimate the effect of RCM for two event windows using a stacked regression model widely used in the applied literature (Backer et al., 2022). Every event (v) has its own dataset-specific event-exporter-product (unit) fixed effects (γ_{epv}) and event-time fixed effects (λ_{tv}). For control variables (X_{ept}), we follow Stiller and Heinemann (2023) and include the RCM in the exporting country (RCM_{ept}), the VAT rate in in the exporting country (VAT_{et}), the THRESHOLD GAP_{et} and EURO_{e} as defined in Table 10, and the rule of law (RoL_{et}) in the exporting country from the Worldwide Governance Indicators provided from The World Bank. Since the Italian Intrastat threshold is constant in each event window, using THRESHOLD GAP or the logarithmic exporter threshold as in Stiller and Heinemann (2023) is mathematically the same. Standard errors are clustered by event-exporter-product

Panel B: Descriptive statistics		Observations	Mean	Std. dev	Minimum	Maximum
lnTDG	if $\mathrm{RCM}_{ipt}=0$	587,757	0.0667	1.7563	−14.9735	13.8368
	if $\mathrm{RCM}_{ipt}=1$	2,003	−0.1346	1.7922	−12.8949	13.8368
$v=1$&TREAT = 1	if $\mathrm{RCM}_{ipt}=0$	993	0.1718	2.1879	−12.8949	13.8368
	if $\mathrm{RCM}_{ipt}=1$	1,574	−0.1532	1.7570	−9.0626	9.7365
$v=2$&TREAT = 1	if $\mathrm{RCM}_{ipt}=0$	411	0.7142	2.3357	−6.5570	9.2263
	if $\mathrm{RCM}_{ipt}=1$	429	−0.0662	1.9164	−7.6042	7.9067
RCM_{ipt}		589,760	0.0030	0.0550	0	1
RCM_{ept}		589,760	0.0406	0.1973	0	1
VAT_{et}		589,760	20.7559	2.1021	15	27
THRESHOLD GAP_{et}		589,760	0.7133	0.6369	−5.6550	2.0149
EURO_{e}		589,760	0.7577	0.4285	0	1
RoL_{et}		589,760	1.3530	0.5257	−0.1283	2.0894

Panel C: Regression results

	(1)	(2)	(3)
RCM_{ipt}	−0.201**	−0.460***	−0.458***
	(0.084)	(0.104)	(0.103)
Observations	589,760	589,760	589,760
Adjusted R^2	0.000	0.397	0.397
Event-unit FE	No	Yes	Yes
Event-time FE	No	Yes	Yes
Controls	No	No	Yes

Table 8 (continued)

Panel A describes the estimation method and variables used in Panel B and C. Panel B shows the descriptive statistics for the included variables. Panel C displays the regression results using the estimation model from Panel A. RCM_{ipt} is a dummy equal to one for event-specific treatment products (TREAT = 1) after the RCM reform, and zero otherwise. The control group (TREAT = 0) consists of products that are never-treated in Italy but in at least one other EU Member State during 2003 to 2019. v represent the event windows that is $v = 1$ for the introduction of the RCM for mobile phones and integrated circuits with effect of April 2011 and $v = 2$ for the introduction of the RCM for game consoles, laptops, and tablet-PCs with effect of May 2016. Each event covers a window of 24 months (12 months before and with RCM). Panel C: The regression model used is displayed in Eq. (A.1). The dependent variable is ln TDG, defined in Eq. (1). The importing country is Italy. Exporting countries are all other EU Member States. For explanations on variables, see Table 10 in Appendix. The identifier for event-unit FE is a combination of the event, the exporting country and the 8-digit product code. Regressions are calculated using OLS. Standard errors are clustered by the event-unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

Appendix B: Heterogeneity analysis

The following section provides additional tests that aim to explore the heterogeneity of the reform. We perform various splits of the sample and adapt our regression model to uncover the effect of e-invoicing more in detail.

Estimates by exporting country

In this first heterogeneity test, we estimate our baseline regression model separately by each exporting country. It appears that the effect is not homogenous over all exporting Member States. E-invoicing seems to have a statistically significant impact on ln TDG when Estonia, Greece, Hungary or Slovakia is the exporting country. However, ln TDG even increases in case of Estonia. In 17 out of 27 cases, the interaction coefficient is negative, indicating that in the majority of cases the TDG decreases (Table 16).

Different susceptibility to fraud

In this second heterogeneity test, we aim to identify products that were most affected by e-invoicing to check if certain products drive the results. We separate products within the treatment group that could potentially be more affected by fraud prior to mandatory e-invoicing and refer to them as RCM POTENTIAL. This group includes products that could theoretically fall under RCM according to the VAT Directive,[34] but Italy has not (yet) decided to introduce this mechanism on these products (for an overview of RCM applications see Table 9, Appendix). The Council of the European Union classifies fraud-sensitive products as a potential scope of the RCM. However, the lack of inclusion in the RCM could indicate that Italy does not identify fraud within the particular product group. Therefore, the expected relationship is

[34] Council Directive 2006/112/EC of November 28, 2006, on the common system of value-added tax.

Table 9 RCM products by country

Product group falling under RCM	Date of introduction	Source
Italy		
Mobile phones	1.4.2011	Circular of 23/12/2010 No. 59
Integrated circuits	1.4.2011	Circular of 23/12/2010 No. 59
Game consoles	2.5.2016	Legislative Decree No. 24 of 11 February 2016
Laptops and tablet-PCs	2.5.2016	Legislative Decree No. 24 of 11 February 2016
Waste and scrap metals	Since 2003	Art. 74 of Decree No. 633/1972
Selected non-precious metals	Since 2003	Art. 74 of Decree No. 633/1972
Greece		
Mobile phones	1.8.2017	Law 4484/2017
Game consoles	1.8.2017	Law 4484/2017
Laptops and tablet-PCs	1.8.2017	Law 4484/2017
Waste and scrap metals	1.1.2007	Law 3522/2006
Lithuania		
Mobile phones	1.8.2019	Resolution No. 395 of April 24, 2019
Laptops and tablet-PCs	1.8.2019	Resolution No. 395 of April 24, 2019
Hard disks	1.8.2019	Resolution No. 395 of April 24, 2019
Selected wood	1.1.2008	Resolution No. 1390 of December 19, 2007
Waste and scrap metals	1.1.2008	Resolution No. 1390 of December 19, 2007
Romania		
Mobile phones	1.1.2016	Law 227/2015
Integrated circuits	1.1.2016	Law 227/2015
Game consoles	1.1.2016	Law 227/2015
Laptops and tablet-PCs	1.1.2016	Law 227/2015
Waste and scrap metals	1.1.2005	Law 571/2003
Wood	1.1.2005	Law 571/2003
Selected cereals	1.6.2011	Emergency order No. 49
Slovakia		
Mobile phones	1.1.2014	360/2013 Coll
Integrated circuits	1.1.2014	360/2013 Coll
Iron and steel	1.1.2014	360/2013 Coll
Selected cereals	1.1.2014	360/2013 Coll
Gold	1.4.2009	83/2009 Coll
Waste and scrap metals	1.4.2009	83/2009 Coll

Table 10 Variable definitions

Variable	Explanation	Source
(ln)TDG	Ratio of exports reported by the exporting country to imports reported by the importing country (trade data gap; TDG). When used in estimations, we calculate the natural logarithm of the trade data gap (ln TDG)	Eurostat
POST	Dummy variable that takes on the value of 0 for observations 12 months before the introduction of e-invoicing on all products in Italy in January 2019 and 1 for observations 11 months after	Italian government
TREAT	Regarding the baseline sample: a dummy variable that takes on the value of 1 if the product is a non-RCM (then 0) and non-FUELS product (then excluded from sample). The dummy turns zero if the product is a RCM product Regarding the alternative control group: a dummy variable that takes on the value of 1 if the importing country is Italy and zero if the importing country is Greece, Lithuania, Romania or Slovakia (the sample is restricted to non-RCM products and in case of Italy also to non-FUELS products)	See Tables 9 and 19 in Appendix
RCM	Dummy variable that takes on the value of 1 if the product is included in the RCM category and 0 otherwise. In the case of the estimation of Table 8, see definition in Panel A of Table 8	See Table 9 in Appendix
RCM POTENTIAL	Dummy variable that takes on the value of 1 if the product is included in the POTENTIAL RCM category and 0 otherwise	See Table 19 in Appendix
OTHER	Dummy variable that takes on the value of 1 if the product is in the NON-RCM product category but not in the FUELS or POTENTIAL RCM category and 0 otherwise	See Table 19 in Appendix
REDUCED A	Dummy variable that takes on the value of 1 if the reduced VAT rate of 10% is applicable to the specific product and 0 otherwise	Hand-collected from Italian VAT Law
REDUCED B	Dummy variable that takes on the value of 1 if the reduced VAT rate of 5% is applicable to the specific product and 0 otherwise	Hand-collected from Italian VAT Law
REDUCED C	Dummy variable that takes on the value of 1 if the reduced VAT rate of 4% is applicable to the specific product and 0 otherwise	Hand-collected from Italian VAT Law
THRESHOLD GAP	Difference in the logarithm of the yearly Intrastat threshold of the exporting Member State and the importing Member State	Eurostat, see Table 12 in Appendix
EURO	Dummy variable that takes on the value of 1 for all observations where both Member States use the euro as the official currency and zero otherwise	Website European Union

Table 11 Descriptive statistics for control variables – baseline specification

Control variables					
	Observations	Mean	Std. dev	Minimum	Maximum
REDUCED A	1,322,023	0.0738	0.2614	0	1
REDUCED B	1,322,023	0.0007	0.0273	0	1
REDUCED C	1,322,023	0.0303	0.1713	0	1
THRESHOLD GAP	1,322,023	−0.6183	0.6333	−7.0413	0.40547
EURO	1,322,023	0.7287	0.4447	0	1

This table displays the descriptive statistics for all control variables used in the baseline model specified in Eq. (2). For explanations on all variables, see Table 10 in Appendix. The corresponding correlation matrix is displayed in Table 13 (Panel A) in Appendix

unclear and needs to be tested. An explanation on the product groups is presented in Table 19 (Appendix).[35]

We make use of our baseline model from Eq. (2); however, we split the treatment group into two separate groups (RCM POTENTIAL and OTHER; see Table 19). According to the baseline approach, the RCM products form the control group. Referring to the descriptive statistics displayed in Panel A of Table 20, it appears that both product groups show a considerably high mean ln TDG before e-invoicing. Before the reform, the ln TDG of 0.2805 for RCM POTENTIAL is only slightly higher than for OTHER (0.2561). This suggests comparable fraud levels pre-reform. The average ln TDG for RCM POTENTIAL is lower after the reform, at 0.1371, however, remains considerably greater than zero. The mean ln TDG for OTHER shows the most significant reduction along the reform, from 0.2561 to 0.0451.

Table 17 presents the corresponding regression output. We first note that the interaction POST×RCM POTENTIAL shows a negative coefficient that is significant in the first two specifications without fixed effects (see Table 17, Columns 1 and 2). Including fixed effects, we observe a lower magnitude of the effect and missing statistical power (see Table 17, Columns 3 and 4). Together with the descriptive statistics that show a comparably high mean ln TDG after e-invoicing (0.1371), it seems that e-invoicing was not as effective as compared to other products. Regarding OTHER (the remaining non-RCM products), we observe statistically significant and negative coefficients throughout the specifications, indicating that the overall effect of e-invoicing is mainly driven by this product group. The effect magnitude of −0.089 (Table 17, Column 4) is slightly higher than our baseline result (−0.073, Table 2, Column 5).

[35] We initially excluded fuels from the sample since they were already covered by the e-invoicing obligation six months before the general introduction. However, we further refuse from using fuels as a further control due to the very low number of observations and products covered by this initial roll-out.

Table 12 Intrastat thresholds

Year	2018		2019	
Code	Arrivals	Dispatches	Arrivals	Dispatches
AT	750,000	750,000	750,000	750,000
BE	1,500,000	1,000,000	1,500,000	1,000,000
BG	219,856	132,936	235,193	143,161
CY	130,000	55,000	160,000	55,000
CZ	320,000	320,000	465,960	465,960
DE	800,000	500,000	800,000	500,000
DK	833,000	631,000	897,197	669,550
EE	230,000	130,000	230,000	130,000
ES	400,000	400,000	400,000	400,000
FI	550,000	500,000	600,000	600,000
FR	460,000	460,000	460,000	460,000
GB	1,711,645	285,274	1,668,870	278,145
GR	150,000	90,000	150,000	90,000
HR	252,000	133,333	296,516	161,736
HU	550,000	325,000	528,700	311,000
IE	500,000	635,000	500,000	635,000
IT	800,000	400,000	800,000	400,000
LT	250,000	150,000	250,000	150,000
LU	200,000	150,000	200,000	150,000
LV	250,000	100,000	250,000	100,000
MT	700	700	700	700
NL	1,000,000	1,200,000	800,000	1,000,000
PL	688,000	458,000	929,880	464,940
PT	350,000	250,000	350,000	250,000
RO	195,746	196,746	192,807	192,807
SE	940,000	470,000	880,290	440,145
SI	140,000	220,000	140,000	220,000
SK	200,000	400,000	200,000	400.000

All values in euros. Thresholds are obtained from Eurostat (2017, 2021). A company must report in the Intrastat system from the beginning of a year if the arrivals or dispatches from the previous year exceed the threshold for the current year. If a company exceeds the threshold during the year, it must submit Intrastat declarations in the year of the transaction that caused the annual threshold to be exceeded

Table 13 Correlation matrix

Panel A: Baseline						
Variables	ln TDG	REDUCED A	REDUCED B	REDUCED C	THRESHOLD GAP	EURO
ln TDG	1.000					
REDUCED A	−0.025***	1.000				
REDUCED B	0.001	−0.008***	1.000			
REDUCED C	−0.020***	−0.047***	−0.005***	1.000		
THRESHOLD GAP	−0.011***	0.024***	0.004***	0.010***	1.000	
EURO	0.014***	0.031***	0.006***	0.033***	0.228***	1.000

Panel B: Alternative control group			
Variables	ln TDG	THRESHOLD GAP	EURO
ln TDG	1.000		
THRESHOLD GAP	−0.023***	1.000	
EURO	0.001***	−0.086***	1.000

Pairwise correlations for all variables included in Table 2 regarding Panel A and Table 3 regarding Panel B. *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively

Table 14 Descriptive statistics – alternative control group

ln TDG(dependent variable)		Observations	Mean	Std. dev	Minimum	Maximum
Italy as importing country/TREAT is non-RCM and non-FUELS						
TREAT = 1	if POST = 0	617,474	0.2624	1.8838	−15.1976	14.2156
	if POST = 1	679,090	0.0683	1.9699	−14.2465	16.7204
Greece, Lithuania, Romania and Slovakia as importing countries/non-RCM products						
TREAT = 0	if POST = 0	1,583,476	0.0167	2.0007	−15.0509	14.4814
	if POST = 1	1,640,882	0.0302	1.9957	−15.9226	14.8371
Independent variables						
THRESHOLD GAP		4,520,922	0.3712	0.8806	−7.0413	2.0794
EURO		4,520,922	0.5445	0.4980	0	1

Equation (1) shows the calculation method for ln TDG. POST is a time dummy that equals zero 12 months before e-invoicing became mandatory for all products in Italy in January 2019 and equals one 12 months after December 2018. TREAT is a dummy variable that equals one if the importing country is Italy and zero if the importing country is Greece, Lithuania, Romania or Slovakia. For all variables, see Table 10 in Appendix

Table 15 Estimation of fraud tackled by e-invoicing

							Fraud base				REVLOSS			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
VAT rate	$\Delta Exports = (1 - e^{-\delta_w})$ export share weighted	$\Delta Imports = (e^{-\delta_w} - 1)$ export share weighted	$\Delta Exports = (1 - e^{-\delta_w})$ import share weighted	$\Delta Imports = (e^{-\delta_w} - 1)$ import share weighted	Sum of 2018 exports	Sum of 2018 imports	Based on exports (2) · (6)	Based on imports (3) · (7)	Based on exports (4) · (6)	Based on imports (5) · (7)	Based on exports (1) · (8)	Based on imports (1) · (9)	Based on exports (1) · (10)	Based on imports (1) · (11)
22%	0.0540948	0.0571884	0.0471665	0.0495013	200,118.65	195,601.06	10,825.37	11,186.10	9,438.90	9,682.51	2,381.58	2,460.94	2,076.56	2,130.15
10%	0.0540948	0.0571884	0.0471665	0.0495013	15,256.85	14,624.33	825.32	836.34	719.61	723.92	82.53	83.63	71.96	72.39
5%	0.0540948	0.0571884	0.0471665	0.0495013	48.30	48.34	2.61	2.77	2.28	2.39	0.14	0.15	0.11	0.12
4%	0.0540948	0.0571884	0.0471665	0.0495013	7,413.73	7,838.45	401.04	448.27	349.68	388.01	16.04	17.93	13.99	15.52
Sum					222,837.53	218,112.18	12,054.34	12,473.48	10,510.47	10,796.83	2,480.29	2,562.65	2,162.62	2,218.18

Monetary values are expressed in million euros. The calculations are based on Eqs. (4) and (5). The coefficients δ_{weighted} (here δ_w) with export and import share weights are obtained from Table 6, Columns 3 and 6, respectively. We use all decimal places given by Stata that is − 0.0556129 for the export share weighted coefficient and − 0.0483151 for the import share weighted coefficient, respectively. Exports and imports are the sum of exports to Italy reported by the 27 exporting countries and imports reported by Italy from the other 27 exporting countries in 2018, respectively. The column headers for Fraud Base and REVLOSS contain information about the multiplied columns

Table 16 Heterogeneous effects — results by exporting country

	Austria	Belgium	Bulgaria	Cyprus	Czech Republic	Germany	Denmark
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
POST×TREAT	0.069	−0.158	0.481	−0.744	−0.030	−0.067	−0.112
	(0.155)	(0.158)	(0.469)	(0.616)	(0.101)	(0.064)	(0.174)
Observations	92,773	92,363	20,794	1,980	63,179	148,438	43,708
Adjusted R^2	0.476	0.447	0.505	0.534	0.498	0.449	0.476
	Estonia	Spain	Finland	France	UK	Greece	Croatia
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
POST×TREAT	0.564*	−0.092	0.003	−0.019	−0.014	−0.314*	−0.135
	(0.322)	(0.102)	(0.347)	(0.073)	(0.095)	(0.162)	(0.203)
Observations	3,476	110,660	15,936	129,528	97,843	20,376	25,642
Adjusted R^2	0.500	0.462	0.415	0.475	0.430	0.540	0.493
	Hungary	Ireland	Lithuania	Luxembourg	Latvia	Malta	Netherlands
	(15)	(16)	(17)	(18)	(19)	(20)	(21)
POST×TREAT	−0.554***	−0.226	−0.928	0.129	0.943	0.126	−0.120
	(0.141)	(0.242)	(0.773)	(0.491)	(0.621)	(0.356)	(0.113)
Observations	42,073	11,807	11,982	12,834	6,366	2,025	106,418
Adjusted R^2	0.468	0.499	0.468	0.466	0.469	0.665	0.511
	Poland	Portugal	Romania	Sweden	Slovenia	Slovakia	
	(22)	(23)	(24)	(25)	(26)	(27)	
POST×TREAT	−0.072	−0.410	0.316	0.142	0.021	−0.416*	
	(0.129)	(0.491)	(0.335)	(0.186)	(0.126)	(0.229)	
Observations	69,769	28,251	51,147	42,451	39,307	30,897	
Adjusted R^2	0.489	0.471	0.528	0.465	0.531	0.551	

The dependent variable is ln TDG, defined in Eq. (1). The importing country is Italy. Exporting countries are separated and indicated above the regressions. For explanations on variables, see Table 10 in Appendix. All regressions include control variables, 8-digit product code FE and time FE. Regressions are calculated using OLS. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

Differentiation of products based on first-digit product code

In our last heterogeneity test, we differentiate products according to the first digit of their product code.[36] For an explanation of the ten first-digit product groups and all 2-digit HS groups see Table 7 (Panel B) in Appendix. Splitting by the first digit

[36] For example, the first digit equals to 7 regarding the 8-digit product code "71089080." Therefore, we construct 10 different groups from 0 to 9 within our dataset. See also Table 7 for the distribution and explanations on these products.

Table 17 Heterogeneous effects — susceptibility of fraud

	(1)	(2)	(3)	(4)
POST	−0.060	−0.059	−0.108***	
	(0.037)	(0.037)	(0.033)	
RCM POTENTIAL	0.254***	0.261***		
	(0.041)	(0.041)		
POST×RCM POTENTIAL	−0.083**	−0.085**	−0.027	−0.028
	(0.038)	(0.038)	(0.034)	(0.034)
OTHER	0.230***	0.260***		
	(0.041)	(0.041)		
POST×OTHER	−0.151***	−0.153***	−0.089***	−0.089***
	(0.038)	(0.038)	(0.033)	(0.034)
Observations	1,322,023	1,322,023	1,322,023	1,322,023
Adjusted R^2	0.003	0.004	0.484	0.484
Unit FE	No	No	Yes	Yes
Time FE	No	No	No	Yes
Controls	No	Yes	Yes	Yes

The dependent variable is ln TDG, defined in Eq. (1). The importing country is Italy. Exporting countries are all other EU Member States. For explanations on variables, see Table 10 and 19 in Appendix. The identifier for unit FE is a combination of exporting country and the 8-digit product code. Regressions are calculated using OLS. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

is mostly descriptive by nature but gives additional insights and understandings of the distribution of the reform effect across the sample. A first look at the descriptive statistics (Table 20, Panel B) reveals some heterogeneity. First-digit product classes 5, 6 and 9 have the highest pre-reform mean ln TDG considerably above our baseline results (0.4852, 0.5576 and 0.41, respectively). After the reform, however, the mean remains on a very high level for first-digit product classes 5 and 6 (0.2764 and 0.3438, respectively). Descriptively, the lowest pre-reform mean ln TDG shows first-digit product classes 0, 1 and 2. Classes 3, 4, 7 and 8 are closest to the baseline. To test which class is most affected by e-invoicing, we run our baseline model on each of them separately. Therefore, we restrict the treatment group to each of the first-digit product classifications and therefore obtaining interaction terms of POST and TREAT for each of the ten classes as independent treatment groups. In all cases, the same RCM products serve as the control group. For reference, the number of observations for the control group is 25,459 and remains unchanged throughout the specifications.

Table 18 summarizes the regression results from which we draw the effect of the mandatory e-invoicing on specific product classes. The strongest effects are observed within classes 3 and 9 (see Table 18, Column 1, Rows 4 and 10, −0.139 and −0.206, respectively). These classes mainly contain products made by the chemical industry, optical and photographical instruments, clocks and

Table 18 Heterogeneous effects — first-digit product code

First-digit product code class	Coefficient POST×TREAT (1)	Observations (2)	Adjusted R^2 (3)
(1) First-digit product code = 0	−0.056	120,465	0.551
	(0.048)		
(2) First-digit product code = 1	0.026	83,283	0.509
	(0.050)		
(3) First-digit product code = 2	0.004	139,170	0.446
	(0.047)		
(4) First-digit product code = 3	−0.139***	144,283	0.480
	(0.050)		
(5) First-digit product code = 4	−0.114**	127,479	0.511
	(0.053)		
(6) First-digit product code = 5	−0.056	96,861	0.460
	(0.052)		
(7) First-digit product code = 6	−0.070	198,450	0.450
	(0.049)		
(8) First-digit product code = 7	−0.092*	156,697	0.469
	(0.049)		
(9) First-digit product code = 8	−0.041	343,359	0.489
	(0.046)		
(10) First-digit product code = 9	−0.206***	141,107	0.495
	(0.051)		

The dependent variable is the ln TDG, defined in Eq. (1). The importing country is Italy. Exporting countries are all other EU Member States. For explanations on variables, see Table 10 in Appendix. First-digit product codes from 0 to 9 are independent regressions that split the initial sample from Table 2 into 10 different treatment group bins. All regressions include unit and time fixed effects and controls. Regressions are calculated using OLS. The identifier for unit FE is a combination of exporting country and the 8-digit product code that is reduced to each first-digit product code class. Standard errors are clustered by the unit FE identifier and are shown in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively

watches, musical instruments, arms and ammunition and art work. However, also the first-digit product classes 4 and 7 show a significant decrease of the TDG after e-invoicing of −0.114 and −0.092 (see Table 18, Column 1, Rows 5 and 8).

Table 19 Explanations of treatment and control group products

Product category	Explanation
FUELS (excluded from sample)	Italy introduced the mandatory e-invoicing for fuels in July 2018 (Circular No. 8/E of 30th April 2018). Since Italy does not provide certain product codes for fuel products falling under the e-invoicing regime, we hand collected these codes by matching the definition by the Italian government with the corresponding product codes "Supplies of petrol or diesel fuel intended for use as motor fuel as well as for services rendered by subcontractors and sub−subcontractors of the supply chain within the framework of a works, services or supply contract entered into with a public administration" as stated in the Circular No. 8/E Date of 30th April 2018 (translated into English)
RCM	We defined the RCM category as products for which the reverse charge mechanism (RCM) applies in the importing country and the products are detectable in the VAT Directive and the corresponding product code. In general, neither the VAT Directive nor the domestic VAT code of the importing country provides a comprehensive overview of HS codes linked to the products falling under the RCM regime. Thus, we had to hand collect product codes when not provided in the VAT Act. The RCM is codified in Art. 199 to 199c VAT Directive. Introduction dates on products and sources are displayed in Table 9
RCM POTENTIAL	RCM POTENTIAL includes products that could theoretically fall under the RCM in the importing country (since they are included in Art. 199 to 199c VAT Directive) but so far were not included in the importing countries' RCM regime. In cases where neither the national VAT law nor the VAT Directive provide for product codes, we have manually collected them. We excluded those products that are not entirely falling under the RCM rather than only under certain circumstances. E.g. art. 199 Paragraph 1 letter e) VAT Directive subsumes the supply of goods provided as security
OTHER	All non-RCM, non-FUELS and non-RCM POTENTIAL products fall under the category OTHER

These classes mainly cover raw hides and skins, leather and a range of wood and wood products as well as natural and cultured pearls, precious and semi-precious stones and metals. However, we cannot observe a significant effect regarding the classes 5 and 6, which show the highest mean TDG prior to the reform.

Prior RCM implementations can be one reason why we observe stronger effects for certain product groups. The RCM is mainly concentrated among first-digit product classes 1, 4, 7, 8 and 9. Three out of those five product groups show significant reductions in TDG after e-invoicing (namely classes 4, 7 and 9; see Table 18, Columns 5, 8 and 10, respectively). An explanation for this could be that fraudsters switched to these similar products in the past after the RCM was introduced. Consequently, we observe strong effects in these groups, since they contain the most fraud. However, to verify this hypothesis, one needs to examine these effects that occurred within these groups around the RCM introduction

Table 20 Descriptive statistics of product classifications

Panel A: Differentiation based on susceptibility to fraud						
ln TDG (dependent variable)		Observations	Mean	Std. dev	Minimum	Maximum
TREAT (= 1) consists of …						
RCM POTENTIAL	if POST = 0	159,205	0.2805	1.8241	− 14.1202	13.5252
	if POST = 1	171,483	0.1371	1.9058	− 13.3833	14.1178
OTHER	if POST = 0	458,269	0.2561	1.9041	− 15.1976	14.2156
	if POST = 1	507,607	0.0451	1.9906	− 14.2465	16.7204
RCM (TREAT = 0)	if POST = 0	12,200	0.0266	1.8705	− 12.1698	11.9568
	if POST = 1	13,259	− 0.0332	1.9731	− 12.6402	10.8908
Panel B: Differentiation based on first-digit product code						
ln TDG (dependent variable)		Observations	Mean	Std. dev	Minimum	Maximum
Results only for treatment group (TREAT = 1)						
First-digit product code = 0	if POST = 0	45,754	− 0.0155	1.9343	− 12.5983	11.1270
	if POST = 1	49,252	− 0.1749	2.0462	− 14.2465	10.6878
First-digit product code = 1	if POST = 0	27,543	0.0189	1.9473	− 12.2107	11.4752
	if POST = 1	30,281	− 0.0911	2.0315	− 12.7930	11.1586
First-digit product code = 2	if POST = 0	55,133	0.0601	1.7359	− 13.7462	14.2156
	if POST = 1	59,010	− 0.0502	1.8522	− 13.1722	16.7204
First-digit product code = 3	if POST = 0	56,439	0.1647	1.7719	− 14.1280	12.6174
	if POST = 1	62,385	− 0.1086	1.8752	− 12.9723	12.4979
First-digit product code = 4	if POST = 0	48,284	0.2325	1.9201	− 12.9055	11.6113
	if POST = 1	53,736	− 0.0044	2.0306	− 13.0351	12.2494
First-digit product code = 5	if POST = 0	33,944	0.4852	1.8895	− 11.1719	11.4873
	if POST = 1	37,458	0.2764	1.9935	− 11.1550	12.8515
First-digit product code = 6	if POST = 0	82,539	0.5576	1.8768	− 13.1126	11.1571
	if POST = 1	90,452	0.3438	1.9470	− 12.1303	12.2835
First-digit product code = 7	if POST = 0	62,808	0.2339	1.8367	− 14.0677	11.3578
	if POST = 1	68,430	0.0235	1.9801	− 13.3833	14.1178
First-digit product code = 8	if POST = 0	151,259	0.2589	1.9142	− 15.1976	13.5252
	if POST = 1	166,641	0.1165	1.9697	− 13.3967	13.4032
First-digit product code = 9	if POST = 0	53,913	0.4100	1.9201	− 12.5014	12.4048
	if POST = 1	61,735	0.0861	1.9731	− 13.1747	10.7098

Equation (1) shows the calculation method for ln TDG. POST is a time dummy that equals zero 12 months before e-invoicing became mandatory for all products in Italy in January 2019 and equals one 12 months after December 2018. TREAT is a dummy variable that equals to one if the product is assigned to the treatment group (non-RCM and non-FUELS products) and zero if the product is assigned to the control group (RCM products). The first-digit product code divides the underlying 8-digit product codes into ten different groups

more in detail. Our model can neither confirm nor reject such hypothesis. We keep it therefore with the descriptive nature of this phenomenon and leave the interpretation to the reader (Tables 19 and 20).

Acknowledgements We wish to thank three anonymous reviewers, Natalie Packham and the participants at the Jill McKinnon Research Seminar 2023 at the Macquarie University in Sydney, CESifo Area Conference on the Economics of Digitization 2022 in Munich, AMEF 2022 in Thessaloniki and EAA 2022 in Bergen for valuable comments.

Funding Open Access funding enabled and organized by Projekt DEAL.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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