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Digitalization to Improve Tax Compliance: Evidence from VAT e-Invoicing in Peru

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Abstract

This paper examines the impact of e-invoicing on firm tax compliance and performance using administrative tax data and quasi-experimental variation in the rollout of VAT electronic invoicing in Peru. We find that e-invoicing increases reported firm sales, purchases and value-added by over 5 percent in the first year after adoption. The impact is concentrated among smaller firms and sectors with higher rates of non-compliance, suggesting that e-invoicing enhances compliance by lowering compliance costs and strengthening deterrence. The reform's positive effects on tax collection are hindered by shortcomings in the VAT refund mechanism in Peru, suggesting that digital tools such as e-invoicing should be complemented by other reforms to improve revenue mobilization.

I. INTRODUCTION

Digitalization is transforming how tax administrations operate, helping to improve process efficiency and service delivery (Gupta et al., 2017). A striking example is the adoption of electronic invoicing (e-invoicing), which allows for the automatic transfer of billing information between firms and the tax authority. Drawn by its potential to strengthen tax compliance and reduce costs, more than 50 countries around the world have already implemented e-invoicing, including ten countries in Latin America and the Caribbean region (EY, 2018; Barreix and Zambrano, 2018).

By replacing more cumbersome paper-based processes, e-invoicing promises multiple benefits for firms and the tax authorities alike, including lower administrative and compliance costs, better integration of billing and payment systems, and improved accuracy and information security. For tax administrations, e-invoicing also delivers real-time information that could be used to strengthen and automate compliance checks. Despite its widespread adoption, empirical evidence on how e-invoicing affects firm compliance and performance is limited, especially in emerging economies. This paper contributes to the literature on digitalization and tax compliance by using administrative tax data and quasi-experimental variation in the mandatory roll out of VAT e-invoicing in Peru.

As in other countries, the electronic transmission of invoice information in Peru required a substantial overhaul of tax administration and taxpayer IT capabilities. As a result, e-invoicing was introduced gradually, with the first reform waves focusing on larger firms and priority sectors (such as mining), while smaller firms were given more time to adopt the new electronic system. Our identification strategy exploits this sequential introduction of the reform to estimate the causal impact of VAT e-invoicing on firm performance and compliance.

We use administrative data provided by the Peruvian tax authority (SUNAT) to conduct our analysis. Our monthly panel dataset covers all small, medium and large (formal) private-sector firms operating in Peru between 2010 and 2017, and includes detailed information on firm sales, purchases, employment, wages, capital, profits, and taxes. This allows us to distinguish between productivity and compliance gains associated with e-invoicing, and its heterogenous impacts across firms. To avoid composition biases, our analysis focuses on a balanced sample panel consisting of the 78 thousand firms that were mandated to adopt e-invoicing between 2014 and 2018, which account for over 80 percent of domestic VAT collections in Peru.

We conduct the analysis in two steps. First, we estimate the impact of e-invoicing reform on sales, value added and tax liabilities across all firms. We find that being mandated to adopt e-invoicing (an "intent-to-treat" effect) increases reported taxable sales and purchases by 7 and 5 percent in the first year, respectively. This impact grows over time, starting from the mandatory date of adoption. Value-added growth does not seem to be associated with a commensurate increase in labor input, suggesting that observed growth is likely to capture an increase in the share of output that is reported to the tax authorities. Furthermore, the increase in sales and

purchases does not translate into a one-for-one increase in VAT collections. Instead, we find that large accumulations of past VAT credits allow some firms to offset VAT liabilities and, consequently, to lower VAT payments in the first year of e-invoicing.

Second, we examine how these estimated impacts vary across firms. We show that the positive impact of e-invoicing on reported sales and tax is driven primarily by relatively smaller firms, which were mostly included in later waves. Specifically, we find that VAT collections increase by over 5 percent in the first year after adoption among the relatively smaller firms, while the effect among large firms is close to zero and not statistically significant.

In addition, we find that the reform had a larger impact in sectors that traditionally suffer from low compliance, such as retail, business services and construction. Firms in these sectors respond more strongly to e-invoicing adoption, suggesting that e-invoicing affects firm behavior in part by fostering greater compliance, possibly because of the perceived threat of greater scrutiny. We also find that firms in these sectors are more likely to exit once the e-invoicing reform was announced, but before the deadlines for implementation are reached. This is consistent with e-invoicing reducing non-compliance and thereby raising the effective tax rate on firms, leading less profitable firms to exit.

We find that the rate of e-invoicing adoption increases steadily around the mandatory date of adoption in every reform wave. This suggests that being mandated into e-invoicing is a strong instrumental variable for studying the average treatment effect of e-invoicing adoption. The result of instrumental variable (IV) regressions are qualitatively similar and quantitatively stronger than the intent-to-treat effects. We find that actual e-invoicing adoption by firms increased their reported value-added, VAT liabilities and VAT payments by over 10 percent.

This paper contributes to a growing literature that examines the impact of digitalization on tax administration.[1] Previous studies for other countries have also found that e-invoicing leads to a gradual increase in reported sales and VAT collection (Ramírez, et al., 2017; Bérgolo et al., 2017; Artana and Templado, 2017; Castro et al., 2017; Lee, 2016). One advantage of our paper is the identification strategy adopted, which exploits the sequential adoption of e-invoicing in Peru to create a quasi-natural experiment. Our paper is closest in spirit to Fan et al. (2018) who find that the introduction of e-invoicing in China led to short-term tax revenue gains, which are partly reversed after a few years. However, their identification strategy is based on the comparison of

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[1] The trend towards digitalization has included not only e-invoicing, but also the electronic submission of tax returns (e-filing) and transaction-level data. Studies of e-filing include Yilmaz and Coolidge (2013), Kochanova et al. (2016), and Okunogbe and Pouliquen (2018). Eissa et al. (2014) and Ali et al. (2015) examine the impact of electronic sales registry machines in Rwanda and Ethiopia, respectively.

specific industries in the manufacturing sector, whereas we study treated firms in all industries, including sectors with high risk of tax non-compliance such as construction and services.[2]

The remainder of the paper is organized as follows. Section 2 describes the reform timeline, while section 3 presents the dataset and stylized facts. Section 4 outlines the empirical approach., and section 5 discusses the main results. The last section concludes.

II. THE E-INVOICING REFORM IN PERU

Electronic invoicing has been available to firms in Peru since the 2000s on a voluntary basis, allowing taxpayers to issue electronic invoices at their discretion.[3] The e-invoicing reform that we study in this paper began in 2013, with the aim of permanently switching away from paper-based invoices to electronic invoices. Firms were required to issue electronic invoices by default, while paper-based invoices are permitted only in exceptional circumstances (e.g., if there is an internet outage).[4]

E-invoicing can bring several benefits to taxpayers, including cost savings (such as lower printing, storing and administrative costs), more secure and accessible information storage, and integration of invoice issuance with other internal (accounting, payment, billing) and external processes (such as accounting, payment and procurement systems of suppliers, clients and the public sector).[5] At the same time, by improving control over the invoicing process and allowing for real-time monitoring of taxable transactions, tax administrations may also be able to reduce sales omission, purchase over-invoicing (including the reporting of purchases that are not related to business operations), fraudulent transactions, and general tax submission errors, thus reducing tax non-compliance and informality at a lower cost. SUNAT's stated motivation for the e-invoicing system was to improve the competitiveness of domestic firms by encouraging their

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[2] There has also been extensive research on the determinants of tax compliance and how these are affected by digitalization, including OECD (2017), and IMF (2018). For example, Naritomi (2019) examines a tax reform in Sao Paulo, Brazil, where e-invoicing was complemented by a system of tax rebates and monthly lotteries that create incentives for final consumers to request receipts and submit them online to the tax authority, which are then cross-checked against the same receipts submitted by firms. She finds that this reform increased reported sales and net tax revenue by 21 and 9.3 percent, respectively, in the first four years after implementation.

[3] Initially, e-invoices could only be issued through a web portal administered by SUNAT. Starting in 2012, taxpayers could develop their own e-invoicing systems, provided they met certain technical and regulatory specifications. This encouraged some taxpayers, especially large firms, to adopt e-invoicing voluntarily early on. In addition to these two options, an app developed by SUNAT and third-party e-invoice services were later made available to taxpayers.

[4] In these cases, firms are required to regularize paper-based invoices on a timely basis (RS 113-2018/SUNAT).

[5] Anecdotal evidence from discussions with private-sector organizations suggests that e-invoicing helps firms reduce the likelihood of receiving substantial fines when audited. SUNAT can fine firms that do not organize invoices properly and the electronic format made it easier to comply with this requirement.

digital transformation; strengthen monitoring and control to reduce the VAT compliance gap; and increase the tax base by bringing more transactions into the formal sector.

Switching to e-invoicing can create significant adjustment costs for taxpayers and the tax administration alike, including updating IT capacity and staff training.[6] Although many of these are one-off costs, they can nonetheless impact tax collections and firm performance. Therefore, e-invoicing requirements in Peru were introduced in a gradual and staggered manner, whereby firms were assigned into reform waves with different deadlines for e-invoicing adoption. Selection of firms into waves was based on administrative classifications and was related to size and compliance factors. Larger firms were more likely to be required to adopt e-invoicing earlier, as they represent a large share of VAT revenue and had more capacity to update their IT systems.[7] The tax administration also prioritized e-invoicing adoption by taxpayers with a record of poor tax compliance, since e-invoicing was believed to have a stronger deterrence effect and would facilitate the monitoring of their transactions.

The first reform wave began in 2014 and included 238 firms among the largest issuers of invoices in Peru, such as large manufacturing, mining and financial firms. The original deadline for this wave was October 2014, but it was later extended to April 2015 and then to August 2015 to allow taxpayers additional time to comply.[8] The second wave comprised 4,959 firms that had been caught in fictitious or fraudulent transactions (*Operaciones No Reales* – ONR) during tax audits, and, therefore, were considered as high risk of tax evasion (see Figure A.1 in appendix).[9] These firms were required to switch to e-invoicing starting from January 2015.

Reform waves in the next two years continued to focus on larger firms. A group of 778 large firms was required to adopt e-invoicing starting from July 2015 (later extended to January 2016), while a further 520 large taxpayers was given until July 2016 (later extended to July 2017) to make the switch. This staggered selection of firms reflected different vintages of the large firm database maintained by the tax administration, and in both cases the original deadlines for e-invoice adoption were also extended (see Figures A.2 and A.3 in appendix).[10]

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[6] For example, some firms complained about payment delays during the transition when buyers had not yet adapted their internal processes to receive e-invoices.

[7] Adoption by large firms can have positive network spillovers, if it encourages clients and suppliers to transition to e-invoicing as well. It can introduce a bias when comparing mandated to not-yet mandated firms if a non-neglectable share of not-yet mandated firms voluntarily adopt e-invoicing in advance. However, the bias works against identifying any effects and our results should therefore be interpreted as a lower bound of the real effect of e-invoicing. Furthermore, we show that voluntary adoption before the deadlines for adoption was rare.

[8] See RS 374-2013/SUNAT for the original deadline, and RS 300-2014/SUNAT and RS 086-2015/SUNAT for deadline extensions.

[9] See RS 300-2014/SUNAT.

[10] The first group was drawn from the large firms register as of 30 September 2014 (*Intendencia de Principales Contribuyentes Nacionales* – IPCN) and was given an original deadline of 1st July 2015 (RS 300-2014/SUNAT),

Figure 1. Timeline of e-Invoicing Adoption Waves in Peru
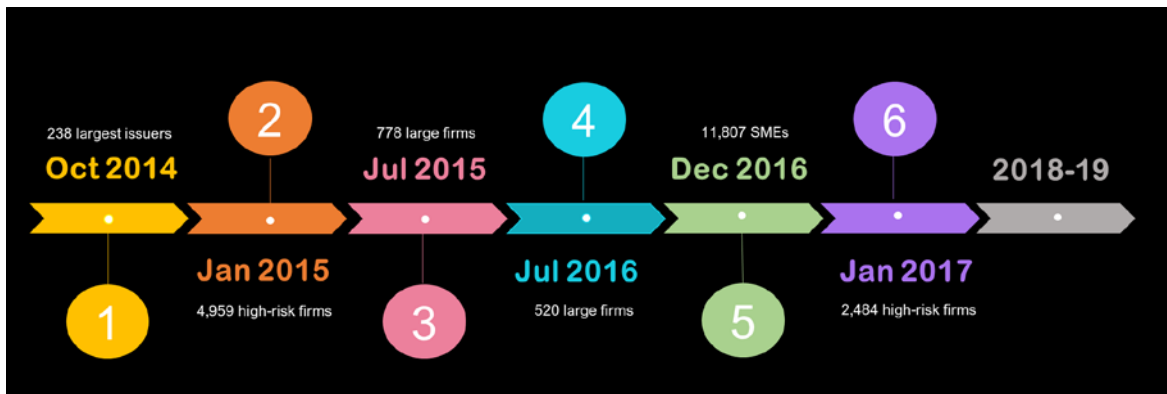
Note: This figure illustrates the stages of e-invoicing adoption in Peru. Reform waves are identified by their original adoption deadline.

As shown in Table A.1, the first waves of e-invoice adoption included the largest contributors to sales, taxable value added and VAT collections. On average, firms in the October 2014 reform wave reported annual sales of $400 million and employed 1,700 workers each, while those in the July 2015 and July 2016 waves had sales of $50 million and $30 million, and employed 680 and 275 employees each, respectively. These firms were also more likely to be exporters and subject to special VAT withholding regimes.[11] Together, the firms in the first four waves represented just over 54 percent of total taxable value added and 27 percent of employment in our database.

The next wave (wave 5) focused on expanding e-invoicing to small and medium size firms. A group of 11,807 firms was drawn from the tax administration's registry of significant taxpayers at the regional and provincial levels and given until December 2016 to switch to e-invoicing. However, this deadline was subsequently extended to July 2017, and then to January 2018.[12] On average, these firms were smaller in size compared to firms in previous waves, with average

which was later extended until 1st January 2016 (RS 137-2015/SUNAT). The second group included new additions to the IPCN registry as of 31 July 2015. Its original deadline was 15th July 2016 (RS 203-2015/SUNAT), but this was later extended by six months (RS 328-2016/SUNAT).

[11] Three special VAT withholding regimes are currently used in the Peru, aimed at improving tax compliance in certain industries or transactions. The "*Retention*" mechanism requires some taxpayers to collect part of the VAT liabilities of their suppliers, while the "*Perception*" mechanism works in reverse by forcing certain suppliers to pay additional tax as part of their customers' VAT liabilities. In both cases, suppliers or customers can later deduct the withheld amount from their tax liabilities. A third "*Deposit*" mechanism (SPOT) requires purchasers of specific goods and services to deposit a percentage of that transaction value into a bank account under the name of their supplier. Suppliers use these accounts to offset future tax liabilities.

[12] See RS 203-2015/SUNAT for the original deadline, and RS 311-2016/SUNAT and RS 155-2017/SUNAT for the subsequent extensions. This group was drawn from registries of small and medium-sized firms (*Principales Contribuyentes* – PRICOS) for Lima and other provinces in Peru, as of 31st July 2017.

annual sales of $5 million and about 100 workers each. However, it still included several larger firms with similar characteristics to firms in earlier waves. Thus, as a group, wave 5 firms account for a large share of economic activity, representing over 20 percent of value added and 30 percent of employment in the database.

A second group of 2,484 firms that had been caught in *Operaciones No Reales* (ONR) was also required to adopt electronic invoicing starting from January 2017, mainly consisting of firms that had shown poor tax compliance in subsequent audits.[13] In the analysis of e-invoicing that follows, we exclude the ONR firms (waves 2 and 6) for two reasons. First, it is difficult to separate the impact of e-invoicing from the impact of the tax audits and increased monitoring these firms were subject to. Second, the observed e-invoicing adoption rates among these waves did not exceed 20 percent, as opposed to rates over 80 percent for the other waves, reflecting economic difficulties and very high exit rates once audits began.[14]

Starting in 2018, reforms focused on extending e-invoicing to a much larger number of small firms, the majority with annual sales between $0.2 and $5 million. Starting from January 2018, the e-invoicing requirement was extended to 4,741 high-risk firms, 4,550 agents of the Retention and Perception withholding regimes, and 943 larger firms.[15] In May, e-invoicing became mandatory for 11,573 small firms that were registered as government suppliers or included in the audited register of inspected goods. In August, the e-invoicing requirement began to apply to 13,837 firms in the manufacturing, construction, hotel and restaurant sectors, and from November onwards to all remaining 54,703 firms with annual sales over $0.2 million. The implementation of e-invoicing across other smaller firms is planned for 2019.[16]

Figure 2 shows the rate of e-invoice adoption as firms reached the deadlines set by the tax administration. The left panel of Figure 2, which shows adoption rates around the original deadline for e-invoice adoption, explains why the tax administration often extended them. While adoption rates increase gradually and then spike just before the deadline was reached, they remained between 40 and 60 percent, suggesting that many taxpayers were unable or unwilling

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[13] See RS 192-2016/SUNAT.

[14] See Figure A.1 in appendix for more details.

[15] See RS 192-2016/SUNAT. The latter group included all firms registered in the IPCN registry as of 29 June 2017, but that had not been included in previous waves (RS 155-2017/SUNAT).

[16] E-invoice requirements were also extended to specific firms or transactions at other dates. Independent contractors were required to switch to electronic receipts starting from 1st October 2014 (receipts issued to public-sector entities) and 1st January 2015 (receipts issued to private-sector firms subject to the general regime of the VAT). These contractors are typically micro firms with few or no employees (often they reflect self-employment), so we exclude them from our analysis. In addition, firms that provide leasing services involving real estate (1st July 2017) or mortgage services (1st July 2018), as well as exporters (1st January and 1st July 2018 for services and goods exports, respectively), were required to issue e-invoices in respect of such transactions (irrespective of whether these firms were not included in the main reform waves). Since these changes involve relatively few firms, and we do not have access to data by transaction, we did not include them in our analysis.

Figure 2. e-Invoicing Adoption Rates Across Waves
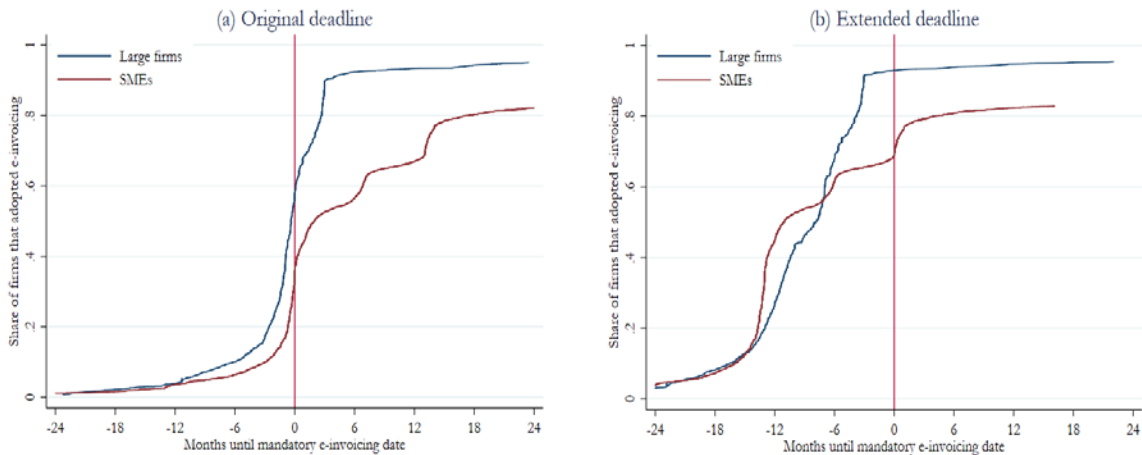
Note: This figure shows the e-invoice adoption rates across waves, using data from SUNAT. The left panel shows adoption rates relative to the original deadline, while the right panel shows adoption rates relative to the extended deadline (final deadline). The month in which e-invoicing would become mandatory is defined as time 0. The blue lines represent all the firms in wave 1, 3 and 4, while the red lines represent all wave 5 firms.

to comply with the e-invoicing requirement on time. Deadlines were then extended, by about one year on average, to give these firms additional time to comply.[17] The right panel of Figure 2 shows that this was a good strategy, since there was typically a high level of compliance by the time the final deadlines were reached. In fact, we see a gradual build up in adoption rates before the final deadline, as firms made the transition to e-invoicing in anticipation of this requirement becoming effective.[18]

While adoption rates are high after the e-invoicing deadline is reached, they never reach 100 percent for any of the reform waves. This reflects the difficulties faced by firms to complete the transition to e-invoicing, even among larger firms. In the analysis that follows, we therefore distinguish between the effects of the reform (mandating firms to adopt e-invoicing whether these firms complied or not) and the actual adoption of e-invoicing by mandated firms.

III. DATA AND STYLIZED FACTS

The VAT is the major source of revenue in Peru, accounting for over half of the country's gross tax revenue. The standard VAT rate was 18 percent during the period we analyze. As shown in Figure 3, the period during which e-invoicing was introduced was marked by a decrease in the VAT ratio from 8.8 percent of GDP in 2014 to 7.8 percent of GDP in 2017. This decline coincided with a slowdown in economic activity after 2014, an increase in the VAT compliance gap, and a

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[17] See Figure A.2 and A.3 in appendix for more details about the deadline extensions of specific waves.

[18] It is also likely that some firms made the switch voluntarily to take advantage of lower processing costs, or to facilitate transactions with their suppliers or clients that had already adopted e-invoices.

Figure 3. VAT Trends in Peru

(a) Gross VAT revenues and GDP growth

(b) VAT credits and compliance gap
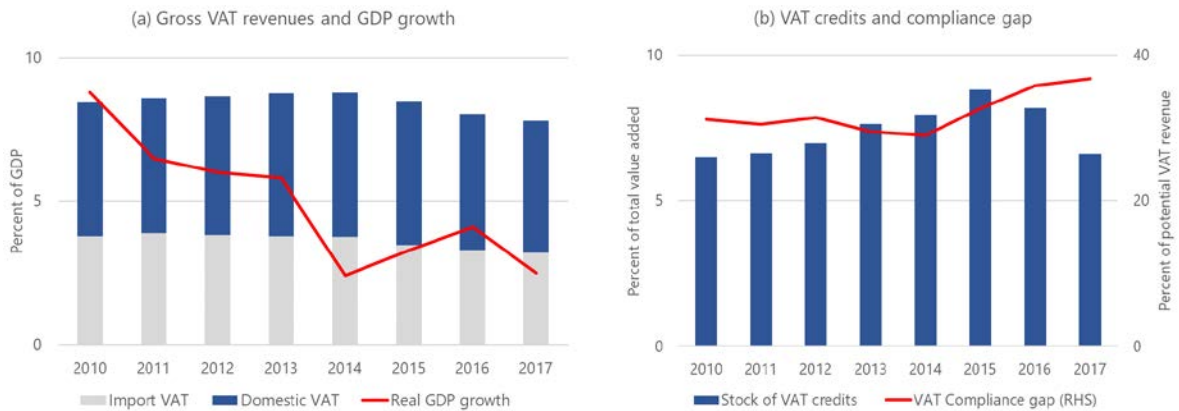
Note: The left panel plots gross VAT revenue in percent of GDP, distinguishing between domestic and import VAT. The growth rate of real GDP is shown in red. The right panel shows the total stock of VAT credits at the end of each year, expressed as share of total firm value added, and the red line shows the VAT compliance gap (Keen, 2013).

marked decrease in the stock of outstanding VAT credits. [19] These credits are the result of VAT paid on inputs that was not refunded in the year they were incurred, and that are then carried over to subsequent years, when firms can use them to offset future tax liabilities.

We use monthly administrative tax data covering all small, medium and large formal Peruvian firms over the period 2010 to 2017. The dataset excludes two important groups of firms. First, micro firms with less than 150 UIT (about $175,000) in annual sales are excluded, as these firms were not targeted by the e-invoicing reform during the period we analyze.[20,21] Second, it also excludes informal firms since these firms are not registered with the tax authority. Although there are many micro and informal firms in Peru, most of these firms are very small and together they make only a small contribution to aggregate value added.[22] Despite these exclusions, our dataset

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[19] The departure of VAT from a perfectly enforced tax levied at a uniform rate on all consumption can be measured by its "C-efficiency", the ratio of actual VAT revenue to the product of the standard rate and consumption as taken from national accounts. Keen (2013) decomposes this indicator further into a policy gap, reflecting rate differentiation and exemptions, and a compliance gap, which measures imperfect implementation of the VAT. Since 2005, the compliance gap in Peru has ranged between 30 and 40 percent of potential VAT revenues, higher than the average across Latin American countries (IMF, 2015).

[20] The Unidad Impositiva Tributaria (UIT) is a monetary unit set every year by the tax authority to calculate tax and regulatory thresholds. for example, firms with less than 150 UIT in annual sales are defined as micro firms in the Peruvian legal system. In addition, firms with less than 96,000 soles (about $29,000) in annual sales were automatically excluded from our analysis because they are subject to a simplified tax regime in Peru (the Nuevo RUS), instead of the VAT regime.

[21] The dataset was constructed by including all the firms that reported annual sales above 150 UIT at least once over the 2010-2017 period.

[22] As shown in Table A.2 in the appendix, firms excluded from our analysis account for less than five percent of total value-added.

has a very large coverage and includes nearly 200,000 firms, representing 53 percent of GDP and 95 percent of VAT collections in 2013.

We exclude from our analysis firms that were caught in fraudulent transactions (waves 2 and 6) and the very small firms that were required to adopt e-invoicing only after 2018. This ensures that we only keep firms that are comparable. Specifically, when we compare firms that are mandated to those that are yet to be mandated, our sample ensures that we compare firms that are reasonably similar in terms of size and administrative characteristics.

We collapse the dataset from monthly to quarterly frequency to facilitate the analysis. In addition, to focus on changes within firms and to avoid composition bias, we also create a balanced panel sample that excludes firms that enter or exit during the sample period (i.e., firms with no reported sales in a given quarter). This balanced dataset includes approximately 78,000 firms that account for 85 percent of the value-added in the original dataset. As shown in Tables A.1-A.4 in appendix, the balanced sample remains representative of the original dataset, since average firm characteristics and the distribution of firms across sectors and risk categories by wave are similar across both datasets.

IV. EMPIRICAL APPROACH

We exploit the staggered adoption of e-invoicing to assess the impact of electronic invoicing on firm performance and VAT collections. This approach compares the change in outcomes for firms that have been mandated to adopt e-invoicing (the treated group) relative to firms that have not yet been mandated (the control group). Since there were no significant changes in SUNAT's compliance risk management strategy during the years we study, this approach will isolate the impact of the e-invoicing reform separately from any changes due to increased monitoring and audit effort.

We specify our panel difference-in-differences model as a fixed effects linear regression:

$$Y_{it} = \alpha_i + \delta_t + \eta_i t + \beta \times I(Treat_{it} = 1) + \gamma X_{it} + \varepsilon_{it} \tag{1}$$

In this model, the coefficient β captures the treatment effect of being mandated to adopt e-invoicing; $I(Treat_t = 1)$ is an indicator variable that takes on a value of one in the quarter that a firm is mandated to adopt e-invoicing, and the first four quarter after that; δ_t is a time fixed effect to control for shocks common to all firms, such as changes in commodity prices or monetary policy; α_i is a firm fixed effect to control for time invariant firm characteristics; $\eta_i t$ is a firm-specific linear time trend to control for heterogeneity in growth paths across firms; and X_{it} is a vector of control variables, including the wage bill, fixed capital stock, and the number of workers. Since some firms were treated earlier than others, we also include as a control variable an indicator for the fifth and following quarters after the date of mandatory e-invoicing adoption. Standard errors are clustered at the firm level.

Even though the original deadlines for mandated adoption were later extended, we use the original deadlines for our identification strategy. From the firms' perspective, the original deadline was the relevant constraint, as reflected by the fact that a large proportion of firms adopted at the time of the original deadline. Moreover, given that the transition to e-invoicing requires substantial administrative and procedural changes within the firm, even those firms that had not begun to issue e-invoices at the time of the original deadline would have made significant progress towards operationalizing e-invoicing, particularly if they are unable to anticipate the provision of an extension. Focusing on the original deadlines allows to capture all these changes.

The identifying assumption in this specification requires parallel trends between the control and treated groups prior to treatment, such that the β coefficient represents the impact of treatment as opposed to differential pre-trends. To test this assumption, we also estimate a dynamic panel difference-in-differences specification which allows us to conduct a pre-trend analysis for treated and control groups and explore the evolution of the treatment effect over the quarters following the mandated date of adoption:

$$Y_{it} = \alpha_i + \Sigma_t^T \beta_t . I(Treat_t = 1) + X_{it} + \gamma_t + \delta_i + \eta_i . t + \varepsilon_{it} \qquad (2)$$

where the β_t coefficients capture the dynamic impact of treatment in 6 quarters prior to and 4 quarters following the mandated date of e-invoicing adoption for a firm[23]. Parallel pre-trends require that the β_t in the pre-treatment period be statistically insignificant, implying no observed differences between the control and treated groups prior to the treatment date. However, given that the date of mandated adoption is pre-announced, some anticipation effects in the quarter leading up to mandated adoption cannot be ruled out.

Since there is imperfect compliance to the e-invoicing reform among mandated firms, the β_t estimates represent the "intent to treat" (ITT) effect. Moreover, firms that are not mandated into e-invoicing may still adopt e-invoicing voluntarily, resulting in two-sided noncompliance. While the ITT is considered the policy-relevant parameter given that policy makers cannot force or prevent adoption, we also estimate the Local Average Treatment Effect (LATE) which represents the impact of being mandated into e-invoicing by compliers only.

To estimate the LATE, we use an indicator for being mandated into e-invoicing as an instrumental variable for predicting actual compliance to treatment. Specifically, we estimate a two-stage least squares model where the first stage uses treatment assignment to predict compliance and the second stage uses fitted estimates from the first stage to predict treatment effects:

$$A_{it} = \alpha_i + \theta . I(Treat_t = 1) + X_{it} + \gamma_t + \delta_i + \eta_i . t + \varepsilon_{it} \qquad (3)$$

$$Y_{it} = \alpha_i + \beta . \hat{A}_{it} + X_{it} + \gamma_t + \delta_i + \eta_i . t + \varepsilon_{it} \qquad (4)$$

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[23] The reference period for the β_t coefficients is the quarter before the reform was mandated (t= -1).

where A_{it} and $\hat{A}_{it}$ represent respectively an e-invoicing adoption indicator and the probability of adoption estimated in the first stage. One note of caution with respect to our LATE estimates is that we do not differentiate between non-compliers and late compliers and assume no change in behavior along other dimensions (reporting of sales, purchases) among this latter group at the time of treatment. However, firms could change their behavior at the time of their mandated date of adoption, even in the absence of having adopted the e-invoicing mechanisms. This could be in anticipation of the eventual switch or owing to the higher threat of audit for being non-compliant. This could bias the LATE downwards assuming the behavior of non-compliers after the treatment date is like the behavior of compliers. The ITT estimate does not suffer from this bias since all firms are considered treated following the mandated date of adoption, regardless of actual adoption, although it might suffer from another bias by not accounting for compliance among untreated firms. However, regardless of the estimator considered, our model is biased against finding a treatment effect and therefore is a conservative lower bound on the potential treatment effect.

V. RESULTS

A. Baseline

We start by estimating the difference-in-differences specification in Equation (1) using the balanced panel sample, with and without control variables. The results are shown in Table 1. In the first three columns, we find that taxable sales, purchases and value-added are significantly higher among the treated firms following the date of the e-invoicing reform relative to the untreated firms. This is true even controlling for the number and wage of employees and the level of capital stock, implying that the results are not driven by a change in firm-level inputs. On average, reported sales and purchases rise by 6.6 and 4.5 percent, respectively, in the year following the date of mandated e-invoicing adoption. This results in an average increase in reported value-added of 5.9 percent naturally translates into an increase in reported VAT liabilities (column 4). However, the impact on actual VAT payments by taxpayers is smaller and less precisely estimated (column 7).

As in other VAT systems, Peruvian firms can accumulate VAT credits that can be used to offset future VAT liabilities.[24] We examine the effect of the reform on accumulation of new VAT credits and the stock of existing VAT credits in columns 5 and 6. We find that e-invoicing is associated with an increase in the new credits and a decrease in the overall stock of VAT credits, although both coefficients are imprecisely estimated and statistically insignificant.

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[24] Except for exporters, firms can use credits to offset tax liabilities, but cannot obtain cash refunds.

Table 1. Difference-in-Differences Results for All Waves Mandated Before 2018

Panel A. Without firm variable controls

(in log of soles unless otherwise indicated)	(1) Taxable sales	(2) Taxable purchases	(3) Taxable value-added	(4) VAT liabilities	(5) New VAT credits	(6) VAT credit stock	(7) Total VAT payments	(9) Productivity
Treatment indicator (1 year after)	0.0744*** (0.0127)	0.0556*** (0.0139)	0.0653*** (0.0123)	0.0808*** (0.0203)	0.0475 (0.0366)	-0.0445 (0.0384)	0.0537* (0.0316)	0.0483*** (0.00926)
Treatment indicator (greater than a year)	0.158*** (0.0269)	0.122*** (0.0281)	0.160*** (0.0287)	0.296*** (0.0760)	-0.277** (0.133)	-0.344** (0.136)	0.378*** (0.0677)	0.128*** (0.0285)
Observations	1,010,437	1,010,439	843,159	1,010,439	1,010,439	1,010,422	1,010,439	842,199

Panel B. With firm variable controls

(in log of soles unless otherwise indicated)	(1) Taxable sales	(2) Taxable purchases	(3) Taxable value-added	(4) VAT liabilities	(5) New VAT credits	(6) VAT credit stock	(7) Total VAT payments	(8) Productivity
Treatment indicator (1 year after)	0.0657*** (0.0124)	0.0453*** (0.0135)	0.0589*** (0.0120)	0.0722*** (0.0202)	0.0470 (0.0366)	-0.0432 (0.0384)	0.0445 (0.0314)	0.0604*** (0.00914)
Treatment indicator (greater than a year)	0.140*** (0.0259)	0.0989*** (0.0266)	0.146*** (0.0282)	0.278*** (0.0758)	-0.283** (0.133)	-0.345** (0.136)	0.360*** (0.0660)	0.159*** (0.0274)
Number of workers	0.483*** (0.0110)	0.483*** (0.0114)	0.411*** (0.0102)	0.442*** (0.0185)	-0.190*** (0.0263)	-0.313*** (0.0264)	0.688*** (0.0242)	-0.354*** (0.00823)
Wage bill	-0.0145*** (0.00308)	-0.00476 (0.00352)	-0.0147*** (0.00306)	-0.00613 (0.00472)	0.0290*** (0.00681)	0.0371*** (0.00705)	-0.0472*** (0.00648)	-0.0230*** (0.00262)
Capital stock	0.00783*** (0.00117)	0.0130*** (0.00153)	0.00609*** (0.00115)	0.00383** (0.00184)	0.0109*** (0.00310)	0.00569* (0.00322)	0.00814*** (0.00296)	-0.0222*** (0.00113)
Constant	10.63*** (0.0259)	10.16*** (0.0320)	9.606*** (0.0259)	7.425*** (0.0398)	3.504*** (0.0589)	3.581*** (0.0615)	4.886*** (0.0574)	1.272*** (0.0231)
Observations	1,010,398	1,010,400	843,147	1,010,400	1,010,400	1010383	1,010,400	842,199

Note: The treatment indicator (1 year) switches from zero to one in the quarter of mandatory e-invoicing adoption and the following four quarter. The treatment indicator (greater than a year) switches from zero to one in the fifth and following quarters after the date of mandatory e-invoicing adoption. Regression results for the balanced sample of firms mandated to adopt e-invoicing before 2019. Firm-clustered standard errors are indicated in parentheses. (* $p<0.10$, ** $p<0.05$, *** $p<0.01$).

In Figure 4, we illustrate the results of estimating the dynamic panel specification in Equation (2) using the same sample. This specification allows us to rule out the presence of differential pre-trends between the treated and other firms, as evidenced by the estimated coefficients being not significantly different from zero in the six quarters prior to the mandated date of adoption.

Following the date of treatment, we find that sales, purchases and value-added rise gradually, in line with the gradual increase in actual e-invoicing adoption rates documented in Figure 2. As a result, the treatment effects in the fourth quarter following the mandated date of adoption are significantly larger than the treatment effect derived from the specification in Equation (1), which

reflects the average treatment effect over the first four quarters. Specifically, by the fourth quarter following treatment, reported sales, purchases and value-added increase by 10 and 15 percent relative to untreated firms. [25] Similar to before, the response of actual VAT payments is positive in this dynamic specification, but smaller than the response of reported VAT liabilities. Still, we do find a statistically significant increase in VAT payments in the fourth quarter after treatment in the order of 10 percent.

It is important to note that the positive impact of e-invoicing on sales, purchases and value added corresponds to greater *reported* economic activity. The data does not allow us to distinguish between whether firms are producing more or continue to produce at the same level but report a larger share of their sales, purchases and value-added. However, we can check if our results are due to a re-classification of tax-exempt sales and purchases (i.e. whether these sales and purchases were previously reported as nontaxable). Panel (a) in Figure 5 indicates that this is not the case as there is no statistically significant change in the ratio of taxable sales to total sales or of taxable purchases to total purchases in the period surrounding the reform.

We also examine whether the reform has any effect on firm reported inputs and productivity.[26] If the observed increases in value-added were real production changes, as opposed to a change in reporting behavior, we would expect labor input to increase as well. Overall, we find no significant change in employment (Table 1, Panel A) and therefore a significant increase in reported productivity. However, the dynamic specification shows there is a statistically significant increase in employment after four quarters (Figure 5, panel B). This may simply reflect an increase in reporting of employment given the pervasiveness of informality in the Peruvian economy. However, the scale of increase in employment is very small (just over 2 percent), relative to the increase in value added (on the order of 15 percent).

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[25] See Figure A.5 for a breakdown of results by reform wave.

[26] We estimate productivity as the residual of a regression of value added on employment and capital with time fixed effects. In our dataset, firm capital stock is measured on an annual basis, and we are therefore unable to assess changes in capital inputs at a quarterly frequency.

Figure 4. Estimated Treatment Affects Around the Mandatory Dates of Adoption
(percent change relative to the mandatory adoption quarter)
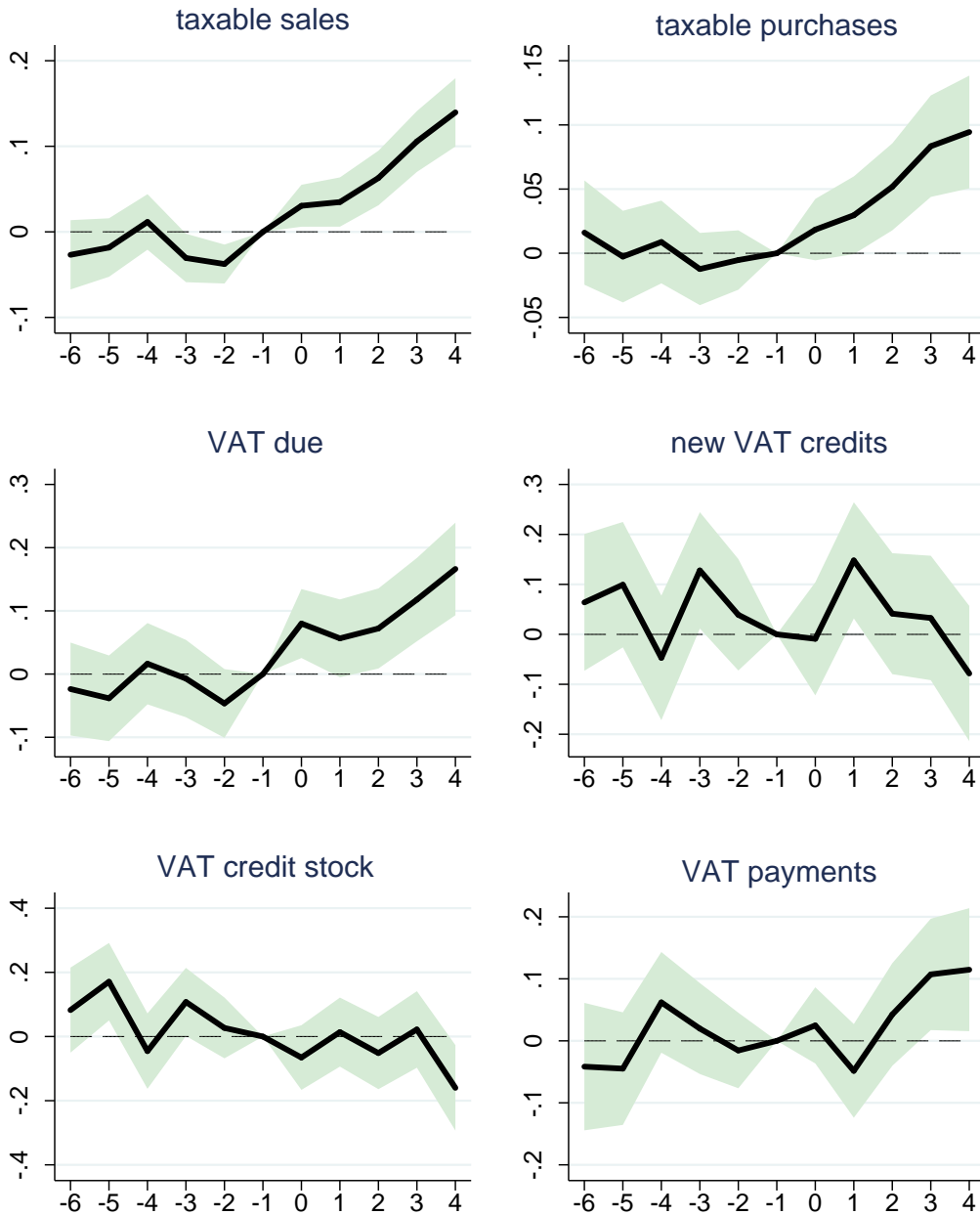
Note: This figure plots the coefficients (solid line) and their 95 percent confidence intervals (shaded area), estimated using Equation (2) and the balance sample over 2013Q2-2017Q4 of firms mandated to adopt e-invoicing before 2019.

Figure 5. Compliance and Productivity
(percent change relative to the mandatory adoption quarter)
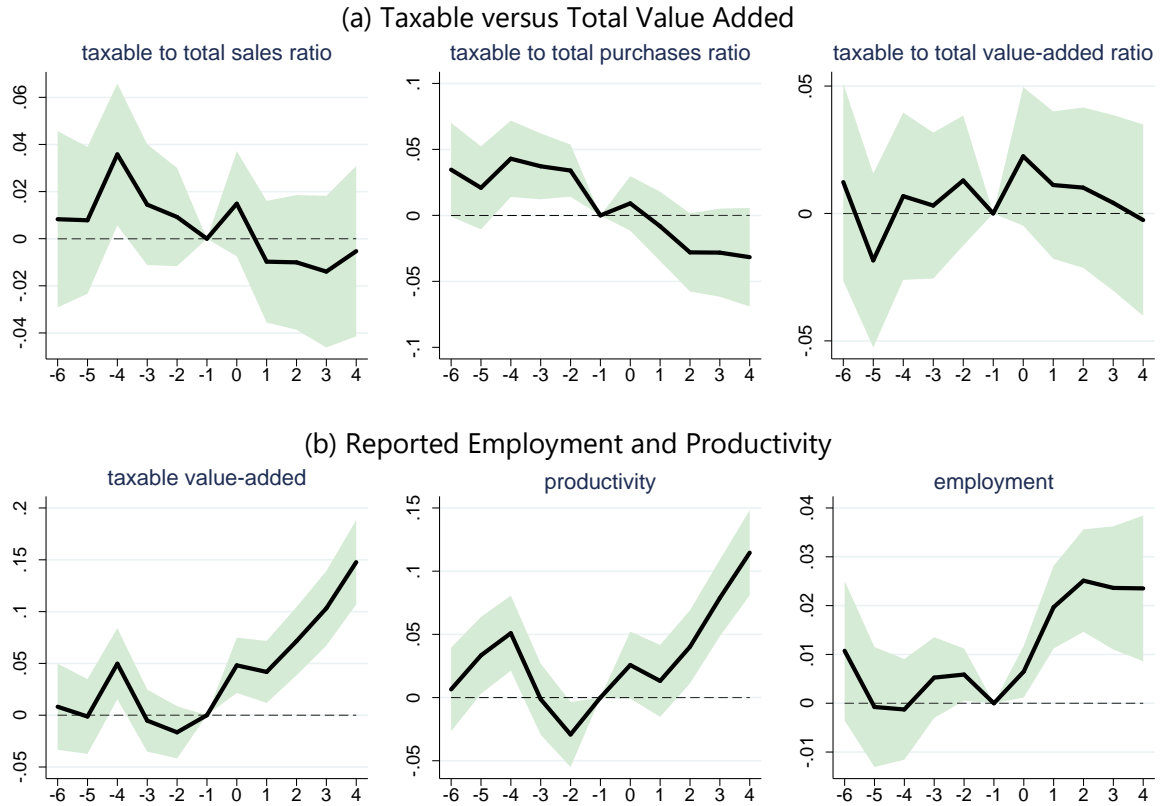
(a) Taxable versus Total Value Added

(b) Reported Employment and Productivity

Note: This figure plots the coefficients (solid line) and their 95 percent confidence intervals (shaded area), estimated using Equation (2) and the balance sample over 2013Q2-2017Q4 of firms mandated to adopt e-invoicing before 2019.

B. Heterogeneity by Size, Creditor Status and Sector

We next assess potential heterogeneity in firm treatment effects across several dimensions, starting by examining the role of firm size. The existing literature on the impact of audit intensity, and specifically on e-invoicing adoption, finds the presence of larger treatment effects among smaller firms. Given that smaller firms are less likely to be the subject of targeted audits (owing to their smaller contribution to overall collections) and conduct many transactions in cash which are difficult to track, these firms are more likely to engage in tax non-compliance. Hence the increase in the threat of audit should disproportionately affect their behavior.

First, we look at the dynamic responses estimated using the dynamic difference-in-differences specification for relatively smaller, and relatively larger firms separately. Figure 6 shows that the significant responses that we noted in the previous section are essentially driven by relatively smaller firms. We formally test for the hypothesis that the effects are stronger for relatively smaller firms by interacting the treatment indicator with firm sales in the first quarter of the sample (Table 2). The firm size interaction term is based on the first quarter of the sample period

(2013Q2) and normalized to facilitate interpretation of the coefficients. The statistically significant negative coefficient estimated for the interaction term in the first three columns of Table 2 implies that the treatment effect is driven entirely by smaller firms. In fact, among larger firms, the effect of the reform on VAT payments is statistically significant so the pooled sample results are muted by the inclusion of large firms who have a weak treatment response.

We further investigate the role of VAT credits by contrasting the responses of firms with a positive stock of VAT credits at the beginning of the sample period and those without. Nearly two-thirds of firms in our sample had no past VAT credits at the beginning of our estimation sample (see Table A.4 in appendix), which implies that only some firms could use existing VAT credits to offset higher VAT liabilities. We test whether this matters by interacting a dummy variable capturing this difference with the treatment variable. The results in columns 4-6 of Table 2 show large and significant differences across firms with and without past credits. Firms without VAT credits experience a stronger increase in VAT liabilities and pay more VAT after the e-invoicing deadline. By contrast, we find that firms starting with a positive stock of VAT credits increase more their reported purchases than their sales and consequently don't experience an increase in VAT liabilities and start accumulating more VAT credits following the reform.

Next, we evaluate heterogeneity in the response of different economic sectors to the e-invoicing reform. Figure 7 focuses on the evolution of taxable value added in six sectors: manufacturing, construction, transportation, retail, the hospitality sector and other services.[27] We find significant increases in taxable value added in the construction, transportation, retail and other services sectors following the reform, but no significant treatment effect in the manufacturing sector or the hospitality sector. Table 3 evaluates sector-level heterogeneity by extending the specification in Equation (2). Here again we find statistically significant treatment effects on taxable value added for the construction, transportation, retail and other services sectors.

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[27] Other services consist of many different sectors, including financial services, consulting companies, IT services, marketing companies, accounting and legal services, rental companies, architecture, research, engineering services and other business services. We exclude agriculture, fishing, utilities, transportation, telecommunication and public administration from the analysis because none of these sectors include more than 5 percent of the total observations or the total value-added in the balanced sample.

Figure 6. Smaller versus Larger Firms

Taxable Value Added (left panel) and VAT payments (right panel)

(a) Relatively Smaller Firms
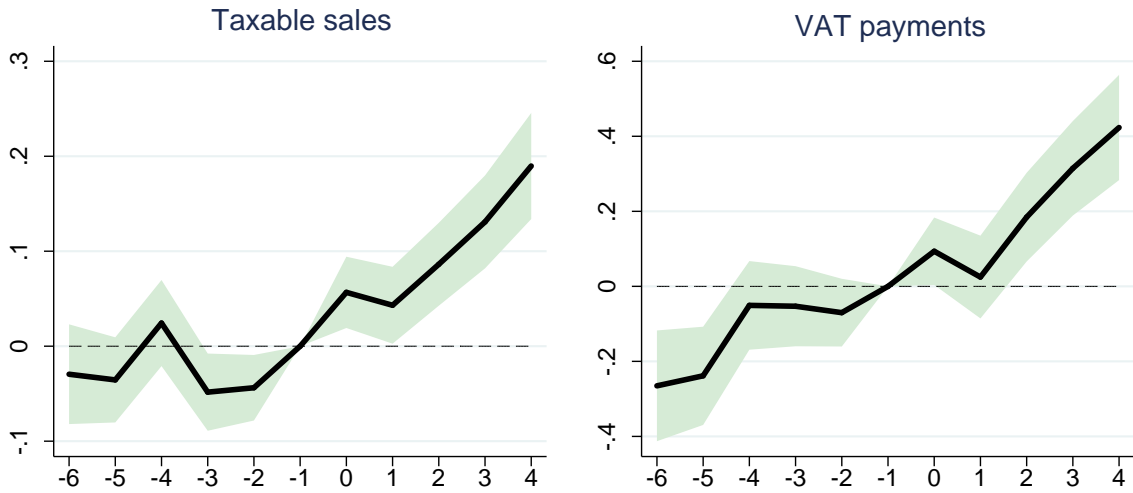
(b) Relatively Larger Firms
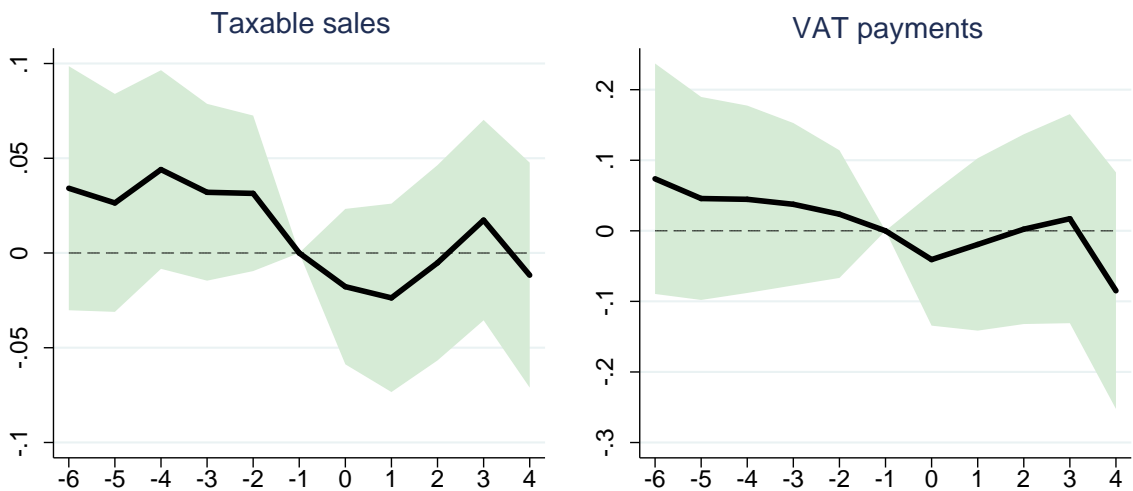
Note: This figure plots the coefficients (solid line) and their 95 percent confidence intervals (shaded area), estimated using Equation (2) and the balance sample over 2013Q2-2017Q4 of firms mandated to adopt e-invoicing before 2019. Each panel corresponds to a separate regression by firm size category. We use a cutoff of 1700 UIT in annual sales as reported in our dataset to distinguish between relatively smaller and larger firms.

Table 2. Difference-in-Differences: Heterogeneity by Size and Creditor Status

(in log of soles unless otherwise indicated)	(1) Taxable value-added	(2) VAT liabilities	(3) Total VAT payments	(4) Taxable value-added	(5) VAT liabilities	(6) New VAT credits	(7) VAT credit stock	(8) Total VAT payments
Treatment indicator (1 year)	0.105***	0.0973**	0.291***	0.111***	0.134***	-0.122*	-0.327***	0.390***
	(0.0228)	(0.0379)	(0.0587)	(0.0234)	(0.0397)	(0.0697)	(0.0727)	(0.0583)
" interacted with:								
- initial log sales	**-0.0627****	**-0.0342**	**-0.328****	**-0.0621****	**-0.0224**	**-0.0580**	**-0.0419**	**-0.297****
	(0.0247)	**(0.0505)**	**(0.0584)**	**(0.0247)**	**(0.0497)**	**(0.0914)**	**(0.0944)**	**(0.0589)**
- credit stock indicator				**-0.0304**	**-0.158****	**0.740****	**1.102****	**-0.434****
				(0.0277)	**(0.0517)**	**(0.0810)**	**(0.0888)**	**(0.0722)**
Treatment indicator (greater than a year)	0.323**	0.556	0.828***	0.317**	0.649	-0.132	-0.627	0.976***
	(0.151)	(0.428)	(0.277)	(0.151)	(0.426)	(0.530)	(0.561)	(0.275)
" interacted with:								
- initial log sales	-0.160	-0.211	-0.517***	-0.163	-0.175	-0.576	-0.428	-0.482**
	(0.104)	(0.303)	(0.187)	(0.104)	(0.302)	(0.374)	(0.400)	(0.189)
- credit stock indicator				0.0417	-0.430**	2.013***	2.761***	-0.585***
				(0.0570)	(0.186)	(0.278)	(0.297)	(0.151)
Number of workers	0.410***	0.442***	0.687***	0.411***	0.442***	-0.190***	-0.313***	0.688***
	(0.0102)	(0.0185)	(0.0242)	(0.0102)	(0.0185)	(0.0262)	(0.0263)	(0.0242)
Wage bill	-0.0146***	-0.00612	-0.0472***	-0.0147***	-0.00616	0.0292***	0.0373***	-0.0473***
	(0.00306)	(0.00472)	(0.00648)	(0.00306)	(0.00472)	(0.00681)	(0.00704)	(0.00648)
Capital stock	0.00610***	0.00384**	0.00816***	0.00609***	0.00381**	0.0110***	0.00588*	0.00809***
	(0.00115)	(0.00184)	(0.00296)	(0.00115)	(0.00184)	(0.00310)	(0.00322)	(0.00296)
Constant	9.607***	7.426***	4.888***	9.607***	7.426***	3.502***	3.577***	4.890***
	(0.0259)	(0.0398)	(0.0573)	(0.0259)	(0.0398)	(0.0589)	(0.0614)	(0.0573)
Observations	843,147	1,010,400	1,010,400	843,147	1,010,400	1,010,400	1,010,383	1,010,400

Note: The treatment indicator (1 year) switches from zero to one in the quarter of mandatory e-invoicing adoption and the following four quarter. The treatment indicator (greater than a year) switches from zero to one in the fifth and following quarters after the date of mandatory e-invoicing adoption. Regression results for the balanced sample of firms mandated to adopt e-invoicing before 2019. Firm-clustered standard errors are indicated in parentheses. (* $p<0.10$, ** $p<0.05$, *** $p<0.01$).

Figure 7. e-Invoicing Impact by Economic Sector

(a) Taxable Value Added
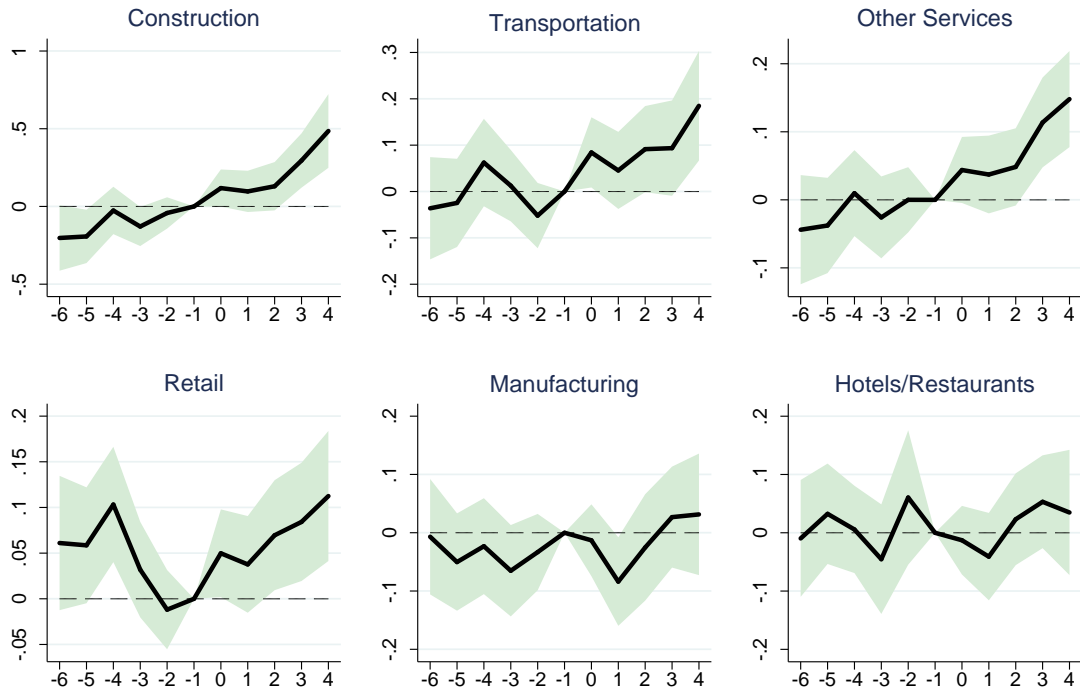
(b) VAT payments

Note: This figure plots the coefficients (solid line) and their 95 percent confidence intervals (shaded area), estimated using Equation (2) and the balance sample over 2013Q2-2017Q4 of firms mandated to adopt e-invoicing before 2019. Each panel corresponds to a separate regression by sector.

Table 3. Difference-in-Differences Results: Heterogeneity by Economic Sector

(in log of soles unless otherwise indicated)	(1) Taxable sales	(2) Taxable purchases	(3) Taxable value-added	(4) VAT liabilities	(5) New VAT credits	(6) VAT credit stock	(7) Total VAT payments
Treatment indicator (1 year after):							
Construction	0.200***	0.118*	0.192***	0.0503	0.00538	-0.123	0.176
	(0.0607)	(0.0619)	(0.0556)	(0.126)	(0.196)	(0.203)	(0.156)
Transportation	0.0657*	0.0155	0.0737**	0.138***	-0.0122	-0.192	0.155
	(0.0348)	(0.0391)	(0.0357)	(0.0529)	(0.114)	(0.128)	(0.113)
Other services	0.0459**	0.0401	0.0604***	0.0757**	-0.139**	-0.0562	0.160***
	(0.0218)	(0.0268)	(0.0213)	(0.0354)	(0.0663)	(0.0664)	(0.0496)
Retail	0.0485**	0.0429*	0.0446**	0.0332	0.227***	0.0669	-0.223***
	(0.0209)	(0.0232)	(0.0216)	(0.0317)	(0.0646)	(0.0677)	(0.0582)
Manufacturing	0.0499*	0.0508**	0.0184	0.104	-0.0760	-0.102	0.247***
	(0.0279)	(0.0233)	(0.0281)	(0.0676)	(0.122)	(0.130)	(0.0773)
Hotels, Restaurant	-0.0240	0.0125	-0.0553*	0.101	0.185	0.0814	0.0692
	(0.0271)	(0.0280)	(0.0334)	(0.107)	(0.132)	(0.150)	(0.101)
Extraction	0.0398	-0.0395	-0.121*	0.0145	-0.185	-0.0597	0.0992
	(0.0983)	(0.0711)	(0.0723)	(0.216)	(0.257)	(0.249)	(0.168)

Note: Results correspond to separate difference-in-difference regressions for every sector. Only the estimated treatment effect is shown, and other controls are omitted. The regressions were performed using the balanced sample of firms mandated to adopt e-invoicing before 2019. Firm-clustered standard errors are indicated in parentheses. (* $p<0.10$, ** $p<0.05$, *** $p<0.01$).

Our estimation results allow us to contrast retail with other services, two sectors with striking differences with respect to the VAT response. In the case of the retail sector, we find a strong and significant increase in the level of new VAT credits and in their overall stock whereas we find a decline (although insignificant) in these variables in the case of other services (e.g., business, professional, accounting services). As a result, we find a significant increase in VAT payments in the other services sector, but a decrease in payments in the retail sector. The positioning of these sector in typical value chains could offer some explanation for this pattern. Other services are more often upstream industries that do not require many inputs from other sectors. Conversely, retail requires sourcing from many industries and selling to final consumers. Therefore, retail firms are more likely to accumulate large stocks of VAT credits that they use to offset their VAT liabilities.

The sectors in which the response to e-invoicing is positive and the strongest, that is retail, other services and construction, are also estimated to have the largest VAT compliance gap after the manufacturing sector (IMF 2015). Additionally, while we don't find statistically significant effects of the reform on reported VAT liabilities in the manufacturing sector, we do find a large and

Figure 8. e-Invoicing Impact on Firm Survival Rates
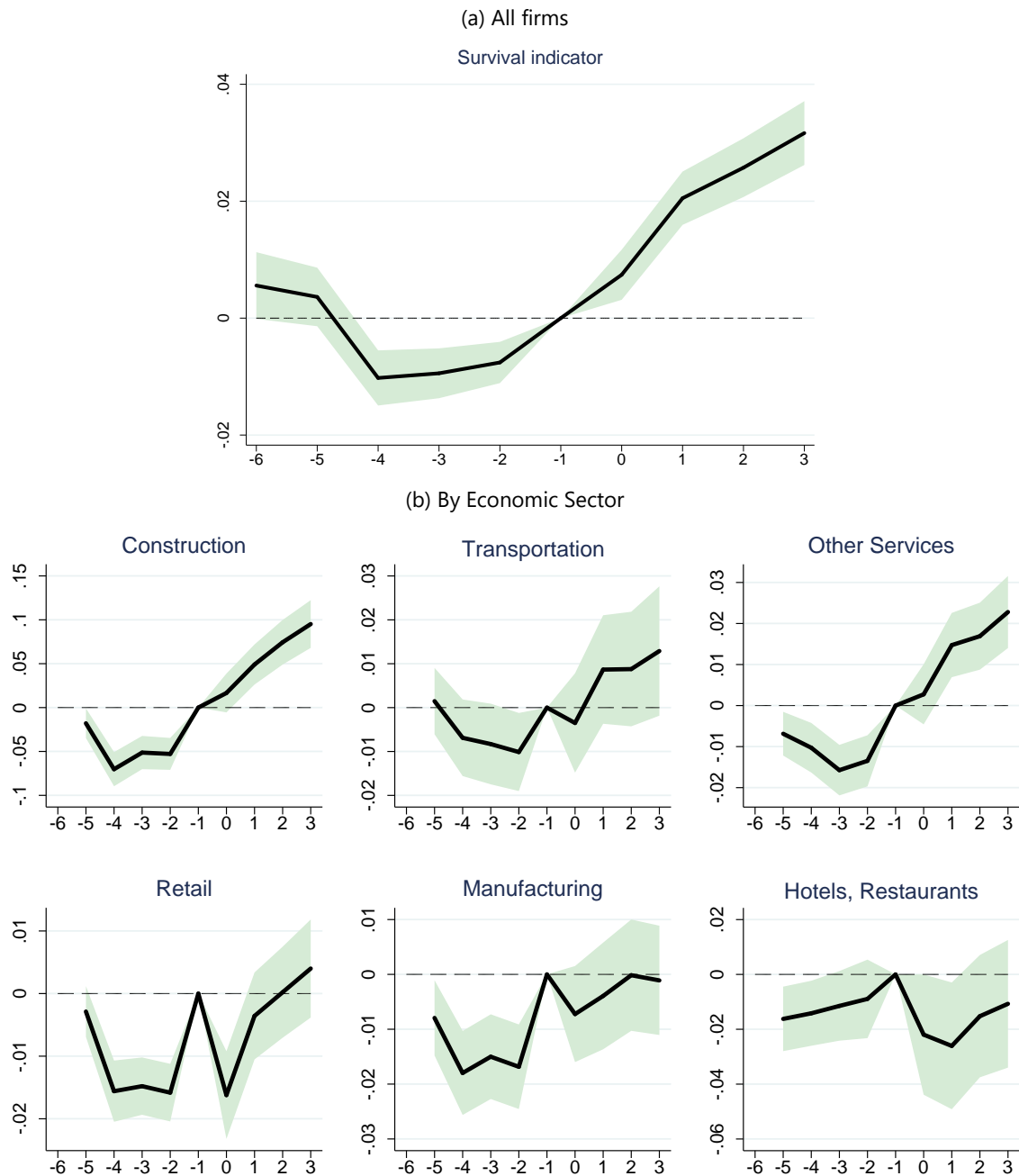
(a) All firms

Survival indicator

(b) By Economic Sector

Note: This figure plots the coefficients (solid line) and their 95 percent confidence intervals (shaded area), estimated using Equation (2) and the balance sample over 2013Q2-2017Q3 of firms mandated to adopt e-invoicing before 2019.

significant positive effect on VAT payments. This is another piece of evidence suggesting that mandatory e-invoicing could induce changes for firms with low compliance.

Finally, we examine the impact of e-invoicing on the extensive margin of firms. If e-invoicing reduces noncompliance, thereby increasing the effective tax rate on firms, one would expect

some firms to exit if they cannot maintain profitability under this higher tax burden. We test this hypothesis by examining changes in the survival rate of firms around the mandatory date of adoption.[28] Consistent with our hypothesis, the top panel of Figure 8 shows that there is a drop in the survival rate in the year before the mandatory date adoption, which is in line with the three to five quarter gap between the announcement of the e-invoicing reform and the original deadline firms were given to comply with the reform. However, we also find a *rise* in the survival rate after the mandatory date of adoption. A potential explanation is that, on one hand, firms that were forced to exit did so at or before the mandatory date of adoption and the more profitable firms that remained exhibit higher survival rates. On the other hand, firms in the control group may be pressured to adopt e-invoicing after the mandatory date because they are trading with mandated firms that are adopting e-invoicing. As a result, some noncompliant firms in the control group may exit, thereby generating an increase in the difference in survival rates between the treated and the control group.

In the bottom panel of Figure 8, we examine heterogeneity in survival between different sectors. Construction firms have the largest drop in survival probability in the quarters leading up to the reform. Although with smaller magnitude, the pattern repeats itself in the transportation and other services sectors, with manufacturing experiencing a reduction in survival pre-reform and no improvements in survival post reform.

C. IV Estimation of the Effects of e-Invoicing Adoption

The previous results only pertain to the effects of the policy, namely mandating firms to adopt e-invoicing. However, because not all firms comply, the magnitude of these effects is different from the effect of actual e-invoicing adoption. In Table 4, we estimate the effects of actual adoption by comparing mandated adopters with non-mandated non-adopters using the instrumental variable approach described in equations (3) and (4).

Results reported in the first column of Table 4 show that assignment to treatment strongly predicts actual adoption across all treatment waves. Because of the strength of the first stage regression, the results allow us to quantify the effect of adopting e-invoicing with reasonable precision. We find that adopting e-invoicing results in a 15 percent increase in sales, 10 percent increase in purchases, 13 percent increase in reported value-added, and a 16 percent increase in reported VAT liabilities. As before, the impact on VAT payments is positive but not statistically significant. The larger magnitudes of the LATE estimates suggest that our ITT estimates are biased downwards by non-compliance among the mandated firms or voluntary compliance among the control group, and that the effects of the reform on firms that have indeed adopted e-invoicing are substantially larger.

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[28] We define survival as having positive sales in the next quarter.

Table 4. Instrumental Variable (IV) Regression Results

(in log of soles unless otherwise indicated)	(1) First stage Adoption	(2) Second stage Taxable sales	(1) Taxable purchases	(4) Taxable value-added	(5) VAT liabilities	(6) New VAT credits	(7) VAT credit stock	(8) Total VAT payments
Treatment indicator (1 year after)	0.448*** (0.00396)							
Adoption indicator		0.147*** (0.0276)	0.101*** (0.0302)	0.132*** (0.0269)	0.161*** (0.0451)	0.105 (0.0817)	-0.0965 (0.0858)	0.0993 (0.0700)
Number of workers	-0.00183 (0.00124)	0.484*** (0.0110)	0.483*** (0.0114)	0.411*** (0.0102)	0.442*** (0.0185)	-0.190*** (0.0263)	-0.313*** (0.0264)	0.688*** (0.0242)
Wage bill	0.000683** (0.000311)	-0.0146*** (0.00308)	-0.00483 (0.00352)	-0.0147*** (0.00306)	-0.00624 (0.00472)	0.0289*** (0.00681)	0.0371*** (0.00705)	-0.0473*** (0.00648)
Capital stock	0.000349** (0.000174)	0.00778*** (0.00117)	0.0130*** (0.00153)	0.00603*** (0.00115)	0.00377** (0.00184)	0.0109*** (0.00310)	0.00572* (0.00322)	0.00810*** (0.00296)
Treatment indicator (greater than a year)	0.463*** (0.00735)	0.0719*** (0.0205)	0.0521** (0.0203)	0.0857*** (0.0236)	0.204*** (0.0717)	-0.332*** (0.125)	-0.300** (0.128)	0.314*** (0.0515)
Observations	1,010,400	1,010,398	1,010,400	843,147	1,010,400	1,010,400	1,010,383	1,010,400

Note: The treatment indicator (1 year) switches from zero to one in the quarter of mandatory e-invoicing adoption and the following four quarter. The treatment indicator (greater than a year) switches from zero to one in the fifth and following quarters after the date of mandatory e-invoicing adoption. The regressions were performed using the balanced sample of firms mandated to adopt e-invoicing before 2019. Firm-clustered standard errors are indicated in parentheses.
(* $p<0.10$, ** $p<0.05$, *** $p<0.01$).

VI. CONCLUSION & RECOMMENDATIONS

This paper investigates the effect of e-invoicing adoption on firm performance and tax compliance using administrative tax data from Peru on all formal small, medium and large firms. Our findings suggest that e-invoicing increased firm sales, purchases and value-added by over 5 percent on average in the first year after adoption, and that this impact grows over time. However, we also find these effects are heterogeneous across firms, with larger impacts among smaller firms and those firms at higher risk of tax non-compliance, whereas the impact on the largest firms is statistically insignificantly. Our results suggest that e-invoicing can improve tax compliance among specific groups of firms by lowering compliance costs and by strengthening deterrence effects.

One key message that emerges from our analysis is that e-invoicing can have a positive impact on tax compliance, especially among specific taxpayer groups. On average, the e-invoicing reform had little impact on reported tax liabilities of larger firms. This is not entirely surprising as large firms typically have more accurate bookkeeping and are subject to heavier scrutiny by the tax authority since they account for larger share of VAT revenue. Instead, we find that e-invoicing primarily impacted small and medium-sized firms, which suggests that it helps minimize tax

return mistakes and reduce compliance costs. We also find that e-invoicing had a larger effect in sectors with large compliance gaps and that upstream sectors exhibit a stronger increase in their VAT payments, while downstream sectors experience larger increases in new VAT credits. The fact that firms at higher risk of tax non-compliance respond more strongly also suggests that deterrence effects are an important benefit of the e-invoicing reform.

Our analysis helps to understand why aggregate VAT collection has not yet significantly increased in Peru in response to the reform. First, the effects are concentrated among relatively smaller firms that account for less than a fifth of the value added in our dataset. From a policy standpoint, since these firms are typically not the target of audit activities as they individually do not generate a significant share of value added in the economy, the e-invoicing reform is an effective strategy to increase voluntary compliance.

Second, the effects of e-invoicing build up gradually, implying that the full effect of the reform is not yet fully accounted for. By 2017, SUNAT had not made significant changes yet to its risk management strategy to make use of the flow of information generated by the e-invoicing system. Hence, the potential of e-invoicing adoption is larger than the effects studied since this technology will generate richer data which will allow improved monitoring and compliance enforcement beyond the pure effects of the reform itself.

Third, the response of VAT payments was weaker than the response of reported value-added, possibly due to shortcomings in the credit refund mechanism in Peru. This issue undermines the self-enforcing characteristic of the VAT and weaken the relationship between reported taxable value-added and VAT payments. Improved strategies to enforce control of VAT credits which, in combination with the improved monitoring capabilities of the e-invoicing system, should have the potential to reduce evasion through misreporting of credits.

The results on heterogeneity in firm survival are also of significance from a policy perspective insofar as indicating potential sectors that are more vulnerable to firms failing or turning informal in response to increased compliance costs. Identification of these sectors can allow for greater state support to be directed towards firms in these sectors in order to lower the cost of their digitalization on the one hand. On the other hand, it also highlights the need for greater monitoring of these sectors during the reform process to prevent transition to informality and leakages from the tax base.

Interesting avenues for future research include studying the spillover effects of e-invoicing adoption on upstream and downstream firms. Adoption of digitalization and improved compliance in some firms can strengthen the incentives for connected firms to also digitalize and improve tax compliance (e.g., Keen and Lockwood, 2010; Pomeranz, 2015). Additionally, e-invoicing adoption in Peru may have a differential impact across the multiple VAT withholding and collection regimes. These regimes differ by assigning different collection agents along the VAT chain. Our results of heterogeneity in the impact of e-invoicing across sectors and types of firms suggest that the reform should also have heterogeneous effect on the efficiency of these regimes, with potentially important implications for the design of VAT collection.

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Figure A.1 – e-Invoicing Adoption Rate for Taxpayers with *Operaciones No Reales*
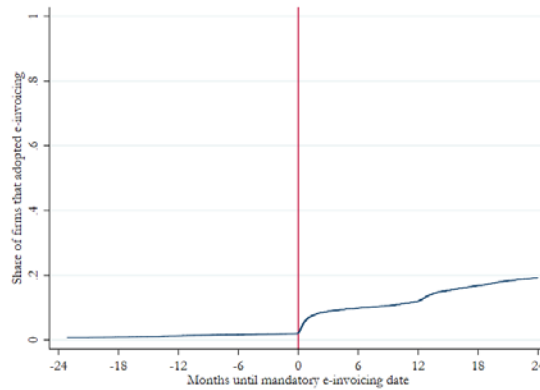
Note: This figure shows the rate of e-invoice adoption across high-risk firms (ONR firms), using data from SUNAT. The month in which e-invoicing became mandatory is defined as time 0.

Figure A.2 – Evolution of e-Invoicing Adoption by Wave and by Initial Adoption Deadline
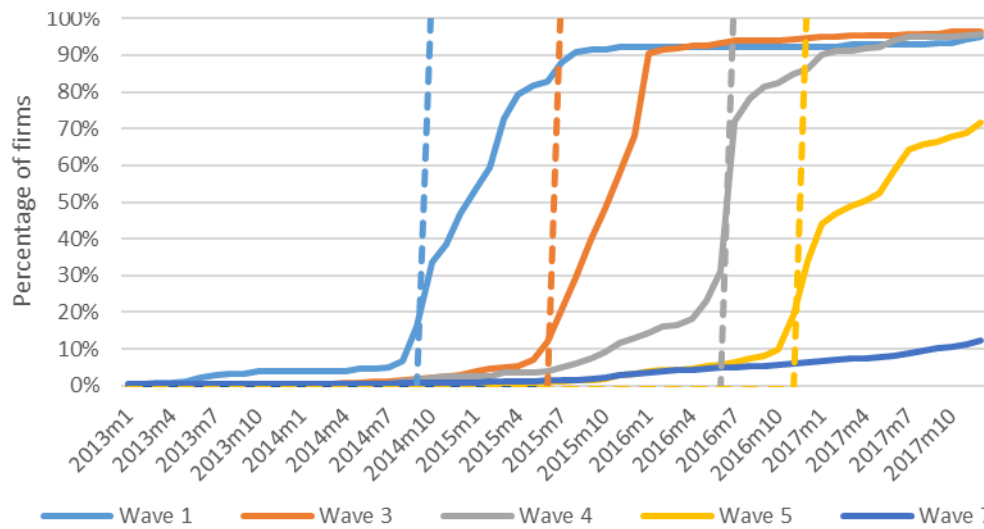
Note: This figure shows the rate of e-invoice adoption for selected waves and their corresponding initial deadline for adoption (the vertical dotted line), using data from SUNAT.

Figure A.3 – e-Invoicing Adoption Rates Around the Initial and Final Deadlines

Panel A: non ONR waves
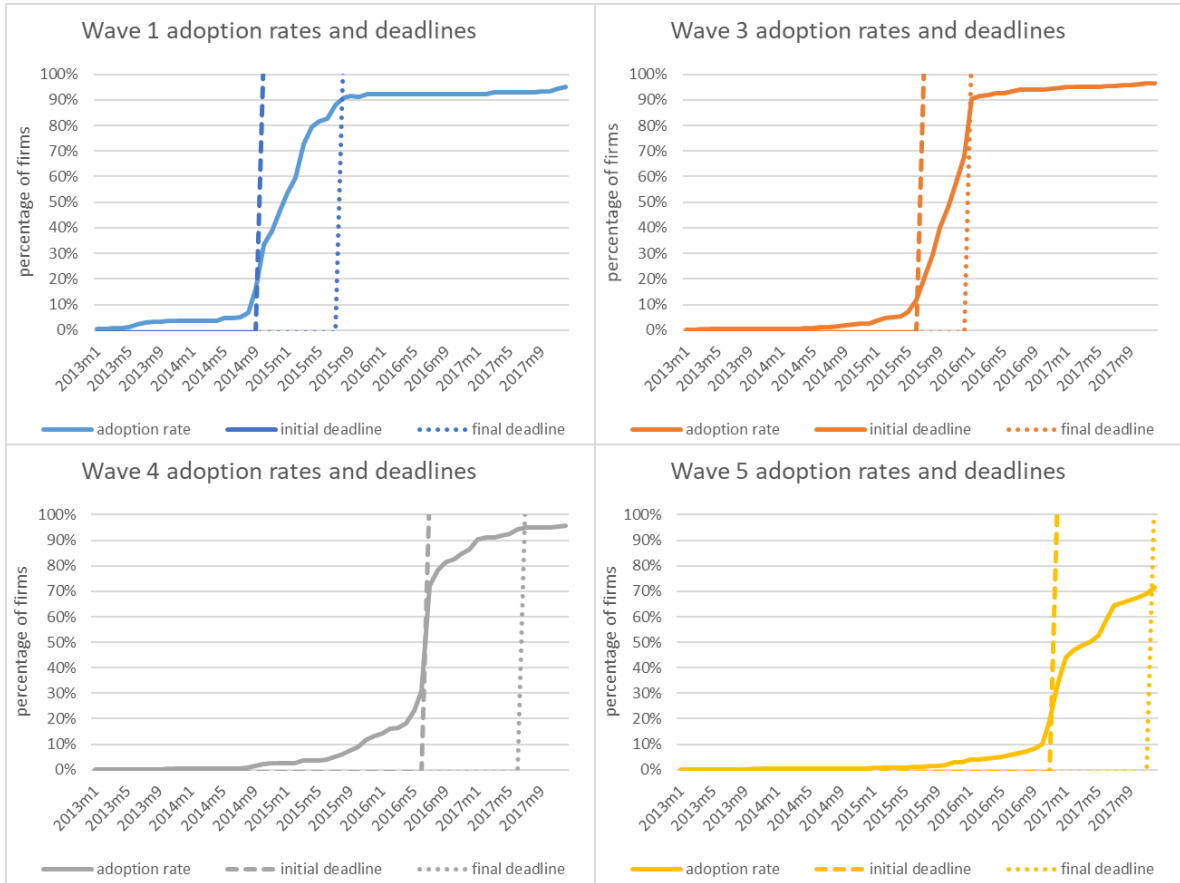
Panel B: ONR waves
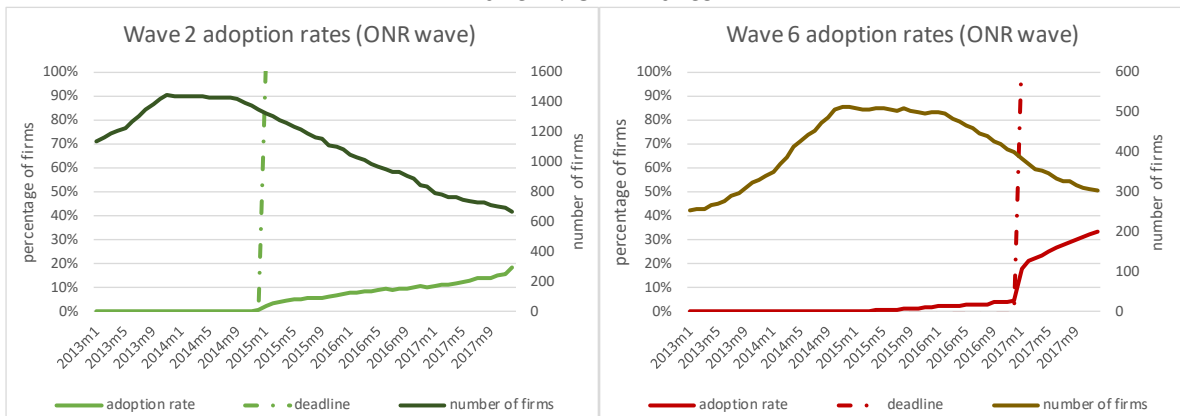
Note: This figure shows the rate of e-invoice adoption for different waves, using data from SUNAT.

Figure A.4. Percent Change in Taxable Value-Added Around the Mandatory Dates of Adoption

(percent change by quarter from the adoption deadline)
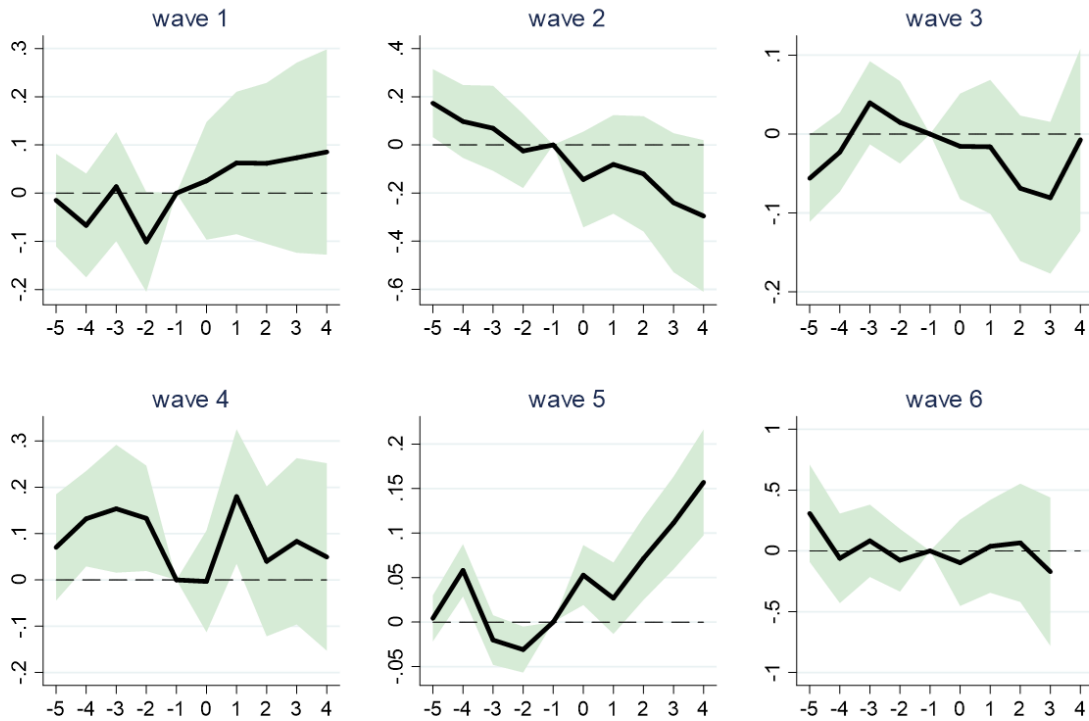
Note: Graph of the coefficient estimates of value-added and their confidence interval from the dynamic difference-in-differences regression for the balanced sample. Each graph corresponds to the sample of the firms mandated in the specified wave and those mandated in 2018.

Figure A.5 Percent Change in VAT payments Around the Mandatory Dates of Adoption
(percent change by quarter from the adoption deadline)
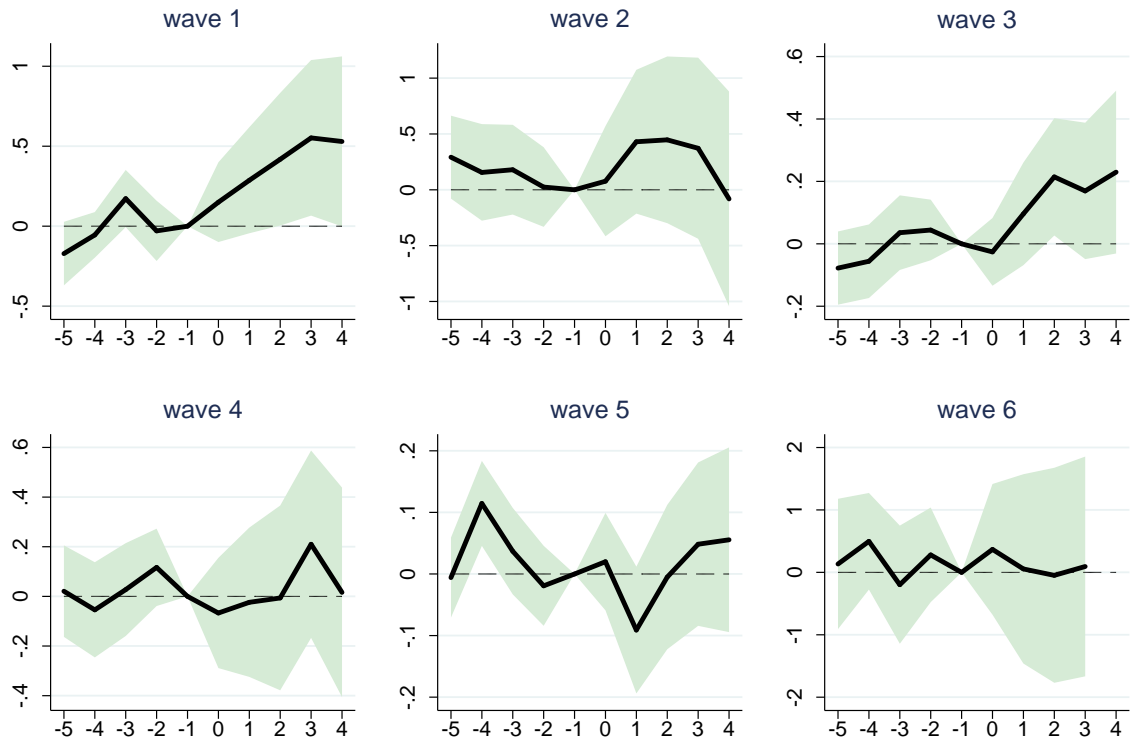
Note: Graph of the coefficient estimates of value-added and their confidence interval from the dynamic difference-in-differences regression for the balanced sample. Each graph corresponds to the sample of the firms mandated in the specified wave and those mandated in 2018.

Table A.1 – Summary Statistics for the Entire Database Over 2014-2017: main variables (1/2)

Values are in thousand 2014 soles unless otherwise specified	wave 1 (October 2014)		wave 2 (January 2015)		wave 3 (July 2015)		wave 4 (July 2016)		wave 5 (December 2016)		wave 6 (January 2017)		wave 7 (many 2018 deadlines)		Firms never mandated or mandated after	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
total sales	1,316,000	(1,768,000)	659	(5,551)	158,100	(183,100)	102,400	(262,500)	15,450	(125,700)	700	(1,181)	2,678	(13,890)	759	(3,634)
total purchases	1,047,000	(1,733,000)	606	(5,334)	114,000	(142,900)	87,220	(215,800)	11,430	(87,320)	643	(1,183)	2,213	(14,730)	629	(4,243)
value added	268,900	(944,700)	53	(309)	44,120	(126,900)	15,220	(154,100)	4,024	(70,050)	57	(263)	466	(8,287)	131	(3,667)
gross VAT	165,400	(243,200)	115	(999)	22,000	(23,290)	13,820	(20,860)	1,721	(8,805)	112	(196)	372	(1,875)	102	(516)
gross VAT credits	164,000	(243,200)	107	(960)	17,360	(23,060)	13,210	(34,990)	1,567	(13,980)	104	(195)	327	(2,122)	88	(599)
VAT due	34,280	(60,830)	13	(62)	7,167	(8,670)	3,723	(5,587)	501	(1,883)	12	(29)	111	(640)	30	(232)
new net VAT credits	32,840	(101,800)	4	(39)	2,531	(11,340)	3,115	(27,120)	347	(10,500)	5	(32)	66	(1,308)	16	(433)
total VAT collection	37,360	(72,380)	6	(20)	7,127	(9,189)	3,032	(5,610)	525	(9,799)	7	(22)	69	(480)	17	(194)
invoices issued electronically in 2018 (%)	0.85	(0.317)	0.63	(0.408)	0.91	(0.243)	0.94	(0.200)	0.93	(0.212)	0.82	(0.315)	0.34	(0.370)	0.18	(0.339)
VAT credit stock	20,540	(100,800)	4	(76)	2,433	(19,950)	3,523	(16,240)	477	(27,400)	3	(28)	90	(8,625)	27	(568)
exporters (%)	0.63	(0.484)	0.00	(0.052)	0.45	(0.498)	0.34	(0.473)	0.10	(0.299)	0.01	(0.093)	0.07	(0.248)	0.02	(0.147)
number of workers	1,729	(2,766)	4	(15)	710	(1,280)	287	(474)	103	(601)	2	(5)	14	(44)	6	(32)
wage bill (5ta)	11,410	(19,500)	4	(16)	2,319	(3,036)	938	(1,082)	292	(4,151)	2	(7)	26	(94)	12	(65)
capital	480,100	(892,800)	32	(96)	66,220	(230,700)	143,500	(974,200)	6,650	(91,900)	50	(133)	1,025	(16,720)	799	(20,840)
profits	123,600	(315,700)	21	(48)	14,630	(53,740)	19,810	(138,600)	1,055	(11,920)	25	(53)	200	(2,545)	102	(2,735)
observations	934		4,734		3,078		2,073		45,075		1,950		294,434		309,498	
share of total value-added	32%		0%		17%		4%		23%		0%		18%		5%	

Note: This table presents summary statistics by reform wave. Values correspond to annual averages and are expressed in thousands of 2014 soles, unless otherwise noted. In 2014, the exchange rate was approximately 0.34 US$ per soles. Waves are identified by their initial deadline, which are indicated in brackets. Shaded columns indicate the waves with firms that had been caught in fictitious or fraudulent transactions (ONR).

Table A.2 – Summary Statistics for the Entire Database Over 2014-2017: sector and risk distributions (2/2)

	wave 1 (October 2014)		wave 2 (January 2015)		wave 3 (July 2015)		wave 4 (July 2016)		wave 5 (December 2016)		wave 6 (January 2017)		wave 7 (many 2018 deadlines)		Firms never mandated or mandated after	
	obser-vation (% total)	value-added share (%)	obser-vation (% total)	value-added share (%)	obser-vation (% total)	value-added share (%)	obser-vation (% total)	value-added share (%)	obser-vation (% total)	value-added share (%)	obser-vation (% total)	value-added share (%)	obser-vation (% total)	value-added share (%)	obser-vation (% total)	value-added share (%)
Agriculture	1.3	1.0	1.7	1.4	0.8	0.6	0.6	0.5	3.4	4.6	4.8	-1.1	2.6	2.6	2.8	4.4
Fishing	0.6	0.4	1.1	0.3	0.4	0.3	0.5	0.4	1.7	1.4	2.1	3.5	0.6	0.8	0.9	1.1
Extraction	18.7	31.3	0.9	0.9	8.4	6.9	7.7	38.0	2.3	7.0	2.1	8.2	1.3	4.1	1.7	5.1
Manufacturing	20.0	7.7	12.8	20.6	17.9	14.5	13.5	8.0	9.0	13.5	11.2	18.4	10.5	10.0	8.9	8.9
Utilities	4.7	5.8	0.1	0.1	1.4	1.7	1.6	-4.6	0.7	2.5	0.0	0.0	0.2	-3.7	0.2	-5.3
Construction	3.5	3.1	9.7	23.8	9.3	8.8	13.8	13.2	9.4	5.1	9.4	9.2	9.8	16.4	14.3	18.8
Retail	32.4	3.2	47.0	21.2	21.7	2.8	24.7	-4.2	33.4	10.3	45.9	33.2	36.6	13.9	36.1	17.6
Hotel-restaurant	0.2	0.1	0.0	0.0	1.5	0.6	1.9	2.0	3.4	1.8	0.1	0.1	3.6	4.0	2.2	2.5
transportation	2.9	0.8	4.7	6.0	4.0	7.5	5.4	5.4	12.3	6.4	6.4	11.6	8.6	4.2	7.8	8.3
Telecommunication	1.9	3.0	0.7	0.2	1.0	0.4	1.9	-5.0	0.6	0.5	0.4	0.3	0.9	0.7	0.7	1.0
Other services	13.6	43.6	21.3	25.4	33.7	55.8	28.2	46.4	22.8	36.9	17.6	16.5	25.2	46.8	24.4	38.8
Public admnistration	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	1.1	10.0	0.0	0.0	0.1	0.1	0.2	-1.2
Small (150 - 1700 UIT[1/])	0.7	0.0	99.5	91.7	6.8	-1.9	9.6	-8.6	63.1	5.0	99.2	102.0	92.9	49.5	98.1	41.7
Medium (1700 - 2300 UIT[1/])	0.1	0.0	0.3	2.5	0.6	0.0	0.9	0.0	6.5	3.1	0.5	3.7	2.3	8.2	0.5	4.9
Large (2300+ UIT[1/])	99.1	100.0	0.3	5.7	92.6	101.9	89.6	108.7	30.3	91.8	0.3	-5.7	4.8	42.3	1.4	53.4
VAT credit stock in 2013Q2	45.7	39.8	30.5	30.1	29.6	20.1	43.4	5.5	27.7	38.5	19.6	24.6	31.9	28.1	33.3	24.7
Total observations	934		4,734		3,078		2,073		45,075		1,950		294,434		309,498	
Total value-added (million soles)		262,332		256		141,144		32,852		189,278		115		143,803		41,905
High risk	26.9	23.9	18.6	16.8	26.5	25.7	29.2	13.0	17.1	20.1	16.8	18.7	25.1	21.0	24.8	17.8
Medium risk	66.0	64.3	70.1	71.6	59.4	65.9	59.4	72.8	68.1	70.0	67.4	67.0	63.8	65.7	60.5	68.6
Low risk	7.2	11.8	11.3	11.5	14.2	8.3	11.4	14.1	14.8	9.9	15.8	14.3	11.1	13.3	14.7	13.6
Total observations	893		3,184		3,042		2,033		42,728		764		215,346		180,375	
Total value-added (million soles)		242,173		194		138,211		32,431		163,045		57		126,611		29,473

Note: This table presents summary statistics by reform wave. Values correspond to annual averages and are expressed in thousands of 2014 soles, unless otherwise noted. In 2014, the exchange rate was approximately 0.34 US$ per soles. Waves are identified by their initial deadline, which are indicated in brackets. Shaded columns indicate the waves with firms that had been caught in fictitious or fraudulent transactions (ONR).

1/ UIT are "Unidad Impositiva Tributaria", that is inflation-adjusted tax units.

Table A.3 – Summary Statistics for the Balanced Panel Sample Over 2014-2017: main variables (1/2)

Values are in thousand 2014 soles unless otherwise specified	wave 1 (October 2014) mean	sd	wave 3 (July 2015) mean	sd	wave 4 (July 2016) mean	sd	wave 5 (December 2016) mean	sd	wave 7 (many 2018 deadlines) mean	sd
total sales	1,315,000	(1,755,000)	168,300	(182,900)	101,800	(217,900)	18,780	(138,300)	2,883	(8,641)
total purchases	1,049,000	(1,735,000)	121,100	(144,200)	83,200	(143,900)	13,700	(92,370)	2,262	(7,534)
value added	266,000	(940,600)	47,140	(125,700)	18,610	(156,400)	5,080	(79,820)	622	(4,506)
gross VAT	164,400	(241,800)	23,470	(23,360)	14,450	(20,820)	2,051	(7,394)	411	(997)
gross VAT credits	164,000	(242,500)	18,410	(23,310)	12,430	(20,890)	1,873	(14,550)	340	(1,009)
VAT due	33,890	(60,620)	7,644	(8,766)	3,718	(5,085)	602	(2,072)	120	(292)
new net VAT credits	33,510	(102,500)	2,584	(11,350)	1,700	(6,559)	424	(11,960)	49	(486)
total VAT collection	36,750	(71,970)	7,604	(9,314)	3,062	(5,331)	646	(11,180)	76	(217)
invoices issued electronically in 2018 (%)	0.85	(0.318)	0.91	(0.239)	0.94	(0.199)	0.93	(0.208)	0.32	(0.358)
VAT credit stock	20,980	(101,600)	1,810	(11,300)	2,035	(10,010)	590	(31,330)	68	(10,410)
exporters (%)	0.63	(0.482)	0.49	(0.500)	0.37	(0.483)	0.12	(0.325)	0.07	(0.262)
number of workers	1,756	(2,796)	742	(1,311)	303	(489)	119	(665)	15	(44)
wage bill (5ta)	11,490	(19,660)	2,378	(3,043)	943	(1,062)	348	(4,662)	27	(75)
capital	475,300	(893,700)	58,940	(187,100)	76,880	(562,400)	6,882	(79,090)	754	(7,531)
profits	117,600	(306,200)	14,630	(48,070)	9,470	(59,930)	1,270	(13,430)	182	(2,000)
observations	900		2,756		1,768		33,792		173,508	
share of total value-added	35%		19%		5%		25%		16%	

Note: This table presents summary statistics by reform wave. Values correspond to annual averages and are expressed in thousands of 2014 soles, unless otherwise noted. In 2014, the exchange rate was approximately 0.34 US$ per soles. Waves are identified by their initial deadline, which are indicated in brackets.

Table A.4 – Summary Statistics for the Balanced Panel Sample Over 2014-2017: sector and risk distributions (2/2)

	wave 1 obser-vation (% total)	value-added share (%)	wave 3 obser-vation (% total)	value-added share (%)	wave 4 obser-vation (% total)	value-added share (%)	wave 5 obser-vation (% total)	value-added share (%)	wave 7 obser-vation (% total)	value-added share (%)
Agriculture	1.3	1.0	0.6	0.4	0.5	0.4	3.2	4.3	1.9	2.8
Fishing	0.7	0.4	0.4	0.3	0.3	0.3	0.7	1.1	0.2	0.4
Extraction	18.6	32.4	7.8	8.9	5.7	37.5	1.6	7.2	0.5	1.7
Manufacturing	20.8	8.0	19.3	14.8	14.9	7.2	10.0	13.6	12.1	12.0
Utilities	4.0	5.1	1.5	1.6	0.7	0.3	0.9	3.4	0.2	0.3
Construction	3.4	3.2	7.5	8.8	12.0	10.7	5.4	4.0	4.8	9.3
Retail	33.0	3.0	22.8	2.9	27.3	-5.2	35.3	9.9	38.9	15.1
Hotel-restaurant	0.2	0.1	1.7	0.6	2.2	1.9	3.6	1.7	4.0	4.0
transportation	3.0	0.8	4.1	7.7	6.1	5.0	13.4	6.4	10.5	7.9
Telecommunication	1.8	1.3	1.0	0.4	2.0	-0.4	0.6	0.5	0.9	1.2
Other services	13.2	44.6	33.3	53.6	28.0	42.2	24.0	37.5	25.8	44.7
Public admnistration	0.0	0.0	0.0	0.0	0.2	0.0	1.2	10.4	0.1	0.5
Small (150 - 1700 UIT[1])	0.1	0.0	1.2	-0.2	3.2	-1.0	55.0	4.6	91.4	44.8
Medium (1700 - 2300 UIT[1])	0.1	0.0	0.5	0.0	0.8	0.0	7.6	2.7	2.9	6.4
Large (2300+ UIT[1])	99.8	100.0	98.3	100.2	96.0	101.0	37.4	92.7	5.7	48.8
VAT credit stock in 2013Q2	46.2	41.2	27.7	21.9	42.3	15.3	27.1	39.6	38.9	30.1
Total (# obs; million soles)	900	252,965	2,756	136,541	1,768	34,552	33,792	181,131	173,508	113,637
High risk	26.4	24.1	26.8	28.3	30.9	11.5	18.7	21.0	24.4	24.0
Medium risk	66.2	63.9	59.4	64.1	58.6	73.9	68.5	69.7	65.0	63.1
Low risk	7.4	12.0	13.9	7.6	10.5	14.6	12.8	9.3	10.6	12.9
Total (# obs; million soles)	864	237,497	2,736	133,676	1,760	34,155	32,648	155,457	162,700	109,632

Note: This table presents summary statistics by reform wave. Values correspond to annual averages and are expressed in thousands of 2014 soles, unless otherwise noted. Waves are identified by their initial deadline.
1/ UIT are "Unidad Impositiva Tributaria", that is inflation-adjusted tax units.

Table A.5 –Results by wave for selected variables

Panel A. Taxable Value Added

(in log of soles unless otherwise indicated)	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6
Treatment indicator (1 year after)	0.0805	-0.0702	-0.0512*	-0.0295	0.0425***	0.0560
	(0.0541)	(0.0957)	(0.0275)	(0.0502)	(0.0147)	(0.158)
Number of workers	0.338***	0.321***	0.321***	0.335***	0.367***	0.337***
	(0.0139)	(0.0140)	(0.0132)	(0.0151)	(0.0142)	(0.0158)
Wage bill	-0.0209***	-0.0183***	-0.0157***	-0.0100**	-0.00380	-0.00348
	(0.00392)	(0.00400)	(0.00392)	(0.00478)	(0.00477)	(0.00524)
Capital stock	0.00627***	0.00490***	0.00134	0.00220	0.00250*	0.00212
	(0.00202)	(0.00158)	(0.00157)	(0.00161)	(0.00148)	(0.00157)
Constant	9.565***	9.594***	9.721***	9.644***	9.598***	9.568***
	(0.0346)	(0.0324)	(0.0314)	(0.0369)	(0.0385)	(0.0397)
Observations	394,989	396,471	403,355	402,353	479,439	362,841

Panel B. VAT payments

(in log of soles unless otherwise indicated)	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6
Treatment indicator (1 year after)	0.131	0.293	-0.0170	-0.109	-0.0459	0.130
	(0.125)	(0.253)	(0.0563)	(0.113)	(0.0382)	(0.579)
Number of workers	0.547***	0.524***	0.538***	0.543***	0.626***	0.562***
	(0.0372)	(0.0360)	(0.0379)	(0.0357)	(0.0337)	(0.0385)
Wage bill	-0.0506***	-0.0457***	-0.0473***	-0.0278***	-0.0176*	-0.0224**
	(0.00890)	(0.00914)	(0.00943)	(0.00980)	(0.00986)	(0.0106)
Capital stock	-0.000405	0.00316	0.00350	0.0111**	0.00762*	0.00521
	(0.00526)	(0.00416)	(0.00472)	(0.00479)	(0.00442)	(0.00480)
Constant	4.732***	4.736***	4.964***	4.838***	4.851***	4.826***
	(0.0805)	(0.0745)	(0.0819)	(0.0859)	(0.0866)	(0.0899)
Observations	479,621	479,600	484,726	482,009	570,053	434,300

Note: This table presents estimates obtained in separate regressions run by wave based on the balanced sample. Each column only includes the wave of interest and wave 7, the control group. For each wave, the estimation period includes 11 quarters, centered around the adoption deadline, with five quarters before and five quarter after the quarter of the deadline.