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ICT adoption in micro and small firms:
Can internet access improve labour productivity?

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The rapid spread of information and communication technologies may increase firms' productivity with important consequences for job creation and for economic growth. This article contributes to this discussion by analysing the impact of internet adoption on labour productivity and the mechanisms shaping this relationship in Peruvian micro and small manufacturing firms over the period 2011-2013. The article estimates a reduced form where labour productivity is a function of internet adoption and other explanatory factors. Internet adoption is instrumented using a measure of the availability of financial opportunities for micro and small firms in Peru. Findings indicate that internet adoption: (i) increases firms' labour productivity; (ii) reallocates employment away from temporary administrative workers and non-remunerated workers and expands employment of permanent production workers; (iii) leads to the formalization of labour relationships, to the implementation of new organizational practices, and to the improvement of training measures. While changes in employment and formalization of workers are linked to labour productivity gains, increases in training measures and organizational changes do not generate any additional productivity increase.

Keywords: internet adoption, labour productivity, micro and small firms, employment structure, organizational practices

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1. Introduction

Information and communication technologies (ICT) have greatly spread around the developed and developing world in recent decades (World Bank, 2016). Simultaneously with the expansion of these new technologies, the need to understand how ICT impact productivity has emerged among researchers and policymakers. Whether ICT are productivity-enhancing factors is a fundamental public policy question with important consequences for job creation (and destruction) and for economic growth.

ICT can impact firms and workers' productivity through different channels. ICT can improve access to information, helping firms to optimize management practices and reorganize their business model, to use their existing capacity more efficiently, and to reduce risks and costs. The literature has highlighted the role of skills and organizational practices to obtain the efficiency gains ICT can provide. The available evidence points to the (low) skill level of the workforce and the implementation of old management practices as weakening factors to the link between ICT adoption and firms' productivity growth (Bresnahan, et al. 2002; Bloom et al., 2012). ICT adoption can also have an impact on the employment level and on the structure of employment. There is evidence for developed countries showing that ICT in the form of computer adoption have changed the structure of employment. The use of computers at the workplace has led to the polarization of labour markets by substituting workers carrying out routine tasks --middle-skilled workers mainly, and complementing workers performing activities difficult to automate, such as problem-solving and creative tasks, typically done by high-skilled workers (Acemoglu and Autor, 2011; Autor and Dorn, 2013; Goos et al., 2014). For developing countries, the evidence of ICT impacts on labour productivity and the structure of employment is still scarce and this paper intends to fill this gap in the literature.

In this article, I analyse the impact of internet adoption on labour productivity in Peruvian micro and small manufacturing formal firms over the period 2011-2013. Micro and small firms are a fundamental part of the productive structure in Peru. They represent more than 95% of firms nationally and employ more than 80% of the economically active population (Ministerio de la Producción, 2015). Despite the importance of micro and small (MyPE) firms in terms of employment, their productivity is way below the productivity of large firms in Peru (Chacaltana, 2008). MyPE firms' low productivity levels has been pointed out as a limiting factor to Peruvian economic growth and development, as large firms do not have access to a stable and high quality supply of intermediate goods and services (Ministerio de la Producción, 2015).

On the technology side, ICT have spread importantly in Peru in the last years. At the level of the household, the Peruvian national household survey shows that 23% of households had access to a computer in 2010 and it increased to 33% in 2015. Access to internet exhibited a similar growth from 13% to 23% over the same period. At the firm level, the MyPE Survey (Peruvian survey to micro and small manufacturing formal firms which is the main source of data in this paper) indicates that the percentage of MyPE firms having access to a computer grew from 65% to 75% between 2011 and 2013, while access to the internet increased from 56% to 68%. The expansion in internet adoption may have been a productivity enhancing factor for Peruvian MyPE firms, helping them to reduce the productivity gap with large firms. Furthermore, internet adoption may have encouraged the implementation of up to date organizational practices, which the literature has found to be ICT complementary factors.

The analysis shows interesting findings for Peruvian MyPE firms with important policy implications. First, older firms, firms with more highly educated managers and male managers, and larger firms in terms of employment and intermediate inputs adopt the internet with a higher probability. Second, internet adoption leads to labour productivity increases at the firm level of 25% on average. Third, the analysis of the mechanisms at play indicates that: (i) productivity increases are related to changes in the structure of employment. Permanent production workers gain a share in total employment, while temporary administrative workers and non-remunerated workers are substituted by the technology; (ii) internet adoption leads to the formalization of labour relationships, and this effect is positively related to productivity increases; (iii) internet adoption leads to the implementation of new organizational practices, such as management, innovation and ICT practices, and to improvement in training measures. However, these changes are not associated with the increase in labour productivity. In sum, these findings shed new light on an important policy question and contribute to a better understanding of the productivity impacts of internet adoption in a developing country context, where micro and small firms' low productivity level is a potential limiting factor for economic growth and development.

Throughout the analysis, I use information from the MyPE firms Survey 2011, 2012 and 2013. This survey is carried out in eight Peruvian municipalities and covers 21 activities of the manufacturing sector. Pooling these cross sections of firms and defining labour productivity as production value per worker, I implement an instrumental variable strategy. As pointed out by previous literature, firms may make their internet adoption decisions based on unobservable factors which may also impact their productivity. Additionally, labour productivity and the decision to adopt the internet may be determined simultaneously. The

instrument is motivated by two features of internet services and MyPE firms' access to technology in Peru. First, internet services are intermediated by an IT device. Second, MyPE firms need to have credit access in order to incorporate new technology. According to the MyPE Survey, more than 90% of MyPE firms asked for credit and had access to it during the analysed period. I define the instrument as a measure of credit *availability* for MyPE firms in the municipality where the firm is located multiplied by a measure of financial instruments *knowledge* by the firm's manager. First stage results show that the instrument is a strong predictor of internet adoption and passes all tests for weak instruments.

This paper makes important contributions to the literature analysing the impact of ICT adoption on labour productivity. First, it provides evidence for micro and small firms in a developing country context, where the low productivity level of these firms has been pointed out as a restricting factor for development and growth. Second, it shows that even when internet adoption leads to the implementation of new organizational practices, such as management, innovation and ICT procedures, these practices are not associated to labour productivity increases, at least contemporaneously. This evidence differs from previous results for developed countries (Bloom et al., 2012) and suggests a potential scarcity of complementary factors, such as skilled workers. Third, it provides evidence of an additional mechanism through which ICT adoption may impact labour productivity –the improvement of working conditions. This channel has not been analysed before and the findings in this article indicate that the formalization of labour relationships is positively associated with labour productivity increases due to internet adoption in Peruvian MyPE firms.

The remainder of the article is structured as follows. Section 2 reviews the literature while Section 3 introduces the data and descriptive statistics. Section 4 discusses the econometric strategy and Section 5 discusses the main results. Section 6 concludes.

2. Literature review

This article builds and extends on the literature analysing the labour market effects of ICT adoption. First, it is related to firm level studies analysing the effects of ICT adoption on labour productivity. Second, it is also connected to the literature studying the impact of ICT adoption on the composition of employment.

The first group of studies dates back to the 1980s. Their findings were not supportive of the hypothesis that ICT investments have a positive impact on firms' productivity (Morrison and Berndt, 1990; Loveman, 1994). Two potential explanations were proposed by the following literature to rationalize this "productivity paradox" (Brynjolfsson and Hitt, 1996).

On the one hand, firms need from an organizational structure and from skilled labour to facilitate the introduction of new technologies. Caroli and Van Reenan (2001), Bresnahan et al. (2002), Brynjolfsson and Hitt (2003) and Bloom et al. (2012) find that organizational practices and human capital are important complementary factors to generate significant returns to ICT investments. On the other hand, the lack of convincing causal evidence was presented as another potential explanation for the "productivity paradox" (Draca et al., 2007). More recent studies have been able to establish causal evidence through natural experiments. Bartel et al. (2007) consider a narrowly defined industry in the US –valve manufacturing- and show that the adoption of new ICT-enhanced machinery improves the efficiency of all stages of the production process with reductions in setup times. De Stefano et al. (2014) find no relationship between internet adoption and labour productivity at the firm level taking advantage of a geographic discontinuity in the availability of broadband internet in the UK. Akerman et al. (2015) exploit the sequential rollout of broadband internet across Norway as a natural experiment and show that access to broadband internet by firms improves labour productivity of skilled workers and worsens the productivity of unskilled workers.

Among the studies analysing the impact of ICT adoption on employment composition, there is a first group of papers using industry, occupation or industry-occupation data, and the use of computers in the workplace as ICT adoption measure. Their findings indicate that computers substitute middle-skilled workers performing routine tasks, while complement high-skilled workers performing tasks difficult to automate, such as abstract or cognitive tasks. A pattern of employment polarization has been reported as a consequence, where middle-skilled occupations reduce their share in total employment, while low- and high-skill occupations gain participation (Acemoglu, 1999; Autor et al., 2003; Acemoglu and Autor, 2011; Autor and Dorn, 2013 and Autor, 2014 for the U.S.; Goos and Manning, 2007 for the United Kingdom; and Goos et al., 2014 and Michaels et al., 2014 for European countries more broadly). A second group of studies used firm level data to report a positive correlation between ICT adoption (measured as IT capital stock, computer adoption, the number of computers, IT investment, and the number of IT workers) and the relative demand for skilled workers (Caroli and Van Reenen, 2001; Greenan and Topiol-Bensaid, 2001; Bresnahan et al., 2002). More recent studies mentioned in the previous paragraph established a causal relationship between ICT adoption and the structure of employment at the firm level. Their findings indicate that the adoption of ICT is generally linked to an increase in skilled workers' employment and a reduction in unskilled workers' employment (Bartel et al., 2007; De Stefano et al., 2014; Akerman et al., 2015; Gaggl and Wright, 2017).

The evidence for developing countries is scarcer and this article intends to fill this gap in the literature. Iacovone et al. (2016) provide evidence on how ICT adoption impacted Mexican firms' performance during 2008-2012. Using panel data and an instrumental variable strategy, they show that ICT (measured as the number of computers per worker and the share of workers using the internet) positively affects labour productivity. This effect is only present for firms facing higher competitive pressures from China. Additionally, they find a positive relation between ICT adoption and organizational changes and innovation. Brambilla and Tortarolo (2017) study the impact of ICT investment on productivity and employment for Argentinean manufacturing firms using retrospective information for 2010-2012. Their findings indicate that investment in ICT leads to increases in firm productivity and to decreases in the share of unskilled labour, supporting the view that ICT is complementary with skilled labour. Almeida et al. (2017) explore a panel dataset of Chilean firms over the period 2007-2013 to study the employment impacts of a measure of advanced technology adoption captured by complex software, which is typically used by more educated workers. Using an instrumental variable strategy they find that, in the medium run, the adoption of complex software by Chilean employers reallocates employment away from skilled workers and expands administrative and unskilled production worker's jobs. For Peru in particular, there is no firm-level evidence on the impacts of ICT adoption on firms' performance. The available studies analyse the effects of the internet and cell-phone expansion on measures of economic development in rural areas of the country. They find that mobile phone expansion increased household consumption and reduced poverty, while internet adoption increased employment and the prices farmers receive for their products (Beuermann et al., 2012; Ritter and Guerrero, 2014).

3. Data and Descriptive Statistics

In this study I use firm level data from the Peruvian MyPE firms Survey during 2011, 2012 and 2013. The MyPE firms Survey was conducted on eight Peruvian municipalities –Lima, Provincia Constitucional del Callao, Arequipa, Trujillo, Chiclayo, Iquitos, Huancayo and Piura in 2011 and 2012, and the coverage was extended to eleven municipalities in 2013. The survey covered 21 economic activities from the manufacturing sector which, according the Peruvian IV National Economic Census, are the activities with the highest share of firms. At the time of the survey, MyPE firms were defined following two criteria –number of employees and value of annual sales. A micro firm was defined as a firm employing between

1 and 10 workers and with sales up to 150 tax units annually, while a small firm was defined as a firm with 11 to 100 employees or sales between 151 and 1700 tax units.

Table 1 provides descriptive statistics for the sample of MyPE firms used throughout the analysis. The sample includes all firms with no missing information on the outcome variables of interest and on the control variables used in the regression analysis, and it is restricted to firms in the eight municipalities covered in the first two waves of the survey.

Panel A of Table 1 provides information on productivity and employment variables. MyPE firms are a fundamental part of the productive structure in Peru in terms of employment, i.e., they employ more than 80% of the economically active population, but their low productivity level is a potential limiting factor to economic growth and development. The productivity measure used as outcome variable in the econometric analysis is the production value per worker. This measure increased between 2011 and 2012, and then fell and ended up in 2013 with a similar value to 2011. The total employment level was 7.2 workers on average; it decreased between 2011 and 2012, but surpassed the initial level in 2013. In terms of employment composition, production workers (permanent and temporary) were the most important category representing more than half of MyPE firms' total employment. The second most important employment category was that of non-remunerated workers which represented approximately one fifth of total employment.[1]

Panel B includes information on ICT measures. The share of MyPE firms with internet access increased over time, from 0.56 in 2011 to 0.68 in 2013. The share of firms owing at least one computer grew from 0.65 to 0.75 over the same period, and the number of computers per workers exhibited an important increase as well, growing from 0.26 computers per worker in 2011 to 0.38 in 2013.

The distribution of firms by aggregate economic sector (at 1 digit level) appears in Panel C of Table 1. Aggregate sector 1, which includes manufacture of food products, wearing apparel, leather products, and products of wood, had the highest share in the sample with an average of 0.6 over time. The second most important sector was aggregate sector 2 including the manufacture of fabricated metal product which represented a quarter of the sample over time. Finally, aggregate sector 3 includes manufacture of furniture and jewellery and had a participation of approximately 0.15 over time. In terms on managers' characteristics, most of them are men, are 45 years old approximately, and have superior level of education.

[1] The non-remunerated workers' category includes unpaid family workers which is an important employment category in Peru, averaging 18.9% of total employment since 2003 (SEDLAC, 2018).

4. Estimation Strategy

To estimate the effect of internet adoption on MyPE firms' labour productivity, I use the following reduced form specification where *i* is a firm, *m* is a municipality and *t* is a year:

$$Y_{imt} = \alpha + X_{imt}\beta + \delta_0 D_{imt} + I_m + I_t + I_m * T_t + \varepsilon_{imt}. \quad (1)$$

I use model (1) to estimate the impact of internet adoption (indicator variable D_{imt}) on labour productivity measured as the logarithm of the production value per worker (Y_{imt}). The vector X_{imt} includes firm's age, an indicator for whether firm *i* is micro, characteristics of the manager such as age, gender and educational level, a set of 21 economic activity indicator variables, and variables capturing the value of production inputs which information is available in the MyPE Survey --the logarithm of total employment and the logarithm of intermediate inputs value per worker. The logarithm of capital value per worker was obtained indirectly assuming a Cobb Douglas production function and using productivity parameters available in the literature for Peru (Miller, 2003; Carranza et al., 2005; Céspedes et al., 2016).[2] Unobservable determinants of Y_{imt} that are fixed at the municipality level are controlled for by the inclusion of municipality indicators (I_m), while common time shocks are captured by year indicators (I_t). Model (1) also includes linear municipality specific time trends ($I_{m*}\ T_t$).

The key threat to identification of the causal impact of internet adoption on firm labour productivity (δ_0) is that firm's decision to adopt the internet is likely to be based on some unobservable firm characteristics, such as quality of products, organization of firms, managers' background, which are also determinants of firms' productivity (omitted variable argument). Additionally, the decision to adopt the internet may itself depend on a firm's actual productivity (reverse causality argument) (Draca et al., 2007). To address these problems, I adopt an instrumental variables strategy. The proposed instrument is based on the following facts: (i) internet services are intermediated by an IT device (computer, laptop, smartphone, etc.); (ii) MyPE firms in Peru depend crucially on having access to credit to compete and grow (Tello Cabello, 2014). Thus, MyPE firms need to have credit access in order to incorporate new technology such as IT devices and internet. Table 1-Panel D presents evidence on MyPE firms' credit access obtained from the MyPE Survey.

[2] The production function was defined as $Y_{it} = AL_{it}{}^{\alpha}K_{it}{}^{1-\alpha}$. Information on *Y* and *L* is available in the MyPE Survey. The value of the parameter α was set on 0.6. The value of capital input obtained after linearizing previous expression is a combination of input *K* and the technology parameter *A*. The use of alternative values for α (0.4 and 0.5) leads to the same econometric conclusions.

Approximately 43% of surveyed firms applied for credit in 2012 and 2013.[3] From them, more than 95% obtained credit, mainly from private banks. The credit obtained was mainly used to finance increases in firm's working capital –65% of the cases approximately, while it was used to incorporate fixed assets in around 10% of the cases.

In order to construct the instrument, I use information on the availability of financial opportunities for MyPE firms. The instrument does not use information on the *actual access* to financial instruments by firms, but on the availability and knowledge about them. I expect the instrument to provide an exogenous shifter for the probability of adopting internet as it affects the firm-level probability of having access to financial instruments but it does not affect and neither is affected by the outcome variable (labour productivity). The instrumental variable is defined as:

$$Z_{imt} = F_{mt} * f_{imt}. \quad (2)$$

F_{mt} in (2) captures the availability of financial services for MyPE firms in the municipality where the firm is located. Specifically, F_{mt} is the ratio between the number of financial institutions providing their services to MyPE firms in municipality *m* and the total number of financial institutions that could potentially provide their services to MyPE firms. The total number is six and includes private banks, cajas municipales (municipal savings and credit associations), cajas rurales (rural savings and credit associations), EDPYME (financial institutions specifically oriented to MyPE firms), NGO's, and other entities such as cooperatives. On the other hand, f_{imt} captures the knowledge of firm *i* about financial instruments for MyPE firms. More exactly, f_{imt} is the ratio between the number of financial products for MyPE firms that firm's *i* manager knows and the total number of products available in the market in the municipality where firm *i* is located.

The instrument presented in (2) may be criticized for three reasons. First, it could be the case that more productive firms are located in municipalities with a higher presence of financial institutions providing their services to MyPE firms (F_{mt} in equation (2)). My reasoning is that, if anything, the factor that could affect MyPE firms' location is not the presence of financial institutions, but the rate at which financial institutions provide credit to MyPE firms. Thus, more productive firms should be located in municipalities where financial institutions provide credit with a higher probability. Similarly, financial institutions may base

[3] Information on firms' application for credit is not available in the 2011 MyPE Survey. This survey has information on credit access, but it is not conditional on having applied for credit. For that reason, it is not comparable to statistics from the 2012 and 2013 MyPE Surveys.

their location decisions on firms' productivity. Regarding this point, I claim that firms' labour productivity is unobservable for financial institutions. Second, more productive firms may have managers with a greater knowledge about financial instruments (f_{imt} equation in (2)). To mitigate this concern, the set of control variables includes managers' characteristics, such as age, education and gender, eliminating any direct correlation between firm's productivity and managers' knowledge about financial instruments. Third, any positive association in the first stage between the availability of financial instruments for MyPE firms and firm's internet adoption may be capturing the use of credit for other proposes as well, i.e. increases in working capital or fixed assets different from the ones needed to have internet installed, i.e. router. To consider this possibility, I will include as a control variable an indicator for whether firm *i* uses credit to increase its working capital or fixed assets –this variable is included in X_{imt}.

4.1. First Stage Results

Column 1 in Table 2 presents first stage results obtained from an OLS regression where the indicator of internet adoption by firm *i* (D_{imt} in (1)) is regressed on the instrument Z_{imt} presented in equation (2) and X_{imt}, I_m, I_t and I_m*T_t. Standard errors in this first stage are clustered at the municipality level and robust to heteroskedasticty. The same applies to the rest of the paper. The estimated coefficient indicates that, given the share of financial institutions in municipality *m*, a one percentage point of increase in firm manager's knowledge about financial instruments for MyPE firms increases the chances of adopting the internet by 0.79 percentage points. The remaining coefficients give some insights on the characteristics of firms adopting internet. Older firms, firms with a male manager or with a high educated manager, micro firms, and firms that use financing to increase the working capital or to incorporate fixed assets, have a higher probability of adopting internet. Similarly, firms with a higher value of intermediate inputs per worker and larger labour force have higher chances of adopting the internet, while the association with the value of capital per worker is negative. The F statistic of the first stage is above 10, passing the Staiger and Stock's (1997) rule for rejection of the hypothesis of weak instruments when there is one endogenous variable. The p value of the underidentification test also allows the rejection of the hypothesis of having a weak instrument.

4.2.Who are the Compliers?

To analyse what types of firm adopt the internet as a response to a higher availability of financial services (compliant firms), I ran the first stage separately for three groups of firms – firms in each economic activity at 1 digit level, and I obtained the percentage of compliant firms in each group.

Table 3 presents the results jointly to a characterization of firms in each of the three groups in 2011 -the first year of data. Column (1) indicates the share of each group in total sample, while column (2) presents the first stage coefficient associated to the instrument Z_{imt} in the group sub-sample. The share of compliers in each group is presented in column (3) and it is calculated following Akerman et al. (2015). For each group, the share of compliers is the ratio between the first stage coefficient in the group sub-sample and the first stage coefficient in the overall sample multiplied by the participation of the group in the total sample.

Compliant firms belong mainly to aggregate sector 1. In 2011, firms in this sector were smaller and less productive compared to firms in aggregate sector 2, but they had better indicators compared to firms in aggregate sector 3. The share of firms with a computer was smaller in aggregate sector 1 compared to aggregate sectors 2 and 3, while the share of low-educated managers was larger in aggregate sector 1 compared to other sectors.

This analysis indicates that firms adopting the internet when the financial channel is activated are those with poorer characteristics. These are probably the firms that could not have access to the internet and IT devices in general in absence of financial instruments. This story differs from Akerman et al. (2015) who, using broadband availability as an instrumental variable, found that firms adopting the internet in Norway are those with an abundance of complementary factors such as computers and skilled labour.

5. Results

This section discusses the instrumental variables estimation results of model (1). I start by discussing the impact of internet adoption on firm labour productivity and I then turn to the analysis of the mechanisms explaining these impacts. In Table 4, I study the effect of internet adoption on labour productivity captured by the logarithm of production value per worker. Results correspond to the second stage of a two-stage least squares estimate and indicate that internet adoption leads to an increase in the production value per worker of 24.5%. The analysis of the remaining coefficients indicates that small firms (compared to micro firms), firms with older managers, and firms with low educated managers are more productive. The use of credit to finance increases of working capital or the incorporation of fixed assets also increases firms' labour productivity. A higher value of intermediate inputs per worker and

capital per worker increases labour productivity, while a larger labour force has a negative impact on it.

5.1. General technical upgrading

The first possible channel to explain productivity increases is a general technical upgrading in firms. Internet adoption may take place simultaneously with the adoption of IT devices, such as computers. In fact, the positive association found in the first stage between the availability of financial instruments for MyPE firms and internet adoption may be capturing the fact that firms can react to a higher probability of having access to credit by adopting internet and IT devices as well. Additionally, the analysis of compliant firms reveals that most of them belong to aggregate sector 1, which had the lowest share of firms with a computer to begin with. In order to control for this possibility, previous estimates included the use of credit to increase firms' working capital or to incorporate fixed assets as control variable. In this sub-section I estimate directly the relation between the availability of financial instruments for MyPE firms and firm *i* number of computers per worker. This corresponds to the first stage model where the dependent variable is the number of computers per worker, instead of internet access.

Results appear in Table 5, both controlling and without controlling for the use of credit to finance increases in firms' working capital or to incorporate fixed assets (column 1 and 2 respectively). The estimated coefficients on the availability of financial instruments for MyPE firms are not statistically significant. The evidence does not support the general technical upgrading channel.

5.2. Employment level and structure of employment

Another potential channel to explain the increase in labour productivity is the change in the structure of employment. A firm may decide to increase the share of certain employment categories and to reduce the share of some others as a result of internet adoption. If employment categories differ in their individual productivity, a change in firm's average labour productivity is possible.

The estimated effects of internet adoption on firms' employment are presented in Table 6.[4] Panel A shows the impacts on the employment level of the seven employment categories

[4] The first stage associated to these models appears in column (2) of Table 2. The specification differs with respect to labor productivity models in the exclusion of the logarithm of the labor force, the logarithm of

covered in the MyPE Survey –managers, permanent and temporary administrative workers, permanent and temporary production workers, non-remunerated workers and sub-contracted workers, and on total employment. Internet adoption leads firms to increase their size in terms of total employment by 65% on average (Column 8 in Panel A). Changes in employment categories are as follows (Columns 1 to 7 in Panel A). There is an increase in the employment level of managers (34%), permanent administrative workers (37%) and permanent production workers (249%). The employment of temporary administrative workers and non-remunerated workers falls (16% and 37% respectively), while the employment of temporary production workers and sub-contracted workers do not change. Changes in employment levels translate into changes in firms' structure of employment. These results appear in Panel B of Table 6 and indicate an increase in the share of permanent production workers of 45 percentage points on average, jointly to reductions in the shares of temporary administrative workers and non-remunerated workers of 4 and 34 percentage points respectively.

Three important observations arise from these results on employment levels and on the structure of employment. First, there is some kind of complementarity between production workers and internet. The category of production workers should include both skilled and unskilled workers, although the survey does not distinguish between them. A complementarity effect is expected between skilled production workers and IT adoption in general (Autor et al., 1998). On the other hand, a substitution effect between unskilled production workers and internet would be reasonable because they perform more routine tasks in comparison to skilled production workers who carry out more cognitive and abstract tasks. The results obtained for MyPE firms in Peru indicate that the complementarity effect between skilled production workers and internet offsets any substitution effect between unskilled production workers and internet. As skilled production workers are arguably more productive than unskilled production worker, the increase in the share of permanent production workers is a clear channel underlying the gains in terms of labour productivity for firms adopting internet.

Second, the reduction in the share of (temporary) administrative workers reveals that internet may be replacing the routine tasks performed by this occupational category, such as sending information to clients/suppliers by email instead of by regular mail, to a greater

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intermediate inputs per worker, and the logarithm of capital per worker from X_{imt}. The first stage coefficient is positive and significant
statistically while the F test of excluded instruments is above 10. The same arguments used to support the validity of the exclusion restriction of the instrument apply here and in next sub-sections.

extent than the increase in any abstract tasks administrative workers may perform, e.g. conducting research on the internet (Autor and Dorn, 2013). The remaining administrative workers can thus focus on activities where they are better than the technology, increasing their productivity. Furthermore, workers hired in a temporary base may be less productive than workers hired permanently. Then, the reduction in the share of temporary administrative workers is a possible channel to explain labour productivity increases in firms adopting internet.

Third, there is a potential improvement in employment conditions as the demand for non-remunerated workers and their share in total employment falls, and these workers are replaced by remunerated categories (permanent production workers). Assuming that workers receiving a wage are more productive than non-remunerated workers, the improvement in employment conditions may explain the increase in labour productivity. In the next sub-section I analyse this channel in more detail.

5.3. Employment conditions

Increases in labour productivity as a result of internet adoption may be linked to improvements in working conditions. For instance, if the adoption of internet is positively correlated with the compliance with labour regulations, workers will be more motivated and potentially more productive.

The MyPE Survey does not include direct information on labour regulations, but includes a set of questions related to the use of government services oriented to MyPE firms. Among these services is the use of the "Planilla". The Planilla is the formal register of labour relationships. Wage employees who are registered in the Planilla are entitled to several benefits according to the Peruvian law (Viollaz, 2018). In order to analyse whether internet adoption impacts positively on labour productivity through a formalization channel, I use as outcome variable an indicator for whether firm *i* uses the Planilla. This information is available in the MyPE Survey of 2012 and 2013. It could be the case that firm *i* uses the Planilla but does not comply with all labour benefits, or that it complies with all labour benefits but only for some of its workers. However, the impact of internet adoption on this indirect measure of formalization can be informative.

Panel A of Table 7 presents the result obtained when estimating model (1) with the indicator for whether firm *i* uses the Planilla as outcome variable. The set of regressors included is the same as for employment variables' models. The estimated impact is positive and statistically significant indicating that internet adoption leads to an increase in the

probability of using the Planilla of about 41 percentage points. Possible explanations are the on-line access to information on labor regulations and penalties in case of non compliance, and the possibility of filling out the Planilla on-line. This result adds to the indirect evidence obtained when analysing employment variables.

The next step is to analyse if the improvement in firms' labour productivity as a result of internet adoption is related to the use of the Planilla. To this end, I extend model (1) by including the interaction between internet adoption and the indicator for whether firm *i* uses the Planilla:

$$Y_{imt} = \alpha + X_{imt}\beta + \delta_0 D_{imt} + \delta_1 D_{imt} * M_{imt} + \delta_2 M_{imt} + I_m + I_t + I_m * T_t + \varepsilon_{imt}. \qquad (3)$$

In this model M_{imt} captures the use of the Planilla by firm *i*. Panel B of Table 7 Shows that both the direct impact of internet (δ_0) and the interaction term with the use of Planilla (δ_1) are not significant statistically. The evaluation of the hypothesis of insignificance of the total impact of internet adoption on labour productivity for firms using the Planilla is positive and significant at 10% level. The evidence, although weak, points to the formalization of labour relationships as a channel explaining the increase in labour productivity.

5.4. Organizational practices, Innovation and Training

Previous literature has found that ICT adoption impacts on firm productivity depend on organizational capital and management practices (Bresnahan et al., 2002; Caroli and Van Reenen, 2001; Bloom et al., 2012). In this sub-section, I first estimate the relation between internet adoption and management, innovation, ICT and training practices at the firm level. The MyPE Survey is rich in capturing this type of measures. I use as outcome variables three score measures of management practices, innovation practices, and ICT practices respectively. Each score is calculated as the sum of the management, innovation or ICT practices firm *i* implemented in year *t*, and then normalized to have a variation between 0 and 1. I also use as outcome variables an indicator for whether firm *i* trains workers, the share of trained workers, and the logarithm of training expenses in a per worker basis.

Table 8 provides descriptive statistics on this set of outcome variables over time. All the score measures are on average very low, indicating that only few MyPE firms implemented new organizational practices over the analysed period. The score of management and innovation practices had an erratic behaviour, while the score of ICT practices increased with the passing of time. On the other hand, the share of firms providing training to their workers,

the share of trained workers and training expenses per worker improved between 2011 and 2013.

Table 9 presents the results of estimating model (1).[5] The estimated impact of internet adoption is positive and statistically significant for all outcome variables. The adoption of internet is thus positively linked to the implementation of new management methods, to the implementation of innovative production techniques, to the implementation of ICT practices and to the training of workers. The positive impact on training variables is in line with the empirical evidence showing that IT is on average skill-biased and requires hiring more skilled workers and/or retraining incumbent workers (Autor et al., 1998; Bresnahan et al., 2002; Bloom et al., 2012; Akerman et al., 2015).

The next step is to analyse if the increase in firms' labour productivity as a result of internet adoption is related to these practices. I use model (3) presented before where I include the interaction between internet adoption and each one of the management, innovation, ICT and training variables, one at a time. Results appear in Table 10 and show that the direct effect of internet adoption (δ_0) continues being positive and significant. The estimated coefficient of the interaction term (δ_1) is not statistically significant in most models. The only exception is the interaction when using the indicator variable for whether firm *i* provides training to its workers. The coefficient associated to this interaction term is negative, indicating that the increase in labour productivity is *smaller* for these firms. A possible explanation is that when workers are receiving training they cannot take full advantage of internet as they are applying less time to produce.

The last part of Table 10 shows the result of testing the hypothesis for the impact of internet adoption on labour productivity being zero for a firm with an average value in variable M_{imt}.[6] Most of the hypothesis can be rejected at the usual significance levels, indicating that a firm with an average value of the management, innovation or ICT practices score, a firm with an average share of trained workers and a firm with an average training expenses per worker experiences an increase in labour productivity as a result of internet adoption and the increase is not statistically different from a firm with M_{imt}=0. The only exception appears when using the indicator variable for whether firm *i* provides training to its workers. For these firms the total effect of internet adoption on labour productivity is statistically zero.

[5] The number of observations is smaller compared to previous models due to missing values in outcome variables. For the logarithm of training expenses per worker, the number of observations corresponds to 2012 and 2013 because data is not available in the 2011 MyPE Survey.

[6] For the indicator of whether firm *i* provides training to workers, the test corresponds to M_{imt}=1.

6. Conclusions

Information and communication technologies adoption can impact labour productivity with important consequences for job creation and for economic growth. From a public policy perspective, the relation between ICT adoption and labour productivity is particularly important in a country like Peru where the low productivity level of its firms is pointed out as a potential limiting factor for economic growth and development.

This paper has shown interesting findings on the link between internet adoption and labour productivity in Peruvian micro and small manufacturing firms, and the mechanisms shaping this relationship. First, internet adoption leads to labour productivity increases at the firm level and to an expansion in firms' total employment. Managers, permanent administrative workers, and permanent production workers are the categories enjoying labour demand increases, while temporary administrative workers and non-remunerated workers are the categories suffering labour demand reductions. The available information is not enough to check if temporary administrative workers and non-remunerated workers switched to permanent and remunerated positions respectively. In that case, internet adoption would imply a net gain for the society, as total employment increased and workers climbed the ladder to better employment positions. However, if temporary administrative workers and non-remunerated workers became unemployed, internet adoption would imply a potential loss for the society, as these workers probably lack the skills firms are demanding.

Second, internet adoption is related to changes in the structure of employment. Permanent production workers gain share in total employment, while temporary administrative workers and non-remunerated workers are substituted by the technology. Assuming that workers hired on a temporary base are less productive than workers hired permanently, and that remunerated workers are more productive than non-remunerated workers, the reported change in the structure of employment help explain the increase in labour productivity in firms adopting internet.

Third, internet adoption leads to the formalization of labour relationships, and this effect is positively related to productivity increases, i.e., increases in labour productivity are larger in firms using the formal register of labour relationships. This result provides evidence on an additional mechanism through which ICT adoption may impact labour productivity that has not been explored before, i.e. formalization of workers.

Fourth, internet adoption leads to the implementation of new organizational practices, such as management, innovation and ICT practices, and to the improvement in training measures. However, these changes are not associated to labour productivity increases. This

finding differs from previous evidence for developed countries and suggests a potential shortage of complementary factors, such as skilled workers.

Fifth, older firms, firms' with higher educated managers and male managers, and larger firms in terms of employment and intermediate inputs adopt internet with a higher probability. These results provide with valuable information regarding where to focus the policy efforts when trying to promote the adoption of digital technologies. For instance, low educated managers may not know the potential benefits of adopting internet, but having them as targets of the policy efforts can result in more widespread improvements in labour productivity.

All these findings suggest potential heterogeneous impacts of internet adoption on labour productivity depending on the structure of employment and the formality status of the workforce. For instance, sectors where firms have larger shares of formal workers and a structure of employment that favours workers hired on a permanent basis over temporary workers, and remunerated workers over non-remunerated workers are expected to obtain larger productivity gains.

In sum, this paper has provided novel and policy relevant evidence on the positive impact of internet adoption on labour productivity in Peruvian micro and small firms. The findings have also highlighted the important facts that internet adoption leads firms to improve working conditions through the formalization of labour relationships and that firms employing formal workers experience larger increases in labour productivity. However, these potential benefits of internet adoption may be restricted by the scarcity of factors which complement the technology. That was the case of micro and small firms in Peru which did not get additional productivity gains from changes in organizational and training practices associated to the adoption of internet. In terms of policy implications, the evidence presented in this paper has shown that policies oriented to promote the adoption of ICT in micro and small firms can be beneficial to close the productivity gap with larger firms in Peru. Moreover, policies directed to the formalization of the workforce can provide an extra benefit, i.e., additional labour productivity gains in firms adopting internet. Finally, policies orientated to the development of digital skills are also important to ease the re-employment of those workers losing their jobs and the achievement of additional productivity gains that new organizational practices can provide.

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Table 1: Descriptive Statistics on MyPE firms

	2011		2012		2013	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Panel A: Productivity and Employment						
Production value per worker	90.21	98.79	97.75	98.33	90.58	89.41
Total employment	7.72	7.83	6.12	5.48	7.88	10.89
Shares of total employment						
Managers	0.10	0.20	0.10	0.22	0.20	0.26
Adm. workers - Permanent	0.14	0.22	0.15	0.28	0.11	0.20
Adm. workers - Temporary	0.03	0.12	0.03	0.13	0.03	0.11
Prod. workers - Permanent	0.36	0.34	0.26	0.34	0.28	0.31
Prod. workers - Temporary	0.16	0.26	0.21	0.31	0.26	0.30
Non-remunerated workers	0.20	0.28	0.25	0.33	0.13	0.20
Sub-contracted workers	0.00	0.05	0.00	0.04	0.00	0.02
Panel B: ICT adoption measures						
Share of firms with access to internet	0.56	0.50	0.55	0.50	0.68	0.47
Share of firms with a computer	0.65	0.48	0.60	0.49	0.75	0.43
Number of computers per worker	0.26	0.45	0.31	0.43	0.38	0.44
Panel C: Firm's characteristics						
Distribution by aggregate economic sector						
Sector 1	0.59	0.49	0.62	0.48	0.56	0.50
Sector 2	0.23	0.42	0.26	0.44	0.26	0.44
Sector 3	0.18	0.38	0.12	0.33	0.18	0.38
Manager characteristics						
Share of males	0.65	0.48	0.77	0.42	0.67	0.47
Age	45.14	11.02	45.09	11.12	46.09	11.29
Share with primary education	0.05	0.21	0.05	0.23	0.04	0.21
Share with secondary education	0.28	0.45	0.39	0.49	0.28	0.45
Share with superior education	0.68	0.47	0.56	0.50	0.67	0.47
Panel D: MyPE firms access to financial markets						
Apply for credit	n.a.	n.a.	0.43	0.50	0.44	0.50
Credit acces	n.a.	n.a.	0.95	0.22	0.97	0.17
Bank	0.91	0.28	0.91	0.29	0.91	0.29
Municipal credit and saving association	0.09	0.28	0.09	0.29	0.10	0.30
Rural credit and saving association	0.00	0.05	0.02	0.14	0.01	0.11
EDPYME	0.03	0.17	0.03	0.18	0.01	0.12
NGOs	0.00	0.03	0.00	0.02	0.00	0.06
Other	0.01	0.10	0.02	0.12	0.01	0.12
Finance of working capital	0.67	0.47	0.64	0.48	0.67	0.47
Finance of fixed assets	0.13	0.33	0.09	0.29	0.10	0.29
Other uses	0.21	0.44	0.26	0.44	0.23	0.42
Observations	1,806		1,775		2,098	

Source: Author, based on MyPE Survey (2011, 2012 and 2013).

Notes: Production value per worker expressed in thousands of Soles of 2011. n.a. not available.

Table 2: Availability of Financial Opportunities for MyPE Firms and Firms' Internet Adoption

	=1 if firm has internet	
	(1)	(2)
Frt*firt	0.786	0.982
	[0.231]**	[0.289]**
Firm age	0.000515	0.00128
	[0.000253]*	[0.000196]***
=1 if micro firm	0.0907	-0.202
	[0.00741]***	[0.0107]***
=1 if male manager	0.0361	0.0521
	[0.00846]***	[0.0114]***
Manager age	-7.05e-05	0.000356
	[0.000321]	[0.000367]
=1 if manager has secondary education	0.0525	0.0686
	[0.0147]***	[0.0133]***
=1 if manager has superior education	0.250	0.304
	[0.0168]***	[0.0183]***
=1 if uses credit to finance working capital or fixed assets	0.0455	0.0779
	[0.00748]***	[0.00880]***
Log of materials per worker	0.0701	
	[0.00195]***	
Log of total employment	0.225	
	[0.00668]***	
Log of capital per worker	-0.00564	
	[0.00288]*	
Municipality fixed effects	Yes	Yes
Sector fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Linear municipality-time trends	Yes	Yes
Observations	5,679	5,679
R-squared	0.228	0.175
F test of excluded instrument	11.56	11.54
p-value of underid test	0.0003	0.0003

Source: Author, based on MyPE Survey (2011, 2012 and 2013).

Notes: Robust standard errors in brackets clustered by municipality. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels, respectively. F_{rt} indicates the share of financial institutions for MyPE firms in the municipality where the firm is located; f_{irt} is firm's i manager knowledge of financial instruments for MyPE firms.

Table 3: Characteristics of Compliant Firms

	Composition of sample	First stage coefficient	Composition of compliers	Characteristics of aggregate sectors in 2011					
				Log value added	Total employment	Share of firms with computer	Low educ manager	Medium educ manager	High educ manager
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Aggregate sector 1	0.59	0.90	0.70	1.66	7.60	0.61	0.06	0.27	0.67
Aggregate sector 2	0.25	0.44	0.14	2.18	8.92	0.78	0.02	0.21	0.77
Aggregate sector 3	0.16	0.70	0.15	1.61	6.56	0.62	0.04	0.38	0.58
Overall	1.00	0.79	1.00	1.82	7.69	0.67	0.04	0.29	0.67

Source: Author, based on MyPE Survey (2011, 2012 and 2013).

Notes: Aggregate sector 1 includes manufacture of food products, wearing apparel, leather products, and products of wood; aggregate sector 2 includes the manufacture of fabricated metal product; aggregate sector 3 includes manufacture of furniture and jewellery. The share of compliers in each aggregate sector (column 3) is calculated as the ratio between the first stage coefficient in the group sub-sample and the first stage coefficient in the overall sample (column 2) multiplied by the participation of the group in the total sample (column 1). The resulting shares are then re-scaled to add up to 1.

Table 4: MyPE Firms Internet Adoption and Labour Productivity

	Log of Production per worker (1)
=1 if firm has internet access	0.219
	[0.0375]***
Firm age	-3.65e-05
	[0.000208]
=1 if micro firm	-0.118
	[0.0107]***
=1 if male manager	-0.0110
	[0.00926]
Manager age	0.00118
	[0.000223]***
=1 if manager has secondary education	-0.0644
	[0.0139]***
=1 if manager has superior education	-0.00140
	[0.00941]
=1 if uses credit to finance working capital or fixed assets	0.0186
	[0.00517]***
Log of materials per worker	0.373
	[0.0109]***
Log of total employment	-0.0458
	[0.0126]***
Log of capital per worker	0.135
	[0.00384]***
Observations	5,679

Source: Author, based on MyPE Survey (2011, 2012 and 2013).
Notes: Robust standard errors in brackets clustered by municipality. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels, respectively. The table reports 2SLS estimates of model (1). Controls include year, municipality and sector fixed effects, and linear municipality-time trends.

Table 5: Availability of Financial Opportunities for MyPE Firms and Number of Computers per worker

	Number of computers per	
	(1)	(2)
Frt*firt	-0.0273	-0.0196
	[0.0567]	[0.0575]
Firm age	0.00126	0.00127
	[0.000323]***	[0.000320]***
=1 if micro firm	-0.222	-0.222
	[0.0262]***	[0.0264]***
=1 if male manager	-0.0275	-0.0271
	[0.00533]***	[0.00496]***
Manager age	-0.00101	-0.00105
	[9.67e-05]***	[0.000147]***
=1 if manager has secondary education	-0.0503	-0.0509
	[0.00755]***	[0.00788]***
=1 if manager has superior education	-0.0866	-0.0880
	[0.00770]***	[0.00719]***
=1 if uses credit to finance working capital or fixed assets	0.00955	
	[0.0124]	
Log of materials per worker	0.00647	0.00674
	[0.00562]	[0.00595]
Log of total employment	-0.417	-0.416
	[0.0106]***	[0.00950]***
Log of capital per worker	0.00276	0.00292
	[0.00332]	[0.00324]
Observations	5,679	5,679
R-squared	0.266	0.266

Source: Author, based on MyPE Survey (2011, 2012 and 2013).

Notes: Robust standard errors in brackets clustered by municipality. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels, respectively. F_{rt} indicates the share of financial institutions for MyPE firms in the municipality where the firm is located; f_{irt} is firm's *i* manager knowledge of financial instruments for MyPE firms. Columns 1 and 2 include year, municipality and sector fixed effects, and linear municipality-time trends.

Table 6: MyPE Firms Internet Adoption and Employment Variables

	Managers	Adm. Permanent	Adm. Temporary	Prod. Permanent	Prod. Temporary	Non-rem.	Sub-contracted	Total employment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Log of employment levels								
=1 if firm has internet access	0.290	0.316	-0.175	1.249	0.0733	-0.442	0.00725	0.503
	[0.0567]***	[0.0439]***	[0.0849]**	[0.218]***	[0.179]	[0.145]***	[0.0140]	[0.0648]***
Observations	5,679	5,679	5,679	5,679	5,679	5,679	5,679	5,679
Panel B: Shares of employment								
=1 if firm has internet access	-0.0661	-0.00443	-0.0367	0.453	-0.0140	-0.336	0.00401	
	[0.0711]	[0.0551]	[0.0141]***	[0.113]***	[0.0608]	[0.0271]***	[0.00513]	
Observations	5,679	5,679	5,679	5,679	5,679	5,679	5,679	

Source: Author, based on MyPE Survey (2011, 2012 and 2013).

Notes: Robust standard errors in brackets clustered by municipality. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels, respectively. The table reports 2SLS estimates of model (1). Controls include firm age, manager gender, age and educational level, an indicator for whether firm uses credit to finance increases in firms' working capital or to incorporate fixed assets, year, municipality and sector fixed effects, and linear municipality-time trend.

Table 7: MyPE Firms Internet Adoption and Use of the Planilla and Labour Productivity

Panel A: Impact of Internet adoption on the use of Planilla	
=1 if firm has internet access	0.409
	[0.118]***
Observations	3,873
Panel B: Impact of Internet adoption on labor productivity	
=1 if firm has internet access	-0.624
	[1.023]
=1 if firm has internet access *	1.360
=1 if firm uses Planilla (Mimt)	[1.440]
Test for $\delta_0+\delta_1$*Mimt=0	
Effect evaluated on Mimt=1	0.736
p-value	(0.084)*
Observations	3,873

Source: Author, based on MyPE Survey (2011, 2012 and 2013).
Notes: Robust standard errors in brackets clustered by municipality. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels, respectively. Panel A reports 2SLS estimates of model (1), while Panel B reports 2SLS estimates of model (3). Controls include firm age, manager gender, age and educational level, an indicator for whether firm uses credit to finance increases in firms' working capital or to incorporate fixed assets, year, municipality and sector fixed effects, and linear municipality-time trends.

Table 8: Descriptive Statistics on MyPE firms Organizational Practices and Training Variables

	2011	2012	2013
Panel A: Organizational practices			
Score of management practices	0.017	0.004	0.008
Score of innovation practices	0.026	0.033	0.008
Score of ICT practices	0.008	0.013	0.022
Panel B: Training variables			
Share of firms providing training	0.119	0.146	0.165
Share of trained workers	0.070	0.141	0.663
Training expenses per worker	n.a.	1.003	1.013

Source: Author, based on MyPE Survey (2011, 2012 and 2013).
Notes: Table reports average values. Score measures are calculated as the sum of the management, innovation or ICT practices firm *i* implemented in year *t*, and then normalized to have a variation between 0 and 1. Management practices include organizational methods, accountability and finance methods, marketing and sales methods, and administration and production methods. Innovation practices include innovation in products or services, in the production process, and in the relation with suppliers and customers. ICT practices comprise web page design, online commerce, online banking, and online operations with public institutions. Training expenses per worker are expressed in local currency of 2011. n.a. not available.

Table 9: MyPE Firms Internet Adoption and Management, Innovation, ICT and Training Practices

	Score of management practices	Score of innovation practices	Score of ICT practices
	(1)	(2)	(3)
Panel A: Organizational practices			
=1 if firm has internet access	0.107	0.129	0.248
	[0.0223]***	[0.0364]***	[0.0548]***
Observations	5,507	5,354	5,679
	=1 if trained workers	Shr of trained workers	Log of training expenses p/w
	(1)	(2)	(3)
Panel B: Training variables			
=1 if firm has internet access	0.713	0.360	0.0831
	[0.134]***	[0.137]***	[0.0238]***
	5,679	4,038	3,725

Source: Author, based on MyPE Survey (2011, 2012 and 2013).

Notes: Robust standard errors in brackets clustered by municipality. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels, respectively. The table reports 2SLS estimates of model (1). Controls include firm age, manager gender, age and educational level, an indicator for whether firm uses credit to finance increases in firms' working capital or to incorporate fixed assets, year, municipality and sector fixed effects, and linear municipality-time trends.