Is your Broadband really broad? Internet Speed, Labour Demand and Productivity Outcomes: Evidence from Italian Firms*

Emanuela Ciapanna† and Fabrizio Colonna‡

Bank of Italy

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Does higher Internet speed connection in firms affect labor productivity and production efficiency? And is the possibly induced technological change skill biased or factor neutral? We combine several Italian datasets to answer these questions. Internet speed varies significantly across locations, even within the same municipality, due to technical characteristics of the broadband network: we exploit speed spatial heterogeneity to identify the impact of Internet speed connection on firms'productivity. By using a nested CES production function, we can account for substitutability/complementarity between skilled and unskilled labour. Our results suggest that higher broadband capacity improves the labor market outcomes and productivity of skilled workers. Furthermore, it enhances firms'efficiency (TFP). We find suggestive evidence that higher broadband capacity in firms complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks. Taken together, our findings have important implications for the ongoing policy debate over government investment in ultra-broadband infrastructure to encourage productivity and firms' performance growth.

Keywords: Broadband speed; skill bias; productivity; and elasticity of substitution
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†Corresponding author: Emanuela Ciapanna, Banca d'Italia, Via Nazionale 91, 00184 - Roma, Italy. Phone: +39-0647922188. e-mail: emanuela.ciapanna@bancaditalia.it.

‡Fabrizio Colonna, Banca d'Italia, Via Nazionale 91, 00184 - Roma, Italy. Phone: +39-0647923867. e-mail: fabrizio.colonna@bancaditalia.it

Introduction

High-speed infrastructures are widely recognized to foster technological progress and economic growth. Motorways, high-speed rail, or airports increase welfare due to travel-time savings and agglomeration benefits, bringing workers and firms closer together, and thus reducing inefficiencies. Speed fosters technological progress, and technological progress brings about new ways of production and new products, which in turn increase speed, triggering a virtuous circle. The positive economic impact of high-speed infrastructure projects is well documented in the literature, and supportive evidence is relatively robust (Baum-Snow and Kahn, 2000; Baum-Snow, 2007; Duranton and Turner, 2011; Duranton et al., 2014; Faber, 2014) .

In this paper, we analyze a particular type of speed and high-speed infrastructure: digital speed in Internet broadband connections. In particular, the research questions we address is: "Does broadband speed matter for firms' economic outcomes (e.g. labour demand, productivity and efficiency)?"; "Does high speed broadband bring about skill bias or factor neutral technological progress?".

The productivity and labor market effects of the diffusion of information and communication technologies (ICT) have been widely investigated by economists and policy-makers. The development of high speed-always-on broadband Internet connections has enabled these time-shrinking technologies to improve the finding, sharing, and storing of information, which have brought about organizational innovations, and revolutionized business processes. The technological dynamism and pervasive use of broadband in the last two decades warrants its classification as a general-purpose technology (GPT) along with other key technological innovations such as the steam engine and semiconductors (Bresnahan and Trajtenberg, 1995; Jordán and León, 2011; Bertschek and Niebel, 2013). Since its introduction, in the late nineties, the main objective pursued by policymakers was maximizing broadband coverage, so to guarantee a decent connection (at least 2 Mbit/s) to the largest number of households and firms. Since 2010, the debate has been shifting towards the need for bandwidth and speed, to keep up and make the most of the possibilities that come with a faster Internet connection, as in marketing, inventory optimization, and streamlining of supply chains (ITU, 2012).[1] A faster Internet connection encompasses an extraordinary potential that, once released, expands the range of production possibilities significantly: cloud computing, IoT, e-commerce, telecommuting, video streaming, to name just a few. John Sviokla, professor at Harvard Business

[1] In the U.S., the National Broadband Plan states that 'every American should have affordable access to robust broadband service' and 'at least 100 million U.S. homes should have affordable access to actual download speeds of at least 100 megabits per second and actual upload speeds of at least 50 megabits per second' until 2020. Similarly, the European Commission launched the Digital Agenda for Europe (DAE) that 'seeks to ensure that, by 2020, (i) all Europeans will have access to much higher Internet speeds of above 30 Mbit/s and (ii) 50% or more of European households will subscribe to Internet connections above 100 Mbit/s'.

School and executive, recently wrote:"what the interstate highway system was to physical productivity, fast Internet is to knowledge work — it is an essential infrastructure that creates value for everyone. Think of the Internet as the highway of the mind. Speed matters: Are you chugging along at 30 mph down a dirt road, or are you flying down the autobahn?". A panel of fiber broadband experts, speaking at CES 2016 in Las Vegas,[2] said the Internet of Things (IoT) as well as the smart factory will not only benefit from fiber-optic ultra-speed broadband, they will require it.

Against this background, the present paper aims to contribute to the debate on the economic impacts of broadband by examining how Internet connection speeds (and not simply availability/adoption of any connection) impact firms' productivity and labor market outcomes, in Italian firms over the period 2000-2015. Our analysis employs several data sources that we can link through unique firm and individual identifiers. This gives us information over time and across areas on workers' wages and employment status as well as on firms' available maximum broadband speed at address point, use of input factors, and output. The identification of a causal effect of broadband speed on firms' efficiency and optimal labor demand is complicated by endogeneity concerns. First, a profit-maximizing telecommunication carrier will preferably roll out Internet infrastructure in areas where customers' willingness to pay for a fast Internet subscription is higher. Likely, firms in these areas tend to be more innovative, export-oriented, and employ a large share of high-skilled workers. Given that these firms' characteristics are correlated with productivity and labor demand outcomes, any effect of Internet speed we might observe on firms' performance is potentially biased. In this paper, we exploit historically inherited technological properties of the preexisting voice copper legacy network, i.e. the distance from facility to the closest local telephone exchange, which provides exogenous variations in high-speed Internet access, to identify its effect on firm-level employment variables and total factor productivity. In fact, while the rolling out of optical fiber and the adoption of FTTx technologies is relatively recent in Italy, in the considered time period, high speed Internet subscription were almost exclusively based on copper technologies, of the digital subscriber line family (ADSL and its upgrades). The speed of data transfer on copper lines depends on the technology that the local exchange is endowed with (whether ATM, Ethernet DSL, VDSL, and so on), which still suffers from endogeneity bias, and, primarily, on the distance between the exchange and the client's facility. In particular, the signal decays exponentially with the distance up to a maximum of 5 Km, farther than that, no broadband is available, as the speed drops below the minimum threshold of 2 Mbit/s. Our identification assumption is that the distance of a firm facility from the closest telephone exchange affects its economic outcomes only through the cor-

[2]CES (formerly an acronym for Consumer Electronics Show) is an annual trade show organized by the Consumer Technology Association (CTA). Held every January at the Las Vegas Convention Center, the event typically hosts presentations of new products and technologies in the consumer electronics industry.

respondent broadband Internet speed. To further substantiate our exclusion restriction, we add that all the telephone exchanges in the country, precisely geocoded in our data, date back to the after-war period, around 1945 (broadband was officially introduced in 1999), and were built by TETI, the telecommunication incumbent —State-owned at the time — following a logic of universal service for the phone, which had to be available to all citizens, and their location never changed since then. Moreover, we restrict our sample to firms that were born before 1999, to avoid the possibility of endogenous location choice.[3] Furthermore, we construct density-type variables to control for possibly confounding network-effects.

The distance form the closest exchange serves us as a plausible instrument for different speed connection available at the firm, and allows us to estimate production functions where firms can upgrade their technology by using higher speed broadband Internet. By using a nested CES production function, we can account for substitutability/complementarity between skilled and unskilled labour. Our results suggest that higher broadband capacity improves the labor market outcomes and productivity of skilled workers, immediately after its adoption. Furthermore, firms having a faster Internet connection display significant improvements in their efficiency (TFP) and growth in their size, though these effects are somehow lagged with respect to the labor quality adjustment.

We further investigate the channels through witch higher broadband speed induces skill biased technological changes and raises TFP. In line with the existing related literature, we find suggestive evidence that higher broadband capacity in firms complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks. Moreover, our estimates suggest an elasticity of substitution between high an low skilled workers lower than unity, indicating higher complementarities than in the Cobb-Douglas case. By comparing our estimates with the ones we would have obtained under the Cobb-Douglas assumption, we show that a more flexible parametrization allows us to retrieve a positive and significant contribution of high speed Internet on TFP, a result often overlooked in previous related analyses. Taken together, our findings have important implications for the ongoing policy debate over government investment in ultra-broadband high-speed Internet infrastructure to enhance productivity and firms' performance.

The topic considered in this article relates to and extends on three strands of the literature: first, the copious literature analyzing *the labor market effects of ICT* (Acemoglu and Autor (2011); Autor and Dorn (2013); Michaels et al. (2014), among others). This research has largely focused on the economic consequences of investing in computers and R&D.[4] We complement this research by providing novel evidence on the skill

[3]Later on in our analysis, we show that relaxing this assumption does not affect our results, so we can rely on a more general sample not subject to possible selection bias sourced from this restriction.

[4]See also Autor et al. (2006, 2008); Goos and Manning (2007); Black and Spitz-Oener (2010); Firpo et al. (2011). A related literature argues that ICT changes workplace organization and practices, by

bias of broadband Internet speed, a relatively recent technological change. Our findings are consistent with the widespread view that ICT is complementary with high-skilled labor. Technological progress that lowers quality-adjusted ICT prices such as higher speed broadband Internet should therefore raise demand for skills and returns to skill.

A second stream in the literature to which we contribute is related to the evaluation of the specific *effects of Internet broadband adoption on economic performance and labor market outcomes*. At a macro level, the seminal contribution of Czernich et al. (2011), using a panel of OECD countries, estimates a positive effect that Internet infrastructure has on economic growth. Kolko (2012) also finds a positive relationship between broadband expansion and local growth with the US data, whereas Forman et al. (2012) study whether the Internet affects regional wage inequality. Greenstein and McDevitt (2011) provide benchmark estimates of the economic value created by broadband Internet in the United States. At the micro-level, Akerman et al. (2015) find that broadband adoption in firms is a skill biased technological change, which increases the marginal productivity of skilled workers, and lowers the marginal productivity of unskilled workers. We complement this research by providing novel evidence on the impact of broadband speed on labour demand and productivity. In fact, while the effects of broadband adoption on economic outcomes has raised the attention of several researchers, the impact of different bandwidths and Internet connection speeds on labour demand and firms' performance has been mostly overlooked. At the best of our knowledge, our paper is the first contribution investigating this "intensive margin" effect on firms' outcomes. Other few empirical contributions can be found, analysing the impact of broadband speed on political economy variables and voting (Falck et al., 2014); on demographic trends (Billari et al., 2017), and on real estate prices (Ahlfeldt et al., 2017).

Finally, our paper is related to the literature on *firm productivity and technological change,* in particular, we consider a production function with a nested CES component to give account of heterogeneity in the labor input (Doraszelski and Jaumandreu, 2018; Grieco et al., 2016; Akhmetova and Ferguson, 2015). This more flexible parametric specification allows us to better evaluate and disentangle the effect of high Internet broadband speed both on firms' total factor productivity and relative skilled-labor productivity. On the one side, higher speed broadband, as a GPT, allows the introduction of new applications and services, and might induce adoption of better managerial and production practices and an updating in production technologies, all of which enhance total factor productivity. On the other side, higher speed broadband might determine a skill-biased technological change, as the implied managerial and technological innovations at the firm may raise the productivity of high-skilled workers more than that of the low-skilled. In

increasing skill requirements, worker autonomy and management's ability to monitor workers (see e.g. Caroli and van Reenen (2001); Bresnahan et al. (2002); Brynjolfsson and Hitt (2003); Bloom et al. (2014)).

turn, the resulting skill-biased technological change would lead to an increase in relative skilled labour demand. While the Cobb-Douglas model, by imposing a unit elasticity of substitution between different labor inputs, tends to over-estimate the effect of technological progress on high-skilled labor productivity and therefore to understate the impact on the TFP, our specification relaxes this constraint and provides an estimate of the substitution parameter. In particular, we retrieve an elasticity of substitution between high and low skilled labor which is less than 1, which implies higher complementarities compared to the baseline model. Moreover, by employing the CES nested specification, we are able to retrieve a positive and statistically significant effect of higher speed Internet both on relative skilled-labor productivity and on firms' TFP, whereas the latter parameter drops in magnitude and loses significance when we conduct the same estimation through a Cobb-Douglas model, in line with the results of Akerman et al. (2015) on the extensive margin.

The paper unfolds as follows. Section 2 discusses the diffusion and technical characteristics of broadband Internet in Italy, Section 3 describes our data. Section 4 presents and discusses our identification strategy. Section 5 and 6 describe our empirical models of labor demand and total factor productivity respectively, report our main findings, discuss their economic significance and statistical validity. The final section offers some concluding remarks. All proves and further descriptive material are relegated to the online Appendix.

2 Broadband in Italy

In this section, we first describe the recent development of broadband Internet in Italy, and then give an overview of its development over time and space, whereas in the next section we will provide a description of our data sources.

The market for Internet services in Italy is characterized by the presence of a network, originally deployed by TETI, the State-owned telecommunication incumbent at the time —after absorbed with other local carriers by Telecom Italia (TIM)— in the post World War II period, between 1945 and 1960, aimed to provide voice telephony services to the universe of the Italian citizens. TIM was state-owned until its privatization in 1996. This network consists of 10,992 Local Exchanges (LEs). Each LE is a node of TIM's local distribution network (sometimes called the "local loop") and is the physical building used to house internal plant and equipment. From the LE, lines are then further distributed locally, by means of copper cables, to each building in which customers live or work, which tend to be, on average, within 2 km from the LE. LEs aggregate local traffic and then connect up to the network's higher levels (e.g., the backbone) to ensure worldwide connectivity, typically by means of high-capacity (optical fiber) lines. Although the basic topology of TIM's network was decided several decades ago, technology has proven extremely flexible, as historically, the length of copper cables connecting the users' facility to the closest LE was very small. The old copper technology, until the end of the 1990s, provided a speed up to 64 kbit/s per channel via dial-up (modem) connections. Thanks to the good quality of the Italian copper lines, without having to change the cables in the local loop, it has been possible to supply high-speed Internet by installing special equipment in the LEs. A breakthrough occurred with a family of technologies called digital subscriber line (DSL), which uses a wider range of frequencies over the copper line, thus reaching higher speeds. The first major upgrade program involved bringing the ADSL technology to each LE. TIM began the program in 1999 and took about three years to complete it and endow all the LEs with a DSLAM-ATM (Digital Subscriber Line Access Multiplexer 'Asynchronous Transfer Mode). This upgrade could initially improve Internet speed by a factor of 40 compared to a standard dial-up modem and, afterwards, allowed speeds up to 8 Mbit/s. Later, starting in 2012, the ATM technology has been flanked and partly replaced by the DSLAM Ethernet technology, implying a speed upgrade up to 20 Mbbit/s. More recently, the increasing demand for bandwidth has required a shift from standard broadband (from 2 to 30 Mbit/s) to ultra-broadband (in the order of Gbit/s), supported by new generation network (NGAN), based on optical fiber technologies (FTTx).

In our analysis we will restrict our attention to the time period 1993-2015, before the advent of the optical fiber, and we will consider copper-based broadband only. This choice is driven by the nature of our IV strategy, which exploits a technological property of DSL on the copper legacy network: the exponential decay of the transmission speed as the distance from the LE increases. Indeed, if the client premise is very close to the LE (within a radius of 100-200 mt), then the theoretical and actual maximum speed of (8 Mbit/s for ADSL, 20 Mbit/s for ADSL2+) tend to coincide, but as the distance gets larger the speed drops dramatically up to the 5 Km threshold, coinciding with the boundary of 2Mbit/s, the minimum speed required to speak of "broad" band (see Figure 1. Thus, the broadband Internet speed connection based on DSL may vary depending on two main factors: the type of technology the specific LE is endowed with (whether ATM or Ethernet and so on), and on the length of the access line. While the latter is an endogenous factor, as it plausibly depends on the economic convenience of a network operator, the distance from the LE is a spatial characteristic inherited form the past, given that the telephone exchanges have remained fixed in terms of their number and location since many decades before the DSL was introduced, and their position, at the time, responded to a logic of universal coverage of the phone service, not subject to the distance-performance trade-off.

3 Data and Descriptive Statistics

3.1 Data description and sources

In this section, we describe our data and sample selection, while details about the data sources and each of the variables are provided in the online Appendix.

We rely on data from multiple administrative sources to build a comprehensive dataset on firms, workers, and Internet broadband connection availability, in Italy for the period 1993-2015. The core of this data construction is the firm-level data sourced from the Bank of Italy's Survey of manufacturing and service firms (INVIND), an open panel of around 4,000 firms per year, representative of manufacturing and service firms with at least 20 employees. We combined these data with the worker individual-level data from the Italian Social Security Administration (INPS), providing the complete work histories of all workers who were ever employed by an INVIND firm in the period 1993-2015, including spells of employment in firms not listed in the INVIND survey. Overall, we have information on about 5 millions workers per year, 25% of whom are employed in firms surveyed by INVIND in any given year.[5] We also add to these two data sources proprietary firm-level data from Cerved, administered by the Cerved Group. These data provide balance sheets and income statements for all incorporated firms in Italy for the 1993-2015 period. On the firms' side, our employer-employee data is further augmented with information on the Internet broadband connection speed and characteristics, available at the firm address point, sourced from Telecom Italia (TIM). These data are finally complemented by the universe of all the Local telephone Exchanges in the country, comprehensive of their precise geolocalization and technological characteristics, also owned by TIM.[6] Table 1 gives a summary of the data sources; in the following subsections, we provide an overview of the data and main steps undertaken during the construction of our data set.

3.1.1 Employer-Employee Data

Our firm data come from two main sources: the Bank of Italy's Survey of manufacturing and service firms (INVIND), an open panel of around 4,000 firms per year, representative of manufacturing and service firms with at least 20 employees and the CERVED balance sheets and income statements data for all incorporated firms in Italy for the 1993-2015 period. The CERVED data offer detailed information from the firm's balance sheets on output (such as revenues) and inputs (such as capital, labor, intermediates) as well as 4-digit industry codes. We consider only the firms that were funded

[5] The remaining ones are employed in about 1,800,000 firms not surveyed in INVIND, of which we only know the industrial sector and the average number of employees during the year.

[6]Both the TIM data-sets are highly confidential data, made available to the authors by TIM under a strict non-disclosure agreement.

before year 1999, the official date of introduction of the DSL broadband connection, and that were present in the sample until 2015. This is to exclude the possibility of firms endogenously choosing their location, conditioning on the distance from the LE. We do not consider the most recent years (2016-2018), as we focus on the copper based DSL technology, whereas, since 2015, a copious investment in fiber to the cabinet (FTTC) and to the home (FTTH) connections has been made by the Telecom network operators, potentially weakening our econometric strategy. We also combine our firm data with the anagraphics and address information provided by the Italian Business Register of the Italian Chambers of Commerce. Moreover, we will restrict our analysis to single plant firms, as for multi-plant enterprises we do not have plant-level data, nor can we correctly match the workers' information to each plant, as production units of a holding company share the same identifier (fiscal code).

We combine the so constructed firm data-set with the employees information sourced from INPS. The Social Security data provide complete information on employment histories. Among other things, we obtain information on the identities of firms they are employed in, job start and separation dates, gross labor income (including bonuses and overtime), number of months/weeks worked in a year, type of contract (e.g., full-time or part-time, permanent or temporary), and occupation description (white-collar, blue-collar and manager classifications). In addition, the data provides individual demographic information. In our specification, we define an individual as high-skilled if he or she holds a white-collar or managerial job qualification, while individuals classified as blue-collars are defined as low-skilled. In parts of our analysis, we refine these often used proxies for skill levels: we divide high-skilled individuals into high skilled (managers only) and medium skilled (white-collars clerks). We also resort to the Labour Force Survey data in order to provide supportive evidence of the goodness of our skill-proxy: in particular, we match the job synthetic qualifications to the ISCO 3-digits codes, which provide a quite accurate description of the worker's task, and find that our classification is consistent with the OECD skill ranking following a task-based approach. Figures 6 displays the distribution of tasks (defined by the ISCO codes on the y-axis) over our professional qualifications (blue collars, white collars and managers). A monotonic relation emerges between the routine degree of the tasks (ranking between 1, which indicates the lowest level of routine and 8, where high-routine tasks are represented) and the level of professional qualifications (from managers to blue collars). The mapping provides evidence that our qualification variable can make a good proxy for skill levels, as our three categories do not show any intersection in terms of tasks in over 75% of cases. As we will see later in section 4, our results can find their rationale in that higher broadband capacity in firms complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks, which is in line with the argument proposed in Akerman et al. (2015) for the extensive margin of broadband adoption.

3.1.2 Broadband Internet Data

The data on broadband availability and speed, provided from Telecom Italia are sourced from two distinct data-sets. The first one, TIM1, contains detailed information regarding the characteristics and speed of the Internet connection available at the firm's address, (geocoded at address point). In particular, each firm in our INVIND sample is linked to its correspondent LE through a univocal identifier. Moreover, for every local exchange we know the exact location, and its technical characteristics (e.g. the DSL technology it is endowed with, if DSLAM ATM or Ethernet, and the exact date of any upgrade), as well as the maximum speed (in download and upload) of the Internet connection available at the firm address within the sample period. We also know whether the firm has been recently connected to a street cabinet via optical fiber and the exact date of starting of the FTTC connection. In the following analysis we will use the TIM1 dataset to build our baseline specification, which will study the effect of Internet speed on several economic outcome variables (e.g. labor demand of high and low skilled workers, labor productivity and so on). Then, in order to address endogeneity concerns and to provide a strong identification method, we will resort to a second data-set, TIM2, containing detailed information on the universe of the 10,992 LEs situated in the country. For each LE, comprehensive of a univocal identifier, we know its precise location (address and geographic coordinates), the DSLAM technology it is endowed with, and the exact date the service was activated, whether the LE is saturated or active, and the possible presence of a bypass, channelling the data traffic to a different commutator. This dataset allows us to compute the Euclidean distance between each firm in our sample and the closest LE and also to identify all the LEs situated in a circle centred in the firm facility having a radius of 5 km, which is the maximum distance from the exchange supporting a broadband connection (requiring a minimum speed of 2 Mbit/s, according the EU standard definition). The TIM2 data-set is fundamental to our empirical strategy. In fact, by computing, for each firm, the minimum distance from the exchange, we can rely on a valid IV for speed: the exclusion restriction behind the instrument is based on two main assumptions: first, the LEs in Italy date back to the mid fourties, whereas the ADSL was introduced in the end of the nineties, second, the LEs were located following a logic of "universal service" for the voice signal over the copper legacy network, which did not suffer of the same decay with distance as DSL. Third, their location did not change over time; fourth, we do not consider the firms who entered the market after 1999, to further avoid reverse causality issues. Thus, broadband Internet speed varies because of two main factors: the technology embedded in the commutator, which is an endogenous characteristic, as the upgrade is likely to follow a logic of profitability, by prioritizing higher-density/higher-demand zones, and the distance from the facility, which is our proposed exogenous source of variation.

3.2 Sample Selection and descriptive Statistics

For the purpose of our analysis, we restrict our focus to all the firms present in the INVIND sample in 2014, active since before 1993 and until 2015, consisting of a single production units. Under these assumptions our final sample is a balanced panel of 1,560 firms/year for 23 years, for a total of about 34,250 observations. Descriptive statistics for the main variables are reported in Table 3. All estimates presented in the paper are weighted by the number of employees.

Our sample selection criterion is motivated by the identification concerns of firms' exogenous location with respect to our instrument (as explained above). Nevertheless, this choice potentially introduces a source of bias in our results, due to the high survival rate of all the firms in our sample. In fact, it is plausible that, following the advent of DSL broadband, firms have positioned themselves closer to an LE, whereas existing companies located far from any commutator have exited the market or have changed their venues in response to expected productivity disadvantages. By excluding these inflows and outflows, we exclude endogenous responses to our treatment, and we have a sample of relatively older firms, independently of their location. The direction of the sample bias is dubious: on the one side, the group of companies having a faster connection could be ex ante stronger, and have a better performance for some unobservable characteristics, which is not correlated to their speed endowment (an upward bias); on the other side, the group located relatively farther from the LE might have developed some very effective survival strategy, which has allowed these firms to survive, no matter their relative slower connection (a downward bias). We will address this selection problem when performing our robustness checks, by replicating the analysis on an unbalanced panel with inflows and outflows and show that our results are not affected by the vintage of the firms. In terms of economic sector representativeness, there are no significant differences between the original INVIND sample and the selected one, a part from a slight reduction in share in the other service sector and a correspondent higher weight of manufacturing (see Table 4). Another assumption we make is on firms' size: we only consider single plant companies, and we exclude those with more than 5,000 employees as outliers. This restriction is imposed because firm's identification code is unique at the company level, but production plants belonging to the same firm share the same fiscal code. Thus, even if we can provide a precise geo-localization of all the plants, we are not able to correctly ascribe the balance sheet and labor market variables at this level of detail. This restriction shifts the weight of smaller firms in our sample compared to the original INVIND sample, particularly in the first size class (below 50 employees), that increases its share of 10 percent, against a corresponding reduction in the 200+ class representativeness (see Table 4). In general, we do not expect this sample selection criterion to strongly bias our results, as if any relationship between performance and size can be retrieved, it would be a positive one, so the bias would be downwards.

Regarding the Internet connection descriptives, no differences emerge between the original INVIND sample and the selected one: the average maximum speed in download as of 2000 is 8.7 Mbit/s for both groups of companies and the average distance from the closest LE is 1.1 Km, so no bias arises from this source. In the next sections we present our empirical strategy aimed to assess the impact of broadband Internet speed on firms' labor demand and economic performance. In particular, we first analyze the labor market outcomes, by studying the effects of different connection speeds on labor demand, looking in particular at its skill composition. Afterwards, we investigate the impact of speed on firms' TFP, by estimating a nested CES production function, allowing for human capital heterogeneity considerations. The identification strategy relies on the technological property of xDSL connection, based on the decay of speed with distance from the LE of the copper network. In particular we'll estimate an intention-to-treat effect by exploiting differences in the maximum speed of the available connection determined by the distance between firms' locations and the closest LE.

4 Identification Strategy and First Stage Regression

We start our analysis by considering a simple linear model:

$$y_i = \alpha + \beta x_i + \gamma_1 speed_i + \epsilon_i \tag{1}$$

where for each firm i y_i is a dependent variable of interest (i.e. size, productivity, share of skilled workers), x_i is a set of controls, and $speed_i$ is the maximum Internet connection available at firm i. Several potential correlation might bias the results. First of all a reverse causality issue might bias upwards the results if Cov($epsilon_i$,$speed_i$) is positive. For instance,larger or more productive firms might have *a priori* access to a better connection: they can require a faster upgrade of the LE they are connected to, or they can ask to be connected to a different LE, endowed with a better performing xDSL technology. In order to address this potential source of endogeneity, we propose an instrumental variable approach, where our IV variable is the distance between firms' facility and its closest LE. As discussed before, the maximum speed available will depend on both the quality of the LE and its distance from the firm. While the former factor is likely to be endogenously correlated with firm's characteristics, the latter is plausibly exogenous, at least in the considered sample. The exclusion restriction behind our identification approach states that the distance between a firm and its closest local exchange influences firm's decisions and performance exclusively through the Internet connection speed available to the firm and not through any other sources. This assumption finds its grounds on two main pieces of evidence: first, as anticipated in the previous sections, our IV is predetermined, as LEs in Italy were installed in the 1940s, after the Second World War, as part of the country telephone network, and their number and location has been maintained fixed over time, whereas DSL broadband dates back to 1999. Second, the structure of the legacy copper network responded to a logic of "Universal service" for the telephone line, which does not have the technological property of signal decay with distance typical of the DSL data transmission. Moreover, to avoid endogeneity of location choice on the firms' side, we restrict our sample to all those companies that were funded before 1995 and did not change their headquarters. Under these assumptions, our first stage regression takes the following form:

$$speed_i = \gamma_1 dist_i + \gamma_2 dist_i^2 + \gamma_3 du_{ind} + \gamma_4 du_{prov} + \varepsilon_i \qquad (2)$$

where $dist_i$ is the distance between firm's facility and its closest exchange, du_{ind} and du_{prov} are sector and province fixed effects and ε_i is a firm-specific iid shock. The first stage regression results are reported in Table 5: as expected, the instrumental variable shows a strong negative correlation with our main explanatory variable and the relation results to be convex, reflecting the aforementioned technological properties of data transmission via copper networks. In order to validate the causal interpretation of the result, the panel dimension of data will also allow for a parallel trend test checking if distance from LE were associated to different firms dynamics even before the introduction of ADSL in early 2000s. A second possible source of bias could arise from an omitted variable issue, if firms having a faster connection are actually located in areas with larger network economies, so that their suppliers and customers enjoy a faster connection, which in turn explains a superior performance of the whole supply chain. To avoid the aforementioned network effects, we control for a measure of broadband "density", by constructing a variable that accounts for the number of LEs within a 5-km radius (Figure 4).[7]

5 Broadband Speed and Labor Demand: Model and Results

As a suggestive evidence Figure 7 compares, for each year, employment characteristics of firms located within a 2 Km radius from the local exchange (from now on *high-speed* firms) and those whose closest LE is more that 2 km away[8](in hereafter *low-speed* firms). Panel a) displays, for each year, the average number of full-time equivalents employees.

[7]The 5-Km radius assumption is not at random. We constructed our density measure for different thresholds, and chose the 5-Km one as the one that maximizes the number of LE allowing for a minimum speed of 2 Mbit/s.

[8]For the sake of the exposition a cutoff value of 2 km-distance is set to distinguish between closer and farther firms. A battery of robustness tests for different thresholds is performed, yelding similiar results.

Not surprisingly, given the sample restriction on surviving companies, average size has been growing until the onset of the Great Recession, but the distance from LE was not apparently associated with any significant differences in the growth rates. Only after 2010, in the aftermath of the sovereign debt crisis, *high-speed*, firms show a slightly better performance. Panel b), c) and d) track average shares of blue collars, white collars and managers. Trends appear to be the same in both sets of firms before 1999, whereas, after broadband introduction, a significant gap emerges: the share of blue collars has dropped for all type of companies, but at a faster rate amongst *high speed* firms. The opposite tendency emerges for the high skilled workers (both white collars and managers, whose number has increased, since 1999, at a higher rate for the treated group (Figure 7). The general baseline OLS model can now be stated:

$$Y_{it} = \beta speed_{it} + \gamma X_{it} + \varsigma_t + \eta_{it} \tag{3}$$

where $speed_{it}$ is the maximum theoretical download connection speed at address point, X_{it} is a vector of controls also containing province and sector fixed effects, ς_t is the time fixed effect and η_{it} is a firm-specific iid shock. As a dependent variable, we first consider the effects on labor demand (total employment) and on the preferred skill composition. Thus, our IV regression equation writes:

$$Y_{it} = \beta_t speed_{IVi} + \lambda dens_i + \gamma X_{it} + \varsigma_t + \eta_{it} \tag{4}$$

where $speed_{IVi}$ is the first stage fit, $dens_i$ is the connection density, i.e. number of LEs within a radius of 5 Km from facility, X_{it} is a vector of controls also containing firm fixed effect,ς_t is the time fixed effect and ν_{it} is a firm-specific iid shock. Our IV is a valid instrument if $\beta_t \neq 0$ after 1999.

Our results are summarized in figures 6-9 and in tables 6-7 for average firm's size and occupational shares respectively. Table 6 reports the effect of the maximum theoretical speed in download, interacted with each year, on number of FTE employees. The first two columns provide the results for the OLS regression. Column (1), where we control for province and sector, displays a positive and significant coefficient for each year in the time range, signalling a systematic difference in unobservable characteristics. Nevertheless, once firm fixed effect are introduced, (Column (2)), broadband connection speed appears to be relevant only after 2010, verifying our parallel trend assumption. The effect remains positive, albeit slightly smaller, in the IV regression (Column (3)). Therefore, the model seems to give account of a general structural break following introduction of the new technology, with the effect being delayed until after 2010 when, upon the aftermath of the sovereign debt crisis, firms endowed with a faster broadband connection might have been more able to adjust to negative shocks. Table 7 reports the results for our IV regression, having as a dependent variable the employment shares by skills (occupations). Before 1999 broadband speed connection was not associated to any systematic difference in the skill mix chosen by firms, a strong effect of Internet speed on re-composition from low towards high-skilled labor appears to arise since 1999. It should be noticed that the gap peaks in 2008, after that *low speed* firms seem to slowly catch up, readjusting their workforce skill composition. Overall, according to our results, firms endowed with a better connection speed first choose to substitute low skilled workers with high skilled, an effect that is statistically significant since the ADSL technology was introduced, and in a second stage, once the optimal skill mix has been reached, they increase their average size. The opposite holds for firms in control group (see also Figure 7).

6 Broadband Speed and Productivity: Model and Results

Previous results indicate that, in the short run, firms with access to a faster internet connection are more likely to upgrade their manpower skill composition leading, only afterwards, to a overall size growth. This might suggest that besides its complementarity with skilled labour, the use of Internet might improve the overall firm's efficiency as well. As reduced forms are not able to carefully disentangle these two effects, we will resort to the classical framework in the productivity estimation literature.

6.1 Theoretical Framework

We extend the theoretical framework proposed in Kasahara and Lapham (2013) by considering a traditional Cobb-Douglas production function with embedded CES aggregator input:

$$Y_{it} = A_{it} L_{it}^{\alpha_i} K_{it}^{\beta_i}$$

where i denotes firms, i time, Y value added, K capital and A_{it} unobservable total factor productivity. Labor input L is a composite of skilled and unskilled labor:

$$L_{it} = \left(\theta_{it} S_{it}^{\frac{\sigma-1}{\sigma}} + U_{it}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad (5)$$

where S_{it} and U_{it} are skilled and unskilled labour inputs, whose substitutability is determined by $\sigma \geq 0$. Finally, the constant θ_{it} denotes the productivity of skilled (relatively to unskilled) labor. The first order conditions of the firm's profit maximization problem are given by:

$$D_{it}\theta S_{it}^{\frac{1}{\sigma}} = w_{st} \tag{6}$$
$$D_{it}\theta U_{it}^{\frac{1}{\sigma}} = w_{ut} \tag{7}$$

where $D = \frac{\partial Y_{it}}{\partial L_{it}} \frac{\sigma-1}{\sigma} \left(\theta_{it} S_{it}^{\frac{\sigma-1}{\sigma}} + U_{it}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma}}$ and w_s and w_u are the wages of skilled and unskilled workers in year t, respectively. Combining 6 and 7 and taking logarithms, we obtain:

$$\log \frac{S_{it}}{U_{it}} = -\sigma \log \frac{w_{st}}{w_{ut}} + \log \theta \tag{8}$$

Traditional approaches in productivity literature, tracing back to Olley and Pakes (1992) and Levinsohn and Petrin (2003) mainly refer to Cobb-Douglas function where Total Factor Productivity can be easily pinned down through a simple log-linearization method. Estimation of a CES function is more complex, since it requires the identification of the substitution parameter σ, which enters the production function non-linearly. We follow a two-step procedure à la Bøler (2015): in the first step we use skill ratio heterogeneity to obtain an estimation of $sigma$ and back out a firm specific time series of skilled labor productivity θ. These estimates are then used to compute labor aggregates that, in the second step, will enter the full production function and will allow us to retrieve firm specific total factor productivity ω_{it}.

6.1.1 First Step

In the first stage skill augmenting productivity is modeled as an unobservable residual in our labor demand function, as total factor productivity is generally backed down as an unobservable residual in production functions. We allow it to evolve as a AR(1) Markov process that acts as a shifter, for a given wage structure, of skilled labor demand. Thus, the baseline specification writes:

$$\log \theta_{it} = \gamma_{0i} + \gamma_1 \log \theta_{it-1} + \gamma_{2t} speed_{it}^{IV} + \xi_{it} \tag{9}$$

where γ_{0i} is the firm specific mean and ξ_{it} is a random shock. Our main parameter of interest, the time variant γ_{2t}, measures the skill augmenting productivity shock due to access to a faster internet connection. Plugging (9) in (8), we obtain our first step estimation equation:

$$\log \frac{S_{it}}{U_{it}} = \gamma_{0i} - \sigma \log \frac{w_{st}}{w_{ut}} + \gamma_1 \left(\log \frac{S_{it-1}}{U_{it-1}} + \sigma \log \frac{w_{st-1}}{w_{ut-1}}\right) + \gamma_{2t} speed_{it-1}^{IV} + \xi_{it} \tag{10}$$

In that, the elasticity of substitution parameter, σ, is not identified by production dynamics, but by the wage elasticity of labor demand. If, for example, firms do not adjust their skill mix according to variations of wage skill premia, a low σ will describe low substituabiltiy between labor inputs. The skill augmenting parameter θ will finally account for labor demand variation unexplained by wage dynamics. This procedures requires the unobserved shock ξ_{it} to be uncorrelated not only with lagged value of skill shares and skill premium (by default), but also with current skill premium. This assumption is not likely to hold since, unless completely rigid, wages easily reflect both firm-specific productivity and labor demand shock. In order to address this issue, we propose an IV approach, using contractually fixed minimum wages, controlling for exogenous wage variation. As Italy is characterized by an highly centralized bargaining system, where industry-specific minimum wages are set at the national level, minimum wages are likely to be binding for low-skill jobs, thus compressing the skill premium. Along these lines, we instrument (log)wage skill premium with nationally bargained sector specific (log)minimum wage. As expected, the correlation in negative: a 1% increase in the minimum wage reduces wage skill premium by 0.17% (8). thus, our final baseline equation will write:

$$\log \frac{S_{it}}{U_{it}} = \gamma_{0i} - \sigma_i \log \frac{\hat{w}_{st}}{\hat{w}_{ut}} + \gamma_1 \left(\log \frac{S_{it-1}}{U_{it-1}} + \sigma_i \log \frac{\hat{w}_{st-1}}{\hat{w}_{ut-1}} \right) + \gamma_{2t} speed^{IV}_{it-1} + \gamma_{3t} dens_{it} + \xi_{it} \tag{11}$$

where $\hat{w}$ denotes instrumented wages and we allow σ_i to take two different values depending on firms being located or not within a 2km radius from the closest LE. Results of the first step are summarized in Table 9 and depicted in Figure 10. Notice, first, that firms closer to an LE, and therefore more likely endowed with a faster connection, are characterized by a lower degree of substituability between skilled and unskilled labour. What is the rationale behind our findings? On the one side, a more intense use of the Internet, as a GPT, might induce firms to require a larger share of highly specialized profiles and/or make intermediate jobs, that can be performed by both skilled and unskilled workers, less in demand. Moreover, access to a better connection seems to increase the relative productivity of skilled labour, leading to an upgrade in labour demand.

6.2 Step 2

In the first step we obtained an estimate of the elasticity of substitution σ and of the whole series of skill productivity component $\hat{\theta_{it}}$. In this second step, we plug the estimated parameters into equation 5 to obtain estimate of labor composite input $\hat{l_{it}}$, and and taking logarithms of 5, we have:

$$y_{it} = \alpha_k k_{it} + \alpha_l \hat{l_{it}} + \omega_{it}$$

A traditional dynamics for the TFP term is adopted:

$$\omega_{it} = \delta_{0i} + \delta_1 \omega_{it-1} + \delta_{2t} speed^{IV}_i + \delta_{rt} dens_i + \pi_{it}$$

where δ_{oi} are firm fixed effect, π_{it} is a TFP shock, unobservable at time $t-1$ and independent of π_{it}. Following Wooldridge (2009) equations 6.2 and 6.2 are estimated in a single step through GMM; the command PRODEST, developed by Rovigatti and Mollisi (2017) for shorter panel data is used. Results of the second step are summarized in Table 10 and depicted in Figure 11. Access to a faster internet connection appears to enhance TFP only from 2009 on.

7 Concluding Remarks

Despite the copious existing research on the economic impacts of broadband both at the macro and micro level, only very few studies specifically investigate the impact of broadband speed on economic outcomes. In fact, most contributions refer generically to broadband as internet connections with download speeds greater than 200 Kbit/s and do not account for faster broadband speeds or different broadband technologies. However, it seems likely that different speeds will have different effects and that production might benefit in particular from higher broadband speeds. The present paper aims to fill this gap in the literature, by evaluating the extent to which broadband speed can affect firms' productivity and labor market outcomes, in Italian firms since the introduction of DSL technologies, in the early 2000s up to the recent advent of optical fiber-based connections. We estimate relative skill labor productivity and firms' efficiency associated with broadband Internet speed, by using linked employer-employee microdata, combined with firms' available maximum broadband speed at address point. The distance form the closest exchange serves us as a plausible exogenous demand shifter, accounting for different speed connections available at the firm, and allows us to estimate production functions where firms can upgrade their technology via higher speed broadband Internet. Our results suggest that higher broadband capacity improves the labor market outcomes and productivity of skilled workers, immediately after its adoption. Furthermore, firms having a faster Internet connection display higher skill complementary, significant improvements in their efficiency (TFP) and, eventually, size growth, though the latter effect is somehow lagged with respect to the labor quality adjustment. We further investigate the channels through witch higher broadband speed induces skill biased technological changes and raises TFP. In line with the existing related literature, we find suggestive evidence that higher broadband capacity in firms complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks. Moreover, our estimates suggest an elasticity of substitution between high an low skilled workers lower than unity, indicating higher complementarities than in the Cobb-Douglas case.

Taken together, our findings have important implications for the ongoing policy debate over government investment in ultra-broadband high-speed Internet infrastructure, to enhance productivity and firms' performance, and also to favour employment and growth. At the same time, however, policy makers will have to take into account the distributional effects that are caused by the skill bias of broadband adoption. Accordingly, it appears recommendable to accompany broadband policies with increased investments in education for both individuals (general education and advanced training on the job) and firms (to facilitate changes in business conduct). In line with our results, such policies would increase not only the share of workers benefiting from broadband, by enabling them to find employment in ICT-intensive jobs, but could also strengthen the overall impacts of broadband on economic growth and employment.

Figures and Tables

Figures

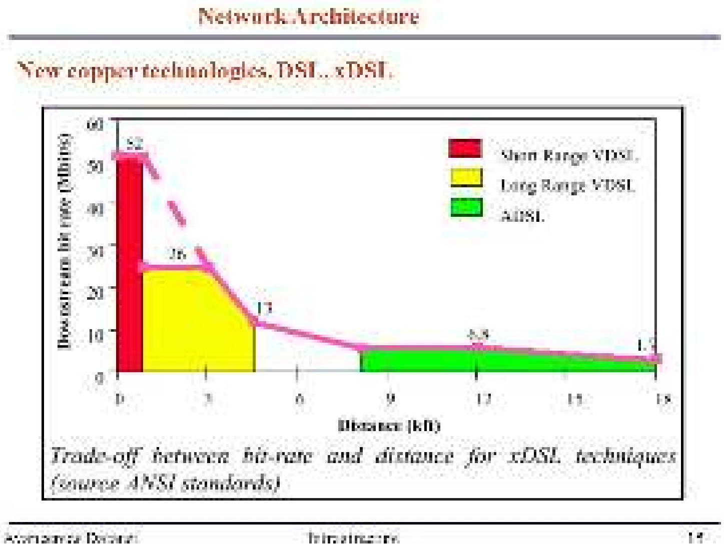


Figure 1: The speed capacity-distance trade-off

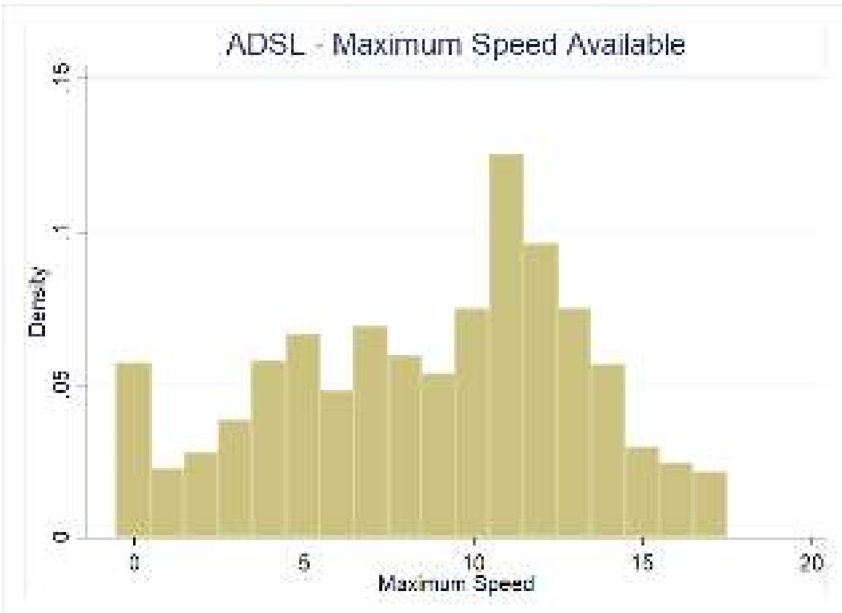
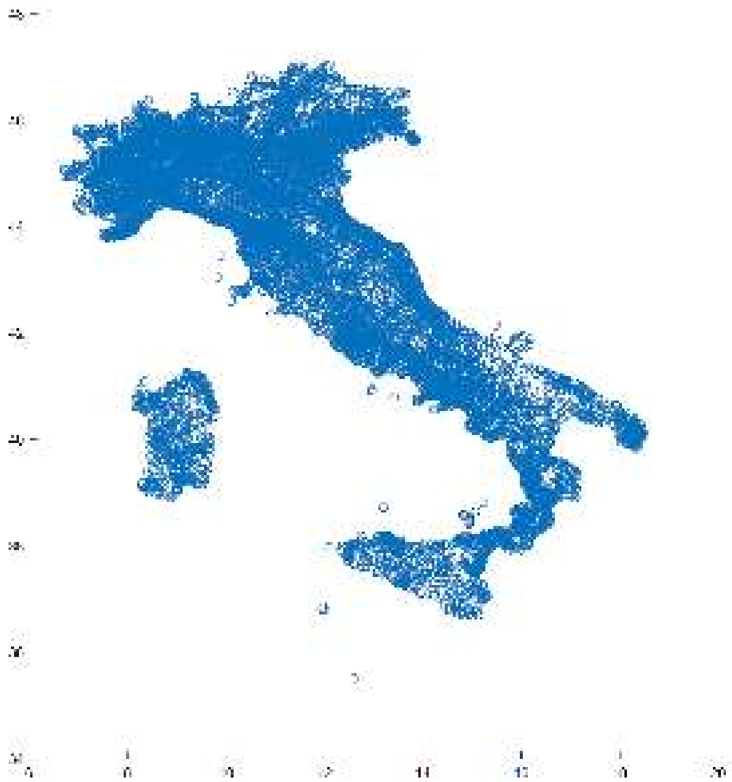
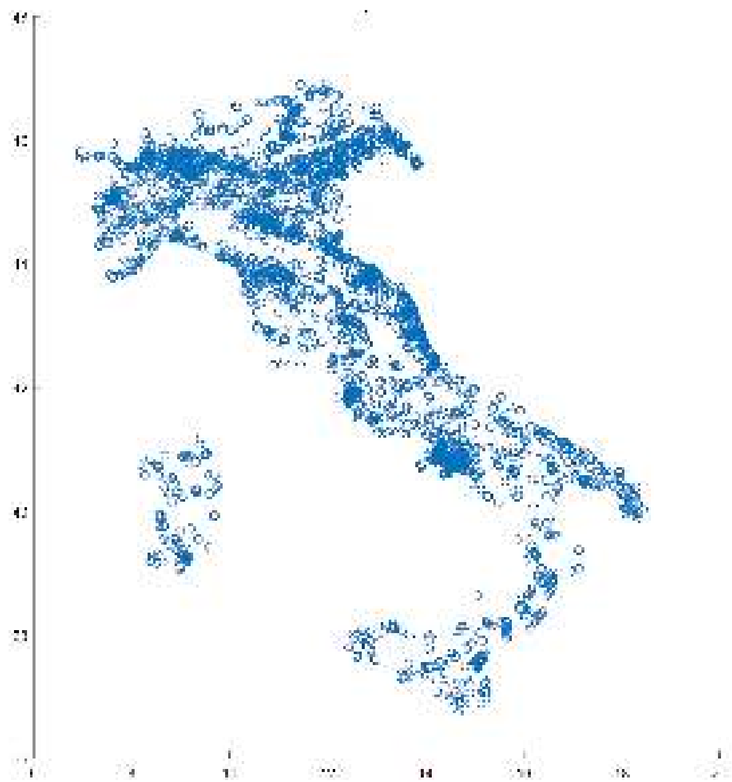


Figure 2: Distribution of available speed in firms as of 2002, TIM-Invind sample.



((a)) Local Exchanges, source: TIM



((b)) Firms, source: INPS-Invind, 2014

Figure 3: Distribution of local telephone exchanges and sample firms, Italy.

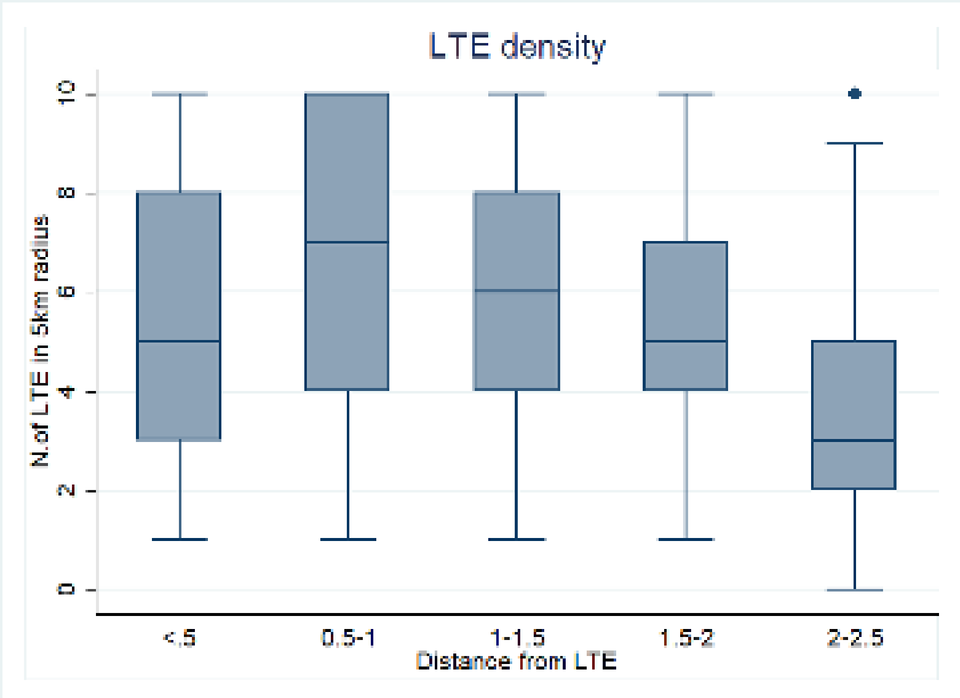


Figure 4: Relation between speed and density

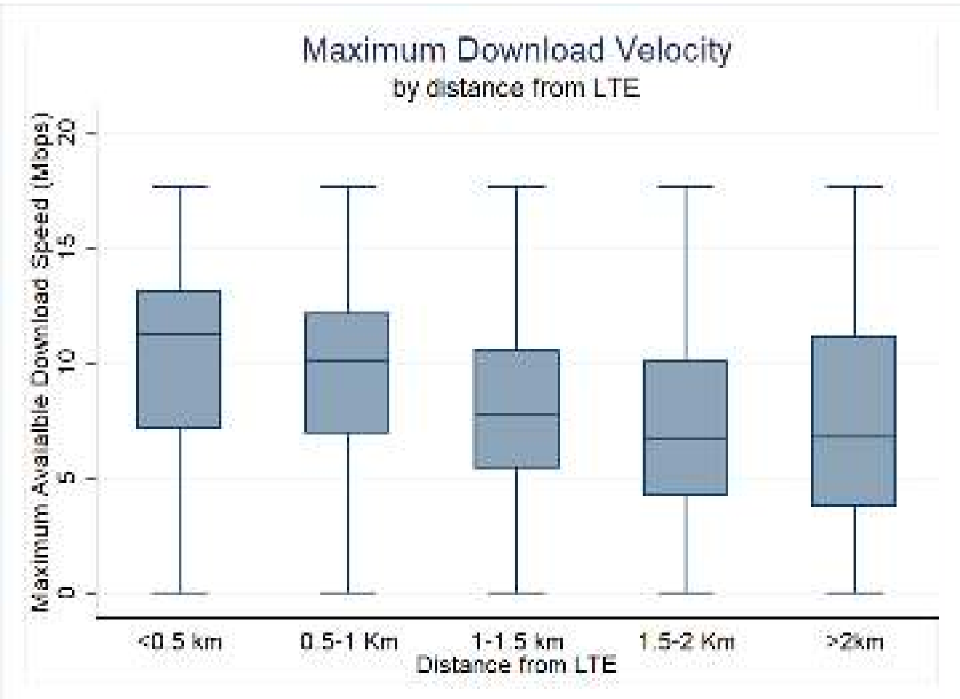


Figure 5: The speed-distance relation

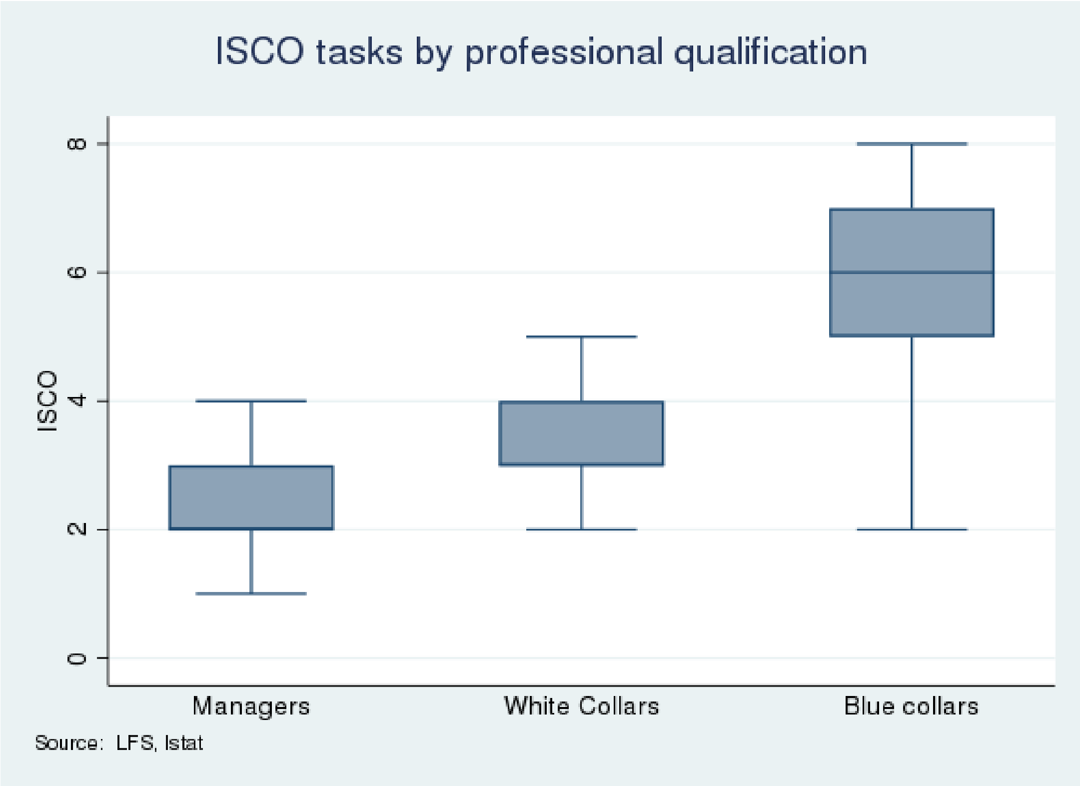


Figure 6: ISCO tasks and professional qualifications

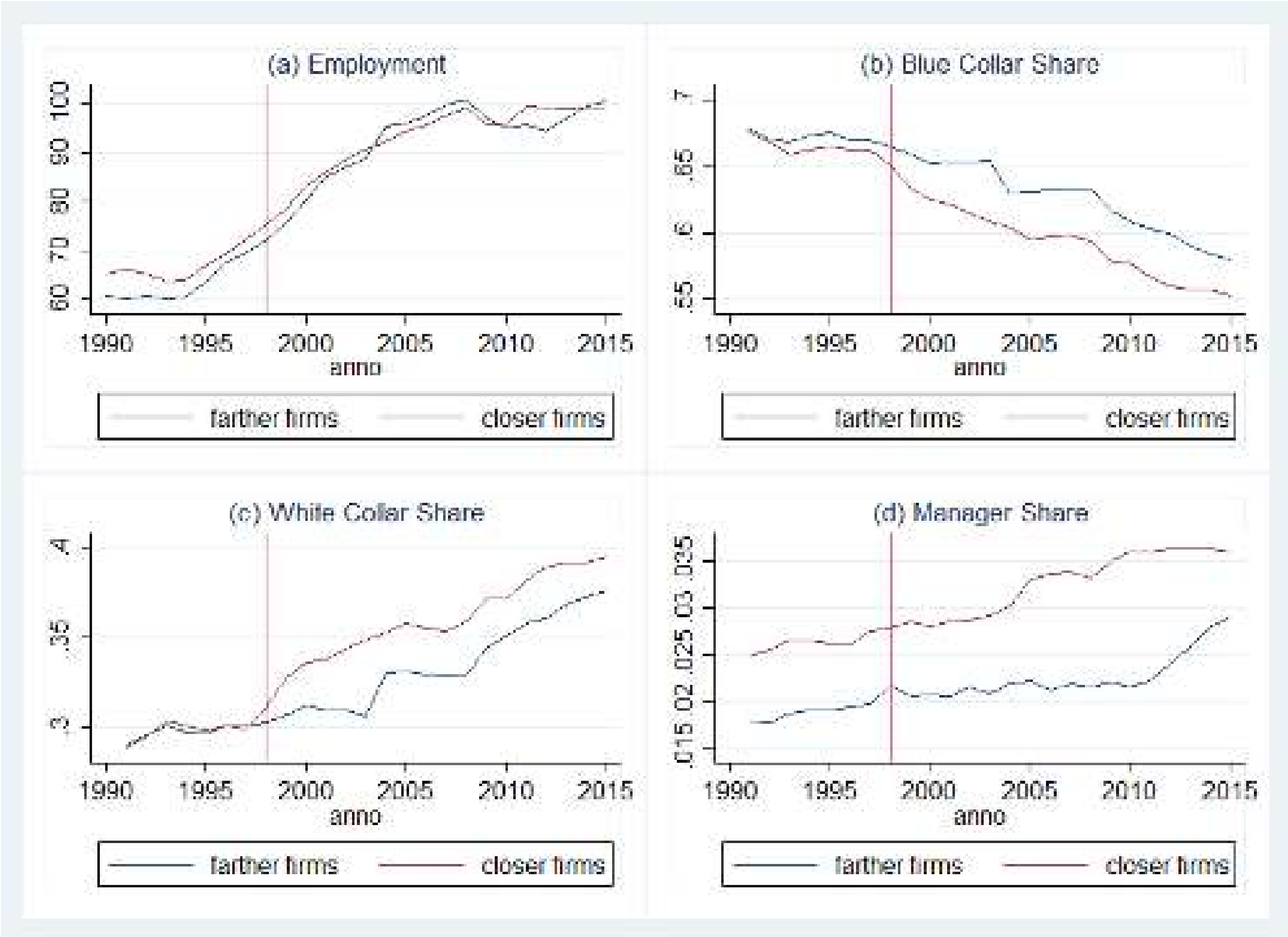


Figure 7: Labor outcomes: differences between firms closer/farther than 2 Km from LE

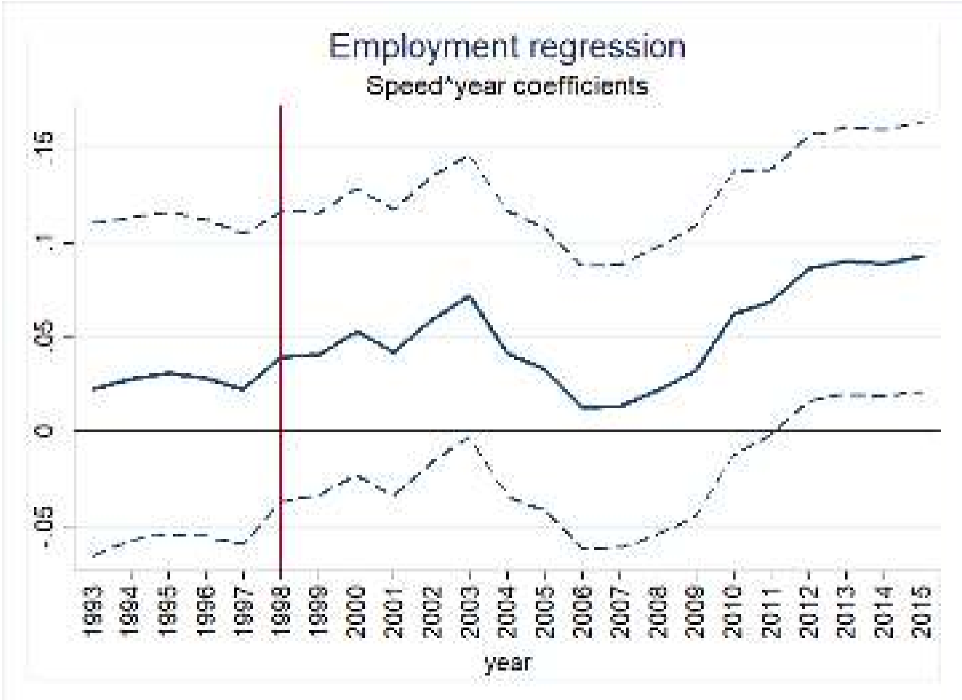


Figure 8: Employment(Average size): differences between firms closer/farther than 2 Km from LE

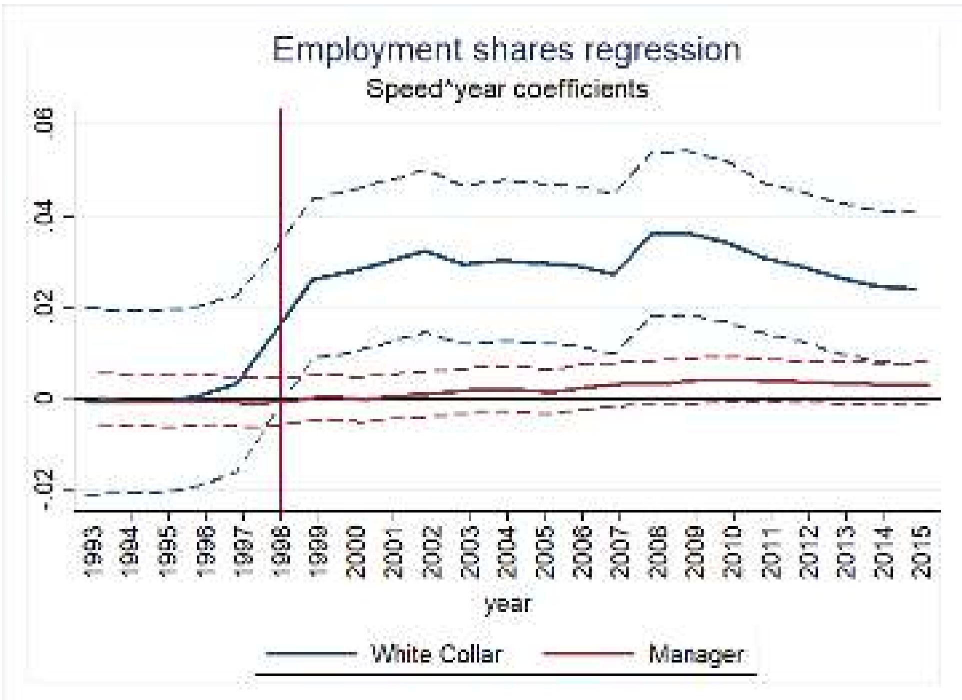


Figure 9: Employment(by skill shares): differences between firms closer/farther than 2 Km from LE

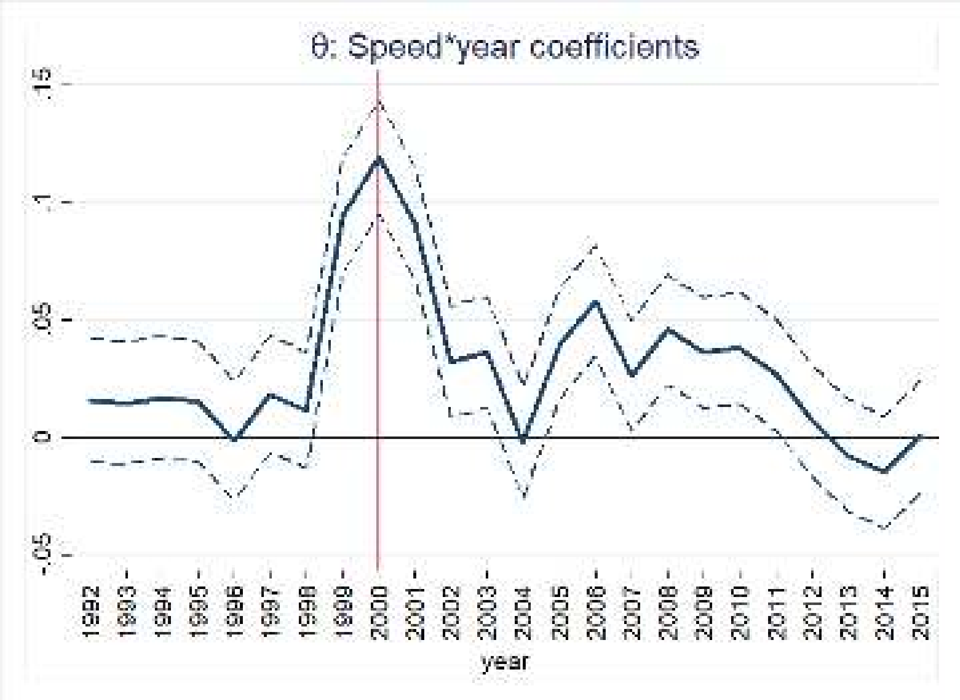


Figure 10: Skilled Labor Productivity: Impact of Broadband

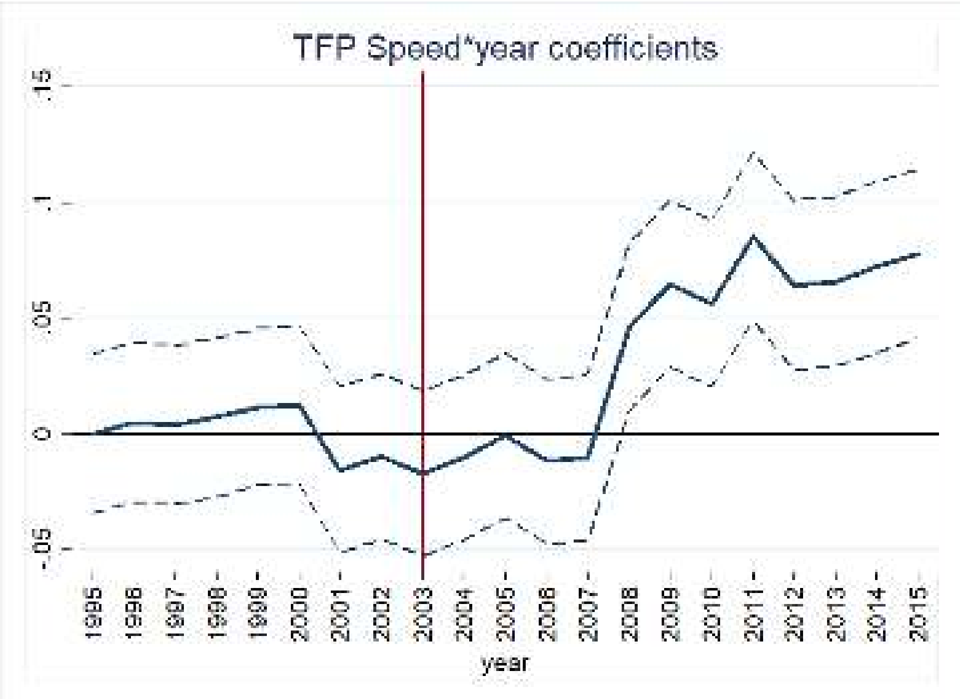


Figure 11: Total Factor Productivity: Impact of Broadband

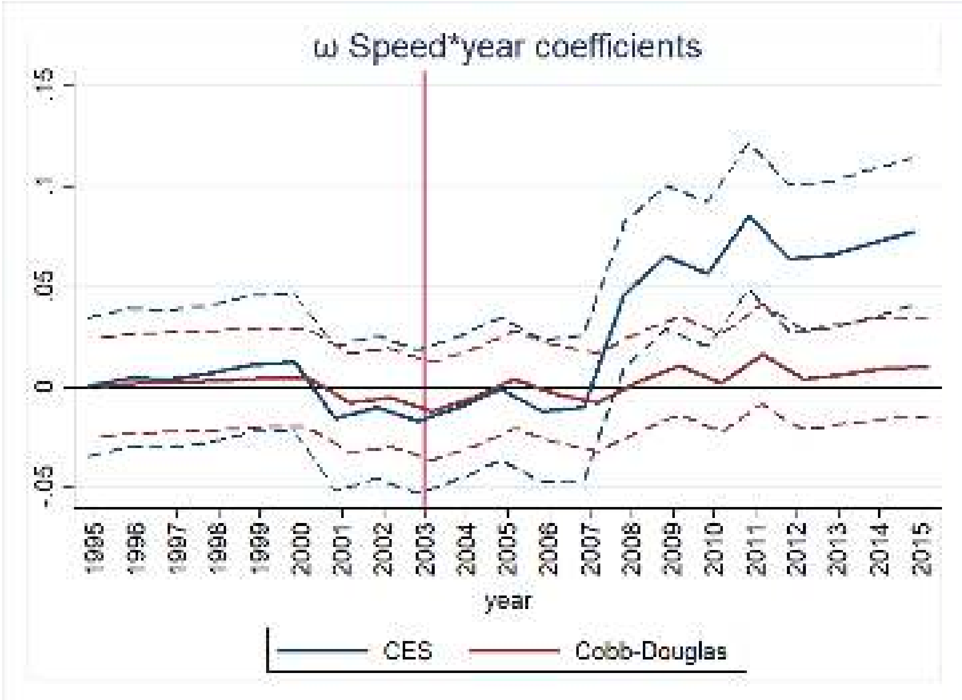


Figure 12: Total Factor Productivity: Nested CES vs. Cobb Douglas Model

Tables

Table 1: **Data Sources**

Source	**Description**	**Coverage**
Invind	BI annual survey of manufacturing and services	firms 20+, 1993-2015
Infocamere	Chamber of Commerce firms' anagragraphics	
Cerved	Balance-sheet data LL companies	Universe, 1993-2015
INPS	Administrative worker individual	Universe, 1993-2015
TIM1	Matched LTE-firm dataset with max speed	firms 20+, 1993-2015
TIM2	Dataset on exact location of LTEs in Italy	Universe, since 1945

Table 2: **Variable Definitions**

Variable	**Description**	**Source**
BB-speed	max BB speed available at address	TIM
BB-dist1	inverse of distance from facility to the closest LTE	TIM
L	number of employees	INPS
Qualifications	Occupational Groups	INPS
Wage	average compensation X number of paid days in 12 months	INPS
Hirings/Firing	number of workers hired/fired in year t	INPS
VA	balance-sheet VA	Cerved
K	balance-sheet material fixed assets	Cerved
Materials	balance-sheet intermediate goods	Cerved

Table 3: **Descriptive Statistics**

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
BB-speed (Mbps)	34,245	11.35	6.76	0.64	20
BB-dist (Km)	34,245	1.11	0.99	0.01	11.6
BB-dens (LEs in a 3Km radius)	34,245	2.68	2.2	0	10
Total employees	34,245	194.7	167.29	20	4,335
Blue collars (number)	34,245	57,93	92.8	0	2,378.6
Blue collars (share)	34,245	0.66	0.24	0	1
White collars (number)	34,245	32.8	153.7	0	1,097
White collars (share)	34,245	0.30	0.22	0	1
Managers (number)	34,245	1.21	2.68	0	65.75
Managers (share)	34,245	0.024	0.052	0	1
Wage (euros*1000)	34,245	78.68	27.27	17.06	1314.3
Wage blue collars (euros*1000)	34,245	68.05	18.98	0.334	1315.3
Wage white collars (euros*1000)	34,245	87.90	28.59	9.66	1308
Wage managers (euros*1000)	34,245	248.91	115.71	11.91	1719
Hirings	29,163	4.12	9.42	0.003	299
Firings	28,982	5.17	18.48	0.003	1725.3
Capital (euros*1000)	34,245	82,331	418257	25	9053672
Value Added (euros*1000)	34,245	46594	261139	-453461	7683976
Materials (euros*1000)	32,904	17589	83932	0	4056001

Source: TIM, Inps-Invind, Cerved, Infocamere 1993-2015

Table 4: **Sample Selection**

Selection criterion	**Invind**	**Restricted Sample**
Industry (%)		
Food, Text. and Wood	17.7	18.98
Chem. and Pharm.	8.74	10.78
Metals	7.76	8.20
Machinery, Equipment	17.29	20.81
Man. of transport equipment	7.02	6.94
Other Man., Gas & Water	12.66	12.49
Wholesale, Transport, and Acc.	13.96	12.70
Other Services	14.86	9.08
Class Size (FTE)		
20-49	38.2	48.2
50-99	22.2	25.8
100-199	16.5	15.1
200-499	13.3	8.1
500-999	5.2	2.0
1000+	4.6	0.8
Average Size (FTE)	194.7	84.3
Average Max Speed (Mbps, 2002)	8.7	8.4
Average distance from LTE (Km)	1.1	1.1

Table 5: **First Stage**

Variable	**Download Speed**
distance	-1.567***
	(0.053)
$dist^2$	0.204***
	(0.012)
Province fix. effect	yes
Industry fix. effect	yes
R-squared	0.187
F-statistics of instruments	52.7
Obs	2250

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$
Standards Errors in parentheses
Source: TIM, Infocamere 1993-2015

Table 6: **Firm Size and Broadband**

Dependent variable:Number of FTE[(a)]			
Max Speed*	OLS (1)	OLS,FE (2)	IV,FE (3)
1992	0.050***		
1993	0.050***	0.001	0.023
1994	0.047***	0.001	0.028
1995	0.046***	0.006	0.032
1996	0.047***	0.003	0.029
1997	0.047***	0.002	0.023
1998	0.048***	0.004	0.040
1999	0.050***	0.004	0.041
2000	0.045***	0.004	0.053
2001	0.040***	0.000	0.042
2002	0.038***	0.001	0.059
2003	0.037***	0.001	0.072
2004	0.039***	0.001	0.042
2005	0.038***	0.001	0.033
2006	0.035***	-0.001	0.013
2007	0.028***	-0.004	0.014
2008	0.023***	-0.007*	0.022
2009	0.022***	-0.007*	0.032
2010	0.020***	-0.007*	0.063
2011	0.030***	-0.001	0.069
2012	0.028***	-0.003	0.086*
2013	0.026***	-0.005	0.091*
2014	0.026***	-0.006	0.089*
2015	0.025***	-0.006*	0.093*
Control for LE-density	yes	yes	yes
Year fixed effect	yes	yes	yes
Sector fixed effect	yes		
Province fixed effect	yes		
Firm fixed effect		yes	yes

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$
Standards Errors in parentheses
Source: TIM, Inps-Invind, 1993-2015

Table 7: **Employment- Skill Shares and Broadband Speed**

Dependent variable: Employment Share$^{(a)}$ by Occupation			
Max Speed*	Blue Collars	White Collars	Managers
1993	0.000	-0.001	0.000
1994	-0.000	-0.001	-0.000
1995	-0.002	-0.001	-0.001
1996	-0.003	0.001	-0.000
1997	-0.005	0.003	-0.001
1998	-0.015	0.015	-0.001
1999	-0.025**	0.0265**	0.001
2000	-0.0265**	0.0285**	-0.000
2001	-0.0295***	0.03***	0.001
2002	-0.033***	0.032***	0.001
2003	-0.029***	0.029***	0.002
2004	-0.0285**	0.030***	0.002
2005	-0.030***	0.030***	0.002
2006	-0.029***	0.0295**	0.003
2007	-0.029***	0.0275**	0.003
2008	-0.038***	0.036***	0.003
2009	-0.037***	0.036***	0.004
2010	-0.035***	0.034***	0.004
2011	-0.033***	0.031***	0.004
2012	-0.031***	0.029***	0.004
2013	-0.027***	0.0265**	0.003
2014	-0.0255**	0.0255**	0.003
2015	-0.0255**	0.025**	0.003
Control for LE-density	yes	yes	yes
Year fixed effect	yes	yes	yes
Firm fixed effect	yes	yes	yes

$^{***}p < 0.01$ $^{**}p < 0.05$, $^{*}p < 0.1$
Standards Errors in parentheses
(a) difference between firms closer/farther than 2 Km from an LE
Source: TIM, Inps-Invind, 1993-2015

Table 8: **First Stage**

Variable	**Skill Premium Wage**
log min wage	-0.174*
	(0.008)
Year fixed effects	yes
Industry fixed effects	yes
F(1,6724)	209.39
Obs	51885

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$
Standards Errors in parentheses

Table 9: **Elasticity of substitution and relative Skill-Productivity**

Parameters estimates for equation 10[(a)]	
Max SpeedIV*	γ_{2t}
1993	0.015
1994	0.017
1995	0.015
1996	-0.002
1997	0.018
1998	0.011
1999	0.094***
2000	0.119***
2001	0.091***
2002	0.032**
2003	0.036**
2004	-0.002
2005	0.040**
2006	0.058***
2007	0.026*
2008	0.046***
2009	0.036**
2010	0.038**
2011	0.026*
2012	0.007
2013	-0.008
2014	-0.015
2015	0.000
$\sigma- > 2Km$	1.048**
$\sigma- < 2Km$	0.370**
Year fixed effect	yes
Firm fixed effect	yes
R^2	.9714202
Obs	49443

$^{***}p < 0.01$ $^{**}p < 0.05$, $^{*}p < 0.1$
Standards Errors in parentheses
(a)γ_{2t} and σ
Source: TIM, Inps-Invind, 1993-2015

Table 10: **Production function parameter estimates**

Max SpeedIV*	γ_{st}
1992	0.004
1993	0.033
1994	0.027
1995	0.019
1996	0.018
1997	0.019
1998	0.015
1999	0.018
2000	0.018
2001	0.012
2002	0.013
2003	0.008
2004	0.016
2005	0.027
2006	0.016
2007	0.006
2008	0.025
2009	0.054***
2010	0.043**
2011	0.054**
2012	0.047**
2013	0.056***
2014	0.058***
2015	0.060***
R^2	.94
Obs	43102
$\alpha_l - > 2Km$	0.48**
$\alpha_l - < 2Km$	0.50**
$\alpha_k - > 2Km$	0.16**
$\alpha_k - < 2Km$	0.18**

Source: TIM, Inps-Invind,Cerved 1993-2015

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