Broadband Adoption and Firm Performance: Evidence from Informal Sector Firms in India

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Abstract

Using unit level data for informal manufacturing sector, drawn from the Government of India's National Sample Survey Organization, this paper addresses the impact of broadband adoption on firm performance. We also consider productivity effects associated with various application of broadband technology. Our measure of firm performance consists of labour productivity, gross value added, total output and total factor productivity. Using recently developed econometric strategy based on quantile treatment regressions we find that the average effect of broadband adoption on small firms' productivity is positive and significant. With respect to the adoption of at least one of the broadband applications, we show that for firms at the upper quantiles of productivity distribution is yielding significant gains in their performance.

Keywords: Broadband technology; Informal firms; Productivity; India

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1. Introduction

It is well recognized that the driver of economic growth is the productivity. But the debate regarding driving forces of productivity is still unsettled. Therefore, studies have looked at the role of ICTs as enabler of long-run growth through productivity improvements. These set of studies have been looking the macro aspect and firm level impact of ICT on productivity. The results of studies based on country level and industry level data provide conflicting results (Van Ark *et al*., 2008) while those based on rich firm level information highlight positive and significant effect on ICT on productivity (Brynjolffson and Hitt, 2002, Commander *et al*., 2011). However, the literature has overlooked the effect of ICT on the productivity of small firms.

It is argued that adoption of broadband internet technology can help to reap the benefits of ICT adoption. Even though there is no universally accepted definition; a rather broad definition is the '*internet access provided at a certain high level of speed*' (Bertscheck *et al*. 2013). Many policy makers have declared improving the availability of broadband infrastructure as a key policy objective. The reason behind such initiative is the productivity improvements associated with entities that adopt such investments. In the case of India, government recently launched Digital India programme to provide broadband connectivity to 2.5 lakh Gram Panchayats (spread over six lakh villages). Aim of this massive project is not only social benefits associated but also to enable the businesses. Even though at the macro level, few studies have shown positive effect of broadband internet on economic growth (Czernich *et al*., 2011), studies at the firm level exploring the productivity benefits associated with broadband technology is still nascent.

Small firms play an important role in the production and employment generation especially in the developing countries. Within the small firms' category, informal sector enterprises constitute a large chunk in India. ICT adoption through broadband infrastructure therefore will be greater enabler of productivity improvements for smaller firms; especially informal sector enterprises. Informal firms face resource constraints and ICT can play significant role in enhancing the competitiveness posing both opportunities and challenges for small firms (Shin, 2006). Adoption of broadband can help the small firms to access distant markets, improve competitiveness in the domestic market. Informal sector firms face severe obstacle due to the information asymmetry and presence of middlemen. ICT can certainly improve formal information and improve marketing practices. Therefore, utilization of ICT in the form of broadband adoption will gear the informal enterprises in improving business processes and productivity enhancement. As highlighted by some of the recent studies, broadband technology is a general purpose technology (GPT) and therefore to capture the real effect of such technology we need to delve into the further applications of such technology. Therefore, we examine not just the impact of broadband technology adoption but also the applications of the technology and its effect on firm performance.

Methodologically, we present novel results based on endogenous selection in broadband adoption by firms. The empirical analysis carried out in this study relies on a quantile regression (QR) models. QR techniques have rarely been used previous empirical works to analyze the ICT (broadband) adoption and productivity effects. Within the family of various QR methods, we adopt the recently developed quantile treatment effects (QTE) which allow for unconditional comparisons of the distributions of adopters and non-adopters, and provide more information on the nature of treatment effects (broadband adoption) on the treated sample firms than mean differences. Specifically, we employ instrumental variable quantile treatment effect (IVQTE) technique (Frölich and Melly 2013). To the best of our knowledge,

the present study is the first of its kind that that convalesces a causal interpretation combining IV strategy and the UQR in order to study the effects of broadband technology adoption on productivity using rich data on small firms. The motivation for using IVQTE over standard unconditional quantile regression is to capture the heterogeneous effect of broadband adoption on the whole productivity distribution. Further, IVQTE approach allows estimating conditional treatment effects under endogeneity.

The rest of the paper is organized as follows: Section two briefly reviews the existing literature while section three presents the key research questions. Section four introduces the data used in the empirical investigation and details the methodology. Results are discussed in section five. Section six draws conclusions.

2. Review of Literature

There exists numerous studies especially on productivity effects of ICT in general (see Bertschek et al. 2016 for an exhaustive review). More recently, few studies have looked into the productivity enhancing role of fixed-line broadband internet using the aggregate and firm level information. At the macro level, various studies show that broadband internet has a positive and statistically significant impact on both productivity and growth in EU and OECD countries (Koutroumpis, 2009; Czernich et al., 2011; Gruber et al., 2014; Kongaut et al. 2014). Using firm-level data for New Zealand, Grimes et al. (2012) examine the impact of firms' broadband adoption on labor productivity report that broadband adoption has a significant positive effect on labor productivity. Bertschek et al. (2013) analyze the relationship between firms' broadband adoption and changes labor productivity using firm-level data for Germany find significant positive impact on labor productivity.

Unlike, other studies which employed data for large firms, Colombo et al. (2013) investigated the influence of broadband adoption on the productivity of Italian small and medium enterprises (SMEs). This study report that productivity enhancing benefits are subject to the

right kind of broadband applications in combination with organizational changes. De Stefano et al. (2014) using a static fuzzy regression discontinuity approach employ plant and firm level panel data for the region around the city of Kingston upon Hull (UK) to analyze the influence of firms' ADSL broadband adoption on their performance. However, the study find no significant impact of broadband adoption on the performance of firms. Similarly, Haller and Lyons (2015) study on productivity as well as productivity growth effects of broadband adoption for Irish manufacturing firms find absence of any significant effect. In general, the existing firm level studies on the relationship between broadband adoption and productivity benefits is mixed. Colombo et al. (2013) report that positive productivity effects on broadband adoption is not automatic but depends on broadband applications.

3. Research Questions

When it comes to Indian context, very little is known about the role of broadband internet connection in influencing firm performance. Existing studies are mostly at the macro level, attempt to capture the productivity effect of ICT on Indian manufacturing sector (Erumban and Das 2016, Sharma and Singh 2013), and report that growth enhancing effects is confined to the service sectors. Although these studies have examined the overall impact of this technology on firm performance, our conjecture is that there exists a fundamental difference between access to this technology and the adoption of it for various services by firms. In other words, the mere presence and access to broadband connection may not automatically help the firms to achieve better performance. We believe that the ability to use it for various services is much more important so as to derive maximum benefits from it. One more notable omission in the literature is the evidence on the possible role of broadband internet adoption on the performance of small firms in India. Given that the major chunk of firms in India are smaller in size, the diffusion of broadband Internet technology among these firms has not

received considerable attention in the literature. These gaps in the existing literature calls for the need to empirically examine the role of broadband internet adoption in small firm performance. To be specific, the study attempts to address the following research questions:

i) Whether broadband internet technology adoption improve the productivity of enterprises belonging to informal sector in India?
ii) Whether the effect of broadband adoption of firm performance evenly distributed across firms?
iii) Whether various applications (basic vs advanced) of broadband technology have differential effects on firm productivity?

We hypothesize that broadband adoption is positively associated with firm performance, as it enable small firms to adopt a series of valuable complementary mechanisms (such as advanced communications and management applications) that are likely to increase firm's productivity and performance considerably (OECD, 2003; Colombo et al., 2013). Colombo et al. (2013) also argue that broadband internet connection offers every firm an opportunity to connect to the global market at a price that that many firms, especially SMEs, could not previously afford, and also permits the use of complementary broadband software applications that provide high value-added services. In short, the study tests the following hypotheses:

Hypothesis 1: Broadband adoption leads to increased firm productivity and better firm performance on average

Our conjecture is that the effects of broadband adoption will not be evenly distributed, and the productivity enhancing effect will be larger in magnitude for firms in the lower end of the productivity distribution. In other words, we expect that at the lower-end of the productivity distribution, these advantages will be amplified;

Hypothesis 2a: Effects of Broadband adoption will be larger for firms at the lower quantiles of productivity distribution

Hypothesis 2b: Effects of Broadband adoption will be smaller for firms at the upper quantiles of productivity distribution

Broadband technology is like a general purpose technology and mere adoption of such a technology is unlikely to bring any benefits to the adopters (Colombo et al 2013). The extent of performance enhancements associated with such a technology depends on the type of applications for which such a technology is employed.

Hypothesis 3: The positive effect on productivity of the adoption of broadband depends on the type of applications it is employed.

4. Data and Methods

This study proposes to use the unit level data for informal manufacturing sector, drawn from the Government of India's National Sample Survey Organization (NSSO) surveys on the informal manufacturing sector undertaken quinquennially using a stratified sampling procedure. The surveys cover all the Indian states and Union Territories (UTs) and gives information on selected indicators – output, labour, capital, materials, profit, ownership, etc. at the unit level for the three categories of manufacturing enterprises – own-account (OAME), directory (DME) and non-directory (NDME) enterprises. Though these micro-datasets are available for four rounds of surveys conducted by the NSSO (51^{st} round (1994-95), 56^{th} round (2000-01), 61^{st} round (2005-06) and 67^{th} round (2010-11)), we will be confining our analysis to the latest round of survey (67^{th} round) carried out for the year, 2010-11. The choice of time period for our study is governed by the fact that the information pertaining to the use of information and communication technology (ICT) by the enterprises are collected only in the latest round. This survey round collect comprehensive information on the use of ICT that include broader questions pertaining to the use of computers and

internet, whether the firms have a web presence, whether they place orders via internet and specific questions relating to the use of broadband technology, and the use of internet banking.

We limit our analysis of informal firms to those which hire outside labour, as there are serious limitations on the quality of data for family firms. One such limitation emanates from the very reason of these firms in business. Family firms (i.e. those which do not hire outside labour) are often in business simply because running a small enterprise allows them to bring in additional income with little additional effort and they are unlikely to expand or invest in their businesses (Banerjee and Duflo, 2008). Hence, following Kathuria *et al*. (2013), we confine our analysis to those informal firms that employ at least one hired worker.

In order to make price corrections to the reported data on gross output, intermediate input, gross value added and gross fixed assets, suitable deflators have been constructed with the help of the official series on wholesale price indices. Data on wholesale price indices were obtained from the report *Index Number of Wholesale Prices in India*, published by the Office of the Economic Advisor, Ministry of Industry, Government of India. The construction of deflator for intermediate output requires that the price indices for various categories of items be combined using appropriate weights (representing their shares in the intermediate input cost). For this purpose, the weights for respective commodities have been taken from the Input-Output transaction Table of India for 2007-08, prepared by the Central Statistical Organization (CSO). The main variables (both dependent and independent) used in our empirical analysis are defined in Table 1.

Empirical Strategy

The focus of this study is to analyse the effect of broadband adoption on firm performance in the informal sector. To be specific, we examine how much variation in the performance of informal sector firms can be explained by the adoption of broadband internet technology by these firms. To test this relationship, we estimate the following baseline specification:

$$FP_{jis} = \beta_0 + \beta_1 FixBB_{jis} + \sum_{\gamma} \beta_{\gamma>1} X_{jis} + \theta_i + \delta_s + e_{jis} \quad (1)$$

where the dependent variable, FP_{jis}, stands for performance of firm *j* in industry *i* and in state *s*. We proxy firm performance using two different measures, namely labour productivity and total factor productivity (TFP). Labor productivity (LP) is defined as the ratio of real gross value added to total number of workers employed. A Cobb-Douglas production function (CDPF) with three factors of production – capital, labour and intermediate inputs – are used to estimate TFP (TFP(Q)). TFP is estimated as the residual term of the production function. As an alternative, we also ran a value added function, that is, CDPF with two factors of production – labour and capital, and estimate the residual term as the TFP (TFP (VA)).

FixBB is our measure of broadband adoption, which takes the value 1 if the firm uses broadband. If the broadband adoption positively influences firm performance, we would expect the coefficient of FixBB (β_1) to be greater than zero. X_{jis} is a vector of control variables that could influence a firm's decision to adopt and use broadband internet. We control for firm specific attributes (size, age, location and ownership of the firm), ability of firm owner and variables capturing ICT intensity of the firm; e_{jis} is the random error term. As our dependent variables, labour productivity and total factor productivity, vary substantially across industries owing to differences in capital intensity and in production processes, we have included in our regressions industry-fixed effects (θ_i), which would control for such industry differences. As region-specific differences could also influence a firm's decision to adopt broadband adoption, we include region fixed effects to control for such influences (δ_s).

In analyzing the effect of broadband on firm productivity, we are much more interested in capturing the effect of broadband on full distribution of firm productivity, rather than

confining to the conventional 'average effect on the average firm'. In this context, the traditional OLS estimations are of limited use, hence we employ a more suitable quantile regression methods. Given that quantile regression is a linear estimator, it too suffers from the limitations of linearity assumption (Koenker and Hallock 2001). As highlighted by Coad *et al*. (2014), this results in problem related to over-smoothing. There is every possibility that quantile estimates emerge from comparing firms that are not strictly comparable. Another issue that is quite often highlighted in the literature with respect to the use of conventional quantile estimator is its failure to distinguish between causal effect and the spurious correlation between productivity and broadband adoption. (Koenker and Basset 1978). This problem will be much more severe if more productive firms are more likely adopters of broadband technology. If unobserved heterogeneity factors influence the adoption of broadband technology, the estimated effect of broadband on productivity will be biased. Therefore, it is important that the econometric procedure employed should account for this endogeneity bias influencing our core results.

In order to address the endogeneity concerns, we make use of the recent developments in quantile treatment effects, especially the one relating to the instrumental variables quantile treatment effects to examine the role of broadband adoption on firm productivity (Frolich and Melly, 2008; 2013). As mentioned previously, since the main objective of this study is to examine whether the effect of broadband adoption varies along the overall productivity distribution (or the marginal distribution), methods proposed by Frölich & Melly (2013) for the estimation of unconditional (QTE) are employed. Unconditional QTE indicate the causal effect of a treatment for multiple covariates and entire population. To be specific, we employ instrumental variables quantile treatment estimation (IVQTE) method in our study to test the relationship that we hypothesize, which we believe would help in deriving causal inference rather than mere associations, as is the case with most conventional estimators.

Consider y, the outcome variable, which is a continuous measure of firm productivity, D the treatment variable taking on the value 1 in case of broadband adoption and 0 otherwise, and X a set of covariates. Let y_i^1 and y_i^0 be the potential outcomes of firm *i* in terms of productivity under broadband internet and without such technology. The realized state of firm *i* is therefore given by $y_i \equiv y_i^1 D_i + y_i^0(1 - D_i)$. Taking the difference between the τ quantile of the potential productivity distribution in the (hypothetical) situation where all firms adopt broadband and the τ quantile of the potential outcome distribution in the (hypothetical) situation where all firms do not adopt broadband provides us the effect of broadband internet on the potential productivity distribution at quantile τ ($\Delta\tau$):

$$\Delta_{QTE}^{\tau} = Q_{y^1}^{\tau} - Q_{y^0}^{\tau} \qquad (2)$$

Where $Q_{y^d}^{\tau}$ is the τ quantile of Although the definition of Δ^{τ} does not depend on *X*, unconditional QTE procedure use the covariates *X* in estimation as it allow for the identification of effects over the entire productivity distribution (Frölich and Melly 2013). In the present case *D* is endogenous, and identification will be achieved via an instrumental variable Z. Frolich and Melly (2008; 2013) combine instrumental variable framework with unconditional QTE in the presence of an endogenous binary treatment.

The unconditional IVQTE with endogeneity developed by Frolich and Melly (2013) can be defined as bivariate QR estimator with weights, for the D = 1 and the D = 0 observations.

$$(\beta_{IV}, \delta_{IV}) = \underset{\beta,\delta}{\operatorname{argmin}} \sum W_i^{FM} \cdot \rho_{\tau}(Y_i - \beta - D_i\delta) \qquad (3)$$

with

$$W_i^{FM} = \frac{Z_i - Pr(Z = 1|X_i)}{Pr(Z = 1|X_i)\big(1 - Pr(Z = 1|X_i)\big)}(2D_i - 1) \qquad (4)$$

The procedure to solve the above optimization problem is by estimating separately two univariate weighted QRs.

Broadband Applications and Productivity

In order to capture the productivity effects associated with various application of broadband technology, we employ principle component methods. First, we conduct a principal component analysis to classify the different broadband applications in different application groups. The application group consists of four main categories which we call as i) advanced, ii) basic, iii) management and iv) supply chain and customer satisfaction. The advanced category consists of three binary indicators, namely, video conferencing, receiving orders via internet and placing orders via internet. The second basic includes three dummy variables: email, internet banking and accessing other financial services. Four binary indicators are part of management: recruitment (internal or external), staff training, getting information from general government organizations and interacting with general government organizations. In the last category of supply chain and customer satisfaction, we include three binary indicators: providing customer services, delivering products online and getting information about goods and services. In our regression analysis, we include both: direct indicator bagging the adoption of broadband internet connection and also indirect indicators reflecting the usage of broadband applications as captured in different application groups classified above. Regarding the direct indicator, our measure of broadband adoption takes the value 1 if the firm uses broadband. The indirect indicators are being captured by the four predicted factor scores that we compute separately for four main categories, namely, advanced, basic, management and supply chain and customer satisfaction.[4]

Second, in analyzing the effect of broadband adoption and applications on firm productivity, we are much more interested in capturing the effect of broadband on the entire distribution of

[4] Given the binary nature, principal component analysis is being performed using a tetrachoric correlation matrix. Factors are identified by the standard rule of thumb of the eigenvalue being greater than one. Our results qualitatively remain the same if instead of factor scores; we use dummy variables representing broadband applications where we create four dummy variables indicating adoption of at least one of the applications included in the different application groups.

firm productivity, rather than confining to the conventional 'average effect on the average firm'. In this context, the traditional OLS estimations are of limited use; hence we instead exploit quantile regression methods. In particular, to explore heterogeneity in the firm performances to broadband adoption and its applications, we segregate the sample into quantiles of firm performance.

Third, one may argue that broadband adoption is endogenous. To address this issue of endogeneity in a quantile regression context, we follow Buchinisky (1998, 2001) and Bächler et al. (2009) correcting for adoption into broadband. In the first step we estimate a probit model for broadband adoption on share of workers who used internet at work in total workers; share of workers who used computers at work in total workers; and a binary indicator for firms that are expanding along with other determinants of factors that we include for firm performance regression. In the second step, firm performance equations include the inverse Mills' ratio (calculated from the first stage probit) and its square.[5]

5. Results

Figure 1 display kernel density distribution of labour and total factor productivity for broadband adopters and non-adopters (upper panel of Figure 1). The distribution of productivity for the adopters lies distinctly to the right of non-adopters. The lower panel of quantile-quantile plots too clearly shows that firms with broadband internet are more productive as compared to firms with no broadband internet connection. These plots thus clearly suggests the positive role of broadband adoption on firm performance. The descriptive analysis is suggestive and therefore, demands a much deeper analysis of the potential interactions between broadband internet connection and its adoption, and firm performance. We undertake this analysis next.

[5] The results reported in the Appendix shows the validity of the instruments. Note the pseudo-R^2 takes a value of 0.50.

Table 1 presents the results of OLS and quantile regression estimations of equation (1). In all, we estimate five specifications. To capture the productivity differences, we rely on two standard measures: (a) labour productivity, (defined as the ratio of gross value added to number of workers); and (b) total factor productivity (TFP). Our results unequivocally suggest that adoption of broadband internet technology increases productivity for firms in the informal sector, thereby supporting our hypothesis 1. The coefficient of broadband variable (FixBB) is positive and significant at the one per cent level across all five models indicating a positive relationship between broadband adoption and performance of informal firms in India. This gives credence to the fact that firms with broadband internet connection are likely to be more productive vis-à-vis firms that do not have access to broadband internet connection. Similar results emerging from OLS and quantile regression estimates indicates the robustness of our main results. We also find that the magnitude of the coefficient of FixBB is relatively higher in the lower quantiles as compared to upper quantiles. This suggests that the productivity enhancing effect of broadband adoption is much larger at the lowest quantiles providing support to our hypothesis 2a and 2b. Our control variables too yielded results on results on expected lines. They suggest that productivity is higher smaller firms, urban firms and firms that work on a partnership basis. Results also suggest strong positive role for ability of the owner and ICT intensity.

Instrumental Variable QTE

As mentioned before, we complement our baseline QTE estimates with IVQTE estimates that control for simultaneity and unobservable factors influencing our results. Table 3 presents the IVQTE estimates, where firm productivity is considered to be endogenous, hence FixBB is instrumented using dummy for firms using computers (Commander et al 2011). In the case of IVQTE estimations too, we used the same three variables to proxy firm performance. The IVQTE estimates yielded same sign as our QTE estimates across the quintiles suggesting the

robustness of our finding related to the positive effect of broadband adoption on firm productivity.

Further, our analysis of treatment effects of broadband adoption on firm productivity involves estimating quantile treatment effects under endogeneity and erogeneity assumption. Table 3 shows these estimated treatment effects. These estimates, clearly show that, broad band technology is associated with a higher productivity. Along the expected lines, productivity benefits associated with the broad band is positive and significant in all quartiles of the distribution. This is possibly because of the numerous business advantages conferred by the broadband technology.

Applications of Broadband and Firm Productivity

We next turn to examine the impact of adoption of different types of broadband applications on the performance of small firms. As discussed previously, our data set contains information on 11 broadband applications. We resorted to standard data reduction technique principal component analysis to reduce the heterogeneity of this set of 11 broadband applications without losing significant information. Varimax rotation was performed on the tetrachoric correlation coefficients to obtain the principal factor loadings (Table 4). Following Colombo et al (2013), we divide the resulting composition broadband application into four factors: (i) ‘‘*Advanced Communications*’’ factor formed by telephoning over the Internet/VoIP, including video conferencing; (ii) providing customer services, delivering products online, getting information about goods and services referred to as ‘‘*Supply Chain and Customer Management*’’; (iii) ‘‘*Management Systems*’’, includes and; (iv) ‘‘*Basic applications*’’, includes internet banking, sending and receiving e-mail, accessing other financial services. We then create a separate dummy variable for each of the four identified factors. For example, dummy take the value 1 if the firm *i* adopt *Advanced Communication* and 0 otherwise. Similar separate dummies are created for other three factors. These dummies are

included in the econometric analysis to assess how the productivity impact varies depending on the number of broadband applications by the sample firms.

We employ quantile and instrumental variable quantile estimations to capture the effect of adoption of different types of broadband applications on the performance of small firms. The results are presented in Table 5 and 6. We estimated five model specifications as in Table 2. Our analysis shows that the effect on productivity is highly apparent for firms at the upper quantiles of the productivity distribution, while the effect seems to be lesser in the lower quantiles. This is revealed by the sign and significance of the sum of coefficients of broadband and predicted factor scores for advanced use, basic use, management and supply chain. The sum yields the effect on firm productivity stimulated by the adoption of at least one of the broadband applications. As is evident from Tables 5 and 6, irrespective of the specification estimated, the sum of coefficients is highly significant in the last two quantiles (quantile = .75 and quantile = .90). This possibly indicates that the adoption of at least one of the broadband applications is yielding significant gains for firms at the upper quantiles of productivity distribution. When we look at individual applications, the use of broadband for *basic applications* produces large gains for firms in terms of productivity. The present results are obvious since our sample firms are extremely small firms employing mostly family or very few hired labour. Therefore, in the case of adopters, one expects vast majority of them depend on broadband internet for basic applications. Our results are in contrast with Colombo et al (2013) who reported negative effects of basic *internet applications* on firm productivity. In certain cases along with the productivity distribution, we observe that *advanced communications* produces a positive and significant effect especially on the labour productivity.

Conclusions

Using recently developed econometric strategy based on quantile treatment regressions the present study find that the average effect of broadband adoption on small firms' (informal sector enterprises) productivity is positive and significant. Compared with standard OLS and IV method, the UQR and the unconditional IVQTE estimators provide a more nuanced description of the relative effect of broadband adoption over the entire productivity distribution. The data we use are unique in this regard since the firms included in the survey belong to informal sector and in that they explicitly ask respondents about broad applications of the broadband internet. Following the literature, we also examine the effect of different applications and its productivity enhancing effects. We find the productivity enhancement effect of broadband is through the *basic applications*. Based on the findings, from a policy perspective, there should be incentives to the small firms to adopt broadband technology given their potential role in increasing the productivity of this category of firms. One limitation of the study is the cross-sectional nature and the survivorship bias. To analyze the long-run productivity enhancing effect of broadband technology requires panel data which future studied should address.

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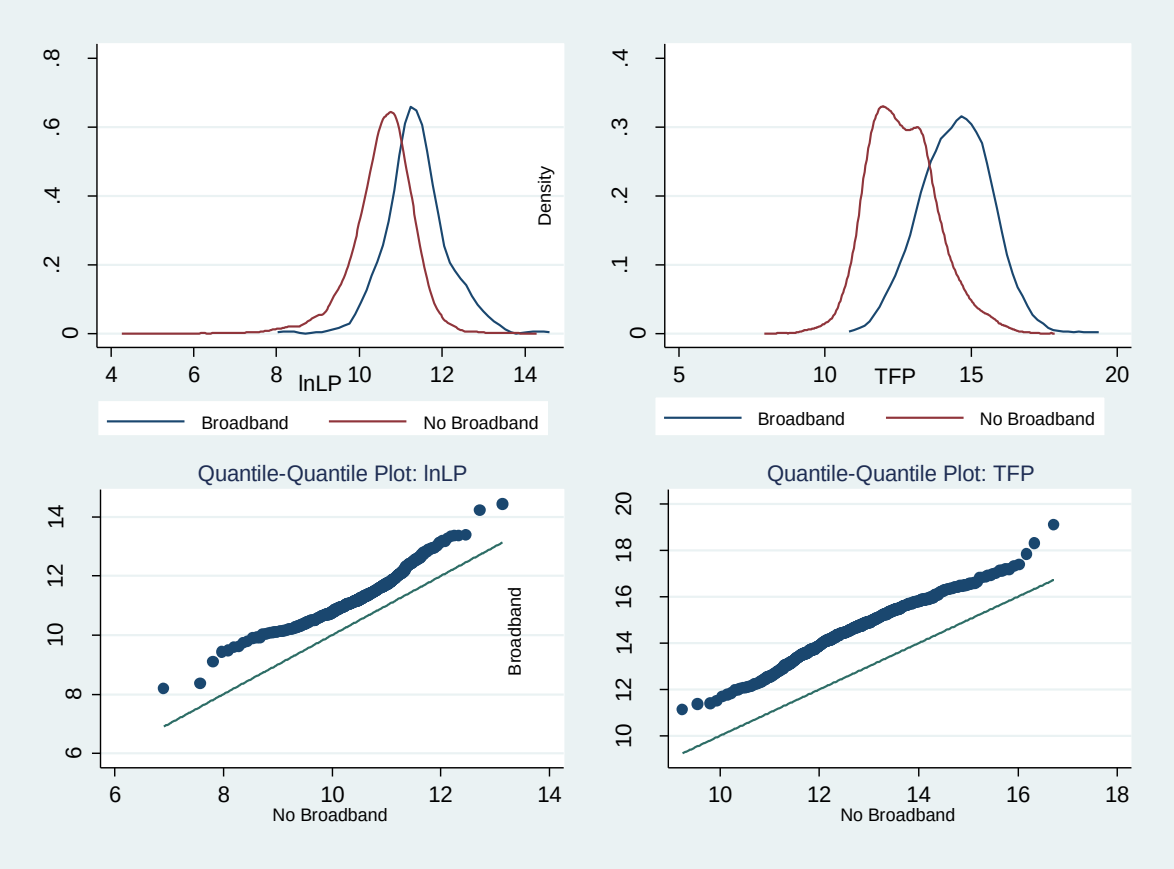
Table 1: Variable Definitions

Variable Name	Definition
Dependent Variable	
Labour Productivity (LP)	Ratio of real gross value added to number of workers.
Total Factor Productivity (TFP)	Residual term of Cobb-Douglas production function. We employed both Gross Output and Value Added approaches.
Broadband Adoption and Application	
FixBB	Dummy for Fixed Broadband Connection (1 for firms with fixed broadband connection and 0 for others)
Customer Service	Binary variable for firms using internet for providing customer services
Email	Binary variable for firms using internet for sending and receiving emails
Infogoods	Binary variable for firms using internet for getting information about goods and services
Financial Service	Binary variable for firms using internet for accessing financial services
Control Variables: Firm Characteristics	
Size	Log of employment
Age	The variable age represents the age of the firm, and is defined as the number of years elapsed since the establishment began its operations
Location	Dummy variable for urban firms (0 for rural firms and 1 for urban firms)
Ownership	Dummy for partnership firms (0 for proprietary firms and 1 for partnership firms)
Control Variables: Ability of Firm Owner	
Acmaint	Binary variable taking the value 1 if the firm is maintaining an account and 0 otherwise
Control Variables: ICT Intensity	
ICT share	Share of ICT investment in total assets
Web Presence	Dummy variables for firms having website
Instruments	
Entcomp	Dummy for enterprises using computers

Figure 1: Broadband Adoption and Firm Productivity



Note: Figures in the upper panel present the productivity (LP and TFP) distribution of firms, depending on whether the firm has broadband connection or not. Epanechnikov kernel. Figures in the lower panel show the distribution of productivity for firms with broadband connectivity in comparison with firms that do not have broadband connectivity.
Source: Authors' estimates based on 67th round of NSSO data.

Table 2: OLS and Quantile Regression Results for the Effect of Broadband Internet on Performance of Small Firms

Variables	OLS					QR – Dep. Var = TFP(Q)				
	Total Output	Gross Value Added	Labour Productivity	TFP(Output)[1]	TFP(GVA)[2]	QR(10%)	QR(25%)	QR(50%)	QR(75%)	QR(90%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FixBB	0.101***	0.203***	0.361***	0.520***	0.187***	0.534***	0.522***	0.541***	0.452***	0.457***
	(0.020)	(0.030)	(0.032)	(0.039)	(0.014)	(0.065)	(0.058)	(0.050)	(0.047)	(0.054)
Factors of Production										
lnlabour	0.394***	0.754***								
	(0.004)	(0.006)	-	-	-	-	-	-	-	-
lncapital	0.076***	0.233***								
	(0.002)	(0.003)	-	-	-	-	-	-	-	-
lninput	0.528***									
	(0.002)	-	-	-	-	-	-	-	-	-
Control Variables: Firm Characteristics										
Size	-		-0.092***	0.882***	0.898***	0.891***	0.898***	0.876***	0.899***	0.914***
		-	(0.006)	(0.007)	(0.003)	(0.012)	(0.011)	(0.009)	(0.009)	(0.010)
Age	0.044***	0.090***	0.095***	0.061***	0.005***	0.074***	0.061***	0.058***	0.041***	0.040***
	(0.003)	(0.004)	(0.004)	(0.005)	(0.002)	(0.009)	(0.008)	(0.007)	(0.006)	(0.007)
Location	0.053***	0.099***	0.212***	0.216***	0.133***	0.194***	0.237***	0.221***	0.168***	0.143***
	(0.005)	(0.007)	(0.008)	(0.009)	(0.003)	(0.015)	(0.014)	(0.012)	(0.011)	(0.013)
Ownership	-0.028***	-0.081***	-0.043***	0.115***	0.046***	0.100***	0.073**	0.070***	0.106***	0.178***
	(0.010)	(0.016)	(0.017)	(0.020)	(0.007)	(0.034)	(0.030)	(0.026)	(0.024)	(0.028)
Control Variable: Ability of Firm Owner										
Acmaint	0.076***	0.197***	0.351***	0.556***	0.183***	0.426***	0.486***	0.488***	0.500***	0.553***
	(0.006)	(0.009)	(0.010)	(0.012)	(0.004)	(0.020)	(0.018)	(0.015)	(0.014)	(0.016)
Control Variables: ICT Intensity										
ICTshare	0.010***	0.021***	0.002	-0.011***	-0.022***	-0.017***	-0.017***	-0.004	-0.002	-0.007*
	(0.001)	(0.002)	(0.002)	(0.003)	(0.001)	(0.005)	(0.004)	(0.004)	(0.003)	(0.004)
Web Presence	0.079***	0.136***	0.176***	0.228***	0.048**	0.120	0.129	0.313***	0.318***	0.340***
	(0.029)	(0.044)	(0.047)	(0.057)	(0.020)	(0.095)	(0.084)	(0.073)	(0.068)	(0.079)
Customer	0.054	0.147***	0.248***	0.333***	0.120***	0.395***	0.408***	0.325***	0.156*	0.148
Service	(0.041)	(0.062)	(0.066)	(0.080)	(0.028)	(0.134)	(0.119)	(0.103)	(0.096)	(0.111)
Industry effects?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
State effects?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Constant	5.334***	8.298***	9.948***	11.440***	10.736***	9.437***	10.181***	11.555***	12.699***	13.076***
	(0.093)	(0.139)	(0.147)	(0.178)	(0.062)	(0.297)	(0.264)	(0.229)	(0.213)	(0.246)

R^2/Pseudo R^2	0.90	0.63	0.23	0.56	0.87	0.26	0.29	0.35	0.40	0.44
F	4597.73	911.62	158.35	669.91	3514.40	-	-	-	-	-
N	35804	35808	35808	35804	35808	35804	35804	35804	35804	35804

Note: (a) OLS stands for ordinary least squares; QR stands for quantile regression; LP stands for labour productivity; TFP(Q) stands for TFP calculated from gross output function; and TFP(VA) stands for TFP calculated from gross value added function. (b) Figures in parentheses are standard errors. (c) ***, ** and * stand respectively for level of significance at 1, 5 and 10 per cent levels. (d) For definition of variables, see Appendix.

[1] TFP is calculated as the residual using real value of output as the output and a Cobb-Douglas Production function where inputs are natural logarithm of labour employed; capital and raw materials in a production function framework.

[2]TFP is calculated as the residual using Gross Value added as the output and a Cobb-Douglas Production function where inputs are natural logarithm of labour employed; capital and raw materials in a production function framework.

Source: Authors' estimates based on 67th round of NSSO data.

Table 3: Effect of Broadband Internet on Performance of Small Firms: IVQTE Estimates

Quantiles	Dep. Var = LP		Dep. Var = TFP(VA)		Dep. Var = TFP(Q)	
	IVQTE Coeff.	z stat	IVQTE Coeff.	z stat	IVQTE Coeff.	z stat
10 %	0.817	15.38	0.935	20.16	1.647	17.75
20 %	0.790	19.04	1.044	24.40	1.841	27.77
30 %	0.745	23.84	1.128	27.54	1.836	26.57
40 %	0.711	22.81	1.182	31.32	1.932	28.52
50 %	0.703	24.33	1.207	35.16	1.921	29.99
60 %	0.687	21.20	1.192	35.03	1.926	31.21
70 %	0.717	20.46	1.202	29.95	1.898	29.19
80 %	0.744	15.16	1.187	20.15	1.875	31.06
90 %	0.958	15.43	1.108	16.83	1.727	23.83

Note: Matching covariates are size, age, ICT intensity, share of workers who used computers and internet at workplaces, dummy variables for location, ability of firm owner, ownership, web presence and customer service, industry dummies and regional dummies.
Source: Authors' estimates based on 67th round of NSSO data.

Table 4: Factor Loadings from the Principal Component Analysis

Variables	Advanced Communications	Basic	Management	Supply Chain and Customer Satisfaction
1. Video Conferencing	0.780			
2. Receiving orders via internet	0.981			
3. Placing orders via internet	0.988			
4. Email		0.963		
5. Internet Banking		0.941		
6. Accessing other Fin. Services		0.968		
7. Internal or external recruitment			0.841	
8. Staff training			0.901	
9. Getting information from general govt. organizations			0.904	
10. Interacting with general govt. organizations			0.930	
11. Providing customer services				0.952
12. Delivering products online				0.857
13. Getting information about goods and services				0.942

Note: Principal component analysis on the tetrachoric correlation coefficients. The figures indicated in the table are the factor loadings. Factors are identified by the standard rule of thumb of the eigenvalue greater than one. Cronbach's alpha equals 0.856 using all the variables.

Table 5: Results from Quantile Estimation

Variable	Labor Productivity[1]	Gross Value Added[2]	Total Output[3]	TFP (GVA)[4]	TFP (Output)[5]
			Quantile = .15		
Broadband	-0.021	0.042	0.040	0.031	0.041
	(0.68)	(0.55)	(0.31)	(0.68)	(0.76)
Advanced	0.058	-0.074	0.001	0.063	0.257
	(0.57)	(0.44)	(0.99)	(0.52)	(0.16)
Basic	0.241	0.284**	0.103	0.302**	0.253
	(0.15)	(0.04)	(0.10)	(0.01)	(0.30)
Management	-0.114	-0.380**	0.008	0.225	0.757***
	(0.58)	(0.03)	(0.94)	(0.27)	(0.00)
Supply Chain	0.108	0.032	-0.069	-0.022	0.244
	(0.49)	(0.81)	(0.33)	(0.87)	(0.29)
Sum[6]	0.264	-0.096	0.082	0.599***	1.552***
	(0.20)	(0.64)	(0.38)	(0.00)	(0.00)
			Quantile = .30		
Broadband	-0.028	-0.046	-0.041	-0.049	-0.018
	(0.57)	(0.42)	(0.29)	(0.43)	(0.85)
Advanced	0.181***	0.152*	0.047	0.043	0.195*
	(0.01)	(0.08)	(0.14)	(0.67)	(0.06)
Basic	0.266***	0.103	0.101**	0.238**	0.213
	(0.00)	(0.36)	(0.05)	(0.03)	(0.25)
Management	-0.096	-0.094	0.010	0.265	0.782***
	(0.43)	(0.49)	(0.87)	(0.15)	(0.00)
Supply Chain	0.092	0.006	-0.032	0.016	0.099
	(0.35)	(0.96)	(0.51)	(0.88)	(0.54)
Sum[6]	0.415***	0.121	0.085	0.513***	1.271***
	(0.00)	(0.44)	(0.24)	(0.00)	(0.00)
			Quantile = .45		
Broadband	-0.067	-0.090**	-0.055	-0.021	-0.039
	(0.14)	(0.04)	(0.08)	(0.72)	(0.73)
Advanced	0.143**	0.085	0.056	0.006	0.025
	(0.04)	(0.13)	(0.22)	(0.94)	(0.83)
Basic	0.201*	0.178***	0.119	0.184	0.416**
	(0.07)	(0.00)	(0.06)	(0.18)	(0.03)
Management	-0.076	-0.184	0.022	0.462***	0.812***
	(0.25)	(0.15)	(0.83)	(0.00)	(0.00)
Supply Chain	0.115	0.060	-0.027	-0.003	0.009
	(0.19)	(0.53)	(0.64)	(0.98)	(0.95)
Sum[6]	0.315**	0.041	0.115	0.629***	1.224***
	(0.03)	(0.72)	(0.15)	(0.00)	(0.00)
			Quantile = .60		
Broadband	-0.118**	-0.071	-0.092**	-0.027	-0.137
	(0.02)	(0.12)	(0.01)	(0.64)	(0.19)
Advanced	0.175**	0.118	0.087	-0.084	-0.042
	(0.03)**	(0.12)	(0.14)	(0.32)	(0.73)
Basic	0.324***	0.210***	0.204***	0.055	0.476**
	(0.00)	(0.00)	(0.00)	(0.60)	(0.04)
Management	-0.102	-0.082	0.026	0.556	0.879***
	(0.57)	(0.57)	(0.81)	(0.00)	(0.00)
Supply Chain	0.150	0.030	-0.018	0.002	-0.060
	(0.11)	(0.76)	(0.81)	(0.99)	(0.76)

Sum[6]	0.43**	0.201	0.208**	0.501***	1.117***
	(0.01)	(0.14)	(0.01)	(0.00)	(0.00)
			Quantile = .75		
Broadband	-0.127**	-0.071	-0.120***	-0.082	-0.065
	(0.01)	(0.13)	(0.00)	(0.26)	(0.55)
Advanced	0.079	-0.003	0.071	-0.005	0.068
	(0.40)	(0.97)	(0.33)	(0.97)	(0.60)
Basic	0.469***	0.314***	0.282***	0.268	0.500
	(0.00)	(0.00)	(0.00)	(0.14)	(0.02)
Management	0.050	-0.064	0.020	0.210	0.788
	(0.74)	(0.73)	(0.88)	(0.29)	(0.00)
Supply Chain	0.173	0.151	-0.045	0.100	-0.149
	(0.12)	(0.12)	(0.62)	(0.55)	(0.52)
Sum[6]	0.644***	0.326**	0.207*	0.492**	1.142***
	(0.00)	(0.02)	(0.09)	(0.03)	(0.00)
			Quantile = .90		
Broadband	-0.114	-0.038	-0.004	-0.165	-0.254
	(0.34)	(0.64)	(0.95)	(0.11)	(0.17)
Advanced	0.080	0.055	0.222*	0.009	0.276
	(0.51)	(0.71)	(0.08)	(0.96)	(0.23)
Basic	0.775***	0.443	0.425***	0.558***	0.462
	(0.00)	(0.02)	(0.00)	(0.01)	(0.11)
Management	0.263	0.318	-0.049	0.396	0.349
	(0.48)	(0.19)	(0.81)	(0.24)	(0.32)
Supply Chain	-0.035	-0.040	-0.237	-0.068	0.105
	(0.87)	(0.84)	(0.20)	(0.83)	(0.74)
Sum[6]	0.968***	0.737***	0.357*	0.731***	0.938**
	(0.00)	(0.00)	(0.07)	(0.00)	(0.02)

Note: Numbers in parenthesis are the p-values. * implies significant at 10%, ** at 5% and *** at 1% level of significance.

[1] Control variables include natural logarithm of age, share of ICT investment in total investment, dummy variable for firms that maintain accounts; use computer and internet; dummy variable for firms with a webpage, dummy variable for urban firms, ownership dummy for partnership firms, two-digit industry dummies and state dummies. The pseudo R^2 takes the value of 0.132, 0.134, 0.138, 0.141, 0.145 and 0.149 for 15% quantile, 30% quantile, 45% quantile, 60% quantile, 75% quantile and 90% quantile respectively.

[2] Same as 1; additional control includes natural logarithm of labour employed, capital and raw materials. The pseudo R^2 takes the value of 0.391, 0.426, 0.457, 0.489, 0.525 and 0.563 for 15% quantile, 30% quantile, 45% quantile, 60% quantile, 75% quantile and 90% quantile respectively.

[3] Same as 2. The pseudo R^2 takes the value of 0.683, 0.689, 0.697, 0.704, 0.707 and 0.709 for 15% quantile, 30% quantile, 45% quantile, 60% quantile, 75% quantile and 90% quantile respectively.

[4] TFP is calculated as the residual using Gross Value added as the output and a Cobb-Douglas Production function where inputs are natural logarithm of labour employed; capital and raw materials in a production function framework. Additional control variables remains same as 1. The pseudo R^2 takes the value of 0.174, 0.196, 0.218, 0.243, 0.281 and 0.339 for 15% quantile, 30% quantile, 45% quantile, 60% quantile, 75% quantile and 90% quantile respectively.

[5] TFP is calculated as the residual using real value of output as the output and a Cobb-Douglas Production function where inputs are natural logarithm of labour employed; capital and raw materials in a production function framework. Additional control variables remains same as 1. The pseudo R^2 takes the value of 0.157, 0.191, 0.227, 0.253, 0.273 and 0.311 for 15% quantile, 30% quantile, 45% quantile, 60% quantile, 75% quantile and 90% quantile respectively.

[6] Sum implies the sum of coefficients of broadband, predicted factor scores for advanced use, basic use, management and supply chain.

Table 6: Results from Instrumental Variable Quantile Estimation

Variable	Labor Productivity[1]	Gross Value Added[2]	Total Output[3]	TFP (GVA)[4]	TFP (Output)[5]
			Quantile = .15		
Broadband	-0.062	0.026	0.019	0.125	0.173
	(0.44)	(0.75)	(0.65)	(0.14)	(0.18)
Advanced	0.044	0.016	0.005	0.102	0.224
	(0.68)	(0.87)	(0.89)	(0.25)	(0.18)
Basic	0.370***	0.345***	0.144*	0.249**	0.138
	(0.01)	(0.01)	(0.08)	(0.05)	(0.59)
Management	-0.124	-0.519***	-0.017	0.226	0.887***
	(0.44)	(0.01)	(0.85)	(0.23)	(0.00)
Supply Chain	0.039	-0.048	-0.103	0.002	0.149
	(0.74)	(0.74)	(0.11)	(0.98)	(0.54)
Sum[6]	0.267	-0.179	0.049	0.704***	1.572***
	(0.21)	(0.31)	(0.611)	(0.00)	(0.00)
			Quantile = .30		
Broadband	-0.097	-0.046	-0.019	0.008	0.005
	(0.13)	(0.42)	(0.59)	(0.91)	(0.95)
Advanced	0.130	0.133	0.043	0.026	0.256***
	(0.08)	(0.14)	(0.30)	(0.67)	(0.01)
Basic	0.303***	0.115	0.097*	0.147	0.204
	(0.01)	(0.31)	(0.07)	(0.14)	(0.25)
Management	-0.133	-0.181	-0.018	0.319**	0.712***
	(0.34)	(0.21)	(0.79)	(0.03)	(0.00)
Supply Chain	-0.002	0.019	-0.072	-0.017	0.172
	(0.98)	(0.83)	(0.22)	(0.86)	(0.24)
Sum[6]	0.201	0.041	0.031	0.482***	1.351***
	(0.19)	(0.77)	(0.687)	(0.00)	(0.00)
			Quantile = .45		
Broadband	-0.117	-0.116***	-0.059**	-0.019	-0.049
	(0.04)	(0.01)	(0.03)	(0.73)	(0.66)
Advanced	0.198***	0.074	0.053	-0.011	0.100
	(0.01)	(0.26)	(0.29)	(0.87)	(0.36)
Basic	0.261	0.182**	0.129**	0.162	0.463**
	(0.02)	(0.02)	(0.03)	(0.14)	(0.05)
Management	-0.109	-0.164*	0.003	0.465***	0.764***
	(0.53)	(0.09)	(0.97)	(0.00)	(0.00)
Supply Chain	0.014	-0.027	-0.039	-0.019	-0.077
	(0.87)	(0.78)	(0.46)	(0.85)	(0.65)
Sum[6]	0.247	-0.051	0.087	0.577***	1.202***
	(0.13)	(0.68)	(0.300)	(0.00)	(0.00)
			Quantile = .60		
Broadband	-0.092	-0.101**	-0.081***	-0.042	-0.128
	(0.12)	(0.03)	(0.01)	(0.60)	(0.13)
Advanced	0.153	0.117*	0.068	-0.031	0.004
	(0.13)	(0.08)	(0.19)	(0.80)	(0.97)
Basic	0.366***	0.197**	0.197***	0.049	0.446***
	(0.00)	(0.02)	(0.00)	(0.78)	(0.01)
Management	0.007	-0.128	0.056	0.510***	0.716***
	(0.97)	(0.39)	(0.61)	(0.00)	(0.00)
Supply Chain	0.055	0.043	-0.032	0.122	0.075
	(0.66)	(0.69)	(0.66)	(0.40)	(0.71)

Sum[6]	0.488***	0.126	0.208**	0.609***	1.114***
	(0.00)	(0.39)	(0.02)	(0.00)	(0.00)
			Quantile = .75		
Broadband	-0.108	-0.044	-0.108***	-0.080	-0.058
	(0.11)	(0.32)	(0.01)	(0.27)	(0.61)
Advanced	0.158	0.064	0.101	-0.043	0.030
	(0.11)	(0.46)	(0.17)	(0.64)	(0.85)
Basic	0.413***	0.251***	0.275***	0.335***	0.500***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
Management	0.048	0.051	0.060	0.254	0.703***
	(0.81)	(0.78)	(0.65)	(0.16)	(0.01)
Supply Chain	0.078	0.078	-0.053	0.145	0.021
	(0.56)	(0.48)	(0.57)	(0.31)	(0.93)
Sum[6]	0.590***	0.402***	0.276**	0.610***	1.195***
	(0.00)	(0.01)	(0.04)	(0.00)	(0.00)
			Quantile = .90		
Broadband	-0.066	0.017	0.009	-0.084	-0.258*
	(0.60)	(0.86)	(0.89)	(0.46)	(0.10)
Advanced	0.012	0.047	0.208	-0.101	0.095
	(0.96)	(0.77)	(0.08)	(0.58)	(0.67)
Basic	0.599***	0.390***	0.410***	0.380*	0.552**
	(0.01)	(0.01)	(0.01)	(0.08)	(0.07)
Management	0.313	0.258	-0.045	0.392	0.677**
	(0.45)	(0.33)	(0.80)	(0.16)	(0.04)
Supply Chain	0.113	-0.093	-0.248	0.113	0.340
	(0.74)	(0.66)	(0.17)	(0.65)	(0.16)
Sum[6]	0.970***	0.620***	0.334*	0.701***	1.406***
	(0.00)	(0.01)	(0.09)	(0.00)	(0.00)

Note: Numbers in parenthesis are the p-values. * implies significant at 10%, ** at 5% and *** at 1% level of significance. In all regressions, broadband is instrumented by share of workers who used internet at work in total workers, share of workers who used computers at work in total workers and a dummy for firms that are expanding. Probit regression as reported in Appendix 1 justifies the use of the instruments. For the methodology see Manquilef-Bächler et al. (2009).

[1] Control variables include natural logarithm of age, share of ICT investment in total investment, dummy variable for firms that maintain accounts; use computer and internet; dummy variable for firms with a webpage, dummy variable for urban firms, ownership dummy for partnership firms, two-digit industry dummies and state dummies.

[2] Same as 1; additional control includes natural logarithm of labour employed, capital and raw materials.

[3] Same as 2.

[4] TFP is calculated as the residual using Gross Value added as the output and a Cobb-Douglas Production function where inputs are natural logarithm of labour employed; capital and raw materials in a production function framework. Additional control variables remains same as 1.

[5] TFP is calculated as the residual using real value of output as the output and a Cobb-Douglas Production function where inputs are natural logarithm of labour employed; capital and raw materials in a production function framework. Additional control variables remains same as 1.

[6] Sum implies the sum of coefficients of broadband, predicted factor scores for advanced use, basic use, management and supply chain.

Appendix 1: Probit Regression of Broadband on the Set of Instruments

Variable	Coefficient	p-value
Share of workers who used internet at work in total workers	0.070	0.000
Share of workers who used computer at work in total workers	0.007	0.012
Dummy for firms that are expanding	0.171	0.000
Log-Likelihood	-1543.309	
Pseudo-R^2	0.496	

Note: Regression includes two-digit industry dummies and state dummies.