The complementarity between ICT use and competition in Mexico*

Leonardo Iacovone† Mariana Pereira-Lopez‡ Marc Schiffbauer§

March 2015

(Preliminary and incomplete version. Please do not cite without permission)

Abstract

This study uses a firm-level data panel for Mexico, with information never used for research before, in order to assess how ICT use influences firm performance. Further, we explore how, in the context of raising competition from China, if this effect is different for firms more strongly affected by competition where incentives for upgrading and innovation may be more intense. In this perspective, we analyze the complementarity between ICT and competition, taking advantage of the exogenous shock generated by Chinese competition. The results indicate that ICT use has higher effects over productivity in the case of firms facing higher competition from China both in the domestic market and in the US market. Furthermore, once we take into consideration the complementarity between these two factors, neither of them influences productivity taken separately.

JEL Classifications:E23, F14, L25, O33

Keywords: ICT, productivity, competition

---

*ACKNOWLEDGEMENTS: We thank Gerardo Durand, Gerardo López, Simón Sánchez Trinidad and Gabriel Romero from INEGI in Aguascalientes for all their support with the data use in compliance with the confidentiality requirements set by the Mexican Laws.

This paper was prepared as background study for the forthcoming World Development Report 2017 "The Internet for Development".

†Senior Economist, World Bank email:liacovone@worldbank.org

‡Consultant, World Bank. Universidad Iberoamericana email:mpereiralopez@worldbank.org

§Senior Economist, World Bank email: mschiffbauer@worldbank.org

1 Introduction

The relation between Information and Communication Technologies (ICT) and productivity has been widely studied. According to Syverson (2011) ICT is one of the "levers" or factors that can be potentially used to increase firm's productivity. However, there is still no much evidence regarding the channels through which this observed relation operates as well as other factors different from skills that could enhance these effects. The knowledge of these complementarities is really important for policy design as it could lead to more efficient mechanisms and programs to enhance firm-level productivity.

On the other hand, recent studies have stressed that external competition shocks induce faster technical change and innovation by speeding up creative destruction and, therefore have effects on firm's productivity. (Iacovone et al., 2013; Bloom et al., 2015) A large part of this discussion has focused on rich countries competing with developing countries specialized in low-skilled intensive goods, a specific of that kind of competitive shocks, on which the literature has focused on, is the impressive increase in Chinese manufacturing exports. Bloom et al. (2015) have found that competition from China has indeed induced both innovation and the adoption of new technologies and ICT in OECD countries, contributing thus to their productivity growth. However, there is little evidence in the case of developing countries.

The purpose of this study is to analyze for the case of Mexico and focus on the effect that ICT use has on firms, but even further evaluate if this effect is heterogeneous depending on the level of competition faced by the firms. The main hypothesis behind this analysis is that firms that face higher competition have more incentives to make an effective use of ICT in order to be able to cope with the challenges posed by the entry of new competitors. More specifically, existing literature has shown that an effective adoption of ICT requires important changes within the firms and is costly in terms of organizational changes, therefore only firms that face enough competitive pressures decide to do so. In this sense, the main contribution of this article is to contribute to the existing knowledge on the relation between ICT use and trade-induced technical change, which have been previously studied as separate topics. Additionally, we test whether previous empirical results regarding ICT use and productivity such as Stiroh (2002); Bresnahan et al. (2002) and Bloom et al. (2012) hold for a developing country such as Mexico, which has a very different structure in terms of management practices than the US or Europe and that has faced Chinese competition not only in its domestic market but in its main exports market, the US, which represents 80% of Mexico's exports. [1]

Most of the studies regarding the effects of Chinese competition for Mexico have focused on aggregate effects on trade and output rather than firm-level effects (Freund and Ozden, 2006; Olarreaga et al., 2007; Jenkins et al., 2008, among others). However, according to recent empirical evidence, there is much more going on at the intra-firm level as competition can lead to organizational changes, more investment

[1] Source: Ministry of Economy. This figure is for 2014

and more investment in technology in order to be able to avoid exit in terms of the extensive margin and to avoid losses (intensive margin). In this sense, this study intends to shed light on the relation between these two variables.

The rest of this article is organized as follows: Section 2 provides a literature review of empirical studies on ICT use as well as creative destruction induced by competition. In section 3, the methodology is presented. Section 4 explains the data used in the analysis as well as some descriptive statistics. Results are discussed in section 5 and conclusions in section 6.

2 Literature Review

This study is closely related with two different strands of economic literature. The first one is the one that analyzes the effects of ICT adoption on productivity while the second is the one related to trade competition and the adjustments needed at the firm level in order to be able to face the pressure generated generated by external competition.

There is a great deal of studies regarding the impact of ICT on productivity both at the macro and country level as well as the micro and firm-level. The first analyses regarding this topic were conducted during the 80s and did not find evidence of any effect of ICT on productivity. This lack of evidence was regarded as "the Solow paradox" (Brynjolfsson and Hitt, 1996). However, improvements in the measurement of ICT as well as more detailed data allowed to find evidence that proved that previous results were not correct and that ICT had an important effect on productivity (Stiroh, 2002). Therefore, most of the recent articles regarding ICT use focus on explaining the increase in U.S aggregate productivity during the period of 1995-2005 and also try to understand the differences in terms of growth between U.S. and another developed economies, mostly in Europe (Basu et al., 2004). Among these studies are Haltiwanger et al. (2003) who find that part of the differences in productivity are because U.S. firms engage in experimentation activities at a rate not matched by its German counterparts. In order to explain these same differences, Bloom et al. (2012) argue that there is complementarity between ICT use and management practices. That is, ICT solely is not sufficient to enhance productivity, and better management practices are associated to higher productivity impacts of ICT.[2]

Another set of studies, related to our paper, is those that focus on the role of skills and the changes on the labor market as a result of skill-biased technological change following Autor et al. (2003). The idea behind these studies is that technological change and ICT act as substitutes for low-skilled workers but as complements for high-skilled workers. Therefore, the wage polarization observed in the US could be

[2] See Draca et al. (2006) for a review of articles regarding ICT use and productivity.

explained by ICT adoption. Michaels et al. (2014) and Akerman et al. (2015) provided evidence to support this idea.

Empirically, one of the main problems that arise in the analysis of ICT use and productivity is, as pointed out by Draca et al. (2006) that ICT investment is a firm's decision and it is not plausible to assume that it is independent of performance. Therefore, ICT use is most likely endogenous and it is important to find an instrument that only affects productivity through ICT use.

Another strand of literature related to our work are the studies analyzing the effect China's competition on Mexico. However, most of these studies have focused on aggregate effects of Chinese competition and on whether Mexican products have been displaced by Chinese competition both in the domestic market and in the US market. For example Freund and Ozden (2006) estimate a gravity model and find that China's exports growth had moderate effects on Latin America's growth as a region, but had negative impact on Mexico only in some sectors. Jenkins et al. (2008) finds that as a result of Chinese competition some countries such as Argentina, Chile and Brazil won while Mexico and Central America experienced losses. Finally, Olarreaga et al. (2007) find no evidence of lost opportunities for Latin America. Furthermore, they find that there may be complementarities between these countries and China in external markets.

However, more recent studies make use of firm-level data in order to assess whether trade competition generates pressure on firms for speeding up ICT use and technical change. In this framework, Bloom et al. (2015) find that Chinese competition led to higher R&D, patenting, ICT and productivity in a sample of European countries. Furthermore, theses pressures contributed to the reallocation of labor towards more technologically intensive sectors. On the other hand, Iacovone et al. (2013) analyze whether Chinese competition operates as a selection mechanism in the Mexican market, taking advantage of this exogenous shock from competition. They find heterogeneous effects on both the extensive (firm's exit) and the intensive margins. Additionally, product reallocation within plants is observed as a result of competition.

3 Empirical strategy

3.1 Modeling strategy

The basic firm-level equation that we estimate is:

$$log(sales/worker)_{i,t} = \beta_0 + \beta_1 * ICT_{i,t} + \beta_2 x_{i,t} + \alpha_i + u_i t \quad (1)$$

Where

$log(sales/worker)_{i,t}$=Logarithm of sales-per-worker for firm i at time t

$ICT_{i,t}$=ICT use of firm i at time

$x_{i,t}$=Vector of control variables such as age, firm's size, region and share of skills

α_i=firm fixed effects

Taking this equation as a basis, we use different specifications in order to test whether the predictions of empirical models previously applied to developed countries hold for the case of Mexico, as well as to analyze the interaction between Chinese competition and ICT use with firm-level data.

3.2 Instrumental variables

Considering that ICT is endogenous to firm performance, we use an instrumental variable approach. The instrument used is defined as follows:

$$IV1_{j,s} = ICT_{int,j} * \Delta ICTHHuse_s \tag{2}$$

Where

$ICT_{int,j}$=ICT intensity of sector j in the US

$\Delta ICTHHuse_s$=Change in the share of households with computers in state s

In order to construct $IV1$ we take the ICT-intensity classification used in Bloom et al. (2012) and O'Mahony and Van Ark (2003), which is based on Stiroh (2002) and interact this sectoral variable with the change in household ICT-use at the state level. [3] The use of this second measure is based on Akerman et al. (2015) To construct this variable we use two alternative sources. The first one is the 2000 and 2010 Population and Housing Censuses, while the second one is the Module on Information Technology Availability and Use in Households (MODUTIH 2010 and 2013). An advantage of this measure is that ICT intensity is based on U.S. data, which is by definition exogenous to what we observe for Mexico.

[3]Considering that these classifications are based on ISIC rev.3.1 we used the correspondences tables between ISIC rev 3.1 and ISIC 4 and then we used the NAICS-ISIC 4 correspondence table. As there are different levels of aggregation in this process, we also tested an ICT intensity variable based on the sectoral descriptions rather than the classification codes, which proved to be more highly correlated with our endogenous variable(ICT use).

4 Data and descriptive statistics

4.1 Firm-level ICT use

Data regarding ICT use was obtained from Mexico's National Survey on Information Technologies 2009 and 2013. This survey was designed by the National Science and Technology Council (CONACYT) and conducted by the National Institute of Statistics and Geography (INEGI). It includes detailed information on ICT use at the firm-level that to, the best of our knowledge, has not been previously used for research purposes.

We constructed a panel including firms that appeared in both surveys. Due to the sample design of this survey we were only able to match 719 firms out of approximately 6,210 included in the ENTIC 2013.[4] Additionally, firms of the trade and services sectors are excluded from the sample, as we focus on manufacturing goods for which we have available trade data.

As our main measure of ICT use, we selected computers-per-worker, a measure which has been used in previous studies such as Bloom et al. (2015). As these authors argue, the main two advantages of this indicator is that it is a physical quantity measure that is recorded consistently across firms and sectors and that it avoids the use of price deflators.

Additionally, we selected three other proxies of ICT use in order to test the robustness of our results. The first one is the share of labor that uses Internet in the firm, the second one is E-commerce Purchases/Total Purchases, which measures a totally different aspect of ICT use and the last one is the share of labor with computer, which should be almost equal to computers-per-worker and is used mainly to test the robustness of our results obtained with that variable. In fact, Bloom et al. (2012) use the share of labor with computer as a robustness test as there could be mismeasurement in their IT stock capital variable that could be biasing their results.

4.2 Trade data

Trade data was obtained from the World Integrated Trade Statistics (WITS) using the HS 1996 classification at the 6-digits level. Considering that some HS6 codes appear in more than one NAICS 4-digits code, we

[4]The ENTIC surveys were designed to gather information for firms with more than ten employees from the manufacturing, electricity, construction, services, electricity, mining, transportation and communication sectors according to the NAICS 2007 classification. The sample design is probabilistic and stratified by employment level. The sample is statistically reprsentative at the national level by economic sector. Due to this probabilistic design it is easier to find big firms in both surveys (2009 and 2013).

reclassified the ones that had more than one match using the Mexican Tariff Classification (8 digits), by including them into the NAICS sector that had the highest share of the 6-digits HS code for total Mexican imports in 2013.[5]

Competition is measured for the period of 2000-2008. This period was selected considering that the first year of our panel is 2008 (ENTIC 2009 gets information for the previous year). We use imports data for Mexico, the U.S. and Europe in order to analyze Chinese competition. Specifically, we calculate the share of China on imports for each NAICS-4-digits code included in the base.

$$Compet_j = \frac{Mj, China}{\sum_{k=1}^{n} M_{j,k}} \tag{3}$$

Where

$Mj, China$=Imports of country j from China

$M_{j,k}$=Imports of country j from country k

4.3 State household ICT-use

As mentioned before, in order to construct our instrumental variable, we combine ICT sectoral intensity for the US obtained from Bloom et al. (2012) with household ICT use.

Information regarding household ICT use at the state level is from the National Population and Housing Censuses 2000 and 2010. We also obtained information from the Module on Information Technology Availability and Use in Households (MODUTIH 2010 and 2013) in order to compare it to the census data.

4.4 Descriptive Statistics

As mentioned before, the random sample design of the ENTIC surveys, made only possible to match 719 firms and around 87% of them are big firms, as they are the ones that must be in both samples in order to achieve statistical representativeness. This fact has important implications regarding the interpretation of our results given that previous studies suggest that small firms are the ones more likely to exit and be negatively affected by the increasing competition. (Iacovone et al., 2013)

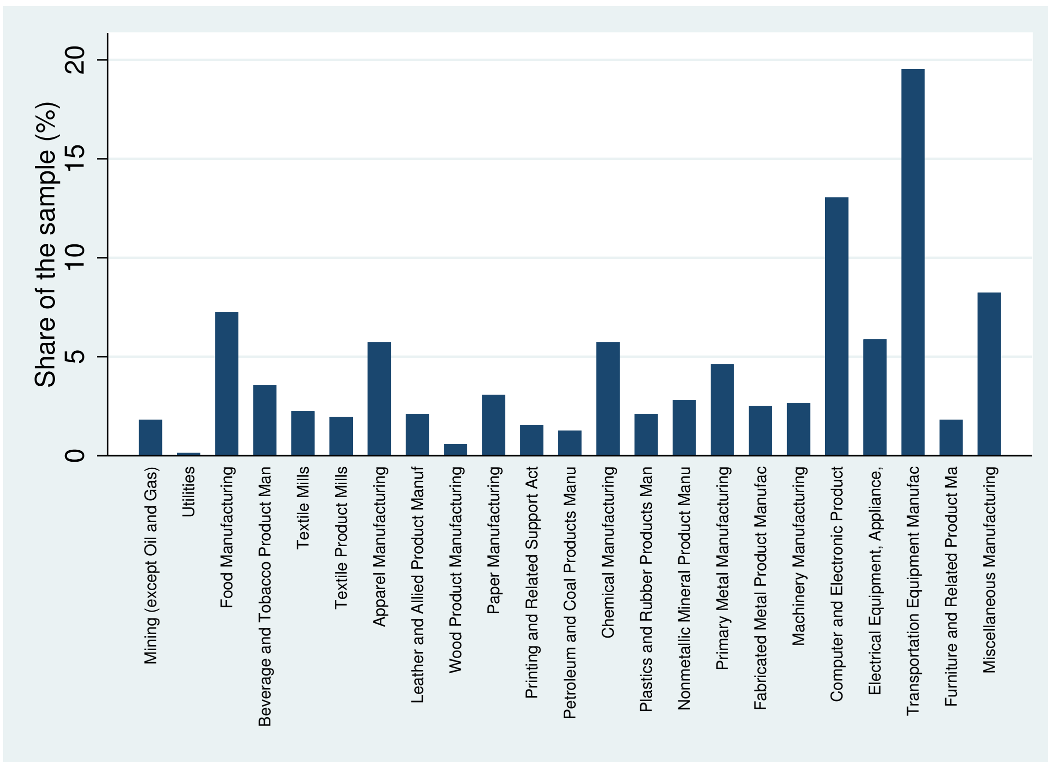
Consistent with the size of the firms in our sample, more than 90% of the firms have a share of

[5]The correspondence tables fore HS 1996 and NAICS generated through this exercise are avaiable upon request.

FDI higher than 80%. Accordingly, the mean of exports/total sales is much higher than the one observed for the whole ENTIC. Table 1 shows descriptive statistics for the main variables used in this analysis for our sample and the whole ENTIC sample.

At the sectoral level, transportation equipment, computers and electronic and food manufacturing comprise almost 40% of the firms in the sample. Figure 1 shows how the firms are distributed by sector in the sample.

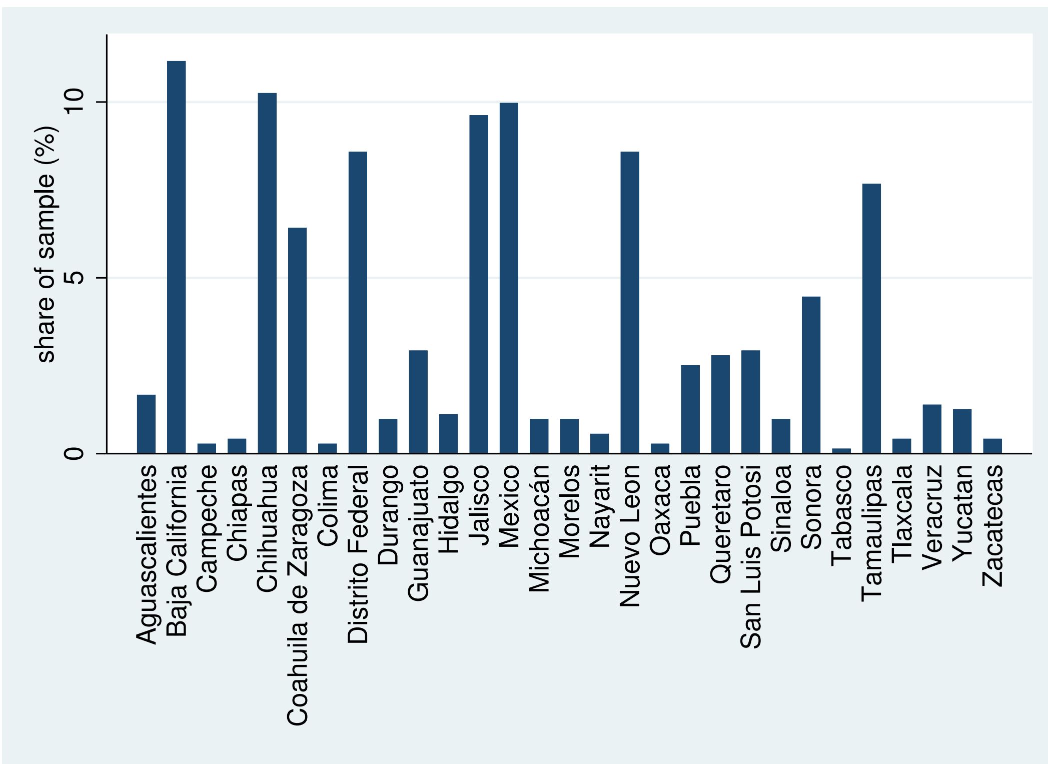
Figure 1: Distribution of firms by sector in the sample



Source: Author's calculations with data from ENTIC 2009 and 2013, INEGI

As Figure 2 shows, around 60% of the firms in the sample are located in six states: Baja California, Chihuahua, Mexico, Jalisco, Nuevo Leon and Distrito Federal. This distribution is really different from the one of the whole ENTIC 2013, but this is natural considering the construction of the panel and that mostly manufacturing goods were selected.

Figure 2: Distribution of firms by State in the sample



Source: Author's calculations with data from ENTIC 2009 and 2013, INEGI

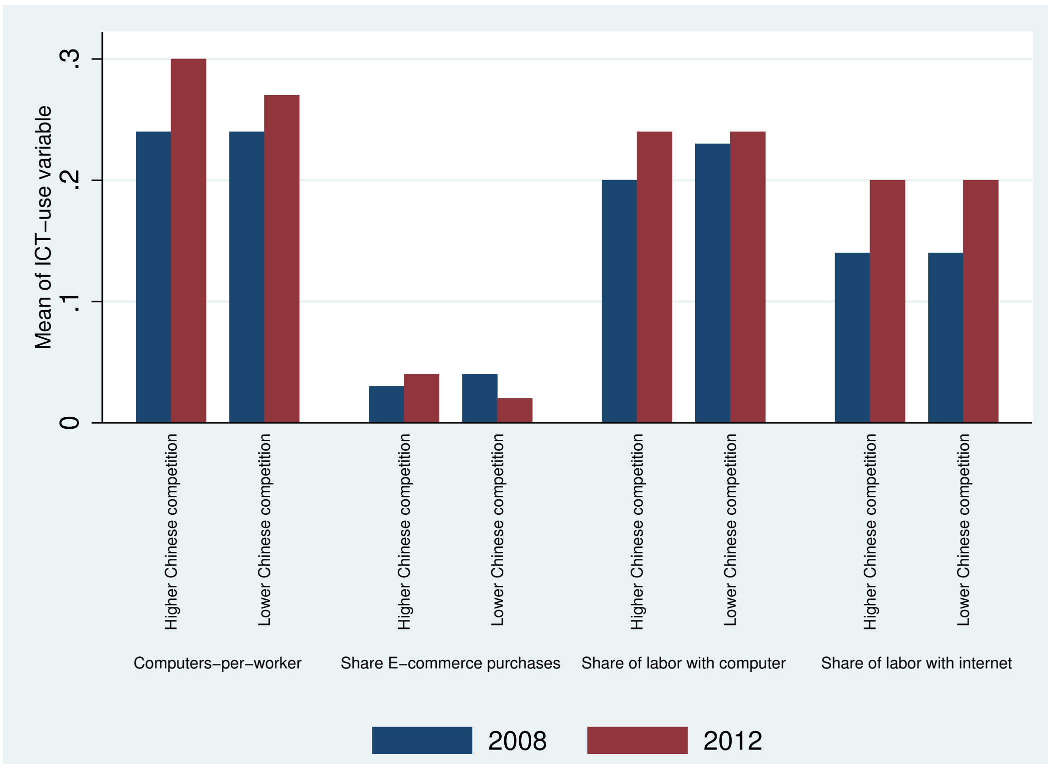
Table 1: Descriptive Statistics ICT use variables

	Sample						Whole					
Variable	Mean	p50	sd	p10	p90	N	Mean	p50	sd	p10	p90	N
2008												
Computers-per-worker	0.27	0.19	0.25	0.06	0.59	715	0.34	0.23	0.34	0.05	0.80	4612
Share of labor with Internet	0.16	0.11	0.18	0.03	0.34	715	0.23	0.14	0.25	0.02	0.62	4658
E-commerce purchases/Total purchases	4.38	0.00	17.43	0.00	1.00	715	4.50	0.00	17.57	0.00	2.00	4658
Share of labor with computer	0.24	0.17	0.22	0.05	0.54	715	0.30	0.20	0.28	0.04	0.81	4658
Sales-per-worker	1170.41	528.77	1773.02	139.82	2663.53	715	954.20	483.87	1385.23	100.30	2293.84	4566
Share of white-collar workers	0.23	0.17	0.19	0.04	0.49	715	0.32	0.22	0.29	0.06	0.90	4658
Exports/total sales	0.45	0.30	0.44	0.00	1.00	715	0.19	0.00	0.35	0.00	1.00	4637
Share of FDI	45.48	0.00	48.75	0.00	100.00	715	20.14	0.00	39.15	0.00	100.00	4658
2012												
Computers-per-worker	0.28	0.23	0.23	0.07	0.57	715	0.39	0.28	0.36	0.06	0.95	6148
Share of labor with Internet	0.20	0.14	0.19	0.03	0.40	715	0.30	0.19	0.29	0.03	0.83	6210
E-commerce purchases/Total purchases	3.79	0.00	14.79	0.00	5.00	715	4.81	0.00	17.00	0.00	10.00	6210
Share of labor with computer	0.24	0.18	0.22	0.06	0.50	715	0.34	0.23	0.30	0.04	0.93	6210
Sales-per-worker	1005.39	471.22	1407.87	131.20	2494.11	715	1018.02	446.88	1608.47	66.00	2471.17	6148
Share of white-collar workers	0.25	0.18	0.23	0.06	0.59	715	0.37	0.24	0.33	0.06	1.00	6210
Exports/total sales	0.38	0.13	0.43	0.00	1.00	715.00	0.16	0.00	0.33	0.00	0.93	6132
Share of FDI	94.10	100.00	19.60	97.00	100.00	383.00	17.16	0.00	36.74	0.00	100.00	6210

Source: Author's calculations with data from ENTIC 2009 and 2013, INEGI

Considering the relation between ICT use and a higher level of Chinese competition, we calculated an indicator variable based on the change in the share of China over Mexican imports. Comparing ICT use between these two groups, as Figure 3 shows in the period 2008-2012, firms that face more competition from China experienced a higher increase in ICT use. Therefore, the data is consistent with the hypothesis of higher competition generating incentives for increases on ICT use.

Figure 3: ICT use by Chinese competition level 2008-2012



[1] Higher competition is defined as a sector that has a change in the share of Chinese imports over Mexico's total imports above the median.

Source: Author's calculations with data from ENTIC 2009 and 2013, INEGI

5 Results

5.1 ICT use and productivity

First of all we estimate the relation between ICT use and productivity using OLS in order to analyze if there is indeed a relation between these two variables without any further consideration regarding endogeneity or the relation with China's competition. As Table 2 shows, for all ICT use variables except for e-commerce purchases as a share of total purchases, we observe that there appears to be a positive and significant correlation between ICT use and productivity measured by sales-per-worker. These results are indeed consistent with what previous studies have found for developed countries.

As mentioned before, ICT use is most likely endogenous because there are likely to be unobservable characteristics that are both positively correlated. Therefore, we adopt an IV strategy to estimate the same equations, where we instrument our ICT use variable with the instruments described in section 3.2. Results are shown in Table 3. The overidentification tests as well as F test, evaluating the strength of our IVs, do not indicate invalidation of our instrument in the case of computers-per-worker and the share of labor with Internet. However, for e-commerce purchases/Total Purchases and share of labor with computer it is not possible to reject the hypothesis that instruments are weak so these coefficients must be interpreted with caution. As the table shows, for computers-per-worker and the share of labor with internet, results are in line with the OLS coefficients, but slightly higher which may be the consequence of treatment effect heterogeneity (Imbens and Angrist, 1994). Additionally, when we include the share of exports and the FDI share as controls, the variables related to ICT use are no longer statistically significant.

In order to analyze what previous literature has found regarding the complementarity between ICT use and skills, we estimated the equation interacting ICT use with the share of white-collar workers in the firm. In all specifications the interaction was not significant.[6] Thus, we don't find much evidence that firms with a higher share of white-collar workers experience greater effects of ICT on productivity as a result of the complementarity between skills and ICT.However, our results may be driven by the fact that the proxy we use is not an appropriate measure of skills within the firm.

5.2 ICT use, Chinese competition and productivity

Previously, we presented some descriptive evidence that firms in sector that experienced stronger competitive pressures because of increasing Chinese experts tend to be more likely to adopt ICT. Further, in this Section, in order to assess whether Chinese competition also enhances the role of ICT use as a productivity lever, we use the indicator variable for the sectors that face higher competition from China and estimate a split OLS regression of sales-per-worker on ICT use variables.[7] As tables 4 and 5 show, for firms that face low competition from China, the effects of ICT use on productivity are not statistically significant. Furthermore, in the case of e-commerce purchases over total purchases the coefficients are negative and significant at the 10% level. On the other hand, when we analyze firms from sectors that face high competition from China,

[6] Results are not shown here but are available upon request.

[7] A sector is classified as facing high competition with China if the change in the share of China on Mexico's total imports between 2008 and 2013 is above the median.

the effects of ICT on productivity are positive and statistically significant in most of the specifications. That is, these results suggest that the effects of ICT use on productivity appears to be entirely driven by those sectors that experienced a stronger increase in Chinese competition.

Taking into consideration the endogeneity of ICT use for the same specifications, as Table 6 shows, once again we find no evidence of the effects of ICT on productivity for firms exposed to lower competition from China. However for firms that face higher competition from China, results indicate that the effects of ICT are not only statistically significant but higher than the ones observed in the OLS specification. (See Table 7)

Finally, we estimate a specification that uses the competition variable (share of Chinese imports over total Mexican imports) interacted with the ICT use variables appropriately instrumented as before. The results of these estimates are shown in Table 8. It is important to note here that in the case of E-commerce purchases/ total purchases and the share of labor with computers it is not possible to reject the hypothesis of weak instruments so the results for these two variables will not be discussed. As the table shows, once we include this interaction the ICT use variables (computers-per-worker and the share of labor with Internet]) are no longer statistically significant except for the case of the interaction. Thus, the effect of ICT on sales-per-worker depends on the level of Chinese competition -and where competition is low there is no effect of ICT adoption on productivity. Evaluating for example computers-per-working on the mean of the share of China in Mexican imports, we get than a change of 0.1 in computers-per-worker generates an increase of around 6 percent on sales-per-worker under specification (2). However, if we evaluate these results on the maximum of Chinese competition, the same change in ICT use yields an increase in productivity of around 42 percent.

5.3 Robustness tests

As a robustness test of the interaction between ICT use and Chinese competition, we consider competition in the US market instead of the domestic measure of competition. The rationale behind this robustness test is that firms may not be facing pressure from Chinese competition in their domestic market but in the US market and that should result in the same kind of heterogeneity.

Additionally, we tested other alternative instrumental variables, constructed as explained in equation 2, but using different measures of household ICT use. The results do not change much, although in some cases it is not possible to reject the hypothesis of weak identification, which make impossible to compare those magnitudes to the results shown in previous tables.

Table 2: OLS estimates of the effect of ICT use on productivity

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable log(sales/worker)						
Computers-per-worker	1.230***	1.230***	1.099***	1.182***	1.177***	1.255**
	(0.326)	(0.218)	(0.219)	(0.274)	(0.267)	(0.522)
N	1,423	1,423	1,423	1,398	1,398	1,076
R^2	0.869	0.869	0.873	0.878	0.878	0.913
Share of labor with Internet	1.266***	1.266***	1.140***	1.192***	1.170***	1.177**
	(0.307)	(0.188)	(0.200)	(0.292)	(0.293)	(0.534)
N	1,427	1,427	1,427	1,402	1,402	1,080
R^2	0.865	0.865	0.869	0.874	0.874	0.909
E-commerce purchases/total purchases	0.00234	0.00234	0.00220	0.00206	0.00204	0.00483
	(0.00484)	(0.00369)	(0.00303)	(0.00266)	(0.00270)	(0.00371)
N	1,427	1,427	1,427	1,402	1,402	1,080
R^2	0.856	0.856	0.862	0.867	0.867	0.906
Share of labor with computer	1.096***	1.096***	1.006***	1.022***	1.004***	1.233***
	(0.239)	(0.162)	(0.159)	(0.256)	(0.258)	(0.399)
N	1,427	1,427	1,427	1,402	1,402	1,080
R^2	0.865	0.865	0.869	0.874	0.874	0.912
Controls						
Sector	No	Yes	No	No	No	No
Age	No	No	Yes	Yes	Yes	Yes
State	No	No	Yes	Yes	Yes	Yes
Firm size	No	No	No	Yes	Yes	Yes
Share of white-collar workers	No	No	No	No	Yes	Yes
Exports/sales	No	No	No	No	No	Yes
FDI share	No	No	No	No	No	Yes

Standard errors in parentheses

All specifications include firm's fixed effects.

* Significant at the 1% level, **Significant at the 5% level, *** Significant at the 1% level

Source: Authors' calculations using data from ENTIC, INEGI

Table 3: IV estimates of the effect of ICT use on firm-level productivity

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable log(sales/worker)						
Computers-per-worker	1.920***	2.206***	3.075***	2.916***	0.668	
	(0.622)	(0.773)	(0.993)	(0.988)	(0.776)	
N	1434	1434	1409	1409	1086	
R^2	0.837	0.833	0.823	0.827	0.866	
Share of labor with Internet	1.666***	2.240***	2.943***	2.929***	0.744	
	(0.562)	(0.793)	(0.949)	(1.005)	(0.962)	
N	1438	1438	1413	1413	1090	
R^2	0.836	0.831	0.824	0.825	0.864	
E-commerce purchases/total purchases[1]	0.0707*	0.0885	0.0760*	0.0721*	-0.0825	
	(0.0413)	(0.0627)	(0.0431)	(0.0419)	(0.194)	
N	1438	1438	1413	1413	1090	
R^2	0.508	0.323	0.457	0.497	0.552	
Share of labor with computer[1]	3.859**	5.093**	9.462*	11.19	1.875	
	(1.513)	(2.335)	(5.726)	(8.301)	(2.430)	
N	1438	1438	1413	1413	1090	
R^2	0.779	0.716	0.382	0.180	0.864	
Controls						
Age	No	Yes	Yes	Yes	Yes	
State	No	Yes	Yes	Yes	Yes	
Firm size	No	No	Yes	Yes	Yes	
Share of white-collar workers	No	No	No	Yes	Yes	
Exports/sales	No	No	No	No	Yes	
FDI share	No	No	No	No	Yes	

Standard errors in parentheses

All specifications include firm's fixed effects.

* Significant at the 1% level, **Significant at the 5% level, *** Significant at the 1% level

1 The test of weak indicates that instruments for these variables are weak

Source: Authors' calculations using data from ENTIC, INEGI

Table 4: Split regression ICT use on productivity: Low competition with China

Dependent variable log(sales/worker)	(1)	(2)	(3)	(4)	(5)
Computers-per-worker	0.313	0.339	0.335	0.320	0.102
	(0.350)	(0.356)	(0.400)	(0.394)	(1.114)
N	703	703	678	678	508
R^2	0.866	0.867	0.869	0.870	0.862
Share of labor with Internet	0.156	0.193	0.265	0.271	-0.0842
	(0.515)	(0.525)	(0.551)	(0.558)	(1.350)
N	706	706	681	681	511
R^2	0.864	0.865	0.867	0.867	0.863
E-commerce purchases/Total purchases	-0.00507*	-0.00514*	-0.00528*	-0.00532*	-0.00651
	(0.00273)	(0.00275)	(0.00287)	(0.00288)	(0.00606)
N	706	706	681	681	511
R^2	0.866	0.866	0.869	0.869	0.865
Share of labor with computer	0.333	0.337	0.341	0.342	0.464
	(0.334)	(0.331)	(0.320)	(0.322)	(0.607)
N	706	706	681	681	511
R^2	0.865	0.865	0.868	0.868	0.863
Controls					
Age	No	Yes	Yes	Yes	Yes
State	No	Yes	Yes	Yes	Yes
Firm size	No	No	Yes	Yes	Yes
Share of white-collar workers	No	No	No	Yes	Yes
Exports/sales	No	No	No	No	Yes
FDI share	No	No	No	No	Yes

Standard errors in parentheses

Source: Authors' calculations using data from ENTIC, INEGI

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Split regression ICT use on productivity: High competition with China

Dependent variable log(sales/worker)	(1)	(2)	(3)	(4)	(5)
Computers-per-worker	1.168***	1.079***	1.353***	1.361***	1.295**
	(0.270)	(0.284)	(0.437)	(0.425)	(0.610)
N	731	731	731	731	578
R^2	0.810	0.814	0.822	0.823	0.881
Share of labor with Internet	1.147***	1.154***	1.313***	1.295***	1.234**
	(0.254)	(0.249)	(0.474)	(0.487)	(0.615)
N	732	732	732	732	579
R^2	0.803	0.811	0.816	0.817	0.874
E-commerce purchases/Total purchases	0.00794	0.00744	0.00694*	0.00694*	0.0135**
	(0.00622)	(0.00490)	(0.00385)	(0.00387)	(0.00531)
N	732	732	732	732	579
R^2	0.797	0.804	0.809	0.809	0.875
Share of labor with computer	1.241***	1.163***	1.328***	1.314***	1.419***
	(0.211)	(0.212)	(0.425)	(0.437)	(0.485)
N	732	732	732	732	579
R^2	0.808	0.813	0.820	0.820	0.879
Controls					
Age	No	Yes	Yes	Yes	Yes
State	No	Yes	Yes	Yes	Yes
Firm size	No	No	Yes	Yes	Yes
Share of white-collar workers	No	No	No	Yes	Yes
Exports/sales	No	No	No	No	Yes
FDI share	No	No	No	No	Yes

Standard errors in parentheses

Source: Authors' calculations using data from ENTIC, INEGI

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Split IV regression ICT use on productivity: Low competition with China

	(1)	(2)	(3)	(4)	c (5)
Computers-per-worker	-0.581	0.519	1.698	1.554	0.948
	(1.705)	(2.294)	(4.078)	(4.379)	(2.997)
N	703	703	678	678	508
R^2	0.863	0.867	0.863	0.864	0.860
Share of labor with Internet	-143.9	-0.862	-0.859	-0.750	-2.097
	(9419.2)	(3.502)	(1.868)	(1.879)	(6.219)
N	706	706	681	681	511
R^2	-66.82	0.861	0.863	0.864	0.856
E-commerce purchases/Total purchase	0.0117	-0.00623	-0.0114	-0.00967	-0.00576
	(0.0361)	(0.0249)	(0.0245)	(0.0239)	(0.0165)
N	706	706	681	681	511
R^2	0.849	0.866	0.866	0.868	0.865
Share of labor with computer	0.775	-0.392	-0.476	-0.412	-0.669
	(2.275)	(1.585)	(1.031)	(1.029)	(1.955)
N	706	706	681	681	511
R^2	0.864	0.863	0.864	0.865	0.860
Controls					
Age	No	Yes	Yes	Yes	Yes
State	No	Yes	Yes	Yes	Yes
Firm size	No	No	Yes	Yes	Yes
Share of white-collar workers	No	No	No	Yes	Yes
Exports/sales	No	No	No	No	Yes
FDI share	No	No	No	No	Yes

Standard errors in parentheses

Source: Authors' calculations using data from ENTIC, INEGI

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Split IV regression ICT use on productivity: High competition with China

	(1)	(2)	(3)	(4)	(5)
Computers-per-worker	2.394***	2.008**	2.895***	2.706***	0.690
	(0.662)	(0.788)	(0.912)	(0.880)	(0.866)
N	731	731	731	731	578
R^2	0.791	0.804	0.802	0.807	0.878
Share of labor with Internet	1.750***	1.588**	2.145***	2.149***	0.527
	(0.491)	(0.633)	(0.673)	(0.709)	(0.804)
N	732	732	732	732	579
R^2	0.800	0.809	0.812	0.812	0.872
E-commerce purchases/total purchases	0.0570**	0.0435**	0.0438**	0.0414**	0.0271
	(0.0227)	(0.0218)	(0.0173)	(0.0168)	(0.0419)
N	732	732	732	732	579
R^2	0.598	0.699	0.702	0.716	0.867
Share of labor with computer	3.244***	2.712**	3.993***	4.223***	1.161
	(0.986)	(1.136)	(1.413)	(1.603)	(1.722)
N	732	732	732	732	579
R^2	0.766	0.789	0.761	0.751	0.879
Controls					
Age	No	Yes	Yes	Yes	Yes
State	No	Yes	Yes	Yes	Yes
Firm size	No	No	Yes	Yes	Yes
Share of white-collar workers	No	No	No	Yes	Yes
Exports/sales	No	No	No	No	Yes
FDI share	No	No	No	No	Yes

Standard errors in parentheses

Source: Authors' calculations using data from ENTIC, INEGI

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: IV regression ICT use on productivity considering China's competition

	(1)	(2)	(3)	(4)
Computers-per-worker	-2.080	-1.526	-0.496	-0.541
	(1.831)	(1.417)	(2.974)	(2.959)
China's competition*computers-per-worker	8.988	9.319*	13.40**	13.41**
	(5.503)	(5.464)	(5.695)	(5.689)
China's competition	-1.831	-2.307	-4.392	-4.396
	(2.552)	(2.368)	(2.696)	(2.694)
N	1428	1428	1403	1403
R^2	0.796	0.809	0.799	0.799
Share of labor with internet	-3.259**	-3.547	-4.456	-4.349
	(1.463)	(2.398)	(4.858)	(4.896)
China's competition*share of labor with Internet	18.15**	19.41*	24.91*	24.69*
	(8.763)	(11.15)	(13.77)	(13.59)
China's competition_	-2.368	-2.787	-4.002	-3.955
	(2.121)	(2.490)	(2.604)	(2.541)
N	1432	1432	1407	1407
R^2	0.793	0.786	0.754	0.757
E-commerce purchases/Total purchases	-1.199	-0.251	-0.166	-0.193
	(14.14)	(1.415)	(0.504)	(0.627)
China's competition*E-commerce purchases/Total purchases	4.238	0.964	0.740	0.835
	(48.33)	(4.739)	(1.798)	(2.236)
China's competition_	-14.15	-2.126	-1.854	-2.273
	(167.5)	(14.03)	(6.160)	(7.821)
N	1418	1418	1393	1393
R^2	-53.64	-1.478	-0.133	-0.488
Share of labor with computer	17.27	10.27	1.395	1.324
	(25.10)	(13.70)	(2.586)	(2.544)
China's competition*share of labor with computer	-31.39	-17.85	9.440	9.647
	(67.47)	(37.32)	(9.768)	(9.787)
China's competition_	7.205	5.050	-2.157	-2.187
	(15.98)	(9.543)	(2.783)	(2.789)
N	1432	1432	1407	1407
R^2	-0.513	0.398	0.816	0.816

Standard errors in parentheses

Source: Authors' calculations using data from ENTIC, INEGI

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Controls: (1) Only firm-level fixed effects (2) age and region (3) age, region and size (4) Adding share of white-collar

Table 9: IV regression ICT use on productivity considering China's competition

	(1)	(2)	(3)	(4)
Computers-per-worker	-0.711	-0.219	0.0426	0.0738
	(0.917)	(0.883)	(0.999)	(0.994)
Competition in US*computers-per-worker	5.385*	4.107*	5.026**	4.745**
	(2.862)	(2.416)	(2.399)	(2.388)
Competition in US	-1.064	-0.584	-0.932	-0.878
	(1.068)	(0.886)	(0.882)	(0.877)
N	1428	1428	1403	1403
R^2	0.835	0.842	0.841	0.842
Share of labor with Internet	-1.501	-0.702	-0.484	-0.467
	(1.057)	(1.231)	(1.354)	(1.331)
Competition in US*Share of labor with Internet	5.479**	4.316*	4.905**	4.832*
	(2.793)	(2.623)	(2.455)	(2.511)
Competition in US	-0.0977	0.0705	-0.105	-0.103
	(0.571)	(0.526)	(0.509)	(0.511)
N	1428	1428	1403	1403
R^2	0.839	0.845	0.847	0.847
shshop_ecom	0.205	0.0799	0.0912	0.0855
	(0.452)	(0.179)	(0.207)	(0.213)
intUSshshopecom	-0.630	-0.143	-0.175	-0.161
	(1.616)	(0.606)	(0.687)	(0.697)
Competition in US	3.057	1.216	1.301	1.224
	(6.409)	(2.297)	(2.585)	(2.675)
N	1428	1428	1403	1403
R^2	-0.635	0.564	0.488	0.528
Share of labor with computer	47.98	73.32	0.342	0.303
	(324.9)	(2421.1)	(7.644)	(8.539)
intUSshslabcomp	-60.07	-90.73	4.633	4.632
	(435.4)	(3121.4)	(7.306)	(7.279)
Competition in US	10.26	18.44	-0.367	-0.370
	(72.19)	(612.7)	(1.418)	(1.475)
N	1428	1428	1403	1403
R^2	-8.401	-20.87	0.845	0.845

Standard errors in parentheses

Source: Authors' calculations using data from ENTIC, INEGI

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Controls: (1) Only firm-level fixed effects (2) age and region (3) age, region and size (4) Adding share of white-collar

6 Conclusion

ICT use and technology adoption have been identified as key factors capable of increasing firm-level productivity Syverson (2011).Even though there is a great deal of evidence for developed countries regarding this relation, it is not clear whether these predictions hold for a developing country such as Mexico or how these mechanisms operate in a context of external competition shocks.

In this paper we analyzed the relation between ICT and competition from China for the case of Mexico between 2008 and 2012 using a firm-level data panel constructed from ICT surveys that, to the best of our knowledge, were never used for research purposes before. Results indicate that on average ICT use positively affect productivity, and these are results to our instrumental variable approach. However, when we dig deeper we find that only firms that face higher competition pressure exhibit a positive effects of ICT use on productivity. We interpret this results as either they make more effective use of ICT in order to cope with the pressures of Chinese competition or they are willing to make also organization changes that improve the returns to the ICT use. Results are robust to the different specifications in the case of the two main ICT use variables analyzed (computers-per-worker) and the share of labor with Internet.

Going forward, one possible extension for this work include allowing for heterogeneity in the effects depending on the productivity levels adopting a quantile IV approach. Further, following the literature regarding the complementarity between management practices and ICT use (Bloom et al., 2012) obtaining better data regarding managerial and organizational practices could allow us to analyze whether the mechanism explaining higher returns to ICT investments is driven by improvement in managerial practices and firm organization.

References

Akerman, A., Gaarder, I., and Mogstad, M. (2015). The skill complementarity of broadband internet. Technical report, National Bureau of Economic Research.

Autor, D. H., Levy, F., and Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. *The Quarterly Journal of Economics*, pages 1279–1333.

Basu, S., Fernald, J. G., Oulton, N., and Srinivasan, S. (2004). The case of the missing productivity growth, or does information technology explain why productivity accelerated in the united states but not in the united kingdom? In *NBER Macroeconomics Annual 2003, Volume 18*, pages 9–82. The MIT Press.

Bloom, N., Draca, M., and Van Reenen, J. (2015). Trade induced technical change? the impact of chinese imports on innovation, it and productivity. Technical report, (forthcoming), Review of Economic Studies.

Bloom, N., Sadun, R., and Van Reenen, J. (2012). Americans do IT better: Us multinationals and the productivity miracle. *The American Economic Review*, 102(1):167–201.

Bresnahan, T. F., Brynjolfsson, E., and Hitt, L. M. (2002). Information technology, workplace organization and the demand for skilled labor: firm-level evidence. *The Quarterly Journal of Economics*, 117(1):229–376.

Brynjolfsson, E. and Hitt, L. (1996). Paradox lost? firm-level evidence on the returns to information systems spending. *Management science*, 42(4):541–558.

Draca, M., Sadun, R., and Van Reenen, J. (2006). Productivity and ict: A review of the evidence. Technical report, Centre for Economic Performance, LSE.

Freund, C. and Ozden, C. (2006). The effect of china's exports on latin american trade with the world.

Haltiwanger, J., Jarmin, R. S., and Schank, T. (2003). Productivity, investment in ict and market experimentation: micro evidence from germany und the us. Technical report, US Census, Economic Studies.

Iacovone, L., Rauch, F., and Winters, L. A. (2013). Trade as an engine of creative destruction: Mexican experience with Chinese competition. *Journal of International Economics*, 89(2):379–392.

Imbens, G. W. and Angrist, J. D. (1994). Identification and estimation of local average treatment effects. *Econometrica: Journal of the Econometric Society*, pages 467–475.

Jenkins, R., Peters, E. D., and Moreira, M. M. (2008). The impact of china on latin america and the caribbean. *World Development*, 36(2):235–253.

Michaels, G., Natraj, A., and Van Reenen, J. (2014). Has ict polarized skill demand? evidence from eleven countries over twenty-five years. *Review of Economics and Statistics*, 96(1):60–77.

Olarreaga, M., Lederman, D., and Soloaga, I. (2007). The growth of china and india in world trade: Opportunity or threat for latin america and the caribbean? *World Bank Policy Research Working Paper*, (4320).

O'Mahony, M. and Van Ark, B. (2003). *EU productivity and competitiveness: an industry perspective: can Europe resume the catching-up process?* Office for Official Publications of the European Communities Luxembourg.

Stiroh, K. J. (2002). Information technology and the u.s. productivity revival: What do the industry data say? *American Economic Review*, 92(5):1559–1576.

Syverson, C. (2011). What determines productivity? *Journal of Economic Literature*, 49(2):326–65.