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Ultra-fast broadband and innovation intensity

A quantitative analysis on Italian firms

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Allo zio Mauro,
che, sempre in silenzio,
sta insegnando a tutti
che cosa sia la tenacia:
ti voglio un gran bene
e ti ammiro
tantissimo.

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Foreword and purpose of the project

This master thesis aims at investigating the causal relationship existing among the recent diffusion of ultra-fast broadband and the innovation behavior of Italian enterprises, as depicted by the evolution of their patent portfolios.

Latest breakthroughs in the ICT field have been positively acknowledged and soon embraced by both national and international regulators, whose policy interventions emphasize the empowering benefits of these technologies. In fact, both in the common sense and in economic literature, they are by now deemed to play a crucial role for modern entrepreneurship, both in terms of direct business advantages and indirect spillovers, which open new competitive opportunities. To this extent, a substantial improvement in ultra-fast broadband services is that associated to optical fibers applications: while establishing as a dominant design for connectivity infrastructures of today and tomorrow, this transmission mean came to the fore in the current debate around future directions for the digital revolution, engaging both scholars and industry experts in the comprehension, measurement and anticipation of its possible, multi-faceted impacts on firm performances.

Concurrently, a diffuse tendency to shift towards more innovation-oriented business models can be easily read underneath the figures of recent patenting procedures and patent-related transactions. Rationally designed to remunerate firm exploratory endeavors, while simultaneously pursuing a global optimum for society development, industrial patents increasingly represent strategical fixed points within a world where virtuous cycles of "technology spurring technology" keep accelerating the continuous displacement of the frontier of knowledge.

To start comparing these two macro trends, a finer discussion on the dual nature of this thesis builds up the bulk of Chapter 1, using real-world data to introduce the relevant background themes and proactively interact the keywords to be further deepened in the following sections.

Once the context has been framed with these technical and factual references, the dissertation steps into the empirical base of the core analysis: a unique set of balanced panel data, gathering yearly observations from 2013 to 2019, where firm economic information was matched with a municipality-based mapping of Italian fiber roll-out, following the birth and expansion of Telecom Italia's New Generation TLC Network. Hence, Chapter 2 is devoted to the discovery and quantitative understanding of the database content: some preparatory, descriptive deductions are presented, seamlessly linking together the progressive fiber wiring of Italian municipalities to the contemporary dynamics of firms' patent portfolios. The qualitative result is a conceptual walk among the operative ingredients for the subsequent estimation outcomes, always keeping ultra-fast broadband as the leitmotiv pushing forward the discussion.

Accordingly, statistical inference and econometric modelling of the relationship under study, enabled by the peculiar structure of the dataset, is finally deployed along Chapter 3. Here, argumentations from previous chapters about the expected space-time effects of fiber connectivity on patents are substantiated with systematic evidence from the available sample: this is preliminarily carried out by shaping regressions with an OLS setting, later refined and enhanced by an instrumental variable counterpart, dealing with likely endogeneity concerns.

1. Connectivity and innovation: the world state of knowledge at a glance

In order to enter the main themes of this study, a brief overview of connectivity technology and patenting aspects is performed along this chapter, thus delimiting the knowledge framework of the work and setting the stage for the analytical considerations that make up the following sections. To do so, two major axes are considered separately, developing the opening dissertation.

On one hand, a technological insight is given in terms of broadband versus ultra-fast broadband, considering technical features (with a specific focus on optical fibers) as well as diffusion facts, moving from worldwide subscription data to business usage of broadband connectivity solutions, with a top-down approach designed in view of the following firm-level considerations.

On the other hand, a dedicated section is devoted to patents, chosen as a proxy for innovation dynamics results within firms. Following some introductory elements around this macro-topic, specific room will be given to real-world data about patent applications and investments in R&D, so that the reader can get an idea about the orders of magnitude and recurring patterns to be taken into consideration when this theme will be subsequently dealt with.

For both parts, after a quick and general overview, the point of view is shifted on Italy (being the geographical core focus of this thesis), outlining an Italian big picture for both dimensions. Also, both sections are endowed with literature insights that complement the exhibited data and set an adequate reference for further related deepening on the matter, while connecting the dots from preceding sections and providing some useful keys of reflection towards the following chapters.

1.1. Technology: ultra-fast broadband as the main driver of the analysis

1.1.1. Definition of broadband and ultra-fast broadband: a techno-lexical issue

When referring to "*broadband*", the term normally identifies the simultaneous transmission and reception of higher volumes of data than exchanged with past technologies; this is achieved through a shared physical medium (i.e. wired or wireless transmission) exploiting a wider bandwidth than employed by previous-generation, telephone-based TLC systems, therefore named "narrowband". This allows to browse the Internet, listen to the radio, watch IPTV cable TV programs and make phone calls in a faster, more reliable, efficient and functional manner than before. Indeed, a more and more performing connection speed is necessary for the deployment of innovative services to consumers and businesses, such as telemedicine, media streaming and videoconferencing, remote working and cloud-based intranet applications, among the others, thus supporting people and enterprises towards empowerment and continuative connectivity, both in healthcare, entertainment and organizational activities.

The term *broadband* (often shortened as BB, for the sake of brevity, in the following) is commonly used to group together a vast collection of technologies designed to achieve the previously stated technical targets. Nonetheless, a static and universally accepted definition of *BB* is still lacking, both at Italian, European and worldwide level.

The major attempt for harmonization was pursued by the ITU-T (International TLC Union – TLC Standardization Bureau), responsible for international standards coordination in the TLC and ICT sectors. Two "indirect" definitions of how broadband should be conceived were initially proposed:

- *BB ISDN*: An ISDN that provides transmission channels capable of supporting rates greater than 2 Mbits/s.[1]
- *BB Access*: An access able to contain at least one channel capable of supporting a rate greater than the ISDN primary rate [i.e. 1,5 Mbits/s in the USA and 2 Mbits/s in Europe], or supporting an equivalent information transfer rate.[2]

The first definition moves a step towards the identification of a quantitative threshold to anchor and objectify the use of the term. This substantively aims at an agreement in the technical world in order to share a more aware comprehension of the topic even with the non-technical community, thus mitigating the inaccuracy and misunderstanding which often accompanies technological progress. On the other hand, the second definition strives for a wider approach to the issue, dealing with the problem in more general terms; in any case, both refer to an enhanced rate of information flows with respect to that granted by past technological solutions. By combining these two proposals, BB access was later defined as anyone "in which the connection(s) capabilities support data rates greater than 2 Mbps"[3], thus balancing the definition on network service capacity: this is the main BB definition leveraged along this thesis work. This statement was afterwards reviewed by other ITU-T Study Groups, which stressed some open issues about this approach: in particular, the fact that the chosen threshold was still a "relatively low data rate relative to the speeds which can be provided with current various technologies"[4]. On one hand, as the proposed definition referred to a minimum value, the proposal was deemed to be a good trade-off[5], eligible as a first-level guideline for technical applications; on the other hand, further objections were claimed, contrasting the previous definition with an alternative, looser one for BB access: "access in which the connection(s) capabilities support data rates *significantly greater* than the narrowband rate access"[6].

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[1] ITU-T Recommendation Q.2931 (1995).
[2] ITU-T Recommendation I.113 (1997).
[3] ITU-T Liaison Statement SCV-LS13 (2017).
[4] ITU-T Liaison Statement SCV-TD66 (2017).
[5] ITU-T Liaison Statement SCV-TD87 (2018).
[6] ITU-T Liaison Statement SCV-TD97 (2019).

However, a misuse of the term *broadband* in the definitions above was reported by some expert study groups, seeming to be more precisely linked to network access bit-rate rather to the bandwidth associated. The advice in this case was to properly shift the focus on access capacity and latency (for which proper metric were developed) and define the stakeholders requirements on this new basis, so as to avoid mentioning "a numerical limit that will require frequent updates", while explicitly considering countries, regulatory and technological differences[7]. After these adverse feedbacks, the ITU-T Standardization Committee for Vocabulary (SCV) conservatively established that "a general definition (...) applicable to the terms *broadband*, *broadband access* and *variants* (...) that would suit the context of work of all the parties involved cannot be given for the time being"[8]; yet, not ruling out the possibility for future definitions within specific contexts of application. Confirming the pattern of normative lack, still nowadays no conciliations have been reached on the defining issue[9].

In terms of applications, the poor results of this harmonization process were (and are) often overrode in practice, with connections somewhat faster than 256 Kbps (but slower than those recommended by the ITU-T) being already sold as "*broadband*" ones. With the passing of time, as foreseen (and warned) by the previous ITU-T statements, "*broadband*" started to informally stand as a synonymous for "high speed", usually for marketing purposes; this led to each subsequent connectivity offer being advertised by the major ISPs as "broad(*er*)band" with respect to the previous generation one, in order to emphasize its innovative nature as opposed to the past. In spite of this bias in the meaning and use of the term, all the main Internet connection offers currently sold as "*broadband*" services at least overcome 1 Mbps.

From a more institutional point of view, the European Commission, in an attempt to restate the need for a common standard, normally uses the term to address Internet connections faster than those granted by an analogic dial-up modem. This is actually the way the label "*broadband*" was originally attributed as a synonym of (A)DSL lines, in order to distinguish it from 56 and 128 kbps analog modems and ISDN lines, state of the technique up to the 1990s. This "historical" use of the term sometimes improperly survives, when the user focuses on the fact that data and voice calls, even though on different channels (i.e. frequency bands), are routed through the same twisted pair, therefore meeting the "shared medium"-condition of the previous definition.

In conclusion, the story of the term suggests to preferably give it a relative meaning. It therefore implies a differentiation between *new versus legacy* TLC systems, therefore discerning t-th from

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[7] ITU-T Liaison Statement SCV-TD102 (2019).
[8] ITU-T Deliberation SCV-LS24 (2018).
[9] ITU-T Liaison Statement SCV-TD112 (2020).

(t+n)-th generation of transmission networks.

Alongside the systematic definition attempts described above, a series of conventional standards *de facto* started to spread and be implemented, both in technical communications and in ordinary language, ranging from 144 kbps to 1,544 Mbps through time and different applications. Being implied by practical purposes, they all start from considering bandwidth (i.e. the quantity of data that can cross a communication line in a certain fraction of time) as the physical driver of reference, directly linked in operation to the transmission protocol for the chosen medium.

Broadband was declared universal service (thereby meaning a minimum bandwidth and an average connection throughput must be supplied by law to every user) for the first time in Finland in 2005, followed by Spain and Switzerland, whereas Japan ranks first as for territorial coverage and average speed of connection, thanks to the highest dedicated public intervention in the world.

Iterating a never-ending lexical problem, the need for a new reference word arose with the paradigm shift from copper cable to optical fibers solutions: here is where "*ultra-broadband*" (UBB[10]) and then "*ultra-fast broadband"* (UFBb) labels were coined. According to different, loose definitions, ultra-fast broadband offers a minimum transmission speed of 30 Mbps and a maximum ranging from 300 Mbps to 1 (potentially, 40) Gbps to the final users, always according to the spectral efficiency of the main network devices: a performance level that only optical fibers, at the present state of the art, can accomplish, which fosters the deployment of Next Generation (Access) Networks (NG(A)N). These networks make up a crucial infrastructural challenge for internet providers, which claim a compensation to extend the fiber coverage to rural, low density or anyhow economically unsuitable areas. With little foresight (and ignoring copper inefficiency), they often argue that such investments are not justified by the current (and likely mid-term) market for web services (with household bandwidth peaks at around 30÷50 Mbps, still deliverable via cable VDSL[11]), while others argue that these investments are anyway worth the effort, in view of potential long term leverage effects on firms (the most innovative ones needing up to 100 Mbps and more) and hence on the economy as a whole. All in all, even though not the most efficient strategy of all, the most reasonable (and concretely pursued) one is that of carrying step-by-step optical fibers ends closer and closer to connectivity customers (be they both consumers and enterprises), with point-to-point periodic reassessments for further modernization chances according to new information on demand becoming available, as well as new market trends and associated local opportunities on the

[10] This label encompasses connectivity solutions providing intermediate performances at around 30 Mbps, with particular reference to FTTC architectures (30÷100 Mbps, see the following subsection 1.1.2), seen as the first target in the Italian process of fiber optics implementation. Although a theoretical distinction exists, the acronyms UBB and UFB(b) are sometimes used as interchangeable in applications at the current state of the technique, so that an explicit reference to Mbps levels involved is usually advisable.

[11] See the next subsection for further details.

supply side: a proof of this strategical behavior being actually implemented can be spotted in subsection 2.2's results.

In particular, the term *ultra-fast broadband* is by now normally referred to fiber optics (as the incoming fastest technology born to replace the past ones) connections, even though alternative acceptations can be considered: for instance, this is the case of "*broadband*" being used to distinguish among subsequent generations of mobile internet systems, capable of reaching remote rural areas and easily avoiding network saturation due to heavier and heavier internet transactions and to the exponential growth in urban areas users. However, it has to be pointed out that the use of the same label could be misleading, since the number and widths of frequencies granted by fiber optics and wireless radio mobile systems significantly differ from one another (with the former outperforming the latter); throughout this thesis, the focus will be kept on fixed fiber optics connectivity.

1.1.2. Technical focus on fiber optics

For the previously introduced reasons, optical fibers infrastructures represent a primary strategical focus for all the main national private and public programs of development activities in the ICT field, aiming at UFBb diffusion among households and firms. The quest for higher bandwidth availability is an empowering condition for the technological progress to spread and trigger positive spillovers throughout the economy, in time and space.

Chronologically speaking, fiber optics timeline is seen as starting with Daniel Colladon, Jacques Babinet and John Tyndall studies on the main physical principle underneath their functioning (i.e., total internal reflection) in 1840 and 1852, which were followed by the first application conceptually associated to fiber optics: the photophone, a pioneering idea by Alexander Graham Bell, implemented in 1880 and technically underlying the development of modern wireless technologies. Almost fifty years later, in 1927, the first fiber-associated patent was that obtained by Baird and Hansell, whose attempts to transmit television images via fiber optics, though, were never commercially exploited. Then, passing through the early systematic experiments in the '30s (with the first fiber optics endoscopy equipment appearing in the '50s for biomedical applications) and the '60s (with the groundbreaking research of Nobel awarded Charles Kao team[12]) and coming down to the early '90s, when the introduction of photonic crystals[13] empowered further improvements in energy transportation performances, the rising attention of the scientific world provided optical fibers with an increasing span of application, spurred by the engineering effort to master their features.

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[12] For further information, see K. C., Kao, G. A. Hockham, *Dielectric-fiber surface waveguides for optical frequencies* (1996).

[13] They allowed to technically treat photons like electrons in electrical circuits, simplifying the design constraints.

Optical fibers made up a breakthrough in TLC applications as they collect and embody the steps forward made in information theory since Claude Shannon's first formulation in 1948: the progressive, Internet-driven conceptual change in the entropy of information sources was practically dealt with by overcoming coaxial cables and enabling the photonic transmission of information.
Before the deployment of UFBb, the state of the technique mainly relied on solutions pertaining to the xDSL (Digital Subscriber Line) family, with the asymmetric ADSL assuming a dominant role among the others. From the early 2000s, ADSL and its subsequent versions have delivered internet connection via traditional copper cables, linking together transmission stations (i.e., commutation exchanges) and endpoint routers. This technical solution was the bridge towards the first properly-named BB connections: exploiting preexisting telephonic lines departing from serving cabinets, ADSL allows the coexistence of two very different data streams (human voice and digital communication) with (theoretical) limited investments in new infrastructures, with an electronic filter choosing usable sub-channels from the user side and a modem empowering twisted pairs towards remarkably fast web surfing opportunities for its age. However, speaking about performances, dissipation and speed reduction, due to the metallic substrate, are main concerns for ADSL architectures, and long-range connections frequently require electrical amplification for a correct reception. Moreover, material limitations set bounds to the reachable speeds in download (640 Kbps÷25 Mbps) and in upload (128 Kbps÷2 Mbps), with this asymmetry naming the technology: such a design is explained by the observation higher data collection occurring outwards from the network rather than in the opposite direction, therefore better adapting ADSL to residential than enterprise usage. Finally, ADSL efficiency is strictly depending on external and network loading conditions, setting further limitations to its functioning instead of outlining development margins. A further improvement of ADSL was VDSL (Very high-speed Digital Subscriber Line), representing the best performing xDSL solution developed so far, normally delivering up to 55 Mbps in download and 3 Mbps in upload and reaching a bidirectional threshold of 300÷400 Mbps with the VDSL2-Vplus standard in 2015, thus overcoming both ADSL asymmetry and SDSL incompatibility with voice-data coexistence; however, VDSL still suffers from linear dissipation along metallic cables, restating the problem of the efficient substitution of copper cables. This is the best available copper technology to interoperate with fiber optics in FTTC/FTTDP-mode[14], supplying an overall bandwidth of up to 400 Mbps (Enhanced VDSL or EVDSL).
Considering these technological bounds, together with growing network loads and performances expectations, both from domestic and (especially) from enterprise users, a consistent shift towards more suitable technologies has started in the last years, leading to optical fibers relentless diffusion.

[14] See in the following for the description of optical fibers architectures.

Coming to technical features, an optical field propagating through a non-conducting dielectric owes its desirable performances to the high frequencies covered by the visible light spectrum[15], which makes it naturally suited for high-rate applications. Light pulses, supplanting electric current as information carrier, run through a low dimensional tolerance waveguide (i.e., the optical fiber), whose physical structure is divided into several concentric layers of flexible cylindrical glass, melted quartz or plastic composites, whose chemical pureness and transparency decreases outwards. This structure is functionally classified as follows:

- the inner *core* (Ø = 8÷50 µm, with high shares of silicon and critical dimensional tolerance, in the order of 1 µm/1 km), which builds up the axial bulk of the fiber, defining its main linear dimension where the refractive index reaches its peak zone;
- the intermediate *cladding* (Ø ~ 125 µm), which performs the containment task (i.e., shielding the signal from external dissipation) and strategically interacts with the core for signal routing purposes;
- the gap-filling *buffer* (Ø ~ 200 µm), sticking together the internal parts and raising the overall robustness of the system, though not contributing to transmission tasks;
- the external opaque *jacket* or *coating* (Ø ~ 400 µm), made with plastic or rubber, acting as forces mediator and protective insulator against adverse environmental conditions (moisture, temperature), and therefore finally allowing breakage-safe usage of optical fibers.

This featuring structure is the key to understand the working principle of optical fibers. First, information is codified into a beam of monochromatic, power-concentrated light by impressing the modulating signal into suitable carrying optical signals via a LED or laser transmitter, which usually operates in the infrared region (due to better scattering and abatement behavior against insertion losses at the input coupling). These are then made bounce along the fibers thanks to the structural system of tubular mirrors, made up by overlapping thin layers of glass doped with semiconductor impurities alleged (B_2O_3, GeO_2) encompassing rays' forced path. By varying the core thickness and composition, the resulting radial profile of the refractive index can be either discontinuous (stepped-index), smoothly tapering (graded-index) or impulsive (single mode fiber, or SMF): these engineered designs, according to the planned layout specifications of lines in operation, help guide signals by refocusing slanted waves and aligning travel times along fiber sections, thanks to a variant number of predetermined allowed trajectories (known as propagation modes). In order to deal with the complex pattern of output reflection angles, causing signal spreading and smearing, as well as inter-symbol interference and effective bandwidth reduction, SMF is specifically used for data

[15] Namely, from far infrared region (10^4 GHz) to the one of near ultraviolet (10^9 GHz).

transportation on longer distances, since they avert dispersion among different modes and thus allow a cleaner flow of information through longer paths to be covered; nevertheless, as a drawback, it is particularly with SMF that accuracy in layers' thickness is a key construction factor.
This fine-tunable mechanism assures total internal reflection (so that no digitalized information is lost, absorbed or scattered in the cladding on the way) and allows the synchronization of components with different frequency, as well as coherence conservation for those with identical frequency: the more slanted with respect to the core, the faster these signals are moving, so that the message can be recomposed by a final receiver, made with a semiconductor diode, at destination, where the incident wavelengths are bound to merge and interfere with each other. Signal confinement is what allows information management towards optical multiplexing, the mechanism with which several ingoing channels share the outgoing capacity by exploiting the degrees of freedom of the transmission mechanism itself (i.e., wavelength, frequency, coding design, time slots allocation). Particularly, the commercial introduction of Wavelength-Division Multiple Access (WDMA) in 1996 by Ciena Corp. is seen as the real start of optical networking: thereafter, this multiplexing scheme has become the common basis for nearly every high-capacity optical system in the world.
Bearing in mind that the transmission bit-rate is proportional to the channel band and decays with increasing distance (due to the dampening of signal-to-noise ratio), all the main properties of optical fibers, making this technological solution so appealing for advanced ICT applications, directly spring from the specific design described above:

- Wider amplitude of exploitable *bandwidth*: this allows higher speed of transmission and a re-balance between download and upload speed, resulting in lower client-server lag and finding a solution to the last mile crosstalk problem, encountered with twisted pair architectures, inherently subject to internal interference.
- *Compactness* and data *density* (volumetric entropy): 30.000 kg of copper are needed to equal the transmission performances of 1 kg of optical fiber, thanks to its reduced encumbrance and weight.
- *Quality* of the transmission channel: even on long distances, the information is safe from deteriorating noise, being substantially not subject to distortion (pulses deformation is reduced to the order of ns/km), leakage or signal softening, kept in the order of 0,1 dB/km, up to one thousand times lower than that associated with copper cables.
- *Stability* of connection: high performance Internet based activities are made possible and more efficient, with immunity to electromagnetic disturbances and the chance for all-optical amplification, thanks to erbium-doped regenerative repeaters on the longest distances.
- *Safety* and *reliability* and under any environmental conditions: fibers are wear and fire-

proof, and capable of saving the signal intensity (and, therefore, content) along space.

- *Eco-sustainability*: no special minerals must be specifically mined to create the fibers, and, since the whole network is passive, fiber cables can lie with electrical and telephone ones, sharing excavation works and minimizing infrastructure duplication.
- Relative *simplicity* in terms of raw components attainability, conceptual functioning and design constraints, with respect to the state of the art for the underlying production technologies.

These are all reasons why optical communication is becoming the medium of choice for fixed, high-speed digital TLC links (intended focus of this thesis work), both on short (e.g. feeder and trunk portions of telephone loops) and long (e.g. LANs for home distribution of data services) distances.
Usually, a sheath of 5 to 7 of the single-strand fibers described above is eventually enclosed within a cable (reinforced by a central supportive member) for parallel transmission, so that all the previous properties can be further enhanced.
Thanks to these characteristics, optical fiber is seen as a future-proof technology, i.e., it is not expected to go out-of-date with technological progress in the medium-long term, being able to face (indeed, to encourage) the forecast growing bandwidth requirements for many years in the future, without suffering saturation. All these considerations logically descend from fiber optics (and (UF)BB in general) being regarded by many as a General Purpose Technology (GPT), i.e. a piece of innovation whose enabling effects spread as a domino effect throughout the economy, thus inducing generalized dynamism and fostering incremental innovations in turn, with complicated patterns of influence on industries and countries through time, as occurred, before in history, with steam engine or semiconductors for electronic applications. The debate on ICT's GPT nature is deemed to start with Bresnahan and Trajtenberg (1995); then, a comprehensive overview on and critical contribution to this theme can be found in Cardona et al. (2013).
Specifically, fiber optics reliability is probably the most remarkable property in view of Infrastructural substitution. This is particularly true if considering that the Italian twisted pair legacy network, on which copper cable TLC relies, was originally rolled out to extend the telephone coverage and was completed around the end of the 1960s. Apart from being 50/55 years old at best, the technology underneath the twisted pair entails high maintenance costs to prevent service disruptions, both with in-ground and aboveground laying. Conversely, fiber optics are more resilient to physical failures and entail lower technical costs of maintenance, with huge installation costs that still persist as the main implementation drawback, even though technological progress, demand rise and market competition have gradually lowered the existing gaps among ADSL and fiber fares, especially after network externalities were enabled by the overcoming of a sufficient critical mass of adoption,

encouraged by systematic infrastructural interventions (see subsection 1.1.5).

During transition between legacy and new generation broadband solutions, copper wires and fiber cables are being arranged to coexist and interoperate, delivering increasing quality of connection towards and ideal full-fiber setup. Still, these intermediate solutions suffer from a self-limit to their own effectiveness, displacing the problem to gradually solve it, since the critical bottleneck of the system now lies within the interconnection between fiber cables and the twisted pair cabling, input/output end of copper lines, the weakest ring of the chain. Nonetheless, the relatively simple concept underlying optical fibers allows for several modular architectures which can address this issue even since the implementation phase. These hybrid layouts are listed under the acronym FTTx and classified by the length of the last network segment (still bridged with metallic wires) between the end of fiber lines and the final user. The main layout labels can be summarized as follows:

- *FTTN*: Fiber-to-the-Node, when fiber lines end up at the backbone exchange hubs and central units, often corresponding to legacy telephone substations, which can be located even several kilometers away from the working optical fibers Points of Presence (PoP), cut-off boundaries of ISPs' LANs, thus providing only slightly better connectivity than ADSL.
- *FTTC(ab)(S)*: Fiber-to-the-Cabinet/Curb (Street), with optical fibers reaching local endpoints set in cabinets within the neighborhoods, which are in turn linked to up to 200 surrounding premises within an average radius of 250÷350m; this hybrid set-up (also known as "super-fast FTTC", for time comparison reasons) is the most common architecture at the present state of network development, with only the so-called "last mile" still relying on copper wiring, allowing 100÷200 Mbps of download speed.
- *FTTDP*: Fiber-to-the-Distribution-Point, where fiber optics connect to the last possible junction box (i.e., the "distribution point", when present) with a cascaded split scheme, and only 30÷200m-long drops to the user premises are made with copper lines, enabling ADSL performance advancements (e.g. VDSL). This solution is sometimes labelled as "deep fiber" and allows near-gigabit speeds, comparable to those reachable with full-fiber frameworks.
- *FTTB(P)*: Fiber-to-the-Building (Premises), when fiber cables directly serve a block of flats or small shops through a shared connection panel in the basement, empowering single users by means of Ethernet technology running on vertical lines.
- *FTTH*: Fiber-to-the-Home, a full-fiber solution in which the fiber cabling covers all the way along the network to the final user.

Whereas the last two definitions have been standardized among Europe, North America and Asia, no formal definition has been agreed yet around FTTN-like and FTTC-like architectures. The roll-out of fiber-based UFBb is commonly performed in waves, progressively extending the length of fiber lines, and thus replacing the copper ones, but proceeding in breadth (for the sake of territorial coverage of UFBb) before going deeper towards FTTH point-to-point solutions (a quantitative evidence of this is found in subsection 2.2). Nowadays, it is estimated that a rough 80% share of Internet information, TV images and phone calls travel through fiber optics infrastructures.

1.1.3. Fixed broadband subscriptions: worldwide data and associated Italian positioning

As diffusely hinted at before, an increasing supply of BB (and, afterwards, UFBb) connectivity was strongly fostered by a consistent demand rise for digital applications, requiring faster and smoother connection performances. To this purpose, Lin and Wu (2013) have studied the dynamics of broadband diffusion in 34 OECD countries from 1997 to 2009, specializing the famous Abernathy-Utterback framework[16] in terms of connectivity services. They found that key determinants of broadband adoption (addressing both consumer and business targets) are:

- income conditions, education level of users and quality of the Internet content (proxied by the number of Internet hosts per 100 inhabitants) in the innovator and early adopter stage of BB, which clearly take cultural and affordability factors to subscription into account;
- platform competition and previous broadband penetration in the early majority stage, when diffusion saturates and operators compete for a quasi-stationary user base;
- broadband price in the late majority and laggard stage, as novelty vanishes, supply competition grows more intense and the service undertakes a slow commoditization process, being progressively taken for granted and considered “normal” by common users, which all end up in a decreasing surplus extraction by suppliers.

Such robust outcomes can provide some useful, conceptual guidelines while discussing the further evidence specifically developed for this work, as described in the following paragraphs.

Clear evidences of the previously-cited chase mechanism in BB market adaptation can be found in real-life data, as allowed by reported figures. Starting from Figure 1.1, the world and European-level evolution of fixed BB subscriptions per capita is depicted by taking two snapshots at the beginning (2013) and closing (2019) of the panel time window considered in this thesis (for grey-filled nations, no data was available for one or both years). The high level of aggregation of these data, along with the broadband inclusive definition they imply[17], allows data about several technologies[18]

[16] See W. J. Abernathy, J. M. Utterback, *Patterns of industrial innovation* (1978), for the original publication.

[17] This data, derived from World Bank extensive databases, refers to *broadband* as “high-speed access to the public internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbps”, including “both residential and organizations’ subscriptions”.

[18] Cable modem, DSL, FTTB/H, other wired-broadband connections, satellite broadband and terrestrial fixed wireless broadband, fixed WiMAX and any other fixed wireless technologies.

to be kept together while starting to explore general patterns, and moreover considering quantitative evidence after demand-supply market matching, since actual subscriptions require a background infrastructure to maintain the offered service. Once population differences are accounted for, as easily forecastable both geographical settings show heterogeneous diffusions of connectivity usage, substantially unchanged in the considered time frame in terms of (chromatic) relative proportions, with developed economies being responsible for pushing higher the scale maximum (from 0,458 to 0,525 subscriptions per person, both attributable to European countries, with a 15% increase[19]). Within the polarized scenario described in the previous paragraph, Italy globally and continentally ranks in intermediate positions according to three out of the four metrics considered in Figure 1.2 a-b, while performing quite well in terms of total subscriptions (11th÷12th and 5th, respectively), fairly reflected by Internet penetration rankings for the country[20]. One-year deltas of subscriptions depict a poorer Italian performance with respect to parallel ones from other countries up to the minimum reached in 2017, when a monotonic turnaround occurs. This evident shift at both geographical levels, once physiological lags between implementation and adoption are taken into account, may suggest some sort of indirect correlation with the actual milestones of the UFBb Italian rollout agenda (i.e., 2015 and 2017, as further treated in the following subsection 1.6 and diffusely in Chapter 2). Finally, the pattern of Italian subscriptions per capita clearly reflects the interaction between the quasi-stationary behavior of total subscriptions and the slowly decreasing demographic trend suffered by the country in recent years.

Changing perspective on the same data, Figure 1.6 shows the absolute and relative trends of total fixed BB subscriptions for the entire world (6a), the (changing) group of OECD countries (6b), the one of European union countries (6c) and finally Italy (6d), with a specific focus on panel years, reproduced on the right side of each chart. Unlike the previous plot in Figure 1.1, this one shows a longer time series, allowing to reveal the consistent rise in subscriptions which took place at the beginning of the millennium for all geographical groups here considered, so that the quest for higher connectivity occurred in recent years, as frequently mentioned in the previous sections, eventually assumes a quantitative shape with this chart. Analogously, all charts exhibit similar trends for both metrics, with qualitatively similar shapes even for the cut out details reported aside, where the maxima of one-year growths of total subscriptions are always reached between 2015 and 2017, with mainly monotonic tails in previous and following years: this chart contextualizes the Italian situation (discussed so far and hereafter) within a wider framework, suggesting it was not a

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[19] About 30 trillion euros were invested by UE countries as public funds between 2014 and 2019 in order to fill the BB infrastructure gaps and comply with DAE 2020 prescriptions (see the following subsection 1.1.5).

[20] Ferruccio de Bortoli, *Le paure che frenano la* crescita, newspaper article from Corriere della sera, p.1, (30/05/2016), relying on Akamai data.

one-off case and allowing for investigations' extension for other geographical focuses.
An analogous pattern to that drawn from Figure 1.1 can be detected by plotting fixed versus mobile BB subscriptions, being mobile-cellular networks excluded from the previous plots. This was performed in Figure 1.4, which also reveals a slight delay of Italy with respect to the aggregate value for OECD countries, even if in presence of a coherent "geometrical" evolution.
Making a step forward, a finer detail of different technologies, previously grouped under the BB label, is provided in Figure 1.5. Here, gradual substitution of DSL by other, better-performing technologies is highlighted by comparing Italy with OECD countries as a whole. While mitigated by combining data from OECD members, this shift is particularly accentuated along panel years when Italy is examined on its own, with DSL going from 21,8 to 11,9 (-45%) and fiber optics from 0,5 to 2,1 (+320%) subscriptions per 100 inhabitants. Although different countries are likely to pursue different rollout policies, so that deducible substitution rates are to be taken with a grain of salt, this "partial derivative" effect of fiber optics constitutes a first, significant example of Italian technological market evolution with respect to the main connectivity driver considered in this thesis.
Finally, after getting some useful insights from adoption-level data, a brief reflection at a fiber deployment-level is due, coming back to the degree detail on which subsequent descriptive and econometric analyses have been performed. Figure 1.3 was designed to this purpose: to the left, the time evolution of UFBb (FTTx and FTTH in particular) municipality availability is plotted through panel years, meanwhile a detail of different connection speeds (and associated commercial Internet offers) is reported to the right. This geographical vertical section of Italian fiber roll-out relies on the huge data set enabling this thesis work, taken as the best available proxy for the country as a whole, as better described in the dedicated subsection 2.1; also, equivalent charts have been drawn in Figure 2.6 a-b for the panel which was concretely used for the statistical analysis, to show coherence with the original dataset, as better commented later on. From this Figure 1.3, some interesting indications can be obtained that will recur in the following:

- first, 2015 and 2017 make up the two milestone years for implementation beginning of FTTx and FTTH, respectively;
- second, the coverages at lower bandwidths (deliverable even with xDSL technologies) were already serving (or would do so by the end of the time period) a substantial share of Italian municipalities at the beginning of the observation period in 2013;
- third, as expectable by a step-wise diffusion plan, this plot shows the more performing the connection, the more delayed its diffusion has been; last, UBB stands as a separating line between (recalling 1.1) narrow and broad band connections, considering how as these two categories can be conceived with respect to the current state of the art in the TLC field.

1.1.4. Business use of broadband and the impact of firms' ICT investments

Once demand-supply growth and concentration have been ascertained, a further step into BB utilization can be made by considering firm-specific shares of broadband subscriptions and related subscription rates through space and time, in order to gradually redirect the discussion from introductory aggregate data towards the actual statistical point of view assumed all along the thesis.
To this purpose, Figures 1.7 and 1.8 (drawn from OECD online public database) show OECD and European countries use of BB in the enterprise market segment, with delayed splines due to subsequent entries or missing data collection at the source. As emphasized by the red arrow in Figure 1.7, a clear increasing overall trend arises, with most time series clustering their paths between 2005 and 2010 and jointly heading towards a dense landing area in 2009-2010 (dashed in red for both Figure 1.7 and 1.8), which could suggest a possible competitive "mathematical attractor" for globalized organizations or simply lead to conclude that more and more economies had bridged the gap and reached substantial saturation of this metric by the end of this time window, therefore flocking in a narrow strip between 70-75% and complete diffusion of BB among national companies. Unraveling the tangle of lines, the equivalent bar chart in Figure 1.9 shows the detail of the nineteen EU countries exhibiting the highest rates of BB business usage, with Italy ranking fifteenth and the first 15-18 countries all settling in a narrow range between 78-84 and 95%.
The understanding of broadband importance for businesses - as a distinguishing element at first, and as a minimum precondition in later markets - has proved to be one of the most relevant modern drivers for firm outcomes: broadband encourages data sharing among companies, making efficiency in trade transactions along their interconnected supply chains; on the other hand, neglecting opportunities of access to broadband networks can be harmful since it slows down firms' core activities, which therefore encounter interoperation hardships with the dominant design in the modern way of making business. When tackling these implications for business use of (UF)BB, academic research hugely focused on different productivity metrics, trying to fill in the gaps in our comprehension of the economic world in the presence of the phantom of Solow's productivity paradox. Considering research achievements with geographical connection to this thesis, Canzian et al. (2019) and Cambini et al. (2021) both assessed the evolution of firms' total factor productivity (TFP) along with the Italian roll-out of BB and UFBb connectivity, respectively, and both showed that a positive relationship emerges when linking together the BB technological variable with the economic one. These two studies also share a specific attention for employment topics, with the first publication finding no significant shifts in personnel costs or hiring rates attributable to different BB speeds, whereas the second one detects proofs of indirect effects of boosted productivity at the workforce level. This leitmotiv is pervasive in broadband worldwide literature; for instance, Bartel et al. (2007) obtained empirical evidence of how ICT (as spurred by faster connectivity) contributes

to the reduction of manufacturing times, with these shifts in business operation modalities affecting in turn the looped, causal chain of skill requirements, labor demand structure and organizational practices. This impact on HR was restated Tambe and Hitt (2011), which, sharing the same US focus, joined the discussion while commenting on the slow concretization of IT long-run differential returns for larger firms, concluding an incremental pursuit of ICT enhancement is mandatory for successful materialization of its benefits.

The abovementioned GPT nature of BB allows for various tunings of the analysis, alternatively coping with firm size (e.g. Colombo et al., 2013), rural versus urban firm location and high versus low knowledge intensity (Grimes et al., 2012) and industry dependency (Tambe and Hitt, 2011), just to cite a relevant few of the possible problem specifications developed on the nexus between connectivity and enterprise performances, which collectively show a comprehensive (even though not always unanimous) evidence on the widespread influence broadband proves to have on modern societies and efficiently evolving value-chains, also considering externalities springing beyond the mere economic income. A clear overview collecting the main thought-provoking works on BB investments and their econometric outcomes can be found in Abrardi and Cambini (2019).

Bringing awareness of these outcomes into the discussion, the previous charts 7-9 confirm that, whatever the underlying econom(etr)ic reasons, the collective intelligence of developed markets had already culturally and factually agreed on broadband differential effects even before the panel observation years of this research work.

Getting deeper into the matter and further in time, data from the Italian Institute for Statistical Studies (ISTAT) confirm the previously detected saturation at a regional level throughout the country. As pointed out by the red dashed intervals in Figure 1.10, the percentages of firms making use of computers in their business (1.10 a), that of firms with Internet access (1.10 b) and that of firms with fixed or mobile BB connection (1.10 c, link with the previously discussed figures) already stood at steady, high levels the year before those included in panel data, and so for basically all main Italian macro-areas; also, these levels were mainly maintained, when not enhanced (such as in Figure 1.10 a and 1.10 b), for the whole following period of observation. Besides that, variability seems to increase in 2018, when a few regions exhibit some values lower than the corresponding from the preceding years. However, it is likely to be an anomaly in short term data recording: the shift appears in all three charts for the same single year, it involves the same small group of regions (mainly Liguria, Marche and Molise) and, meanwhile such a structural change would be expected to gain momentum (and possibly disappear) in the space of some years, it only lasts one time-bucket, with 2019 values coming back to the red strip drawn for the first part of the time series. These three charts take stock of the incoming Italian situation for the period under analysis, outlining the picture of a country where business models relying on connectivity had already become established.

All the previous considerations can be conveniently read in parallel with ancillary data about ICT firms' investments, in order to roughly assess the equipment pool of those devices which directly operate with (and create value thanks to) the faster internet connections granted by UFBb. In this regard, Figures 1.11, 1.12 and 1.13 give combined, international information on macro ICT trends, even though on different time periods, so that cross-deductions should be performed with caution. In the first one, Italy exhibits a substantially horizontal path up to 2010, settling in the bulk of plotted countries, only slightly displaced upward at the end of 1990s (an inflation possibly influenced by the dot-com bubble) and seemingly insensitive (unlikely best performing countries) with respect to any relevant milestones, such as year 1991, when the WWW was born. On the other side, Figure 1.12 (with the attached Table 1.1) and Figure 1.13 should be considered in sequence, with the consistent rise in secure internet servers (a proxy for enterprise cloud services attractiveness, among the others) reasonably spurring a simultaneous (or only slightly lagged) increase in the share of final users requiring/having internet access, along which metric Italy shows a substantively constant positive slope for the whole time period with available data; however, the country ranks very well in terms of servers increase factor (compared with second-bests, *x*41 versus *x*32 and *x*163 versus *x*103 along the two computed time intervals). Providing a useful counterpart for the interpretation of previously discussed insights, this brief, qualitative glimpse of Italian ICT attitude, chances and efforts returns the image of a country that might not be exploiting at most the opportunities created by incoming UFBb-like connectivity technologies: a situation that could be profitably enhanced, as further statistical researches on those beneficial effects are performed.

1.1.5. Fiber optics in Italy: historical-geographical overview and current political programs

After this quick round up on auxiliary data at different geographical levels, paving the way around the actual focus of this work, the circle can be closed with a short overview on Italian infrastructural situation and development programs concerning network solutions relying on fiber optics.

A basic overview on Italian historical facts around fiber optics should start with the first scientific researches on the matter conducted by Centro Studi E Laboratori Telecomunicazioni (CSELT), one of the most important continental study centers on fiber optics understanding and applications. CSELT was headquartered in Turin, which made it become the first Italian site for field experiments of fiber optics setting in operation in 1977, only seven years after the first TLC fiber optics realization and eleven years before the first transatlantic optical fibers cable was laid on the ocean floor. This exploratory project witnesses an interesting attempt, precursory on a worldwide basis for those years, to concretely find a substitute for copper telephone lines, with an eye on anticipating practical installation issues. The project consisted in the layout of the baptized "COS 2", an optical wire which enveloped eight single-strand quartz fibers, set between two SIP exchanges in the northern part of the city. These fibers showed a pioneering design to operate with low abatement and wide band, thus already striving towards the abovementioned features of modern optical fibers. All the process was technically and financially guided by a pool of international industrial investors, such as the Italian Sirti, Pirelli and the American Corning Glass Works[21]; they jointly faced the high costs of a relatively new material as the main hardship through optoelectronic design and execution phases. The physical connection of the 4 km-long closed ring was hence segmented and used for cascade digital transmission experiments on a 17 km overall wiring circuit, whose results were diffusely presented, shared and discussed during the international sectorial conventions. Also, restating the progressive role played by this Italian institute, researchers from CSELT were involved in the 80s' EU project RACE[22], towards a European optical fibers network (named IBC[23]) coping with the overcoming of frontier fragmentation through national programs coordination. Unfortunately, these ambitious endeavors may have been too innovative for those times, when policy makers and institutional sponsors would hardly be so forward-looking to forecast such long term returns, anticipating, forty years in advance, the modern shift in competitive models and, particularly, the demand expansion for a service which was still nonexistent at that time, i.e. connectivity[24].

After this first episode, the story reaches 1995, when the Italian telecommunications incumbent Telecom Italia launched the Progetto Socrate. This was meant to deliver fiber optics connectivity throughout the national territory, with full-fiber transport backbone crossing the country, branching out in fiber splicing backhaul segments ending in copper coaxial cables covering the last miles (also known as local loops or user access network). This project was specifically intended to foster BB services diffusion, with all the associated positive externalities that could be foreseen even at that point of Internet development. Unfortunately, the project was suspended due to financial and technological issues, among which the contemporary uptake of ADSL solutions, more economical and deemed capable of providing sufficient performances in the mid-term. When halted in 1997, Socrate had already reached 1,5 million households (out of the 10 million target) in 64 Italian cities. In spite of these marginal outcomes, Socrate's purposes drew the Italian TLC community attention to fiber optics attractiveness, with other operators (e.g. Fastweb) planning to recover and widen its original program, eventually improved with technological breakthroughs occurred in the meantime. Another coeval experiment, extending the COS 2 paradigm, was that of the civic fiber network Metrocore, installed in 2001 to connect the University of Pisa with the Italian National Research Center

[21] i.e., the author of the first fiber optics abovementioned prototype.
[22] Research on Advanced Communications in Europe.
[23] Integrated Broadband Communication.
[24] As a reference, the World Wide Web dates back to 1991.

(CNR), the site where the first Italian internet connection had taken place in 1986. Designed for academic purposes, this photonic pilot-architecture grew up to 10 Gbps local performances, comparable to the notorious "Internet 2", through which a series of research centers communicate with some US big companies' main venues: a partnership, reckoned to have been a crucial driver for USA competitive advantage recovery on connectivity topics after the web global diffusion.

Moving ahead in time, with ADSL diffusion among 2000 and 2010, Italian awareness about BB relevance for web-based services, as well as its differential role for firms' IT applications, grew among household and business, and, following demand rise, so gradually did the supply of broadband connections, as shown and discussed in the previous Figure 1.3. However, as reported by the Italian Observatory on Broadband, ADSL diffusion already started to slow down in 2008, with a slight 2% increase in the second semester, reaching a total of 10,7 billion accesses. This phenomenon can be read as a first symptom of inadequacy and insufficiency of ADSL connectivity with respect to usage opportunities; nevertheless, it should also be partly attributed to an incoming saturation in the IT-alphabetized Italian user base of that time, with 14 billion Italian families lacking a BB connection by June 2008 and 11 among those not even owing a PC. On the other side, the main web usage by that time still concerned e-mailing, instant messaging and web browsing for news and shopping purposes, together with the rising use of "young" services such as e-Banking, online auctions and IPTV. Hence, considering both sides of the market structure in this snapshot, and knowing what happened later on, it is clear that both demand and supply dynamics were about substantively to evolve towards significantly new competitive shapes, which would have consequently required new supportive technological solutions in the following years.

Coming to the present with UFBb, the following decade saw a consistent step forward, both in terms of policy agenda and infrastructural interventions, at a communitarian - before than national - level. In fact, optical fibers availability in Europe was significantly lower than that reported by US and Sout-Eastern Asia coutries (e.g. Japan and Soutch Korea). Particularly, the "Digital Agenda for Europe" (DAE), effectively issued by the European Commission in 2010, was developed to foster a sustainable digital economy throughout the continent, for internal strengthening and profitable interactions with the rest of the world. This plan set a series of progress targets to be reached by signee members within 2020, thus reviewing and revising the programmatic lines of the preceding Lisbon agenda, which was enacted in 2000 but whose declared objectives were not fully met by the expected deadlines. The DAE strived for both harmonization on national regulation and coordination as for international technological exploitation; practically, this implied a unique, interoperable and standard digital market, with safe ultra-fast Internet transactions (as for electronic trade, consumer protection, digital authentication and property rights enforcement) and a consequent enhancement in digital inclusion (towards the so-called "network neutrality"), thus conceptually configuring ICT as a huge servo-system for society as a whole and in all its parts. As prerequisites to these macro-targets, a UBB/UFBb coverage increase, the rationalization of frequency spectrum access and transnational e-Government public actions were systematically pursued in the plan, brightly linking the DAE formalization to the contents of this thesis, meanwhile, on the other hand, it also explicitly underlined the centrality of those ICT improvements in creating a virtuous cycle of scientific research and technological-based innovation. Speaking in quantitative terms, the DAE sought "to ensure that, by 2020,

- all Europeans would have access to much higher internet speeds of above 30 Mbps, and
- 50% or more of European households would subscribe to internet connections above 100 Mbps"[25].

The accomplishment of such ambitious targets was a priori reckoned as particularly challenging, both from a financial and a regulatory point of view. Moreover, according to the state of the art in connectivity technologies up to then, these network performances were feasibly deliverable to such shares of population only by means of fiber optics wiring getting as close as possible to user end-points[26]; thus, with DAE prescriptions, the UE set the targets to definitively spur national agendas towards consistent optical fibers FTTH implementation plans.

Even if outside the time scope of this thesis work, it is useful to remind that recent follow-up to this European deliberation has been given with the "Digital Compass 2030", which from 2021 upgraded the previously cited targets towards some firm-specific more demanding values, e.g. "at least 75% of EU companies should introduce new digital services (such as cloud computing, artificial intelligence and machine learning, or the use of big data and data analytics) by 2030" and "at least 90% of EU firms should enhance their (basic) levels of digital intensity and skills"[27]. Investing in broadband enhancement, UE countries expect significant positive spillovers on several other areas of intervention, such as healthcare, goods and people transport, energy and climate change.

In order to visualize what were the effects of interest moved by these communitarian guidelines, it is appropriate to finally zoom back at a national level along the same years. Italian research had never stopped contributing to the worldwide effort to bring UFBb closer to physical implementation on a large scale; this technological endeavor, after an initial delay in political attention and factual adoption, found a suitable policy counterpart in a series of government programs, as described

[25] European Commission, *A digital agenda for Europe*, p. 19 (2010).
[26] Maddalena Camera, *Telecom, tutti pazzi per la rete (in fibra)*, newspaper article from ilGiornale, p. 18, Economia (02/12/2015).
[27] European Commission, *2030 Digital Compass: the European way for the Digital Decade* (2021).

below, which acknowledged how quickly TLC was globally shifting to ICT and concluded that the strategical need for fiber optics wiring couldn't be put off any longer, with the aim of preventing Italy from structurally lagging behind other developed economies.
Looking at the Italian situation at the beginning of the decade, inefficient supply was claimed by enterprises by the end of 2011. While reporting about a deadlock in suitable Internet connectivity provision, firms argued they were already aware about broadband competitive usefulness for their businesses, and it was not a matter of demand if the opportunities detected by the end of subsection 1.1.5 were not fully exploited in practice. A study conducted by Politecnico di Milano in partnership with Confindustria revealed that this bottleneck of the national BB deployment marked a consistent digital divide in the business environment, so that not all firms could equally take advantage of broadband enabling features. And even though a reasonable minimum of 2 (symmetric) Mbps was supplied to almost the entire firms' population (95%), poorer levels of service were accomplished with higher-speed offers: for instance, 20 Mbps from ADSL 2+ only reached 53% of firms, versus 65% of consumer clients served by the same technology, whereas the 100 Mbps scheduled by the DAE were only available to those companies having sufficient resources to obtain tailor-made network connections by a TLC operator. Thus, due to an inevitably lower user density and a greater average distance from the closest telephone exchanges, industrial districts ended up served worse than civil users, losing the chances for significant productivity empowerments[28]. Going deeper into the matter, the same study highlighted a factual segmentation in firms' needs for connection speed: particularly, increasing differences emerged with respect to more dynamic and innovation-oriented enterprises (proportionally creating higher added value for the economy) especially when exportations, new markets exploration and strong international partnerships were involved[29]. Again, these evidences prove the inherent link between innovation and broadband, which this thesis work is devoted to investigate in major depth.
The flip side of the previous matter is that of household usage of BB connectivity: by 2011, 6% of Italian population still couldn't benefit at all from BB access, living in such zones (named "white areas" for their blank filling on BB coverages heat maps) that made TLC operators' investment in network expansion complex, longer and (per se) not economically profitable; and this percentage only decreased to 5,9% and 4,6% by the end of 2013 and 2014, respectively. These areas, specifically tracked in the data set underlying this thesis work, configured a market failure in broadband provision and required specific treatment to bridge the baseline digital divide in ICT access that

[28] World Bank estimates a +10% increase in BB penetration can lead to a 1,2% GDP-per-capita increase in developed countries.
[29] Alessandro Longo, *Le aziende in cerca di banda larga*, newspaper article from Il Sole 24 Ore (28/02/2012).

hindered BB full rent extraction. Indeed, subsequent political and legislative mandates included BB concerns in their agenda. Particularly, data on which this thesis relies specifically feel the implementation effects of the "Strategia Italiana per la Banda Ultralarga"[30] (from now on, simply BUL Strategy), the main UFBb Italian institutional plan so far, approved by the Italian Government on 03/03/2015; this was only the latest of a series of briefer-scope institutional strategies, as shown in the Gantt chart's timeline of Table 1.2. With an initial budget of 7 trillion euros from both European and Italian funds, the BUL Strategy acknowledged the crucial role of TLC infrastructures in such a complex value chain as the digital one, and therefore aimed at equipping the national territory with a public NGAN (destined to concession in favor of private operators) that could comply with the abovementioned DAE 2020 prescriptions, giving 100 Mbps access to 85% of Italian population (and 30 Mbps access to 100% of it). Particularly, civic buildings (such as schools and hospitals) were programmatically meant to benefit from the 100-Mbps service level since the beginning of fiber rollout. A mix of technological solutions (i.e., fixed and mobile, using copper and cable lines), regulation instruments (such as, bureaucracy streamlining, voucher mechanism for subscriptions support, hyper-amortization incentives and participation to roll-out expenses) and public versus private investment responsibilities made up the strategy, in order to maximize the objective function (i.e., degree of coverage with high-quality UFBb) while optimizing State financing. To develop the plan, the European Commission territorial classification[31] was retrieved, distinguishing areas in white, grey and black, respectively corresponding to none/single/multiple presence of UBB/UFBb operative networks and decreasing likelihood of private autonomous investments within a three years' time window: as outlined in the following, this differentiation helped define where State aids were needed and where market compatibility of State commitment could be evaluated on an individual basis.
Towards the planning execution, an in house reference company (named Infratel Italia S.p.a.), was established under the control of the Italian Ministry of Economic Development (MiSE), with the mission of leading the operations for an integrated change in both fixed and mobile infrastructures, towards the mitigation (and, where/when possible, the elimination) of local infrastructural gaps in markets for connectivity, such as those hinted at before. This issue was particularly critical for Italy, since there, as shown in Table 1.3, the share of population living in huge Italian metropolitan areas (i.e., enclosing more than 250.000 inhabitants), that of residents in urban areas and the one of people living in the most populated city of the country were the lowest (respectively, 16%, 69% and 4%) if compared with Germany, UK and France (as a significant sample of main European countries).

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[30] Presidenza del Consiglio dei Ministri, *Strategia italiana per la banda ultralarga – Piano d'investimenti per la diffusione della banda ultralarga* (2015).
[31] European Commission, *EU Guidelines for the application of State aid rules in relation to the rapid deployment of broadband networks* (2013).

Similar considerations occurred when facing extensive information on Italian municipalities, population, buildings and real estate units, as broken down into Table 1.4 population classes: as shown by cumulative statistics, small towns (i.e., with less than 5.000 inhabitants) accounted for 72% of Italian total municipalities, but less than proportionally gathered only 17% of Italian population by 2014; this pattern is restated once the number of buildings (25%) and real estate units (43%) settled in small municipalities are considered. This comprehensively shows the extent to which the problem of reaching out smaller communities affected a large number of territorial units, and, in turn, a non-negligible (although dispersed) share of households and enterprises, and justifies the specific focus dedicated to this issue within the BUL Strategy. Acknowledging social and geographical differences with a bottom-up approach, these localized market failures were to be preliminarily addressed with specific national and communitarian subsidies for State-run direct interventions, to cope with the poor spontaneous private initiative otherwise detected in active cooperation with local administrations. Further interventions were then to be performed in the modalities of public-private co-investment partnerships or public incentives administered to tender-winning TLC operators, in order to re-aggregate local interventions and exponentially boost their impact on competitiveness at a national level[32].

During implementation, the incumbent operator Telecom Italia, owner of the preexisting copper network, took on the FTTC cabling in breadth along the country in 2015, with the full-fiber national backbone, connecting the North to the South of the country, being substantively accomplished within a few months from the start of the execution stage. Moreover, the first two calls for bids specifically dedicated to market lacking areas, aiming at reaching 20÷25% of Italian population with FTTH, were won by OpenFiber (OF), the only alternative operator comparable to Telecom Italia, which entered the market in 2017 thanks to an *ah hoc* partnership between Cassa Depositi e Prestiti and Enel (clear signs are visible on both Figure 1.3 a-b and Figure 2.6 a-b with a wholesale-only business model[33]. This thesis work develops on data from both operators' activities, deep diving into UFBb staggered rollout, as further described in the dedicated subsection 2.1.

In synergy with the aforementioned European deliberations following the DAE, a follow-on to the BUL Strategy has been embedded into the "Strategia Italiana per la Banda Ultralarga – Verso la Gigabit Society", approved by the Inter-Ministry Committee for digital transition on 25/05/2021. This document defines a first investment plan for the shares of Recovery Fund (Next Generation

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[32] A map of real time civil works progress status is available on dedicated web pages of MiSE and OF, where the cabling process can be browsed at a street number level, accessible via this links: https://bandaultralarga.italia.it/ - https://openfiber.it/piano-copertura/stato-dei-lavori/.

[33] i.e., OF deals with network management and licenses actual service provision to fixed BB/mobile operators (such as Fastweb, Tiscali, Vodafone and Wind), with whom final users sign their contracts.

EU)[34] specifically devoted to digital transition by act of the Italian "Piano Nazionale di Ripresa e Resilienza" (PNRR) and sets the Italian development guidelines for the ultimate uptake of the digital culture envisaged by UE: apart from white areas coverage completion, this new plan aims at service balancing and enhancement throughout the country, even where connectivity had already been established, as broken down in five micro-planning campaigns[35].

1.2. Innovation capacity: patents portfolios as the outcome of interest

1.2.1. Overview on patents: technological implications and variable choice

After a dissertation on the broadband technological focus, this introductory chapter naturally comes to the dual counterpart involved in the present analysis: firms' innovation capacity. First of all, it has to be highlighted that a quantitative parameter, reflecting the innovativeness degree of an enterprise, is not univocally rigorously identified, since several related aspects take part into an inevitably firm-specific definition of what innovation means; therefore, many supporting proxies can be chosen, each capable of capturing different, partial features of a firm's innovative nature with its implications for strategical value generation processes. In the context of this thesis work, considering the information available within the baseline dataset, a very concrete connotation was given to such a complex theme to be handled as that of innovation: indeed, the information of patent portfolios' extent was quantified at each firm-year observation level. Hence, the operative panel turns balance sheet figures into the number of underlying justifying titles, which make up the entries labelled as "BI3 - Industrial patents and similar intellectual property (IP) rights", a sub-item of intangible fixed assets[36] collecting IP internal production/external purchase expenses, license fees and know-how costs (when legally applicable).

From a legal point of view, IP rights represent a legal acknowledgment of those intangible assets' relevance within an enterprise's set of value-producing activities. In particular, industrial patent titles certify the 20-year-long exclusive right (to which a firm or a private citizen is entitled) to technically and economically exploit the outcomes of an invention, i.e. establishing a de facto legitimate monopoly around its implementation and the collection of associated profits. The legal rationale of this formal instrument is that of assuring territorially-temporally limited protection (enforceable by act of law) to human creative endeavors, thus giving impulse to technical progress in products/processes while aiming at a proliferation of incrementally enhanced technological applications. This

[34] Granted at a European level to spur economies rehabilitation after the Covid-19 pandemic shock.
[35] Respectively baptized Piano "Italia a 1 Giga", Piano "Italia 5G", Piano "Scuole connesse", Piano "Sanità connessa" and Piano "Isole Minori".
[36] Italian Accounting Authority (OIC), *Intangible fixed assets – OIC principle number 24* (2017).

allows to eventually push forward the state-of-the-art frontier, spreading new technical knowledge to inspire further innovation deployments, while making aggregate parallel efficiency against unwelcome duplications of R&D expenses, with the filer gaining time to recoup incurred costs and strengthen firm's market position; these should all ultimately act as rational investment incentives for economic players. By doing all of this, patents make up a rational legal device to address technological safeguard in broad terms, establishing a systematic treatment of emerging, worth-protecting rights through innovation-driven economies.

Patents are considered a key measure of innovation output (and input, in turn), since indicators pivoting on them reflect the inventive performances of statistical units (in the present case, firms) and also allow studies on the output of R&D, its productivity, structure, the diffusion[37] and the degree of technical advancement of a specific technology/industry. This metric is also employed to track the level of knowledge internationalization across technology areas and competitive sectors (even though regulation differences and changes may hinder trend analysis through space and over time). Moreover, patents cover a broad range of technologies on which there are sometimes few other sources of data, whereas patents documentation is usually very informative and methodically gathered, stored and maintained by patent offices as the reference institution.

Some may argue that considering patents is a somewhat restrictive approach when coping with innovation, since different cultural backgrounds usually entail different propensities to patenting, with inventors having alternative ways to preserve their discoveries (e.g. industrial secrecy and non-disclosure agreements, economies of rapidity, asset complementarities, lock-in scenarios). Nonetheless, once it is acknowledged that any indicators' system inevitably presents its own drawbacks, patents prove to be a good trade-off expedient that make possible to figure out reasonable approximations of innovation patterns along industries development, as better outlined in the bullet point list at the end of this subsection.

Back to patent characterization, these titles are granted to non-self-evident, industrially applicable new inventions[38], as well as utility models capable of significantly enhancing the functionalities of a previous invention. In order to assess the compliance with legal requirements of novelty, inventiveness and industrial applicability[39], meticulous prior art searches are undertaken, with ex post market analyses and the expert judgment of average professionals are called upon to evaluate whether they are facing a "flash of genius", considering potential underlying "long felt needs" and

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[37] For evidence of how patent information can be used to track innovation diffusion (deriving firm positioning in innovative industries), see A. B. Jaffe, M. Trajtenberg, R. Henderson, *Geographic localization of knowledge as evidenced by patent citations*, 1993.
[38] Presidenza della Repubblica Italiana, *Codice della proprietà industriale*, Decreto Legislativo n. 30 (2005).
[39] These criteria descend from the UE harmonization activities of the EPC (articles 54, 56 and 57).

the likewise potential (but not compulsory) inherent pioneering character of the examined invention. By itself, innovation implies demanding challenges, like complementarities selection and tuning, the arising of adjustment and project failure costs and background inefficiencies due to information asymmetries, which all often lead to a vicious credit rationing mechanism. Within this framework, the patenting procedure in particular can be quite long, is usually expensive and inherently uncertain in terms of its binary outcome; the amount of resources and costs of transaction (linked to ex ante due diligence and ex post auditing) often disheartens firms, even when aware of the long-term benefits they would capture, to undertake this journey. Moreover, another degree of freedom in patenting decisions lies in the office to which the firm may eventually decide to file: much depends on the product category of the invention and on the market perspectives defined during firm's product development studies. Besides the twelve-months, fast-track priority opportunity, granted to early filers to encourage them and extend their application abroad, international conventions were set to simplify decisions on the target office and mitigate the rise of a dysfunctional plurality of foreign applications (with the associated costs). Among the most famous ones, a mention is deserved by the European patent unified procedure, as structured by the European Patent Convention (EPC), first come into effect in 1977, which can originate a bundle of individual national patents; going beyond European borders, a similar deal is found in the Patent Cooperation Treaty (PCT), collecting 156 contracting States from all over the world, which relies on an international sorting hub for the coordination of national verification and validation procedures.
Once the patent title is officially released by an authorized patent office, according to the licenser market position and power (i.e, an incumbent or an outsider) the right can be successively either held, shared in technological alliances, sold (through private negotiation, specialized patent auction houses, e.g. Ocean Tomo, and/or IP exchange web-platforms[40]) or licensed to third parties against payment to the licenser; a duty the licensee(s) can comply with in several ways, for instance:

- being charged with a lump-sum or periodical payments (with or without installments);
- by transferring shares of sales (i.e., royalties, usually 3÷5%) to the licensor;
- by granting entry fees, in order to remunerate the privileged access to the product's streams of revenue;
- by committing to minimum guarantees, thus setting a lower bound to the licensor's income derived from the active licenses.

The subsequent reduction in licensor's exclusivity is (hopefully, more than) compensated by the agreed fees and the opportunity to use the system of licenses towards a geographical expansion

[40] For instance: IPAuctions.com, PatentAuctions.com, IPMarket.com and FreePatent.com, Tynax, Yet2.com.

(and diversification) of that exclusivity, by exploiting licensee's production assets while dampening (and sharing) outward the competitive risk associated to technological shocks on the market.

Another interesting, cutting-edge application of patents is that of IP-backed securitization, a sort of structured financing that creates marketable rated bonds, issued by a Special Purpose Vehicle society (SPV) with a seniority repayment structure, starting from illiquid assets (e.g., patents); famous examples are the "Bowie Bonds", backed by sales revenues of David Bowie's catalogue, as well as securities based on proceeds from blockbuster films, like "The Matrix", "Gladiator" or "A beautiful mind". This and similar financing schemes (such as IP-focused private equity investing, IP collateralization of loans and IP sale lease back) are being more and more used to support the ramp-up phase of start-ups with a (hopefully) self-sustaining business cycle centered on innovation: a modern example of how IP rights (and related titles) are innovating the way innovation is financed, through a positive loop creating conditions for the onset of new professional figures (like patent attorneys) as well as new strategical processes mastering the skills required by innovation-oriented markets (first of all, IP titles assessment, which the banking system has strongly invested in along recent years).

Once the stage on patents' framework has been set by replicating the approach of the previous BB analysis, some references from academic literature can help draw nearer the two extremities of this thesis work. In fact, several publications employed broadband-related measures to make causal inference of statistical effects on innovativeness metrics, therefore moving from initial considerations on BB diffusion patterns (introduced in subsection 1.1.3) to the associated outcomes on firms' innovation performances: a conceptual path this thesis wishes to join. For instance, Bertschek et al. (2013) data on DSL durability to infer on draw conclusions product/process innovations' likelihood, discovering broadband encourages the probability of NPD positive outcomes, with binary impacts from adoption on average treatment effects estimated in the order of 41÷45% for product innovations and in the order of 28÷35% for process innovation (even though a certain degree of correlation with unobserved factors may have inflated these results). This virtuous path for BB effects was later systematized in Zhong et al. (2020), who tracked the cascade effects of the Internet on firms' internal features and particularly on feedback mechanisms underlying the functioning of organizational frameworks. On the other side, as it usually occurs in real-world economic studies, contrasting evidence of no desirable links between ICT and innovation was obtained by Bartelsman et al. (2019), whose research deduced that within-firm innovations are normally neither depending on productivity, nor on the extent to which this productivity is enhanced by Internet access.

Researches on innovation and connectivity interaction also dived into the analysis of managerial handling of big data insights, made more and more easily accessible by faster Internet, growingly embodied in firms' decisional schemes: an example of this focus is the paper by Ghasemaghaei and Calic (2019), whose survey on middle and top-level managers entered competencies and uses of

organizational data, showing that, while velocity, variety and veracity (in descriptive and prescriptive terms) foster data-driven contributions, the impact of data volume and prescriptive insights is not (yet) statistically significant, suggesting professional critical thinking and expert judgment may still be preferred to the guidance of computer processing outcomes. Zooming out on innovation, and considering the inherently intertwined, non-linear nature of innovation processes, Kaufmann et al. (2002) analyzed Internet participation to the outward extension of innovation networks, as well as the paradigm shift in partners' selection and globalized ways for knowledge sharing. Finally, from one more possible perspective, advanced ICT has proved to play an entry-ticket role for young innovative firms striving to launch themselves on the market, with the opportunity for a win-win mechanism resulting in positive spillovers for incumbent players as well (Aghion et al., 2009).
Hence, taking into consideration all these defining, situational and research aspects, the adoption of the abovementioned patents counter variable to describe a firm's innovation attitude presents a series of pros:

(+) it describes a very variegated concept in the simple format of an (absolute) tally, whose interpretation is straightforward and whose content is easily comparable with that of other metrics, being defined on a ratio scale.

(+) This variable allows to reason on patents while avoiding to rely on their value assessment, which is usually conventional and split in balance sheets, as for acquired titles, or not objective nor certain[41] (being based on unknown future benefits), as for internally developed/never traded ones; also, the discrete counter is insensible to depreciation/amortization accounting adjustments made through time.

(+) This variable provides cleaner information than that deducible from the accounting entry itself, which, as previously mentioned, also gathers value contributions from a variety of other IP titles, such as registered industrial designs and software code (as protected by copyright regulations on intellectual works), not patentable by itself.

(+) The number of patents grants access to a richer piece of information than that normally disclosed by firms, since the detail of patents' breakdown is not required by Italian Chambers of Commerce within corporate mandatory reporting.

(+) Focusing on patents as acquired IP titles is a sounder approach than relying on research and

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[41] Common methods implied by patent brokers include:

- comparable forward-looking analysis;
- opportunity costs of discounted royalties, and/or
- reproduction expenses of alternative technical solutions, possibly parametrized with stock exchange prices;

see also Roberto Moro Visconti, *Il valore economico dei brevetti* (2007).

development expenses, which are normally more volatile and recorded in a looser way (being their outcomes uncertain by definition).

(+) The variable is quite stable through time (in absence of IP transactions), since a patent lasts twenty years before expiry, which make up a convenient multiple when compared to the seven years' extension of the panel used for this research.

(+) Finally, this counter focuses on new titles generation, irrespective of their future applications, and thus avoids being affected by implications of a common under-exploitation trend. In fact, niche implementation contexts, hard enforcement, litigation risks and a skewed Poisson-like value distribution[42] set hurdles to patents monetization and proper management planning; considering these aspects would introduce a lot of noise into the data base, which the chosen variable avoids by gathering information at a fair level of compromise.

On the other hand, a possible, marginal disturbance to a genuine interpretation of these data could come from patent buying-and-selling transactions, which would affect firms' patent counts with no magnitude variations in the overall pool of titles in circulation; however, as reported in Gambardella et al. (2007), the market for patents is nowadays up to 60% undersized (i.e. it could be up to 70% larger) with respect to what subjacent fundamental values could justify, therefore indicating that these transactions are not usually a main purpose, and thus a primary concern, when dealing with patents management. Again, distortion may (partially) derive from patenting policies within firms, which may pursue new patents for merely strategical reasons, thus with no focus on technological advancement (e.g. in the case of the so-called "patent sharks/trolls"[43] or in presence of cross-licensing agreements); however, it is quite likely that these patterns constitute a minor driver in the Italian entrepreneurial framework, where a different innovation culture traditionally persists with respect to what happens in Anglo-American countries, where these issues represent a growing concern. Finally, since the chosen proxy accounts for the results of the patenting procedure, a slight survivorship bias and possible time-lags might make this ex-post measure a more severe one than that provided by the ex-ante volume of patent demands filed by firms; nonetheless, as later exhibited in Figure 1.15, success rates tend to be sufficiently steady in the long term, so that proportional deductions could be easily drawn (even if with a pinch of salt) by scaling up from released patents to filed applications, or vice versa.

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[42] See F.M. Scherer, D. Harhoff, *Technology policy for a world of skew-distributed* outcomes (2000) for a detailed study on this aspect.

[43] Non-practicing entities which acquire IP titles with an aggressive "wait-and-sue" business model, based on infringements and counterfeit increased ease, that are not interested in carrying out the underlying inventions: they're more focused on legal trials and IP trade rather than on technical issues.

1.2.2. Patent applications and grants: an empirical overview of the Italian situation

Analogously to what was previously done with trends associated to broadband diffusion and usage, a brief analysis was performed exploiting public data on innovation, in order to counterbalance previous quantitative aspects on broadband and get a sense of the most relevant issues to be kept in mind while going through later statistical investigations.

Exploiting OECD data on the time-space evolution of patenting activities, Figure 1.14 shows the applications' time series at the European Patent Office (EPO), which thus take advantage of EPC for the streamlined continental extension of national filing for patents. Within this Chapter, EPO is seen as the main international node of convergence for Italian patent filers, exploiting its institutional unicity and a fairly aggregate geographical level (standing between national local offices and world-wide ones). Moreover, when evaluating the flow of applications issued from different sets of countries, and looking for a significant pooling, the wider-scope count of triadic patent families[44] suggests OECD countries as an appropriate level of aggregation, since countries within it cover approximately the whole volume of EPO applications through the available time window (1985-2019).

The six charts grouped in Figure 1.14, which plot the overall trend next to five main patenting categories, compare the time evolution of applications heading to the EPO and coming from all over the world (red spline) or specifically from Italy (yellow spline), respectively: the trends of totals among 1998 and 2012 are nearly parallel for the two geographical references, showing Italian responsivity to global upward and downward waves and exhibiting a general growing pattern, with only a small divergence for the two charts in the last years of the captured window. As for the shape of the industry-specific charts, Italy appears to move coherently to the world (as proxied by the OECD cluster), apart for the last years on ICT patents (likely to explain the abovementioned mismatch between totals) and on biotech ones, with the country registering increasing applications within this sector and therefore behaving in countertrend with the rest of the world. Also, this first set of graphs allows to detect a potential periodic component in patent applications across the industries, clearly visible in all figures but 1.14 c at Italian-level while not evident when a wider geographical scope is considered, probably due to mutual compensation among the OECD countries grouped by the metric. This emerging mid-term pattern suggests interesting implications for the design of patenting quantitative models with oscillating terms; however, the short time extension of the operative panel employed in this thesis work is likely not suitable for such deepening on the

[44] A triadic patent family is defined as a set of patents registered in various countries to protect the same invention. Triadic patent families are a set of patents filed at three of these major patent offices: the EPO, the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO). These counts are attributed to the country of residence of the inventor and to the date when the patent was first registered. Visit OECD website at https://data.oecd.org/rd/triadic-patent-families.htm for quantitative evidence.

matter, thus leaving room for further, future investigations.

For a more comprehensive look at worldwide available data, thus opening the analysis to other nodes of the institutional patenting network, applications filed under the PCT are also considered in Figure 1.16 c-d three-dimensional donut charts, plotted for comparison with the recovered EPO ones (1.16 a-b) while maintaining the same aggregation levels (world versus Italy, as left versus right charts) and the years contrasted in output (2000 versus 2012, as inner versus outer rings)[45]. Within the five considered categories, and reading the charts' content along the three available dimensions, all snapshots reveal a relative prevalence of ICT patent applications, even if with different proportions at worldwide and Italian levels (where a lower share of total applications is explained by these five macros) as well as through time (with other categories growing wider from 2000 to 2012 along both geographical perspectives). While the former (geographical) discrepancy may hint at a peculiar Italian firms' approach to patenting as an instrument to compete within their specific industrial structure, the latter (temporal) one suggests a possible gradual shift in the ranking of innovation-intensity sectors, thus making the five macro categories tracked within the OECD database progressively less descriptive of actual innovation trends. Nonetheless, when fixing the other two (i.e., time and space) dimensions, EPC and EPO plots significantly recall one another among corresponding rings, eventually proving the previously chosen focus on EPO applications (as carried on in the following graphic contents) to be a non-restrictive one. Hence, zooming back to the sole EPO applications, and moving through the process towards IP titles release, the rate of successful grants is broken down by industry in Figure 1.15; as a methodological reference, measures associated to patent grants are sometimes also used as econometric controls in the assessment of innovation propensity of firms or geographic areas[46]. As partially anticipated at the end of the previous subsection, after choosing a geographical focus among the two available ones, success rates seem to be quite rigid through time, with non-negligible temporal offsets exhibited only on healthcare-related titles; as for the orders of magnitude, all categories approximately settle within 40% and 70% along this metric, with the exception of ICT applications, where more aggressive competition or higher likelihood of previous patents' overlapping may explain the detected harder obtainment of new titles. Furthermore, shifts of any magnitude within 2000 and 2012 describe a positive trend of patent grants; since the number of existing titles is growing through time (as discussed with Figure 1.14) and thus flat or decreasing rates wouldn't be surprising, detecting

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[45] In these charts, the green category labelled as "Others" accounts for a mixture of (incoherent) patenting categories put together, and was included in the circles only to normalize them to 100% and thus make the remaining slices comparable with one another.

[46] For a practical application of this setup, see C. Forman, A. Goldfarb, S. Greenstein, *The Internet and local wages: a puzzle*, p. 8-11 (2012).

increasing rates instead highlights even more a significant trend, attributable to the effects of streamlined institutional procedures combined with enhanced skills by filing firms, which are likely to have improved their preliminary evaluations (better filtering the most promising opportunities) while also performing a better drafting of the formal documents, mandatory to enter the application procedure. This may suggest that the focus on innovation has become more severe year by year within the plotted industries, so that firms may have reacted as above to the threat of an innovation-based market selection. Moreover, comparing bars for Italy and for OECD countries as a whole, the former always outweigh the latter, witnessing an above-average capacity of patent attainment exhibited by Italian firms.

As a further insight, Italian firms' aggregate efforts on patenting applications at EPO are displayed along the dashed lines of Figure 1.17, for an ordinal comparison to those of firms from other OECD countries, now taken individually. Besides Figure 1.17 a, where absolute counts are stacked one on top of the other, the measure discussed so far was related to an economic (i.e., current $ GDP) and two demographic (i.e., number of national firms and country residents) statistics, as shown in order from Figure 1.17 b to 1.17 d. When unbundling the previously used pool of OECD countries, relative balances of power are made explicit, with Italy lagging behind many other developed economies, even when measures are normalized on either the number of firms or citizens (which can in the first place proxy the amount of "thinking minds" within a nation) or the extent of the gross domestic product (a common indicator for value creation and economy dimension, to which innovation opportunities may be linked through a sort of "winner-takes-it-all" mechanism). These outcomes provide a useful counterpart to previous evidences and, as concluded by the end of subsection 1.1.4 when dealing with ICT investments, they also point out wide margins of improvement for Italian firms, this time in terms of innovation inclination and its effects on business development: in order to assess the current scenario in this regard, a finer focus on Italian firms' innovation appetite will be given in the following subsection.

Finally, previous trends concerning the quest for new patents can be further understood by getting deeper into the detail of local applications of Italian firms, as clustered by OECD data: this time, a provincial degree of granularity is viable, thus allowing a useful step into national recent performances discussed so far. This information served as an input for the creation of Figure 1.18: here, the previous time fences employed for international analyses, were recovered, and the two so-obtained snapshots of Italian patent applications are both plotted in form of heat maps (for spatial, qualitative evidence) and complementary frequency histograms (for quantitative reference), a detail of which is reported sideways, instrumentally drawn for a comparison à-la Pareto. Patenting attempts appear to be more concentrated in Northern provinces as for both periods, with an even steeper cumulative for the snapshot taken in Figure 1.18 a: in fact, the first 8 provinces (against 11 in 1.18 b) account for a half of the overall volume of applications, whereas respectively 22 (24, in 1.18 b) and 27 (30) provinces must be grouped in 2000 (2012) to account for 80% and 95% of the same total. This empirical, progressive dilution along the metric can be mainly explained by the different height of maxima in the two years, amounting to 681 and 414 applications and therefore with a decreasing trend, even though both ascribed to the province of Milano. Furthermore, considering that the famous "20:80" Pareto law suggests 80% of applications should be enclosed within the first 21 provinces (20%) in ranking, both empirical trends exhibit a density comparable to a theoretical Pareto distribution. Finally, steady rankings can be observed in the medium-long term for the best performing positions, with 9 out of 10 among the first provinces in 2000 statistics ranking within the same range in the second time bucket, and particularly the first three provinces (i.e., Milano, Torino, Bologna) holding the head of the chart in unchanged order. These combined infographics witness an evident prevalence of patenting focus in the North of Italy along the years before the panel window; a pattern, which subsequent econometric analysis will systematically take into account and further stress along with fiber optics deployment.

1.2.3. R&D investments for Italian firms

Research activities are commonly agreed to be essential premises towards business competitive advancements, and particularly in some industries, where innovative solutions make up a major, ruling force of the market. As background activities to patenting ambitions, therefore, the output of R&D enterprise functions from Italian firms can be checked out, with the aim to outline possible cultural elements featuring the Italian entrepreneurial ecosystem and preliminarily (though, indirectly) explaining some ex post results detected on innovation-based metrics.

For a synthetic, structured overview of these propedeutical components of firms' innovation, Figures from 1.19 to 1.22 were specifically designed. Recovering the format and point of view of OECD data base, Figure 1.19 plots the evolution in time of national, gross investments in research and development projects, expressed as a percentage of GDP; in order to contextualize the message that this metric delivers, its academic applications affirm its relevant role as innovation tracker, since it is sometimes used as a proxy for absorptive capacity[47], to exploit its sensitivity to an innovation-prone competitive (and/or regulatory) environment[48]. As emerged from the previous Figures 1.11, 1.13 and 1.17 on related topics, not even on this metric Italy outstands among developed

[47] Namely, the ability of "learning to learn", i.e. recognizing the value of new information, embracing it within the organization and implementing it in new, profitable applications: for accurate reference and deepening on the matter, see also W. M. Cohen, D. A. Levinthal, *Absorptive capacity: a new perspective on learning and innovation* (1990).

[48] See J. Jung, E. López-Brazo, *On the regional impact of broadband on productivity: the case of Brazil*, p. 8, (2020) for an example.

economies. However, as a clear effect of the changing of times, the country makes no exception in experimenting a long-term positive shift upward, following the sheath of OCSE splines with a roughly linear evolution that leads it to a doubling of the index value (from 0,828% to 1,531%) between 1981 and 2020. By looking at Figure 1.20, where the absolute counterpart to these percentage values is provided, Italy ranks steadily fourth within European countries along the last twenty years, acting as a separating line among the three best-performing nations (i.e., Germany, France and United Kingdom) and the bulk of poorly-performing residual countries. Nonetheless, although the previous shares (Figure 1.19) are referred to a growing total (Figure 1.20), they are kept bounded in a very narrow strip of low percentages, which suggests the presence of intrinsic or extrinsic constraints to growth. These results are confirmed by Figure 1.21 b, where a comparison with a series of major geographical-economic groups is displayed, again stressing a relevant gap between Italian R&D relative expenditures and other developed economies, even though a consistent, linear growth trend is restated, both at a national and at lower levels, as made explicit in Figure 1.21 c. Consequently, as expectably induced by this macro evidence, the number of professional researchers per one million people (plotted in Figure 1.21 a) is significantly lower in Italy than that measured in other countries.

However, in spite of the apparently pessimistic scenario depicted by this macro measure, auxiliary evidences taken from different perspectives can reveal some interesting trends that are worth a reflection, especially once they are matched with the available panel window and the abovementioned milestones in broadband diffusion. When segregating firms by employee class in Figure 1.21 d, for example, it appears that a major impulse to innovation activities of Italian enterprises (excluding private universities) has been given by larger companies, as physiological and foreseeable in a modern market economy; nevertheless, micro firms have been interestingly enhancing this indicator at a faster pace than any other cluster, depicting innovation as a “polarized matter”, either suitable for the biggest players, who want to maintain their market role, or for the smallest ones, striving to make their way to success, so that firms from other size classes end up stuck somewhat in the middle of these two opposite. And meanwhile the setup of R&D Italian investments gradually shifts from a prevalence of applied research purposes to a stronger focus on experimental development ones (Figure 1.21 e), the employed ISTAT data report about a relevant spike, particularly localized in Northern areas, regarding the volume of co-operation deals for innovation projects among firms (Figure 1.21 f), such as new joint ventures and other co-investment agreements on risky activities. This insight is also strengthened when additionally considering Figure 1.22: here, all three displayed metrics (i.e., firms classified as having innovative business, focused on product-process innovation and/or having effectively introduced such innovations in recent years) exhibit a similar convex trend, reaching the bottom in 2014 and then increasing up to higher values than initial ones, always with the same ranking of Italian macro-areas, coherent with patterns discussed with Figure 1.21. This charts provide more encouraging insights from Italian firms' appetite for innovation, and contribute to the sought big picture when read in parallel with previous evidences; nonetheless, it must be emphasized that biennial data availability may provide only a partial view on the graphical shape of significant trends from Figure 1.22.

Finally, introducing an industry breakdown that will be further exploited in the following chapters, a pie chart with in-house R&D attribution is shown in Figure 1.23, structured by considering years 2013 and 2019 as the beginning and end of the current time window, in agreement with the setup of the operating panel used for statistical analyses performed in subsequent sections. As explicated by the captions, more than 95% of Italian firms' expenses devoted to research and development is accounted for by the nine industries summarized within the chart, amounting to over 9 trillion € in 2013 and, after a six-years, 51% increase, over 13,5 trillion € in 2019. More in particular, four slices alone occupy almost the entire surface of the circle (98,13% in 2013 and 96,64% in 2019, respectively), with manufacturing playing the lion's share (and thus reflecting the typical industrial structure of the Italian economy), followed from afar by ICT services, scientific-technical-professional activities and trade businesses. This macro picture of Italian industrial texture will be better detailed by the end of Chapter 2, where an extensive investigation on firms composing the quantitative panel will be performed, before passing data to the econometric modeling.

2. Panel overview: introduction to the data and descriptive insights

This thesis work aims at shedding some light over the relationship between ICT technology rollout and firms' innovation, specifically traced by the dynamics of their patents portfolios. This chapter sets the statistical basis to dive deeper into the data content, exploring the main trends and detecting some peculiarities which can help draw a "big picture" of reference, to be further investigated afterwards: gaining knowledge of the panel and interpreting the information underlying the data, in fact, will be preparatory to the final econometric analysis, developed in detail in the last chapter of the thesis.

The chapter is divided into a few main focuses, structured as follows. First, a brief section is dedicated to the process behind the panel generation, the data sources and the major virtues and constraints about the implemented collection mechanism and dataset design. Next, the argument concretely steps into the data, showing preliminary non-inferential evidence. Hereinafter, the focus is split in two perspectives: municipalities and ultra-fast broadband time-space uptake, on one hand; firms and patents portfolios patterns, on the other one. These two perspectives are treated in parallel with interactions among single sub-chapters, to start connecting the dots towards the final econometric analysis.

The central part of this chapter thereby opens by considering the features of municipalities encompassed by the study, the finest level at which fiber optics connectivity diffusion is tracked; hence, the discussion of technology implications on the data follows straight away this part. Then, the most interesting aspects about the sampled firms are made quantitative and comparable, in preparation for the final model and regression estimates, of which firms represent the panel states/units. Finally, recalling what has been seen in Chapter 1 at a wider geographical level, innovation proxied by patents is examined through the whole panel. This closes the descriptive phase of the thesis, with all the ingredients ready to approach the conclusive model analysis.

2.1. Database creation

Before dealing with data details and the first statistical results obtained by looking at the panel, it is suitable to begin with a short introduction to where data come from and how they are structured, which will beforehand help better figure out data relationships and implications, as well as detected patterns and/or possible puzzles encountered all the way through the descriptive analysis.

This thesis work moves its steps from a unique dataset of firms' observations, whose time extensions ranges from 2013 to 2019. This dataset gathers municipality-level information on UFBb availability, subsequently matched with firm-level data on a sample of Italian private-sector incorporated companies, neglecting agricultural and financial sectors. The so-built knowledge base was gently granted for this degree final project by the courtesy of professors C. Cambini, E. Grinza and L. Sabatino, who previously exploited it to produce relevant results about ultra-fast broadband effects on several economic outcomes, e.g. TFP measures, labor productivity and Italian firms' entry-exit dynamics in recent years.

Firms specifically included in the operative panel were extracted from the dataset by collecting all the records with usable data on firm's patent count, a precious information available in the original database, deemed suitable to investigate the declared outcome of interest. Once these pre-processing was accomplished, observations were further filtered to create the balanced panel, therefore keeping track of all those businesses that were active for the entire time window under study. This initial data handling brought the number of firm-year observations from 2.302.567 to 299.992 (42.856 firms along 7 years); to visually assess the associated orders of magnitude, observations for dataset and panel firms and municipalities are compared to the overall Italian reference in Figure 2.1 for each of the panel years.

As far as connectivity is concerned, this dataset benefits from access to TIM and OpenFiber archives, which enables the crucial tracking of the staggered technological rollout of fiber optics connections for all Italian municipalities. A richer insight in the cabling process was also made possible, by distinguishing whether network expansion waves reached municipalities by means of any kind of optical fiber connections (i.e. FTTx, recalling the acronyms listed in Chapter 1) or in particular by means of the most performing full-fiber solutions (i.e. FTTH). TLC operators (particularly, TIM) also shared information on topographical locations of Optical Packet Backbone nodes (OPBs), which make up the multi-service, single platform network where Internet and telephone signals are rerouted through the country from senders to end devices. The data set also includes the exact locations of Optical Line Terminals (OLTs), the main fiber optics input which upgrades the network to ultra-fast broadband. Indeed, passive optical networks spring from these endpoint cabinets in a point-to-multipoint mode; this is therefore the interface where optical multiplexing[49] is accomplished by means of optical splitters, which allocate frequency bands in several sub-channels to single connections and thus enable parallel transactions without mutual interference. This additional information on the evolution of network devices through time was used to define the yearly distance of each municipality from the nearest connectivity infrastructures of reference.

On the other hand, information about firms was extracted from the web-based database AIDA (a paperless information warehouse, specifically focused on Italian enterprises), edited by the Bureau Van Dijk. This is a Moody's Analytics company dealing with the management and diffusion (for academic and other research purposes) of corporate data, which in turn are drawn from compulsory

[49] i.e. the sharing of transmission capacity, as described in subsection 1.1.2.

commercial communications required by Italian chambers of commerce. Beyond balance-sheet information, AIDA makes also available data on other useful aspects, e.g. economic classification (i.e. 1-digit Ateco 2007 identifiers), employees number, firm addresses and so on.

Thereafter, these two data streams were merged with one another by matching the operating center locations of each firm (derived from AIDA) to the municipality-level information of UFBb deployment, which allowed to yearly identify firms that had (potential) access to ultra-fast broadband versus those that couldn't exploit it yet. In particular, the operating center reference was preferred to the legal site one, since that is where the firm properly produces value and effectively performs its core business(es), as far as innovation and research activities are concerned, too.

At this stage, a clarification is due as for the meaning of the available data for Italian companies. Since the application of new connectivity technologies is meant to be used as an explanatory driver for firm outcomes, some sort of link between potential supply (observed in the panel) and actual usage (point of view for subsequent inferential reasoning) needs to be provided. In this regard, the evolution of UFBb subscriptions for both households and firms between 2015 (i.e. the rollout kick-off) and 2019 (i.e. the end of panel visibility) is reported in Figure 2.2. As discussed in Akerman et al. (2015), a clearly similar pattern can be detected for the two trends, suggesting a very marked correlation between UFBb usage in households and firms; the fact that these two measures develop coherently with one another allows to set the whole work on the available municipality-level rollout data, reasonably assuming that the provision of ultra-fast broadband connectivity to firms is safely proxied by the household availability that these data describe.

Finally, information about municipalities demographics was retrieved from the Italian Statistical Office (ISTAT) with reference to the year 2011, when the last census preceding the data set time window took place. Apart from playing a functional role as control variables in the econometric model, this data was also used to perform some of the descriptive analyses developed in the following subsections of this chapter.

2.2. Municipalities

Carrying year-by-year information about the expansion of municipality-level UFBb network, the balanced panel covers 4.454 Italian municipalities from all regions (a finer breakdown can be found in Figure 2.3) and 105 out of 107 Italian provinces (98,13%).

All along panel description, the geographical perspective will be often taken into consideration; according to each context, time after time it has been chosen to think about Italy either as a whole, or broken into single regions, or in terms of conventional macro-areas, which group together regions with historical and/or political common features, henceforth defined as follows:

- *North*: Valle d'Aosta, Piemonte, Lombardia, Trentino Alto Adige, Veneto, Friuli Venezia Giulia, Liguria, Emilia Romagna; further split into two subsets:
    - *North-West*: Valle d'Aosta, Piemonte, Lombardia and Liguria;
    - *North-East*: Trentino Alto Adige, Veneto, Friuli Venezia Giulia and Emilia Romagna;
- *Center*: Marche, Umbria, Toscana, Lazio and Abruzzo;
- *South (mainland and islands)*: Molise, Puglia, Campania, Basilicata, Calabria, Sicilia and Sardegna; further split into two subsets:
    - *Inland South*: Molise, Puglia, Campania, Basilicata and Calabria;
    - *Islands*: Sicilia and Sardegna.

A first remark as for municipalities is related to the change in their number through time. In fact, as shown in Table 2.1, the number of municipalities went monotonically decreasing along the entire time window covered by the analysis, due to subsequent administrative merges. However, the coverage difference between the first and last year of the panel, with respect to the overall country number of municipalities, is reasonably low (from approximately 55% to 56%), leading to an almost constant proportion along the analysis, with more than a half of all existing municipalities that ended up included in the panel.

The original dataset can be taken as the best available proxy for the whole country dynamics, considering the extent of municipalities that it gathers. For this reason, the diffusion estimates performed in Chapter 1 relied on this data base, so that the following corresponding estimates on the extracted panel could be comparable with those. Moreover, the panel derived from the full dataset keeps well representative of the main trends described by the data. Indeed, the reduction in the number of covered municipalities, occurred for balancing needs, doesn't substantively impact on the major trends detected, as far as coverages and UFBb diffusion are concerned, as displayed in Figures 2.6 a-b later in the dissertation.

A more specific detail of municipalities-region correspondence is depicted in Table 2.2. The heat map in Figure 2.3 a, which complements the table (where the darkest the region, the highest the number of municipalities touched in that region), clearly emphasizes a frequently met trend during panel description: the prevalence of information related to Northern regions (particularly, Lombardia), which is evidently rooted at the level discussed here, i.e. in the abundance of Northern municipalities with respect to Central and Southern ones. Nonetheless, apart from this pattern, the number of municipalities by region appears to be proportional to the size (and geographical detachment/marginality, e.g. in the case of Sardegna) of each region, with the smallest ones participating in the panel with less cities.

Along with this information, the table presents a link between locations and firms, by considering the average and median number of firms per municipality. The presence of big administrative centers, that are usually wider industrial hubs as well, manifestly biases upwards the mean of firms per municipality: therefore, the corresponding median (and the associated 2.3 b heat map) can be taken as a more reliable indicator of firms' concentration. Moreover, as underlined by the comparison among the two heat maps, a clear difference arises when considering the (exact) number of municipalities per region and when the (median) number of firms per municipality is considered instead. This is likely to have a differential multiplying effect in deploying the impacts of technology rollout among firms, partially anticipating the differences detected with the econometric analysis of Chapter 3.

Another insight to help better visualize the spatial distribution of firms is given by Figure 2.4: on the x axis, a progressive number for distinct municipalities by region (one per each color series) is displayed, while, on the y axis, the number of firms by municipality is plotted. The detail below the main graph is obtained by removing the five cities with the highest number of firms within the panel, seen as outliers in this regard (as already stated in the previous sub-chapter): Milano, Roma, Torino, Napoli, Genova. Once these extreme values have been wiped out, the relative proportions of both municipalities and firms can be more clearly assessed, even though systematic differences persist. Again, the highest number of statistical units, with respect to both dimensions (i.e., number of municipalities and number of firms per municipality), are referred to the Northern regions, with the hugest amount of information coming from Lombardia.

Coming to the peculiar characteristics of municipalities, Table 2.4 collects some demographic, urbanistic and orographic indicators, grouped at a regional level. In particular, the urbanization degree is defined on a conventional ordinal descending scale, ranging from 1 to 3, starting from a cellular partition of each municipality's territory and computing the shares of population (with a threshold of 50%) living in clusters labeled as “urban” and “rural”, respectively. Similarly, municipalities are divided in 5 groups according to the altimetric zone indicator, jointly considering the altitude of their city center (mountain, hill and lowland municipalities) and sea proximity (internal and coastal municipalities). Even here, the median evaluation appears to be a sounder reference, particularly for demographic and urbanistic indicators, where the size of big cities surely affects the magnitude of the averages. Besides, urbanization degree and altimetric zone are expressed on poorer scales than a ratio or interval one, so that averaging over these values (according to Stevens scales of measurement theory) is not an advisable calculation.

Finally, putting all the previous information together, we can synthetize from the data the main features of a typical municipality in the panel: a town of around 5.000 residents, 7% of which are graduated, located on the hills somewhat far from the sea, with intermediate levels of urbanization

(2 out of 5) and three firms headquartered in it. The estimated population density in a median year within the panel is 210,42 inhabitants/km^2, which is just slightly higher than that obtained after the 2011 population census (201 inhabitants/km^2) and still comparable with the latest available estimates (195 inhabitants/km^2 at the end of 2021). The small overestimation is easily attributable to selection bias, since smaller municipalities, having less or no firms with their venue located there, are less likely to meet the requirements and cross the filter imposed during panel creation. This representative municipality is coherent with the Italian geopolitical structure, typically made up by relatively small territorial units dispersed in space; therefore, the panel, in spite of being limited in scope, proves itself to be a good descriptor of the national geo-political situation.

2.3. Ultra-fast broadband

In order to create a link with the previous sub-chapter, a time evaluation of municipalities reached by different connectivity levels is shown in Table 2.5, both at a dataset and at a panel level. Even in presence of these municipality-level offsets, the panel reproduces well (despite scaled down) the trend shape of the whole dataset, and will still reveal itself descriptive, as anticipated, even when computing the same statistics at a firm level, as detailed in the next sub-chapter. As expected, the overview of the Italian situation derived here is consistent (both in terms of trends and in terms of values magnitude) with what was found and discussed in Chapter 1, where the information coming from the whole original dataset was exploited.

Furthermore, the graphs attached to the table (together with their percentage versions in Figure 2.6) represent the expected panel-level comparable for the dataset approximation of Italian ultra-fast broadband evolution, as depicted in Figures 1.3 a and 1.3b. These homologues of the previous figures, confirm that the effects of the undertaken infrastructural policies, described in Chapter 1, are correctly recognized even at the panel level, where the analysis is actually performed. In particular, the years 2015 and 2017, when the factual network interventions began, are highlighted with dashed lines: the beginning of ultra-fast broadband deployment and fiber-to-the-home diffusion in these years, respectively, is clearly reflected in the panel data, where the related splines arise from the null baseline right in those two years.

Comparing corresponding figures from Chapter 1 and 2, the slight emerging panel-level overestimation is arguably due to the balancing process giving birth to the patent-focused panel, and should be therefore reasonably attributed to sampling variability. Again, in both cases the emerging trend is that of a substantial initial upsurge, being easier for technology to spread when no areas have been previously covered; then, after crossing an inflection point, the speed of diffusion has started to diminish. To explain this pattern, three main interacting causes can be called into question:

- for the same reason a sharp rise is not surprising at first, since the course of any project follows a sigmoid path, completion is typically reached with a non-linear progress, less than proportional to the effort required to accomplish it;
- it is logical to assume that TLC operators have cabled the more convenient areas first, leaving behind the less attractive ones (the “white areas” where market failures are more likely to occur), which represent a minority of holes in the quasi-uniform lattice of service coverage, harder to reach and discouraging towards “100% coverage target”;
- after reaching a service level deemed to be temporarily satisfying, the policies driving the change, after assessing descending returns, may have opted for funds (re)allocation on different strategical investments.

As for UFBb, for whose evolution a longer time series is available, the sigmoid shape is already clearly detectable in all the subsequent related graphs, moving towards the at a decreasing, seemingly logarithmic pace. Since it started at a later date, a shorter time window can be used to evaluate the progression of FTTH deployment, making the assessment and forecasting more uncertain due to lacking data. However, from an industrial economics point of view it is reasonable to assume that the main drivers for its advancement are those captured by the bullet points listed above.

The analogy with Chapter 1 outcomes is completed by taking into consideration Figure 6 (b), which shows connectivity coverages and fiber diffusion at different municipality-level bandwidths, perfectly in parallel with the contents of Figure 1.3. Such as there, a wave structure of innovations subsequently introduced spreads from the higher-left corner down to the lower-right one. Both graphs show how narrowband services (7 Mb, 20 Mb) had already reached (or were about to reach) a substantial saturation in terms of geographical coverage over the country at the beginning of the panel period. 2015 is again the year when U(F)Bb network interventions start to produce some effects, and in 2017 the rise of higher-performance connectivity services (e.g. commercial 100 Mb, 200 Mb and high-speed FTTH architectures) ramps up, marking the time evolution of Internet access offer to businesses and consumers. Also, the pattern is still the same as that already discussed in Chapter 1, being a natural one: whatever the year, the higher the bandwidth required, the lower the associated coverage, since it consists of a more complex technology, possibly developed later (and thus vertically lagged behind in the plot) and usually requiring huger investments to be implemented, which normally slows down the deployment program, in spite of the benefits attainable.

Complementary, aggregate information about the roll-out is exhibited in Figure 2.7, where the time evolutions of minimum distances from panel municipalities to the closest network elements (i.e., OLTs and OPBs, as discussed in section 2.1) are plotted: unlike what happens for OPBs, whose geographical locations are time-invariant through the panel window (green spline), the rise in fiber endpoints is clearly witnessed by the shortening of municipality-OLT minimum distances (orange spline) and, similarly, by the increase in the number of municipalities hosting an OLT themselves (blue spline).

A progressive top-down decomposition allows to deeper investigate the technological rollout, since the data enable a richer level of granularity. As a result, the evolution of Italian ultra-fast broadband connectivity (in terms of network performances made available to final users) has been hereafter outlined in three steps. First, in order to set a useful aggregation level for visual representation, the country is divided into previously defined conventional clusters: this allows performing some estimates in terms of shares of population served by ultra-fast broadband. Then, region-level dynamics are shown separately, unbundling the previous aggregation in the form of a tabular output on cabled municipalities, which is more suitable for detail rendering at this level. Finally, introducing the themes of the following sub-chapter, an equivalent table is shown by considering firms located in cabled municipalities.

The results of the first clustering are exhibited in Figure 2.8. With data available on municipalities population only in 2011, an estimated projection was performed, neglecting demographic dynamics and imagining a constant number of residents. This necessary assumption, however, is likely to be conservative: as made explicit in Table 2.3, the actual population evolution at a country level from 2011 to 2019 has a minimum right in the first year of this time series, so that the share of population to which new connection speeds have been made available through time is reasonably underestimated with the applied method. Moreover, the relative change in national population (both with respect to the reference year 2011 and in terms of first differences between adjacent years) is very restrained, which again supports the acceptance of the assumption made.

By cumulating residents through municipalities, an overall of 50.275.806 people sample is obtained, which represents a share of Italian population between 82,70% and 84,30%, depending on the year considered within the panel. Since no assumptions are made on actual subscriptions, and the focus is merely on availability of service, this proportion of coverage appears to be wide enough to extend the main deductions from the panel (potential) user base to Italian population as a whole.

In Figure 2.8, the first row of two plots (a, b) is referred to ultra-fast broadband deployment in general, while the following row (c, d) relates to FTTH; the left charts (a, c) conceive the country as divided into the three macro-areas defined before, while the right ones (b, d) go deeper into data content, refining the granularity for Northern and Southern clusters; in all plots, country average is shown as a reference.

The finer focus here pursued confirms the country-level deductions made at the beginning of this subsection, reassuring about the fact that no outliers are to be treated separately: in all plots, all macro-areas splines lie close to one another, developing according to the same pattern seen before, with a significant spike in kick-off years, a positive first derivative for the lines envelope but a negative second one, modulating the coverage expansion in time. As for FTTH pattern, instead, additional information arises from both breakdowns: Italy Center and South appear to have been cabled at a faster pace than Northern regions (for which the usual previous trend repeats), so that the resulting Italian average moves forward on an approximately linear path (even if the time series is still too short to forecast subsequent plot shape modifications).

Critically reflecting on this outcomes, it is quite unlikely that they might have been biased by different population or surface values, since, as exhibited in Table 2.13 (maintaining the colors of Figure 2.8 a and c, for comparison ease), no clusters of Southern or Center regions are ranked systematically ahead of Northern ones in terms of this two dimensions, being rather Northern regions those that tend to concentrate in the first positions of each classification. The extensibility of these outcomes to the panel period has already been discussed as for population data, and surface data are surely more stable than the previous ones.

Moving forward in the descriptive analysis, data refining comes down to the regional level. Here, a tabular breakdown was performed at a municipality (Table 2.6) and firm (Table 2.7) level, sequentially linking together the previous and the following chapter by means of information on ultra-fast broadband. As it happened before, this further deepening on data confirms, in an exploded view, the deductions made at the higher levels (e.g. timing of relevant years, overall trend), making now explicit the relationship among regions in terms of relative performances. Two different palettes were used for the dynamics of the share of region municipalities and firms (increasing from white to light blue, crossing grey) and the share of panel municipalities and firms (from white to green, crossing yellow), in columns A-C and B-D, respectively. Values shown are in percentage.

Grouping data both at municipality and firm level substantially leads to the same conclusions in terms of visual patterns, especially once insights from sub-chapter 2.2 are taken into account. Speaking in broad terms, the diffusion of ultra-fast broadband in general appears to have been globally carried out in a homogeneous way. The big picture of infrastructural upgrading develops in breadth throughout the country rather than in depth within single specific regions: rollout started in the same year and proceeded quite in parallel from North to South, leading to a 2019 scenario of covered firms which is described by a narrow interval of percentages (mainly, from 80 to 99% of regional firms), with only a few regions lagging behind, possibly owing to marginal geographical position (e.g. Friuli Venezia Giulia) or to some orographic hardships to installation (such as in the case of Valle d'Aosta and Trentino Alto Adige). Nevertheless, the corresponding municipality-level table shows more dispersed values, suggesting that technological deployment might have been geographically driven, as logical, by industrial hubs location, therefore reasoning at a firm before than municipality level, which results in the quite uniform national coverage detected a few lines above.

Evidently, these partial rankings are strictly depending on regional mismatches as for the number of municipalities and firms included in the panel, as discussed in previous Table 2.2 and in the following Table 2.10. Considering this premise, even if high percentages are present from North to South with respect to both dimensions, a slight relative advantage for Southern regions can be noticed, particularly if considering that Northern municipalities in the panel normally have a higher number of firms based within their borders (see Table 2.2). Indeed, this feature should help them rise the percentages at a higher pace with every new town or city reached by fiber optics connections, therefore possibly partially compensating an underlying existing gap in deployment speed between North and South, better focused in the following Table 2.8. Here, considering only relevant years I.e., from 2015 ahead), the progressive absolute increases from initial values of covered municipalities (in 2015 and 2017, respectively) are shown. Peaks are now evident for those regions with a higher number of statistical units in the panel, like Lombardia, Piemonte, Campania and Veneto, which obviously looked less outstanding according to the previous tables building perspective, based on ratios over different denominators among regions. Therefore, this output provides a necessary counterpart to complete the discussion conducted so far, rationally weighing the trends that can be read while interpreting the figures. Another interesting part of this table is that holding average and median evaluations through time of new cabled municipalities, both in absolute and relative terms, afterwards computed with respect to firms in each region and labelled with colors, increasingly ranging from light blue to green. Once more, the arithmetic average depicts a more uniform scenario than that returned by the median yearly shift, statistically more robust to extreme values and thus somehow dealing with the aforementioned mismatches. Intermediate results are obtained when considering a weighted average, computed using previously cabled municipalities within the region as weights, and thus embodying into the calculations the extent of "choice" for new interventions gradually available to TLC operators. Nonetheless, best performing regions eventually appear to be recurrent along multiple axes within those considered: Toscana, Sicilia, Lazio, Liguria, Campania above all.

A partially different trend can be commented for FTTH. Although the later operational start of implementation surely plays a role in figures interpretation, the overall progress appears slower and with frequent stops through the regions if compared to UFBb as a whole. Whereas works parallelization and harder technological difficulties associated to the newer technology could be sufficient sources of explanation for this pattern, it has to be specified that gaps on FTTH diffusion are contained within a narrower range of percentages, so that all detected deviations (and associated deductions) end up to be resized for their impact.

All these tables also highlight that, whereas the rollout of UFBb started in the same year for all regions, some were reached later than the others, particularly by FTTH services: Basilicata, Molise and Valle d'Aosta. It is still possible that some municipalities within these three regions were reached by new connectivity technologies in 2017, like the others. However, these are the less densely populated regions in the country, and Valle d'Aosta and Molise are the smallest ones as well. These aspects may have made it more likely to miss some cities along the sample selection process within these regions: in fact, these are also the last three in term of number of municipalities involved in the panel and, as later shown in Table 2.10, the last ones in terms of participating firms, too. Another possible explanation for this pattern is that TLC operators found economically less convenient to invest from the outset in these regions. Due to their smaller potential user base, and considering environmental obstacles to civil works (e.g. mountains prevalence in Valle d'Aosta and Basilicata), they may have delayed infrastructural updating in these areas until joint investments in bordering regions, and network externalities from users acquired in the meantime, made interventions eventually cost-effective and profitable for them to pursue.

2.4. Firms

In this section, a sequence of descriptive tests on firms' features is performed within the panel, dealing with qualitative (categorical) and quantitative aspect that will act as possible regression leverages in Chapter 3, always aiming at introducing at best the content of information available for further formal analysis, providing premises for their conclusions.

As previously mentioned, this panel contains data about 42.856 firms through 7 years (2013-2019), resulting from the balancing and pre-processing activities described in sub-chapter 2.1. These firms play the role of sampled individuals for the statistical study, being the entities at which level the outcome variable (i.e., patents number) and the variable of interest (i.e., broadband availability) concretely interact with one another.

Starting from Table 2.9, a brief outline of balance sheet and income statement most relevant entries, together with some not-strictly financial items (e.g. employees, firm age and especially patents counts), are exhibited. In particular, this output aims at conveying the idea of the extent of variability inherent in the data, along all considered dimensions: however, thinking about the scope of the analysis, and also bearing in mind that no specific requirements on candidate statistical units were imposed in the data selection stage, this scenario was reasonably to be expected, as well as wished, being heterogeneity a necessary (but not sufficient) condition for regression estimates, in presence of varying inputs (here, UFBb rollout). Again, as in many real life applications with huge datasets, average and median values remarkably differ from each other, since the biggest firms are disproportionately bigger than the bulk of firms with respect to how much the smallest are smaller. The so-introduced asymmetry in data distribution (as witnessed by relatively high skewness values) can nevertheless be tracked by maintaining the mean-median dualism under control, as coherently done up to now. As a result, the mean-to-median ratio ranges from 5,17 (as for employees) to 1.444,12 (as for intangible fixed assets), without considering that the most interesting variable (i.e. patents) falls from over 110 to 0 per firm within this comparison, therefore revealing a majority of firms with no innovation focuses according to the chosen metric. However, this insight is not to be considered peculiar or idiosyncratic about this specific panel, since it is a fact that only a minority of firms undertake patenting activities, which in the end makes of this metric a quite restrictive proxy for innovation.

As already done in sub-chapters 2.2 and 2.3, when dealing with geopolitical units and technological rollout respectively, this overview on panel firms coherently opens with a regional classification, also exploiting the macro-areas and clusters previously defined in 3.3. As already touched upon along sub-chapter 2.2, here is quantitatively shown how the highest share of available information is related to Northern regions, with almost two thirds of panel firms located there, and particularly to the North-Western ones, which make up the biggest macro-area in terms of businesses provenience, even though the region with less participant firms (i.e., Valle d'Aosta) is also part of this cluster. In particular, looking at the panel through the lens of firms' number clearly highlights how the amount of statistical units monotonically decreases from Northern to Southern clusters, as sequenced in the table. This is largely due to a different native distribution of firms through the country, with a higher density of firms concentrating in the North of Italy, as it was previously reported in Table 2.2. There, two out of the three highest median values (all the ones above the overall median) of firms per municipality (and four out of the six highest average values) were referred to Northern regions, with the remaining one – two – coming from central ones. Moreover, if Table 2.2 and 2.12 are compared, they show coherent values for Northern macro areas, whereas Southern and central regions play a wider role as for municipalities rather than firms, as justified by lower values of firms-per-municipality, especially for the South of Italy.

Many other aspects can be investigated by exploiting the panel content. For instance, Tables 2.11 a-c return some key statistics about firm size and its dynamics through panel years. As far as relative proportions are concerned, the panel appears to be composed by a majority of medium-sized firms (i.e., with a number of employees ranging from 50 to 249), which at least partially recalls the notorious prevalence of SMEs in the Italian entrepreneurial system. Coming to the size-transition table (Table 2.11 b), firms composing the panel generally maintain their size class along the 2013-to-2019 time window, as it usually happens, once classes widths are taken into account; nonetheless, upgrading overtakes downgrading for panel firms, as shown by frequencies comparison between triangular lower and upper sub-matrices as well as restated in Table 2.11 c, which explicitly exhibits positive employment macro-dynamics, too.

Similarly, a short discussion can be dedicated to firms' legal form (Table 2.12). Unlike before, in this case no transitions occurred, with all tabled values corresponding to the establishment ones, normally quite steady along firm lifecycle. The panel correctly mimics the country in the sizeable abundance of limited liability companies (S.R.L.), representing by themselves three quarters of the whole panel, leaving the rest to stock companies (S.P.A.). Both macro types are further split into sub-categories, even though "pure" original legal forms are preferably chosen by the majority of founders, covering together more than 85% of firms. Marginal shares are finally left to limited partnership enterprises (labelled S.A.P.A.), so historically less and less frequently adopted by Italian firms.

Another interesting opportunity is that of classifying panel firms with respect to their age: in order to do so, Table 2.14 and Figure 2.9 have been developed. The table allows visualizing the progressive age shift of firms growing older through the observation period (by design, all firms in the panel stay up and running for the whole time window under consideration). Coherently with the value calculated and reported in previous Table 2.9, the higher-frequency clusters are the 10-to-25 years old one for the first three years and then the 25-to-50 years old one for the remaining four, as soon as the average age (starting at 22,42 years old in 2013) turns older than 25 (25,42) in 2016. Changing perspective above the same aspect, the below figure plots the very skewed empirical distribution of establishment years. Due to its considerably leftward stretched tail, and considering the swinging trend in recent years (when some major economic cycle fluctuations may be recognized), the three canonical central position measures were drawn explicitly, in order to help summarize data content in a few reference values: 1991, the arithmetic mean, in red; 1993, the median, in green; 2001, the mode, in orange. The time range covered by firms in the panel starts back in 1865, only four years after Italian unification, with almost 50 firms aged one century or more at the beginning of the panel: this shows that, in spite of sampling limitations, panel creation included information about firms with a long business history and, consequently, with longer time to invest and innovate within their sector. Also, their survivorship up to recent years and all through panel years could be also partly linked to their ability to measure up with their sectors evolution and stay up to date pursuing the state of the technique affecting their core businesses, being innovation a key success factor in the long run, which makes of this restricted subset of firms an interesting cluster with possible differential behavior as for the innovation analysis performed in this thesis. However, beyond the deep dive into Italian industrial history allowed by this group of firms, the most fertile time frame as for firms participating into the panel is the last decade of the millennium, where all abovementioned statistical references lie.

An important aspect to be eventually considered is that of firms' distribution by sector. Following Ateco 2007 classification, also adopted by the Italian Institute for Statistical Studies (ISTAT), fourteen sectors are present in the panel. As it has been done for geographical areas, this classification can be simplified bottom-up towards the definition of five macro industries, as listed in Table 2.15, segregating trade from other services (seen as a single block) and extracting manufacturing and construction businesses as for secondary sector. Primary sector is absent from the dataset, apart from mining activities, which by the way represent a marginal share of overall data. Within the same table, a symbolic legend is presented, so as to match each sector with a single identifying letter to be referenced in subsequent charts and paragraphs, for the sake of synthesis.

As quite common in many developed economies, trade covers a relevant part of total businesses (more than a quarter), even if the lion's share, as typically Italian, is played by manufacturing companies, which accounts for more than a third of all enterprises; by adding construction firms, another relevant activity class in the country, almost 75% of panel units are included in one of these three industries, a fact that witnesses a very concentrated industrial structure around a few main strategical businesses.

In order to complement the information from previous table, enriching the mere frequencies with the additional layer of regional breakdown, two mosaic charts have been developed in Table 2.16 and Figure 2.10. They basically provide the same information of a pie chart in a more compact and visually comparable way, allowing to keep together all decompositions and thus vertically compare blocks extension within and between regions. While the first chart focuses on positional aspects, delivering merely ordinal information, the second chart, where sectors are conventionally ordered by descending averages of regional shares, exhibits the quantitative (thus, cardinal) extent of industry shares in each region. Again, after being aggregately ascertained, the prevalence of C, G, and F industries (corresponding to manufacturing, trade and construction sectors, respectively) is restated at a regional level: even if with some ranking shifts among the three, they always occupy the first three positions (with the exception of Liguria) and always jointly account for at least 61,22% (at most, 83,03%) of regional firms. On the other side of the plot, industries R, S, B and P steadily fill the last four slots of all rankings, with only four exceptions out of eighty values, and only nine percentages overcoming 1%: these are the less represented industries in the panel, and not by chance they all ended up included in the macro industry "services", when considering a rougher level of granularity.

In particular, apart from the first and the last four positions, which can be quite easily assigned on an overall basis, the intermediate six columns of the second mosaic chart show high variability, with industries M and Q being the most erratic among the fourteen considered, ranging from the 4th to the 12th position through the country seen through panel data. Thus, several statistical measures (computed on the first mosaic chart) were combined to outline the global ranking, reported in Table 2.17, always referencing Table 2.15 codes list.

2.5. Patents

This overview around the ingredients of panel analysis, started at municipality level and proceeded towards firms by means of connectivity associations, finally comes to a logical end when data about patent-proxied innovation is specifically considered. Conceptually, ultra-fast broadband was initially used to contextualize firms into the geographical background where they perform their innovation activities, and then firms were exploited in turn as linking key between the new connectivity technology and the output of interest, the main elements on which the whole thesis is pivoting.
First of all, a preliminary analysis regarding patents dynamics was performed, as for the extent of data variability among statistical units. This aimed at assessing whether sufficient shifts could be detected on the metric chosen to lead the analysis, so as to soundly set the econometric framework upon these values and finally try and interact this changes with different possible explanatory strategies. Outcomes from this qualitative-quantitative initial evaluation are exhibited in the following Table 2.18.
In the upper part of the table, the time evolution of patent portfolios throughout the panel is outlined. Here, the year-to-year differences (up to the sixth order) are computed year by year; next to the arithmetic average for each category, a moving average of first differences (from a 2-year bucket up to a 4-year bucket) is shown to enrich the time picture; finally, the median values for each n-th difference completes this overview, showing, as expected, that patents are pursued by a minority of firms, again restating it as a severe proxy for innovation intensity and diffusion. As clarified by color labels, ranging from red to green, all other measures highlight an initial decrease in the number of patents per firm up to 2015, while growth is detected whenever from then on. At a higher level, when considering the whole time window of the panel, the lower part of the table shows the same pattern described before, with increases detected on average at every degree of yearly difference, from lower values for short term shifts to consistently higher ones in the medium-long term (D4, D5 and D6, corresponding to p_t-p_{t-4}, p_t-p_{t-5} and p_t-p_{t-6}, respectively). This twice spotted pattern clearly allows to conclude there has been a non-negligible change in patent portfolios magnitude for panel firms: this is the change whose relationship with ultra-fast broadband is systematically inspected through Chapter 3, as programmatically set up for this thesis work.
Similarly, innovation expansion can be analyzed by means of the usual regional breakdown, as often performed so far. The perspective was accordingly switched from the number of patents to the number of patents-owning firms, in order to further deepen the previous insight and see how that patent increase spread through the country.
First of all, the time trend of firms with at least one patent ascribed among its assets is shown for each Italian region and every year between 2013 and 2019 in Figure 2.11. The so-produced plots

show a limited number of different patterns, but all coherent, from a new point of view, with the previous finding of an increase in activities affecting patenting. Apart from some almost monotonically increasing splines (mainly concerning Northern regions), convexities show minimum points in the first years of the pattern (i.e. always before 2016), with many of the regions following almost linear paths and all of them closing with a positive (or at least stationary) trend between 2018 and 2019: a very interesting emerging feature of panel data, reasonably non-spurious and significant as far as some fundamental processes are concerned in the underlying economics. More complex trend shapes are exhibited by those regions already discussed as problematic in previous sub-chapters, as for data quality and availability (namely, Valle d'Aosta, Trentino Alto Adige, Basilicata and here Sicily and Sardegna, as well). Globally, these plots suggest in macro terms how (and how much) innovation-based competition and quest for patents acknowledgement and business validation became more and more common (and eventually crucial) for Italian enterprises among panel years, with industrial property rights gaining increasing importance for strategical purposes.

Figure 2.12 complements the previous deductions by showing that the relative shares of patents-owning firms, while increasing in absolute number, remain substantially constant along the panel time window, with clustered bar charts that are almost horizontal within each regional group. This figure also allows to visually compare regional shares with each other, again leading to the major relevance of Northern regions (two from North-West and two from North-East in the first four) even in terms of patents property; Central and Southern regions follow in sequence, with few exceptions such as Liguria or Valle d'Aosta, mainly explainable with abovementioned geographical peculiarities or limited surface extensions.

Also, once data about patents-owning firms have been extracted from the panel, they can be enriched if combined with the total number of firms per region, thus obtaining a rough indicator for innovative areas through time, as depicted by panel information. This indicator is reported in percent values in the following Table 2.19, where the metric is increasingly tracked from white to dark yellow. Beyond the usual Northern regions, already top-ranked in many of the previous comparisons, some "new" regions outstand with respect to this specific focus, particularly Central ones, with Marche ranking second by the end of the panel period and first in terms of relative evolution (with a +7,81% of net change from 2013 and 2019). With this perspective, Southern regions are lagging behind more than in past comparisons, with the best ranked being Campania (only 12th): the yellow shades clearly encompass the Southern regions and Islands within brighter bands, emphasizing systematical differences among the macro-areas defined before.

Finally, another featuring aspect to be taken into account is that of differential industrial focuses on patent acquisition. In this regard, Table 2.20 is ordered by decreasing number of patents-owning firms per industry in year 2013; as it can be verified straight away, even though the overall values monotonically increase by 17,65% in the following seven years (leading to the same previous interpretation about a growing "patent culture"), the ranking is substantively unchanged in 2019, apart from sector F, which gains two positions, finally ranking fourth from sixth as it was.

Furthermore, in the surface plot of the associated Figure 2.13, the previous counts are made visual and computed in percentage of total patents-owning firms per year (the area below 50% was neglected to better zoom on the narrowest strips): as occurred while considering the regional evolution of this metric, industrial proportions of innovative firms show to be basically constant along panel years, too. This plot also shows how the Pareto principle is respected as for patents concentration, with 20% of considered industries (i.e. 2,8 ~ 3 out of 14) including around 80% of patents-owning firms.

When comparing these values with the national ranking of firms' abundance by sector (Table 2.16), the two rankings are qualitatively coherent with each other, especially in the first and last positions. This suggests that proportions of the surface plot considered here may be (at least, partially) explained by selection proportions; however, the macro differences between better and worst ranked industries are so significant that the overall pattern should be reasonably considered independent from sampling implications.

In conclusion, both data from geographical and industrial decomposition of firms starting or enhancing their patent portfolios depict a homogeneous growth along panel years. This closes the circle of the extensive descriptive analysis conducted so far, finally making way to the formal assessment of how innovation and technological changes may be related to one another from a statistical point of view; an econometric problem, to which the whole following chapter is dedicated.

3. Ultra-fast broadband and patents: an econometric evaluation

Collecting institutional, global evidence in Chapter 1, as well as operative, situational information in Chapter 2 was intended to create a strong base of suitable prerequisites for outcomes deployment through the incoming, final section of this master thesis.
Within this chapter, econometric inference is performed, so as to address some of the major open questions arisen along the dissertation.
First, an introductory presentation of the theoretical framework will be provided, outlining the features of the main variables, empirical constraints and modelling directions which programmatically built up and drove the quantitative estimation process since its early stages.
Therefore, once all the useful elements have been made explicit and organized towards their subsequent implementation, Chapter 3 enters its key-value section, where the incremental steps of the research are put together to bring out the progression in the discovery of systematic effects, better contextualizing final outcomes by retracing the path leading to them. In particular, several specifications, all consistently meeting the theoretical equations presented beforehand, are encountered through this analytical journey, with the objective of emphasizing different, thought-provoking aspects emerging from data; this is achieved by examining panel behavior from multiple modelling perspectives, leveraging on available expedients in order to summarize a set of major dynamics that are worth reflecting on.
While discussion on results' interpretation and associated implications is developed throughout the section, the Chapter specifically closes with a heterogeneity assessment, applying the baseline model to relevant subsets of economic data, therefore testing it on the field, with results that intentionally wink at possible future advancements of the research, conclusively outlined in the following, last paragraph.

3.1. Theoretical setting and empirical strategy

After parsing Italian fiber deployment from 2015 to 2019, the natural, subsequent analytical step is that of investigating the causal effect of this *UFBb* diffusion pattern (mapped along municipalities and years) on firms' innovation proxy, *I*.
In particular, ultra-fast broadband deployment is hereby measured according to two different perspectives, both evaluated at a municipality level:

- one, reflecting the intensive, binary nature of the rollout, with a variable notifying the absence/presence of UFBb in municipality *m* at time *t*, hereby labelled $\text{UFBb availability}_{m,t}$;
- another, more refined one, witnessing extensive, chronological features of the rollout, by

computing the (discrete number of) years elapsed (by year *t*) since fiber reached municipality *m*, thus giving importance to the age of NGAN's local segments; accordingly, this variable is hereby labelled $\text{Years of UFBb availability}_{m,t}$.

On the other side of the regression equations, as for the quantitative rendering of firm innovation, a target variable (defined at firm level) was derived from patents observations: the natural logarithm of the number of patents, $\text{Ln(Nr. of patents)}_{i,t}$, which mathematically smooths the original counter variable through a monotonic transformation and also allows relative comparisons, irrespectively of the absolute orders of magnitude among firms; this should also deal with scale effects in the data and/or possible flaws inherent to the original dataset, such as imputation mistakes of balance sheet figures at the original collection source.

Hence, once firm and municipality level controls have also been included in the model, the general problem under study can be formalized as follows:

$$I_{i,m,t} = f(UFBb_{m,t}, \vec{\mu}_{m,t}, \vec{\varphi}_{i,t}) \tag{A}$$

In particular, municipality controls $\vec{\mu}_{m,t}$ and firm controls $\vec{\varphi}_{i,t}$, even though not strictly explanatory by themselves, are meant to account for those unobserved factors, to whom they are correlated, that could influence the outcome variable besides the variable of interest, conceptually (and numerically) introducing an omitted variable bias if excluded from the modelling and left uncontrolled within the regression error ($\varepsilon_{i,m,t}$ or $\delta_{i,m,t}$, as in the following equations (B), (C), respectively). This is due to imperfect randomization of the treatment (i.e., fiber wiring), which, as it usually happens for observational data in social-economic studies, was not administered for statistical purposes via a planned experimental protocol. Therefore, these variables help disentangle the variable of interest and the econometric error, avoiding systematic disturbance and raising the quantitative reliability (in magnitude and sign) of its coefficient.

Conceptually recovering the setup of Cambini et al. (2021) and Cambini, Sabatino (2021), the previous meaningful items can be combined into the following two regression settings of reference, from which all subsequent specifications descend:

$$I_{i,m,t} = \beta_{1.0} + \beta_{1.1} UFBb_{m,t} + \vec{\beta}_{1.2}\vec{\mu}_{m,t} + \vec{\beta}_{1.3}\vec{\varphi}_{i,t} + \vec{\beta}_{1.4}\vec{S}_{i/m} + \vec{\beta}_{6}\vec{T}_{t} + \varepsilon_{i,m,t} \tag{B}$$

$$I_{i,m,t} = \beta_{2.0} + \beta_{2.1} UFBb_{m,t} + \vec{\beta}_{2.2}\vec{\mu}_{m,t} + \vec{\beta}_{2.3}\vec{\varphi}_{i,t} + \vec{\beta}_{2.4}\vec{S}_{i/m} + \vec{\beta}_{7}\overrightarrow{RY}_{r,t} + \delta_{i,m,t} \tag{C}$$

where $UFBb_{m,t}$ summarizes $\text{UFBb availability}_{m,t}$ and $\text{Years of UFBb availability}_{m,t}$, $\varepsilon_{i,m,t}$ and $\delta_{i,m,t}$ being the usual mean-zero regression errors.

Both equations are structured as two-way fixed effects difference-in-differences (DiD) models, with treatment administration (i.e. municipality broadband provision) being non homogeneously distributed through time and space. This is a common starting OLS framework to be applied for the exploitation of panel-data peculiar information content. In fact, it enriches the flat-time results of cross sections that could be extracted from the panel (where a systematic difference among treatment and control groups would be sought through statistical units as "out of time") by also considering time-series complementary insights (capturing, for a single unit within the panel, response variable deltas over time) that explicitly carry the dynamic, inherent nature of panel data into the analysis. Once acknowledged the analytical influence of time, further dimension, a natural concern is that of accounting for likely absolute or relative (i.e., discerning by region) time-trends: this is accomplished by alternatively introducing either year or region-year fixed effects ($\vec{T}_t$ and $\overrightarrow{RY}_{r,t}$, respectively), whose mutually exclusive choice basically differentiates (B) from (C). These arrays of dummy variables control for all those unobserved trends developing through time (and space, such as in (C)) that are invariant with respect to municipality and firm's selection through the panel (or through a specific region, as for $\overrightarrow{RY}_{r,t}$, where subscript r identifies a regional effect[50]).

The second-way fixed effect is analogously implemented by state variables $\vec{S}_i$, representing a vector of time-invariant firm- or municipality-conditional indicator variables (respectively, $\vec{F}_i$ and $\vec{M}_m$), comprehensively absorbing idiosyncratic, unobserved aspects related to the i-th enterprise or the m-th municipality, which all together usually account for consistent shares of total data variability. These two wide families of dummy variables prevent the emergence of basic omitted-variable biases, which would be normally embodied into the model when neglecting the multi-dimensional, panel nature of available data.

Technically speaking, both setups also declare an event-study underlying design, since they exploit the staggered roll-out of UFBb as the situational occurrence used to statistically explain time variations in the innovation paths of firms, before versus after the discontinuity brought by fiber wiring. Moreover, as expressed by the differing subscripts between *I* and *UFBb*, this methodological setting is pursued with an intention-to-treat (ITT) approach: firms included in the study are considered as belonging to the group they were originally assigned, regardless of whether the units which were expected to be treated finally were or not; in other words, in order to assess a firm-conditional variable such as innovation *I*, inference is performed by borrowing *UFBb* year-by-year municipality-level information, thus reasoning from a firm's "potential access" point of view, ignoring the amount and distribution of actual ultra-fast broadband adoptions. The model tests the effect of

[50] The regional, additional dimension also helps deal with the disproportion affecting observations from Northern regions with respect to Southern one, as discussed along Chapter 2.

“assigning” (i.e. UFBb coming to town), rather than “receiving” ultra-fast broadband (i.e. gaining access to it), as due to the inherent structure of the starting dataset, which doesn’t capture the detail of firm’s ICT capital nor tracks the existence of commercial agreements of Internet provision for the enterprise segment, finally making firm’s decision-making processes around subscription, as well as the evaluation of Average Treatment effects on the Treated (ATTs), out of reach (and scope) at a firm level with present data.

3.2. Definition course of baseline model

The first, exploratory applications of this modelling strategy are exhibited in columns from (1) to (4) of Table 3.1. Since $\mathrm{Ln(Nr.of\ patents)}_{i,t}$ is expressed as a logarithmic function, using all observations from the panel (whose patent median is equal to zero) would cause an uncontrolled loss of information for the huge amount of impossible calculations encountered, leading to panel unbalance and making inference tools (and results) weaker. For these numerical reasons, preliminary estimations have been conducted on a reduced subset of the panel, creating a spin-off with those firms that have been owners of at least one industrial patent through all the time window of the analysis, hence ensuring mathematical existence of the associated logarithmic values.

Through a stepwise approach, varying one parameter at a time so as to better identify the drivers of subsequent changes in regression coefficients, columns (1) and (2) embody municipality fixed effects (i.e., $\vec{S}_{i/m} = \vec{M}_m$) whereas specifications (3) and (4) are set with a firm’s fixed-effects layout (i.e., $\vec{S}_{i/m} = \vec{F}_i$); furthermore, moving from (1) to (2) and from (3) to (4) reflects a model change from previous equation (B) to equation (C).

As far as controls are concerned, an invariant item through all discussed specifications is the minimum distance from each municipality to the fiber infrastructural inputs at OLTs, accounting for municipality’s detachment from fiber upstream endpoints and thus providing a proxy for civil works costs associated to UFBb provision to final users; the absolute population count accompanies this first element and completes municipality-level controls through Table 3.1**,** working as modulators of municipality’s influence on the outcome variable.

From a firm’s point of view, the accounting added value was transformed by means of natural logarithm and selected as a firm control in addition to employees count, which creates a parallel with municipality population: while the latter tries to seize the effect of firm’s size, the former is deemed to broadly approximate “health conditions” of businesses and, above all, capture a reasonable connection with firm’s innovation intensity.

Through this summary output, with clustering performed at municipality level (the finer granularity for fiber information), the variable of interest $\mathrm{UFBb\ availability}_{m,t}$ is moderately significant, with an associated p-value ranging from 3,6% to 8,1%, along three specifications out of four, with comparable orders of magnitude of beta estimates (3,77% ÷ 4,37%) which thus appear substantively irrespective of state $\vec{S}_{i/m}$ and time $\vec{T}_t$ (alternatively, space-time $\overrightarrow{RY}_{r,t}$) fixed effects' choice.Moreover, time and region-year fixed effects prove to be highly significant in all the estimations considered in Table 3.1, suggesting a remarkable role for innovation waves in time and for the heterogeneity of innovation habits and culture through the country, as already diffusely highlighted and discussed along Chapter 2.

These results, consistent with the economic literature expectations, manage to capture some preliminary evidence of the causal relationship being investigated, pointing out some interesting trends underlying data variability and fostering further research towards a deepening of the analysis; also, it has to be noted that evidence of these effects stems out in spite of using the candidate explanatory variable with the least rich information content[51], which reveals the intensive nature of fiber roll-out is already enough descriptive to bring out systematic statistical evidence to detect hardly-random outcomes. In particular, this means that the resulting effect may exhibit a binary nature, as if duration of patenting procedures (as reasonably conceivable) was not that relevant: a possible, reasonable explanation of this outcome is that, anticipating the stages of infrastructural roll-out (which is publicly disclosed) affecting their businesses, firms may implicitly include fiber benefits in their objective function, thus fostering innovation and applying for industrial patent titles even before the actual wiring of their neighborhood. Starting earlier with the deployment of preparatory practices could finally help firms have an adequate pool of resources to be ready and exploit the incoming complementarities of ICT asset, betting on economies of quickness to achieve competitive advantage.

Despite these encouraging, early insights, some comments could be made on the underlying setup, highlighting room for model improvement.

First, the spin-off creation, although simplifying the scenario, reduces at the same time external validity and applicability of deduced coefficients, due to extrapolation limitations, potential selection bias and lower accuracy coming from the partial view based on a reduced sample. Second, even though individually and jointly significant in statistical tests, a measure of firm's added value potentially introduces endogeneity into the model, since the direction of the causal influence

[51] For the sake of thoroughness, it has to be specified that four more regressions, equivalent to the ones displayed in Table 3.1 a, were fitted with categorical levels of $\text{Years of UFBb availability}_{m,t}$ as the variables' set of interest, obtaining high joint significance (F-tests with p-values lying in the interval [1,09% ; 2,58%]); however, due to no individual significance and an ambiguous pattern of algebraic signs, this output wasn't deemed informative as it was, which finally led to not include it in the present dissertation.

among patents and added value is not clear, nor theoretically predetermined: in fact, even if businesses structurally pursuing (and attaining) innovation are likely to achieve a price premium for their innovative products/processes, thus leading to higher added value figures, it is also reasonable to think of firms with high(er) added value as being more productive and successful, therefore having more financial resources to invest in research and foster a positive feedback, rising cycle of innovation. That said, previous coefficients determination could actually be biased by this loop mechanism of reverse causality, with regressive coefficients diverting from their real, unknown values since forced to incorporate and quantitatively reflect both ways of the implication with half of the necessary terms a system of two equations would have. This substantially reduces estimates reliability because of omitted variable bias, being violated the assumption of exogenous covariates on the explanatory side of the equation, and requires further deepening on the matter to confirm or redefine these provisional outcomes (specific discussion on this matter is provided in the following section 3.4).

Solution to both these issues, along with additional advancement into the analysis, is provided with specifications enclosed in Table 3.2. For all regressions presented in the following, *ln*(added value) was replaced by the balance sheet entry for intangible assets, which coherently sets an accounting lower bound for firm patents, entering the composition of assets towards a (proxied) insight on businesses' innovation focus; moreover, this value is less likely to generate endogeneity concerns with respect to value added, being it conceptually more loosely and indirectly bound to the value generation processes that could cause the model to drift towards the aforementioned inconvenience[52].

In addition to that, counts serving as controls (i.e., population at municipality and employees at firm level) have been here redefined by once more exploiting the mathematical benefits of the usage of natural logarithm, as described above in this subsection: this helps hopefully better describe the (often non-linear) dimensional impact of statistical units (through regression variables) on the outcome variable, while also increasing formal coherence in the diffuse usage of logarithmic expressions of variables throughout the equations, working in the context of a log-linear model.[53]

Instead, estimation sample restriction from 42.856 to 11.039 firms (and from 4.454 to 1.984 municipalities) can be overcome by incrementing original patent values so as to admit all observations

[52] Alternative controls capable of forestalling endogeneity, such as total assets and capital structure, were tested on the same baseline models described in the following, obtaining comparable outcomes in terms of economic implications; however, intangibles were selected for their intrinsic connection with patents.

[53] Moreover, using employees and intangibles as explicit controls produces better estimates than those obtained with $\frac{patents}{employees}$ or $\frac{patents}{intangibles}$ as dependent variable; indeed, once tested, equivalent models ended up with higher standard errors, due to the hardships in disentangling the parallel variation of numerator and denominator when employees/intangible assets were brought to the left side of the regression equations.

to the logarithmic transformation, as shown below:

$$patents \rightarrow patents + 1,$$
$$\ln(0)\ (undefined) \rightarrow \ln(0+1) = \ln(1) = 0$$

This transformation has little quantitative impact with respect to how data are processed through these regressions: logarithms allow to interpret coefficients as percent effects induced by explanatory variables on response variable, and such a relative interpretation should mitigate potential drawbacks of the shift, particularly considering that around three quarters of observations couples through the panel (186.855 out of 257.136, i.e. 72,67%) are composed by both null values, so that *ln*(1)-*ln*(1)=0, correctly meaning no variation occurred along the last year and witnessing the benefits of this transformation, since the original zeros wouldn't have been comparable in relative terms before applying it.

After these re-design actions, model estimations are displayed in Table 3.2: sample size is restored to the original 299.992 observations, averting information under-exploitation and recovering sampling proportions described in Chapter 2, which make up the best available proxy for the country as a whole.

Nonetheless, the sub-panel on which previous regressions had been fitted was composed by a specific type of firms, characterized by the fact of persistently owning patents through the whole seven years of panel time scope, whereas the overall panel is more variegated, also including firms not holding a patent portfolio in one ore some of the years under study. This difference in selection mix is reasonably to be addressed as the main cause for significance decrease on coefficients of interest in specifications (5) and (6) from Table 3.2. Re-expanding the estimation sample, indeed, is likely to have rescaled the effects, due to the inclusion of observations with portfolio patterns other than the only one observed within the previous spin-off.

Moreover, a choice among firm and municipality fixed effects, alternatively tested in the previous regressions, was made in favor of firm-specific fixed effects, considering patents are defined at this level. However, by doing so the sample for the definition of the dummies' vector is broken into 42.856 instances (the number of firms) rather than 4.455 (the number of municipalities), spreading information over a wider set of variables, which make up the majority of regression items and are responsible for segregating units' inherent features from fiber-specific effects: hence, higher uncertainty around firm effects' estimation leads to reasonably worse separation and attribution of variability to specific effects, and it joins the abovementioned causes in hindering the unveiling of potential non-random dynamics.

This apparent deadlock is broken by explicitly adopting a measure of innovation intensity to account for the peculiarity of the spin-off panel, which suggested that the systematic ownership of patents,

achieving the continuation in time of firm IP portfolio, could be a relevant aspect behind the considered response variable, consistently witnessing firm's will of pursuing a business model which steadily relies on innovation. To do so, being constrained by the limited number of years spanned by the dataset, a quite severe proxy for innovation intensity was defined, creating a binary variable that turns to 1 if and only if firm *i* owns at least one patent through all panel years; the choice of such zero threshold was targeted on the value of patents' median[54]. This auxiliary variable, which both conceptually and practically brings estimations back to the spin-off setting, can be thought as having been "pulled out" from firm fixed effects, and performs a reallocation in the mathematical duty of explaining shares of observed variability, by means of a finer, more structured scheme than that implied before, which emphasizes the descriptive relevance of innovation intensity, previously poorly managed for being implicitly drown into the idiosyncratic, constant term of each firm.
By interacting this dummy with the main effect of UFBb availability, the evidence on sign and significance of fiber connectivity is specifically restated, consolidated and even strengthened with respect to Table 3.1 through the interaction term, considering that relevant p-values significantly fall to a minimum of 0,1‰, decreasing from the previous, "best" value of 3,6%, which was already per se desirable. Decoupling the effect of innovation intensity demonstrates ex post the suitability of controlling for innovation intensity, with a differential influence (at least significant at 0,1‰ α-level) being only felt by those firms that, when UFBb reaches the municipality of their operating site, were previously equipped with expertise in patenting procedures and active patents' exploitation. Once more, both time and region-year fixed effects reveal to be an important aspect of the world described by the model; nevertheless, different specifications prove themselves resilient to the inclusion of one or the other, considering the comparable size of the estimated effects (7,84% and 6,91% in (7) and (8), respectively). The importance of these fixed-effects layout is reaffirmed by even their single levels being individually, highly significant, in spite of inevitable internal collinearity, whose discrete scattering normally inflates standard errors and can therefore easily lead to non-significance of single coefficients, even in presence of joint significance of the variables set as a whole.
These significant deductions can be further reinforced and even expanded, by showing complementarity of results when rephrasing the analysis and re-routing quantitative exploration on the extensive aspect of fiber rollout, thus employing $\text{Years of UFBb availability}_{m,t}$ in the shoes of the variable of interest. To this purpose, results of Table 3.3 a-b complete the latter table towards the identification of the baseline, econometric framework of the thesis, which will be assumed as a reference for later remarks and heterogeneity checks.

[54] Alternative values (namely, threshold = 5, 10, 25, 50, 100) were tested, always exhibiting (ceteris paribus) no significance at all for coefficients of interest.

The two specifications within the tables exploit the dynamic perspective granted by $\text{Years of UFBb availability}_{m,t}$: taking the null-level combination of both variables as the interaction baseline, $\text{Years of UFBb availability}_{m,t}$ and $\text{Innovation intensity}_i$ outline different evolution paths for fiber effects along a 5-years horizon, therefore normally allowing inference in the short-mid term, when reasoning in terms of usual characteristic times of enterprise processes.

Thanks to the versatility of interaction estimates on categorical variables, these outcomes are presented in two ways, providing complementary insights on coefficients interpretation, as displayed through Table 3.3 a to c and later Figures 3.1 a to d; the connection among these two coefficients layouts, showing them as the two sides of the same coin, can be ascertained by considering the equivalence among the following pseudo-equations (D) and (G).

A legend for tables and figures comprehension can be given by means of simple, intuitive pseudo-code, aimed at giving the conceptual intuition underlying tabulated output by showing the generating computations; this will also hopefully make the meaning of labels, as used in table titling, clearer. In the following pseudo-equations, sentences in brackets indicate the effect on the group being from time to time considered for comparison among discrete levels of one categorical variable, whereas the “@” indication outside main calculations sets the explicit level of the other categorical variable, defining the value of the second dimension of the two-way analysis.

Starting with figures from Table 3.3 a, and recovering table labels for a proper matching, the meaning of quantitative estimates can be deduced as follows:

- $Main\ effects\ of\ fiber:$

$$[(UFBb\ years = n) - (UFBb\ years = 0)]\ @\ Innovation\ Intensity = Low \tag{D}$$

- $Differences\ in\ effects, matched\ by\ innovation\ intensity$:

$$\{[(UFBb\ years = n) - (UFBb\ years = 0)]\ @\ Innovation\ Intensity = High\} + \\ - \{[(UFBb\ years = n) - (UFBb\ years = 0)]\ @\ Innovation\ Intensity = Low\} \tag{E}$$

Instead, numbers from Table 3.3 b can be interpreted as below:

- $Main\ effect\ of\ innovation\ intensity$:

$$[(Innovation\ Intensity = High) - (Innovation\ Intensity = Low)]\ @\ UFBb\ years = 0 \tag{F}$$

- $Main\ effects\ of\ fiber$:

$$[(UFBb\ years = n) - (UFBb\ years = 0)]\ @\ Innovation\ Intensity = Low \tag{G}$$

- $Two - way\ difference\ in\ connectivity\ and\ innovation\ among\ firms$:

$$[(UFBb\ years = n)\ @\ Innov. Intensity = High] - [(UFBb\ years = 0)\ @\ Innov. Intensity = Low] \tag{H}$$

Finally, to complete the framework, a straightforward evaluation of UFBb specific effect within the group of innovative firms can be derived from table estimates by summing (E) and (D) together. Conceptually, this corresponds to adding the interactive effect of the two dimensions of the analysis (E) to the basal UFBb effect (formally, the main effects of $\text{Years of UFBb availability}$, labelled as D), which was statistically assessed in firm conditions of low innovation intensity:

$$\{[(UFBb\ years = n) - (UFBb\ years = 0)]\ @\ Innovation\ Intensity = High\} \qquad \text{(I)}$$

A final visual rendering, useful in tidying figures up by unwinding them through time, is also given in the following Figures 3.1 a-d, which are built on previous equations from (D) to (I) written in pseudocode. Here, confidence intervals (CIs) have been plotted at conventional 10%, 5% and 1% bilateral levels; hence, CIs boundaries are displayed as dashed lines confining estimates' splines, with a density of marks that is function of the associated significance level.

All things considered, some interesting patterns arise from the econometric layout of Table 3.3.
First, even for those firms not (possibly, not yet) reached by UFBb connections, an innovation-oriented personality and management style still shows to play a significant role in explaining patents increases, with a coefficient comparable to those exhibited by fiber impacts through previous regressions, again quite invariant to the choice among year and region-year fixed effects.
Then, going deeper into estimates implications, Figure 3.1 a shows that being reached by the ultra-fast broadband NGN appears to mark an advantage for those companies having a high propensity to innovate, with respect to those that are little (less) innovative and not reached by the service. Even if the limited time window makes it harder to work out deeper conclusions on the analytical shape of fiber age's impact on innovation, the detected virtuous trend exhibits a clear concavity: whereas the initial growth in coefficients could be interpreted as an early trace of delay mechanisms in fiber exploitation[55] and patents attainment, saturation appears to arise among the second and third year of fiber availability, suggesting the possible relevance of quick investments against the catch-up threat provided by local or industry competitors. These deductions are mitigated, however, when specifically entering the group of highly innovative firms (according to the elected proxy) and assessing the within-group "treatment effect" of UFBb provision: as shown in Figure 3.1 d, the expected yearly effects are scaled down with respect to the previous ones and the overall influence is shortened in its time span. Even though higher uncertainty in (E) values estimation, reflected in the variability composition of (I) CIs, make not significant the negative mid-long term

[55] In particular, the evidence of slow rent extraction associated to ICT assets finds a quite unanimous agreement in economic studies about the effects of technology advancements on developed markets and internal functioning of businesses; to this purpose, see for example P. Tambe, L. M. Hitt, *The productivity of information technology investments: new evidence from IT labor data*, from Information Systems Research, 2012.

shift detected on coefficients, this also means the as-is model allows only partial conclusions around potentially more persistent effects of UFBb on the outcome of interest.
Moving to the counterpart focus, Figure 3.1 c shows evidence of a potential polarizing effect of UFBb deployment: here, municipality wiring seems not only neutral, but could be even detrimental for less innovation-focused firms, with their patent portfolios significantly, monotonically shrinking through time after their municipality was fiber-wired. Considering UFBb base-level is conventionally set at 0, i.e. in conditions of fiber absence, this detected pattern shows that firms with inherently low innovation appetite may have, for the specific nature of their businesses, no decisive interests nor convenience in exploiting fiber benefits, thus restating the crucial modelling importance of the interaction setting towards the clustering of relevant subsets of firms.
As for a possible mechanism justifying these results (particularly, the negative sign of the estimates), it can be noted how wider access to digital applications is likely to jeopardize the conservation of patent portfolios, with titles that may move "upstream" among firms with different degrees of innovation intensity, being transferred to more innovative businesses, which could be also more experienced in envisioning and realizing competitive advantages springing from ultra-fast broadband implementation. The result outlines a world where less innovative firms, even when willing to employ UFBb, may be progressively penalized in time for their initial, weak strategic profile around innovation, adopted before fiber roll-out and revealing its hurdling implications only with the event of wiring, i.e. with a form of path dependence that might finally overcompensate benefits extraction.
Moreover, the expected, negative effect suffered by less innovative businesses numerically outweighs the negative one on innovative firms, with the latter being, however, less precisely estimated. Towards a better understanding of innovation dynamics, this disproportion, typical of a negative feedback system, suggests the potential existence of a non-linear, underlying process were innovation value is globally (i.e. from a firms' population point of view) filtered, well reflecting reasonable competitive schemes at a deeper, more intrinsic level than that of ultra-fast broadband provision.
Nonetheless, these peculiar trends would surely deserve a specific deepening in future research, possibly by tracking patent transactions among connected value chains, with potential implications on vertical integration of innovation and industry structure as a whole. On the other hand, the persistent detection of coefficients patterns possibly hints at dynamic modelling as a natural follow-up for further, future explorations along these branch of research.
All previous considerations can be applied to both (A) and (B) regression frameworks, i.e. to the inclusion of either year or region-year fixed-effects in specifications 9 (a, b) and 10 (a, b), respectively. This is clearly exhibited throughout Figure 3.1, with model (A) results being plotted in green

and model (B) results plotted in yellow: indeed, colored splines are systematically coupled, lying close to one another in all boxes; this evidence strikes a blow for robustness of coefficients of interest, which thus result substantively insensitive to the choice among setting (A) and (B). Accordingly, in order to avoid an excessive overlapping of plots, CI construction was pivoted on the sole outcomes from (A): in fact, counterpart CIs for model (B) would have been very similar, therefore bringing little additional information to the discussion.

Again, in spite of likely multi-collinearity concerns, trends at both levels of innovation intensity are quite significant in their single components, and for both fixed effects settings (years in (9), combination of region and year in (10)); moreover, the inclusion of one or the other, i.e. the adoption of model (B) or (C) leads to very similar estimates, as generally happened with previous specifications.

3.3. Ancillary modelling considerations on FTTH

After examining the impact of fiber connectivity as a whole, a conclusive appendix to this validation process, which contextually tested inherent robustness of specifications on the way, can be constituted by the investigation of potential, specific effects of FTTH connections[56]. As discussed in Chapter 1, this is currently the fastest fiber architecture being implemented in New Generation Access Networks; a deepening on the (statistical) benefits of this fiber layout, straightforwardly comparable to global results presented before, is displayed in Table 3.4.

The main difference among Table 3.3 and Table 3.4 involves the varying significance of coefficients of $\text{Years of UFBb availability}_{m,t}$[57] levels, being the increase in the granularity of the variable of interest the only change occurred in the model. The diminishing pattern detected for low innovation-intensity firms still persists (column "Main effects of fiber" in the cross tabulation), with comparable figures to those previously obtained. However, as far as high innovation-intensity firms are concerned, the virtuous dynamic affecting their patent portfolios ("Two-way difference in connectivity and innovation among firms", in the table) quickly loses significance through time when refocusing the analysis on Fiber-To-The-Home alone.

This apparent step back in the identification of causal effects is likely due to information shortage specifically regarding FTTH: as diffusely discussed in Chapter 2, the roll-out of FTTH best-performing lines began later than that of other fiber solutions, with at most 3 (versus 5) years of availability for

[56] Whereas specifications (11) and (12) reported here highlight some interesting insights to be discussed, an attempt to disentangle FTTH from UFBb on this dataset (by estimating a model explicitly controlling for high-speed connections) didn't produce significant nor univocal results during model fitting, and was therefore excluded from the present dissertation.

[57] No significant pattern, with rather ambiguous multiple sign shifts encountered, was detected when using $\text{UFBb availability}_{m,t}$, i.e. by trying to estimate models (7) and (8) with a specific focus on FTTH "sub-"effect.

those municipalities reached first by civil works. Thus, by the end of 2019, statistical information contained in $\text{UFBb availability}_{m,t}$, grouping together all fiber architectures, was majorly related to less penetrating solutions in terms of length of fiber segments, e.g. Fiber-To-The-Cabinet, exploiting the previous TLC infrastructure to stage the deployment. The shorter span of the deployment as "sensed" by the operating dataset, when combined with the lagging nature of ICT benefits' emergence, is thus likely to explain the main offsets among these related estimations, dealing with the partial drift in conclusions that could be drawn at first sight when reading Table 3.4. Also, unlike mid-range solutions coping with the same technological problem, higher-speed connections are likely to be adopted by business clients in a more selective way, which is harder to be detected by means of brief panels; besides, this differential effect may be still partially unexpressed, and its early traces could be reasonably embedded in the macro, binary effects of UFBb availability detected so far.

3.4. Dealing with endogeneity concerns

The implications of rising availability of fiber connectivity on the thriving of IP portfolios, as detected and discussed along the previous sections, may still feel the effects of potential model endogeneity, with non-exogenous influences affecting the truthfulness and reliability of coefficients of interest, thus biasing the estimation process of the investigated causal relationship. Indeed, it has to be recalled that ultra-fast broadband deployment was not planned by default so as to homogeneously spread fiber through the country; being it the result of private-public mixed investments (as discussed by the end of Chapter 1) may have led to targeted UFBb diffusion according to the economic convenience of TLC operators, which would result in the treatment being not randomly administered to statistical units, as assumed in the introductory theoretical framework. Also, the confounding effects linked to the abovementioned implementation plan design are not necessarily offset when considering the mismatch existing among private interest and the public object function, which should by definition aim at prior fiber diffusion (towards productivity and innovativeness enhancements) right where it is less appealing to private intervention; the unknown weights in the actual co-existence of these two incentives makes the overall effect (and the algebraic sign of the associated bias) not soundly forecastable beforehand.

In terms of regression estimates, the result of such real-world dynamics would overlap an additional causality relationship to the ones, with the degree of firms' innovation locally influencing the steps of fiber roll-out, thus moving in the opposite direction with respect to the effects that are object of this thesis; such underlying mechanism of reverse causality, as already mentioned in section 3.2, could systematically bias the defined baseline estimates, and with an unpredictable direction.

To cope with such dangerous modelling inconveniences, potentially threatening the main results of the thesis, an instrumental-variable (IV) evaluation was set. Speaking in current terms, this conventional approach against endogeneity biases aims at systematically isolating the approximately endogenous share of ultra-fast broadband; this "re-written" version of UFBb is subsequently implemented as the variable of interest, working to explain fluctuations in patents portfolios. This Two-Stage Least Squares (TSLS or 2SLS) estimation shuts out endogenous stresses on the model by unloading the variable of interest with spurious, extraneous explanatory responsibilities, reallocating regression duties on the set of employed variables.
To this extent, exploiting the incumbent upstream infrastructure (as mapped and matched with firm information throughout the original dataset), the choice of the prior regression instrument fell on what was labelled $Distance\ from\ closest\ OPB_{m,t}$: in fact, the distribution of TIM's backbone nodes, dating back to the early 2000s, can be considered exogenous[58] to any later contingencies connected to firm innovation[59]. Subsequent interaction of this variable with a post-UFBb dummy, accounting for differential effects around UFBb introduction[60], coherently triggered the IV assessment, which was performed on both model (A) and (B) frameworks.
Moreover, in order to fine-tune the analysis and better highlight useful instrumental insights, additional covariates were included in the two tested specifications, by interacting them with the abovementioned post-UFBb dummy, finally joining usual controls employed so far. Generalizing previous regression layouts, these further elements include both municipality-level features (in particular, the average numbers of patents and employees, the urbanization degree and the number of panel firms) and firm-level ones (specifically, a sector classification through the five macro levels defined by the end of Chapter 2); apart from the first two, baselined in year 2013, the others are time-invariant elements within this panel. Information coming from these additional controls was also used to build auxiliary regressors for the 1st stage, proper IV estimation, declined in the form of trends through interaction with panel-years dummies.
Such overall set of modelling tools, by controlling for basal differential trends in firm's innovation, is meant to reorder the mathematical attribution of variability shares to regression items, thus providing suitable sensitivity and accuracy to first-stage estimations (whose reliability is crucial for

[58] An evidence of this time-invariance can be found in the previous Figure 2.8.
[59] See also Cambini et al. (2021) for an analogous setting.
[60] This variable takes the value of 1 for years later than 2015, when fiber roll-out started approximately on a national scale; the consequent exclusion restriction assumption is that, whatever relationship may exists between firm innovativeness and municipality distance from the closest OPB, this relationship should be constant in spite of the onset of ultra-fast broadband, choosing year 2015 as the first relevant milestone in the deployment (see Chapter 1, sub-section 1.1.5 and Chapter 2, section 2.3 for further details).

an effective implementation of the method) and consequently to their final, 2nd stage application to the outcome of interest.

Results of this progressively constructive evaluation are separately presented in Table 3.5 a. Investigation is performed on the entirety of the operating panel, thus exploiting all the available information towards the best possible refinement of coefficients; being in the context of a fixed effects, i.e. within-panel estimation, the within R-squared values from (13 I) and (14 I) give positive, preliminary evidence about the sturdiness of this IV variables setting, substantively enhanced by the highly significant F-tests of Table 3.5 b[61].

Coming down to 2nd stage outcomes, UFBb-implied effects on portfolio dynamics now amount to roughly 14% and 10% in the two considered layout, incrementally reaffirming the positive, hardly random influence of ICT improvements and New Generation Access Network implementation on innovation figures from specifications (5) to (10). The revealed, slight increase with respect to the previously determined coefficients (which makes up a quite standard occurrence in IV evaluations) is what numerically witnesses and quantifies the likely extent of endogeneity bias embedded into baseline specifications, which appear to be therefore mildly underestimating the importance of the causal relationship under study. This scaling-up[62] that occurs with (13 II) and (14 II) IV estimates (allowing backward inferences that move in a desirable direction of growing effects) is an additional, decisive proof that statistically confirms the existence of a link among connectivity and firm innovation, finally providing relevant indications for the definition of economic policies and the associated future regulatory interventions.

3.5. Further specifications: expanding the issue under analysis

During preliminary setup of estimation activities, the issue under analysis was also tackled from another empirical perspective, which can be in turn quantitatively rendered by means of a further econometric model, so as to expand the methodical of the current dissertation.

To this purpose, a dummy variable labelled $\text{Portfolio increased}_{i,t}$ was created, capturing both the event of a patents portfolio creation and that of an increase associated to a preexisting one, occurring between two consecutive years. This supplementary, binary variable, sharing the data content

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[61] Once more, although not displayed here for the sake of compactness, even single levels of these categorical variables resulted highly explanatory, with 55% and 68% of controls respectively being significant at least at a 1% α-level (rising at 68% and 84% when considering multicollinear, omitted levels); these shares improve to a 72% and a 96% of controlling items, respectively, when the significance threshold is lowered to α= 10%.

[62] Robustness of these outcomes was also checked with respect to the choice of the central measure employed in summarizing information about municipality-level firm patents and employees, thus shifting from mean to median: significant coefficients of 14,35% and 11,06% were obtained for specifications (13 II) and (14 II), respectively, fully comparable to those reported in Table 3.5 a.

of $\text{UFBb availability}_{m,t}$ and $\text{Years of UFBb availability}_{m,t}$, once used as a response variable in regressions allows to explore the probabilistic aspect of patents dynamics, identifying the share of causal effects which are ascribable to UFBb variables of interest.

In order to originally test whether this alternative research branch was promising, an introductory Linear Probability Model (LPM) was computed, re-adapting the OLS framework with firm idiosyncratic terms to the case of a binary outcome variable. The implementation of a LPM notoriously has two main drawbacks, namely:

- the inability to model non-linear responses to different levels of explanatory variables, and
- the possible forecasting of probability values lying outside the range [0;1]);

nonetheless, it is commonly employed as a modelling primer to verify whether inherent data variability may justify higher-level econometric evaluations.

On the basis of previous estimates, the importance of interactively controlling for innovation intensity has led to the inclusion of another possible proxy for the same unobservable: a dummy defined $\text{Patents portfolio at t} - 1_{i,t}$, yearly taking the value of 1 in case the firm already owned industrial patent titles by the end of the previous year, and 0 otherwise. This makes up a finer control for firm innovativeness than that employed before, since it tracks portfolio development through time (thus escaping absorption by firm fixed effects) rather than defining once for all (as done above considering the panel as a significant time frame) innovation leanings of each firm.

Results of LPM estimates, respectively using first $\text{UFBb availability}_{\text{m,t}}$ and then $\text{Years of UFBb availability}_{m,t}$ as the variable of interest, are exhibited in Table 3.6 a-b, under the specification labels (15) and (17). Alongside with the same municipality and firm controls used before, a set of year fixed effects[63] was included, in order to avoid the usual omitted variable bias caused by potential time trends, resulting in individually and jointly significant estimates, meaning that this control, as it frequently occurs with panel data, is effectively dealing with systematic data patterns.

As programmatically expected, controlling for previous patents results in very significant coefficients for both the interacted and the stand-alone terms within the two specifications; these coefficients exhibit a (perhaps partially surprising) negative sign, suggesting the owning of patents is likely not to trigger a positive loop towards further IP acquisitions: this is intuitively reflecting the low average innovation focus of Italian businesses.

As for specification (15), Table 3.6 a says the availability of UFBb at a municipality level has a mean

[63] Unlikely previous estimates on $\text{Ln}(\text{Nr. of patents} + 1)_{i,t}$, a setting with region-year fixed effects for the LPM model, although delivering coherent estimates to the ones in (13) and (15), was not reported in this section, since a direct FE logit comparable couldn't be estimated, because of non-concavity of likelihood functions.

effect of increasing by 1,07% the probability of a concurrent positive shift for patents portfolios in cabled municipalities: a low, though very statistically significant effect, which, in addition to the encouraging fitting statistics from Table 3.6 a, moves towards the quest for an enhanced model, such as the one in (16). Instead, outcomes from (17) are somewhat ambiguous, less significant and smaller in magnitude, which in turn fostered a parallel deepening on the estimation method; this led to output (18), aimed at evaluating whether the detected non-significance was only depending on the regression framework, or if it hinted at a substantial descriptive uselessness of the yearly breakdown of UFBb roll-out, unlike what diffusely happened with specifications (1)-(12).

To push the evaluation method forward, a conditional logistic framework with firm and year fixed effects was implemented behind outputs (16) and (18). By optimizing a maximum-likelihood function on observed data, this setting solves both the abovementioned inefficiencies of LPM while dealing with panel data peculiarities at the same time, thus providing a sounder insight into the matter of ultra-fast broadband causality on the probability of patents upward shifts. However, the drawback of such a layout is given by the shrinking of the estimation sample, due to the abundancy of firm-level clusters with all positive-all negative outcomes, which therefore do not contribute to event evaluation, since no shifts or shifts for every year are detected with respect to these units.

Beyond being coherent with the directions of statistical effects from the first LPM based on $\text{UFBb availability}_{m,t}$ (i.e., all coefficients signs remain unchanged from (15) to (16)), logit outcomes produce strongly significant estimates, exhibiting the expected sign, even for specification (18), relying on $\text{Years of UFBb availability}_{m,t}$ as the independent variable of interest. As displayed in Table 3.6 c, both the factorial model as a whole (including both main effects and interactions) and the interaction itself end up to be highly significant within these two new specifications, therefore substantively contributing to the explanation of data variability. Again, the pre-existence of patents portfolios exhibits the already detected, mitigating role on increase probability, bringing into question a potential role for competitive forces: in fact, firms that have managed to gather a portfolio of patents prior to fiber roll-out are likely to feel an increase in innovation-based competition once UFBb provides easier access to IP to a wider range of competitors. Interpreting the same figures from another perspective, these outcomes from both previous tables could also hint at a possible, differential effect of fiber connectivity, specifically fostering portfolio creation, rather than the growth of existing portfolios; such traces of a potential impact on portfolios' births, considering the desirable nature of the causality it implies, is likely to be quite appealing when looking for future development trajectories in the field of ICT impact assessment.

As for evident changes in coefficients magnitude, they can be explained, apart from by better model fitting, also by the fact that the estimation process is now linked to the sigmoidal functional form of the logistic probability model:

$$IP\ [Patents\ portfolio\ increases] = IP\ [\cdot] = Y = \frac{1}{1+e^{-\vec{A}}}$$

with $\vec{A}$ being the array of explanatory variables, controls and fixed effects included in the analysis. That said, an easy way to directly assess the quantitative impact of UFBb variables on the probability of the studied event is to explicitly plot the estimated probability shifts induced by the sole change in UFBb variables (e.g. from fiber absence to fiber presence), while controlling for the impact of other regression variables in a *ceteris paribus*, partial derivative scenario.

Such evaluation is performed in the following Figure 3.2, where the differential effect of $UFBb$ $\text{availability}_{m,t}$ differential effect is plotted in red, in order to distinguish it from the *n*-th main effect of $Years\ of\ UFBb$ $\text{availability}_{m,t}$, whose categorical impacts are represented in shades (getting increasingly darker with *n*) of blue. These graphs derive from the finite-differences expression of probability shifts, expressed as a function of fiber alternative variables:

$$\Delta\, IP\ [\cdot] = \frac{e^{\vec{A}}\left(e^{\Delta UFBb}-1\right)}{\left(e^{\vec{A}}+1\right)\left(x^{\vec{A}+\Delta UFBb}+1\right)}$$

In particular, considering firms with no patents in the previous year, having had ultra-fast broadband available for *n* years (with respect to municipality-level fiber unavailability) produces an increase in the probability that certainly depends on the value of controlled variables (i.e. the pre-shift value of $\vec{A}$), but whose maximum value ranges between +9,44% and +27,77%; this impact is (as expectable) monotonically increasing with the years of fiber availability, and, therefore, with the time span along which firms have had the opportunity to train their digital exploitation skills. Considering UFBb availability through a flat time perspective, the associated effect can explain probability increases which amount up to a +18,40%, coherently included in the previous range defined by levels of $\text{Years of UFBb availability}_{m,t}$.

These logit estimations return a huger numerical impact of ultra-fast broadband on the analyzed probability than that provided by the LPM setting: in spite of the simple regression layout, these outcomes restates the relevant influence of UFBb on patents dynamics, expanding the deductions of the main modelling previously performed on $\text{Ln}(\text{Nr. of patents}+1)_{i,t}$

3.6. Assessment of effects' heterogeneity

Once systematic effects at stake have been modelled, it can be interesting to implement the most promising specifications on specific subsamples, thus testing robustness when specializing underlying data. This approach allows to shed some light on aspects that have been neglected so far, while also taking the chance to test responsiveness and sensibility of the model itself, when stressed along dimensions not programmatically involved in its definition. To carry out this deepening, specifications from (7) to (10) have been selected for specific applications, which can also give additional insights on model strength and on the differential description performed by the two main variables of interest employed through the discussion.

Before doing so, with a quick throwback, FE coefficients from baseline specifications can be specifically considered due to some interesting evidence they deliver, reported in Table 3.7 and 3.8 a-b. In both outputs, visual rendering was employed to make quantitative information clearer: years have been shaded in three tones of progressively darker blue with respect to the significance level (among conventional ones) of the associated fixed effect estimate, whereas estimates themselves have been colored according to the sign (red versus green) and magnitude of the implied effect.

As for yearly fixed effects, Table 3.7 demonstrates the model correctly (and significantly) accounts for the increasing trend of patents along panel years, already emerged during Chapter 2 preliminary investigations: indeed, these indicator variables are equivalent to the inclusion of a control for the total amount of patents within the panel. Beyond consistency with descriptive statistics, the resulting time influence is coherent and quantitatively comparable among the two outputs.

On the other hand, Table 3.8 a-b provide a bi-dimensional view on space-time patent trends within the model. Here, the information difference among the two variables of interest (and therefore among intensive and extensive aspects of UFBb roll-out) is reflected in the comparison of significant trends, not always corresponding in sign between the two sub-tables. This output further enriches considerations made in Chapter 2, where patent and fiber trends were observed separately, with no causal connection linking them together. This enrichment is achieved by coming to explain those trends with regression estimates produced in the meantime: in fact, with x and y variations now matched in space and time through the econometric model, i.e. using fiber to comprehend changes in patents, the amount of variability taken on by fiber variables outlines regional time trends of both signs, unlike the output of Table 2.10, where the mere growth in patents almost only exhibited positively monotonic trends for Italian regions. This suggests fiber is a strong regression element, leaving only marginal patents' variations unexplained, so that these residuals can easily end up of both signs to minimize model-reality offsets, being captured by these regional, diffusely significant fixed effects. To this extent, $\text{Years of UFBb availability}_{m,t}$ appear to detect a higher number of relevant background tendencies than the alternative $\text{UFBb availability}_{m,t}$, reasonably thanks to the richer, dynamic concept underneath $\text{Years of UFBb availability}_{m,t}$.

That said, a disentanglement of region and year dimensions can be achieved by means of model (B), where no geographic control is explicitly performed; though this is not feasible by simply including region indicators in model specifications (that would be systematically absorbed by fixed effects), a possible alternative is given by model re-estimation on regional sets of observations, whose results are displayed in Table 3.9 a-b. By testing the joint significance of interaction coefficients, a sequence of clusters is progressively created, recovering and expanding macro areas defined in Chapter 2 for descriptive purposes.

In the columns labelled "interaction significance", p-values for F-tests are reported, related to the conceptual block of considered models, with the table background formatted in green shades according to increasing significance of underlying estimates; auxiliary adjacent weights are given by regions' representatives through panel observations.

Overall, significance of variables of interest (interacted with innovation intensity) improves while moving from cluster 0 (i.e., no cluster at all) to cluster II (where 20 regions are grouped in only 3 families); this was expected, being the model fitted on national data as a whole.

A global, better regional fitting of models embodying $\text{Years of UFBb availability}_{m,t}$ emerges when comparing the two halves of the table, especially when individually considering single regions, where this specification results significant (at least at a 10% level) in approximately one regio47%n every two (47,98%), and particularly significant with α=1% for the biggest region (i.e. Lombardia). Once more, this hints at a major sensibility of specification (10); however, preference for this version rapidly turns into substantial indifference when reaching scenarios I and II.

Analogous implementations, again more aimed at seeing the model in action rather than explaining all idiosyncracities of discrete variable levels, can be applied with respect to other relevant dimensions seen along previous firms' analysis, as briefly done with the two following outputs of Table 3.10 a-b and 3.11.

The first couple of tables shows an industry breakdown structure; here, only specification (10) is displayed, both adopting equation (B) and equation (C) setting, due to poor significance of interaction coefficients associated to (8) when run on sector subsets, once more indicating (10) as preferred specification. Again, recovering the aggregation proposed in Chapter 2, re-estimation is performed in two steps, from single industries to sector macro groups. Although the model with yearly fixed effects shows better performances in terms of successfully significant re-estimates (49,47% ÷ 52,34% of weighted regions), a precise explanation of coefficients' patterns exhibited through this check could only be achieved by means of finer modelling, specializing the research in order to directly include industry effects into the specifications. This would operatively imply a subtle model tuning: indeed, pure levels of an industry indicator variable, being generally firm-invariant, would fall within firm fixed effects, and therefore wouldn't be estimated separately conditionally on FE-setting: the additional inconvenience of rethinking the model to find some more refined ways to account for these effects is what made post-estimation exploration herein preferable.

Finally, an equivalent reasoning (with equivalent conclusions) can be repeated on model re-applications by firm class size (Table 3.11), an effect already, alternatively taken into account with the inclusion of *ln*(Employees count) among firm controls. Indeed, omitting such variable and estimating models on size families, high significance of the interacted model setting is detected for 3 classes out of 4, for both year FE and region-year Fe, which somehow intuitively suggests that size discrimination accounts for the same variability previously captured by *ln*(Employees count): apparently, the revealed innovation impulse of UFBb (at least, as modelled within this thesis) is not only experienced by larger firms, as the common sense could possibly advice at first. Again, even if both specifications had been re-estimated, only p-values for (10) are displayed, due to detected low to no significance of model setting when format (8) is employed.

Generally speaking, event though the analysis didn't enter single coefficients' behavior through each re-estimation, this high-level assessment returns supplementary impressions on the baseline model, which appears to adapt discretely well when applied to different sub-samples, each cropped by exploring new perspectives of the N-dimensional problem at issue, for whose categorical levels the model itself wasn't preliminarly endowed with dedicated controls. Considering model relative simplicity against the underlying complexity and variability of data, these final outcomes give a positive feedback, both in terms of potential scope and functional versatility, on the model under discussion, which results still quite responsive to a series of effects he wasn't programmatically designed to embody.

4. Concluding remarks and development prospects

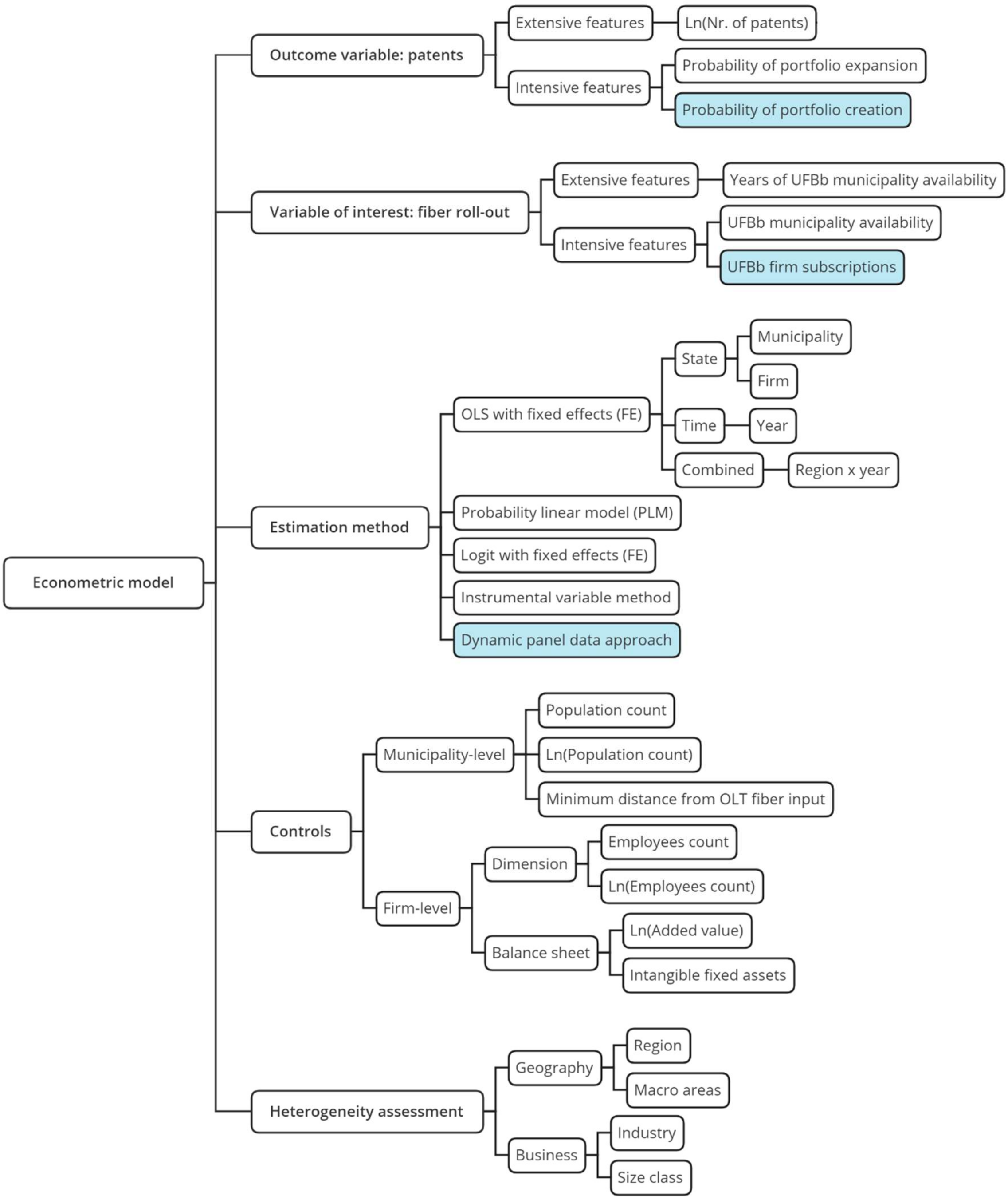


Figure 4.1. Empirical strategy recap: breakdown of modelling features of Chapter 3, together with possible extensions of the analysis (shaded in azure).

In this thesis work, the main aspects regarding ultra-fast broadband as a global phenomenon have been outlined. In Chapter 1, a technical and regulatory background has been established and contextualized at a progressively deeper geographical level, combining quantitative and qualitative deductions along the way. Entering the panel features in Chapter 2 subsequently allowed to shift the discussion on the actual focus of the thesis: the Italian case on the deployment of fiber New Generation Access Networks, which shows clear coherence with macro trends at above-national levels, both in qualitative and quantitative terms. UFBb saw a rapid spread through the country, reaching saturation with a logarithmic-like trend, due to unsolved inefficiencies in surviving white areas. This staggered roll-out has been methodically mapped and finally linked to the outcome of interest, i.e. the innovation behavior of Italian firms, as captured by data regarding their patent portfolios. Looking at the issue from different theoretical and empirical points of view, the modelling journey was recreated, justifying baseline selection for final applications; econometric elements and strategies pursued along Chapter 3 are synthetized and gathered in the mind map composing Figure 4.1.

Drawing conclusions after this structured dissertation, and speaking in terms of results, estimated regressions endorse the existence of reasonable UFBb effects on firm innovation, once the innovative leanings have been taken into account to control for different business focuses; this suggests the opportunity of establishing positive incremental loops of technology-spurred progress.

Even though conceptually simple and relying on a limited data base (both in time and statistical population), this preliminary model manages to tackle an interesting issue about technological externalities, eventually supporting the thesis around the "General Purpose Technology" (GPT) nature of ICT and possibly inspiring subsequent refinements to give it an even wider scope, aimed at confirming its robustness or alternatively revising its outcomes towards the definition of effective policy recommendations.

As far as potential developments of the research are concerned, of course much can still be said around the relationship studied along this master thesis. Once acknowledged that a causal effect is likely to influence real businesses, several continuation paths can be easily sketched, such as (see also Figure 4.1 for a proper contextualization):

- the breakdown of (potential) regional and industrial effects, expanding our comprehension of the phenomenon by revealing further conditional specificities;
- a model re-setting with UFBb data on firms' subscriptions and Internet services usage, rather than on basic information about progress statuses of municipalities wiring;
- the investigation of alternative proxies for innovation, possibly tackled with different modelling techniques, e.g. further exploring fiber impacts on the event of IP portfolios' creation;
- an alternative declination of the present analysis, specifically focused on the intrinsic dynamic nature of fiber staged deployment, i.e. adopting a Dynamic-Panel-Data (DPD) perspective, which considers the chance of significant adjustment mechanisms to overcome the inherent lack of memory embedded in previous models. While the availability of longer

sets of panel data is a quite necessary condition to methodically achieve this target, a standard approach to face related modelling issues is the set-up of an Arellano-Bond estimator, employing lagged values to embody the iterative influence of response variable on itself.

5. Index of tables and figures

5.1. Chapter 1

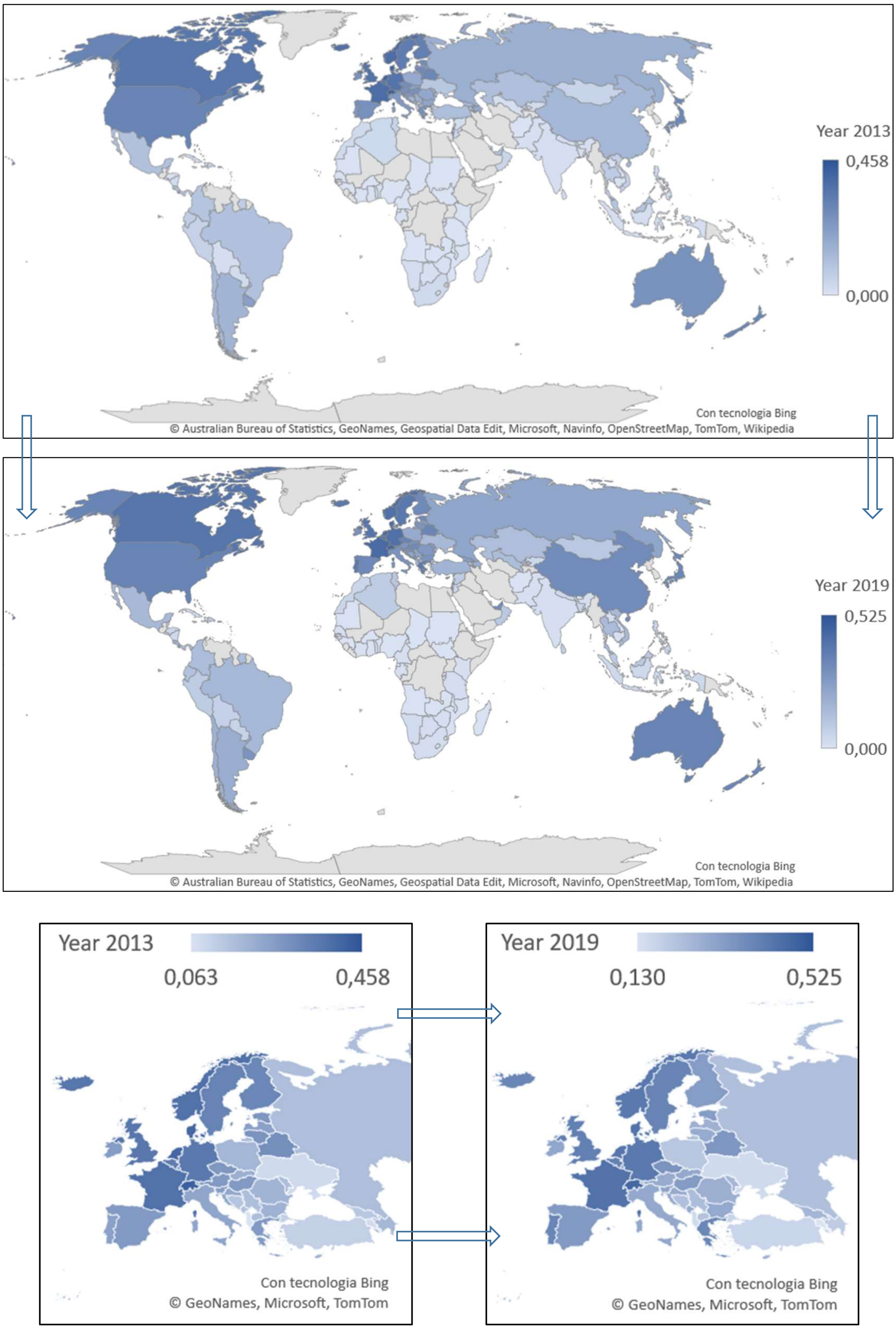


Figure 1.1. Fixed BB subscriptions per capita, at a world and European level, respectively; 2013-2019.

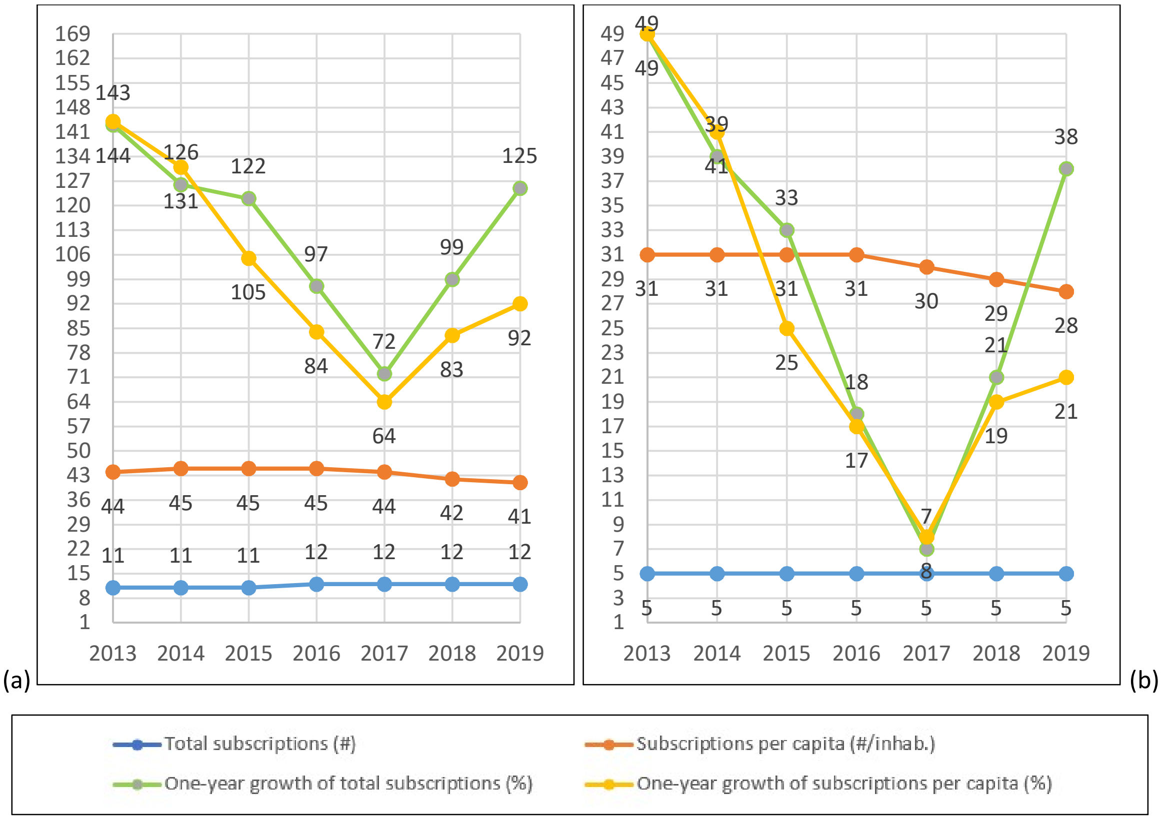


Figure 1.2 a-b. (a) Worldwide and (b) continental Italian rankings as for number of fixed BB subscriptions (with the four indicators listed in the legend), 2013-2019.

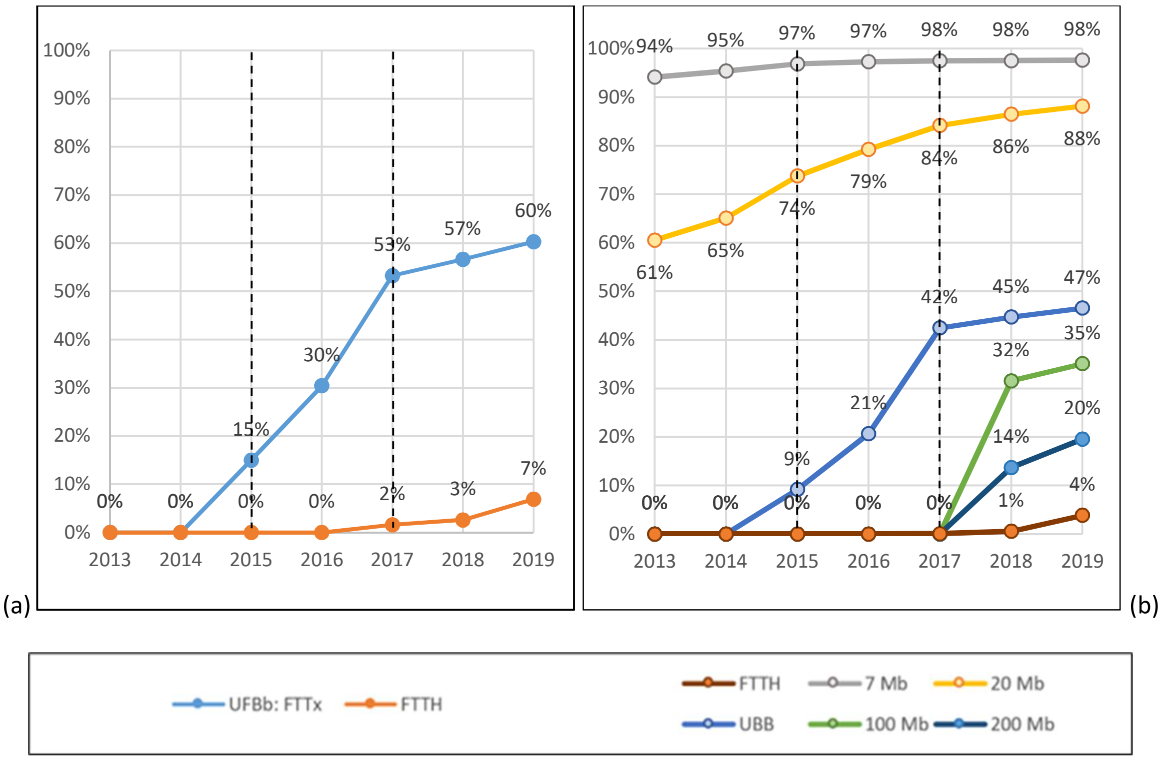


Figure 1.3 a-b. (a) Ultra-fast broadband availability and (b) coverages at different bandwidths, both measured at a municipality level within the dataset, 2013-2019.

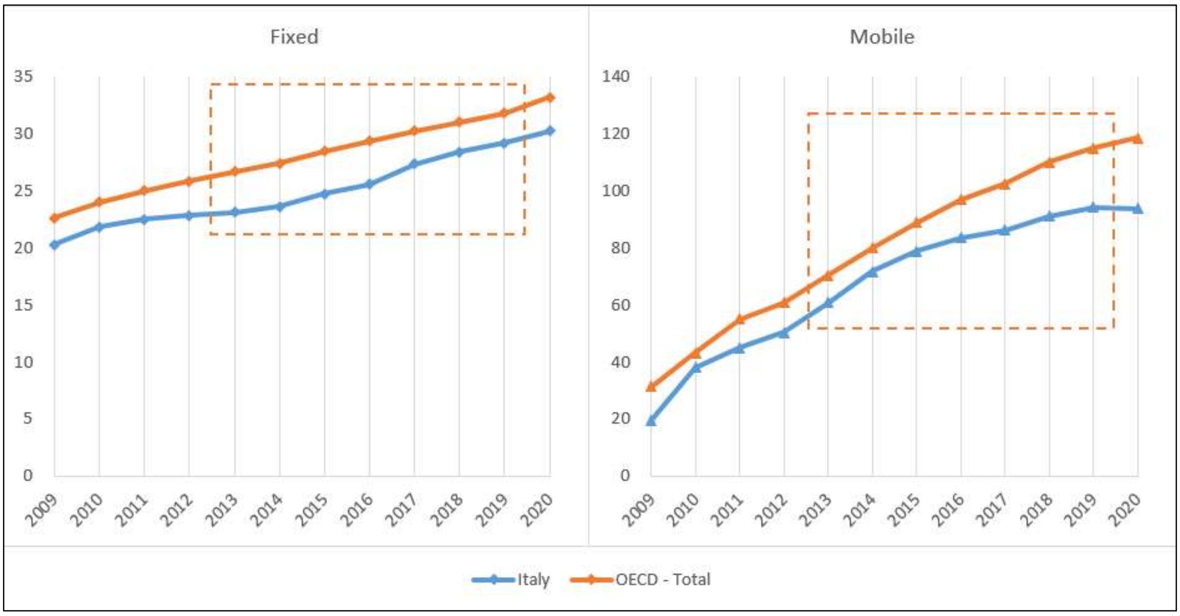


Figure 1.4. BB subscriptions per 100 inhabitants, comparing OECD countries (as a whole) and Italy with respect to fixed and mobile connectivity; 2009-2020 (with highlighted the period under investigation, 2013-2019).

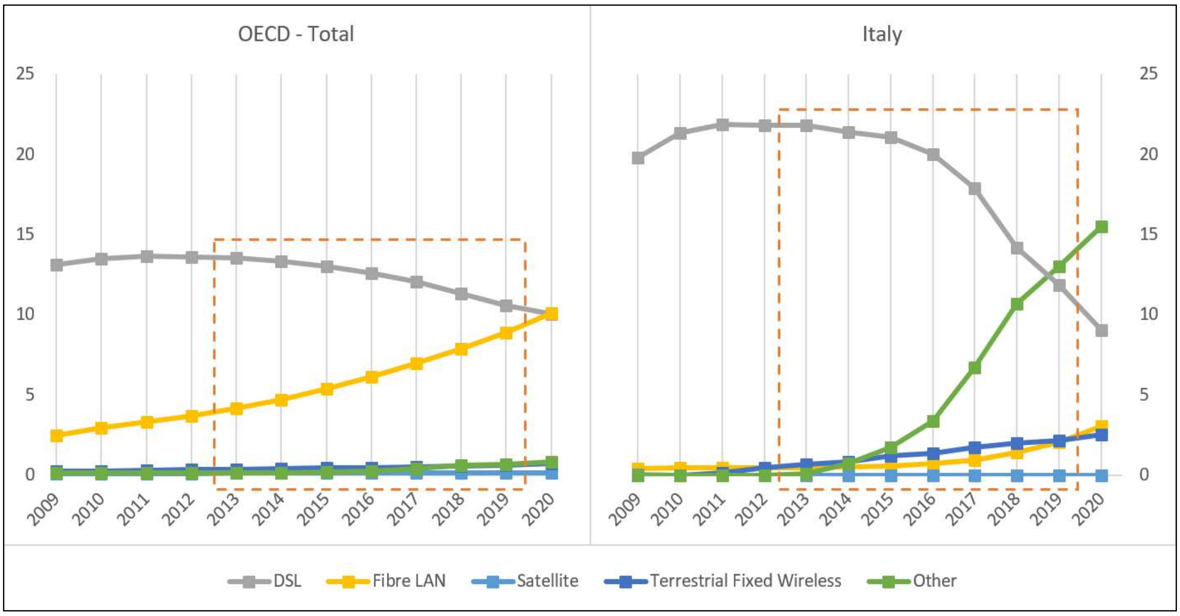


Figure 1.5. Fixed BB subscriptions per 100 inhabitants, broken down by transmission technology, comparing OECD countries (as a whole) and Italy in terms of main trends; 2009-2020 (with highlighted the period under investigation, 2013-2019).

Figure 1.6 a-b-c-d. One-year percentage growth of total fixed BB subscriptions and total fixed BB subscriptions as for: (a) World, (b) OECD countries, (c) European Union and (d) Italy, respectively; 2013-2019.

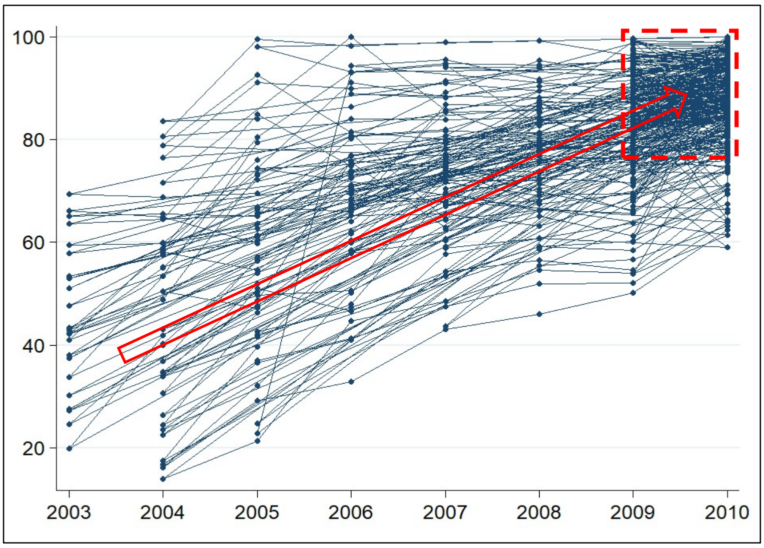


Figure 1.7. Business use of BB, OECD countries (with subsequent entries, % of country firms), 2003-2010.

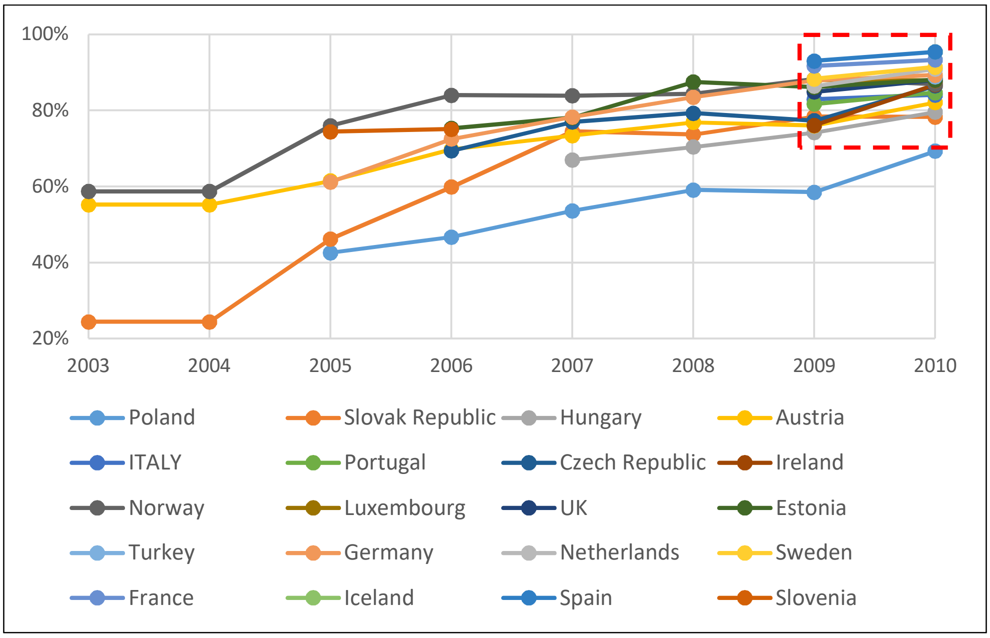


Figure 1.8. Business use of BB (% of country firms), evolution detail for European countries, 2003-2010.

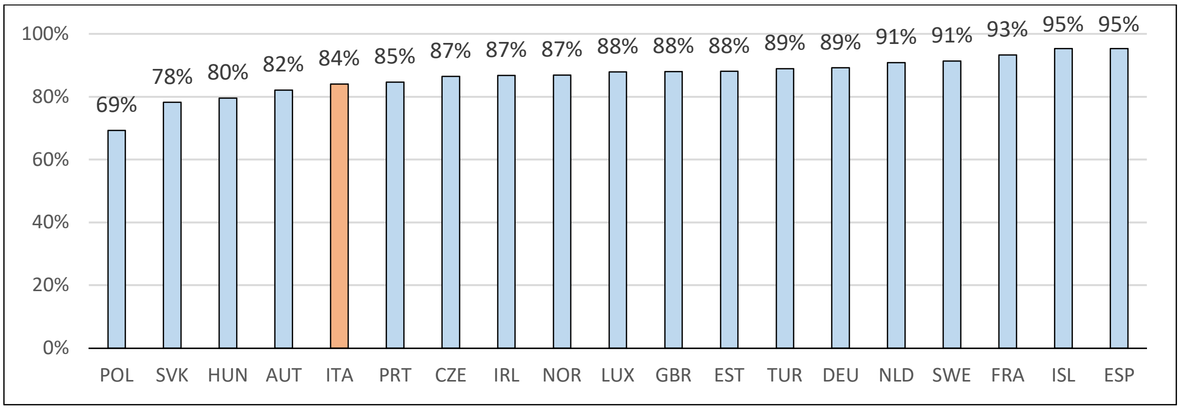


Figure 1.9. Business use of BB (% of firms), 2010.

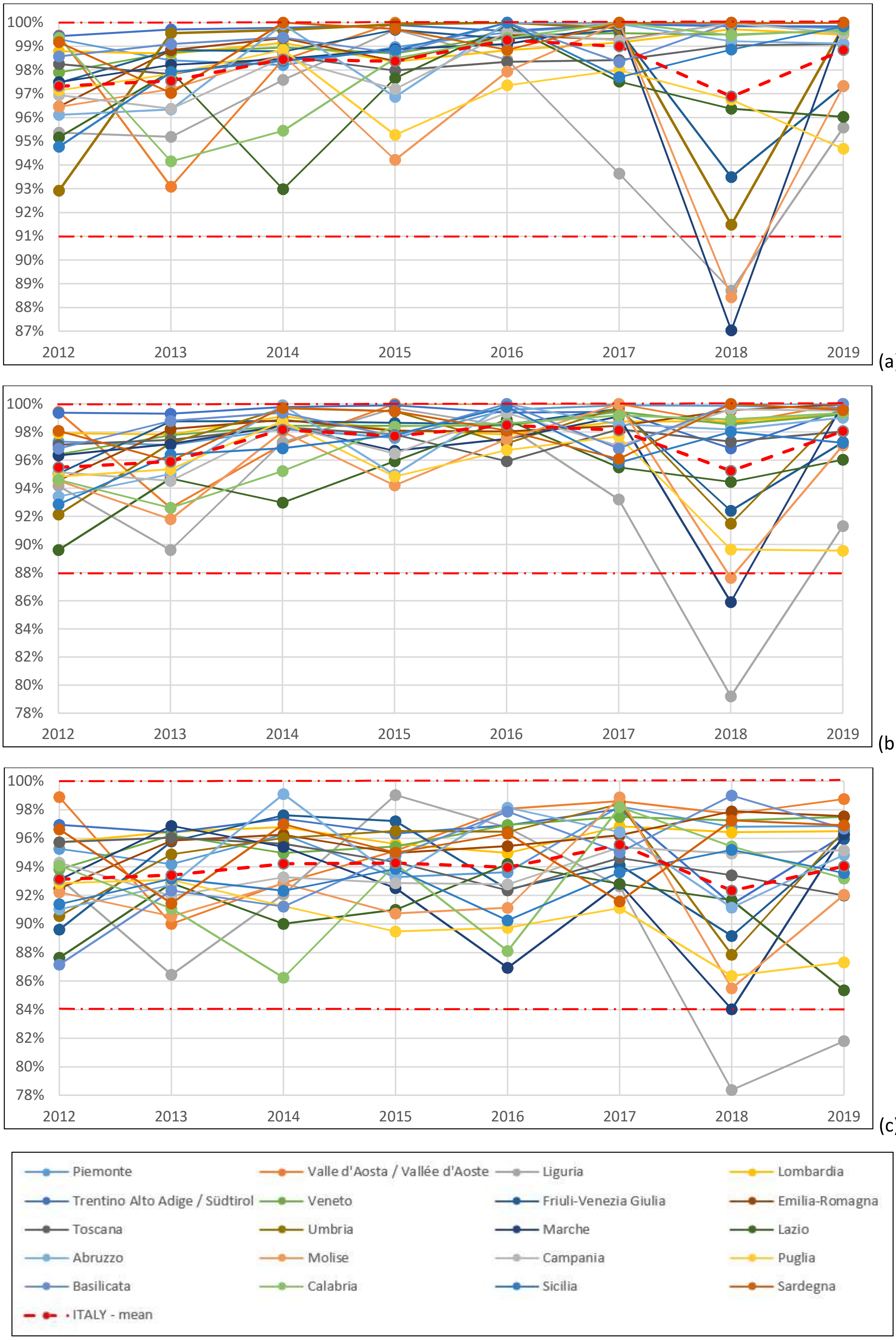


Figure 1.10 a-b-c. (a) % of firms making use of computers in their business, (b) % of firms with Internet access and (c) % of firms with fixed or mobile BB connection, respectively; 2012-2019.

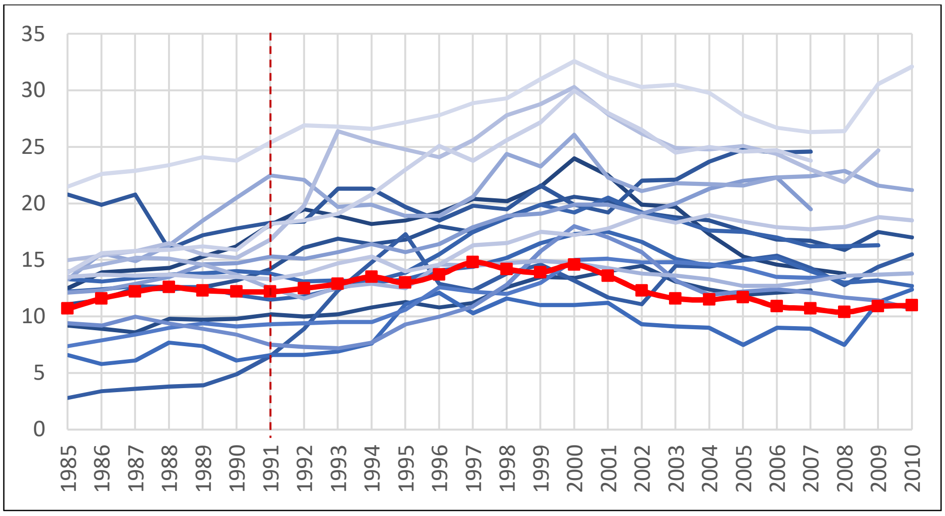
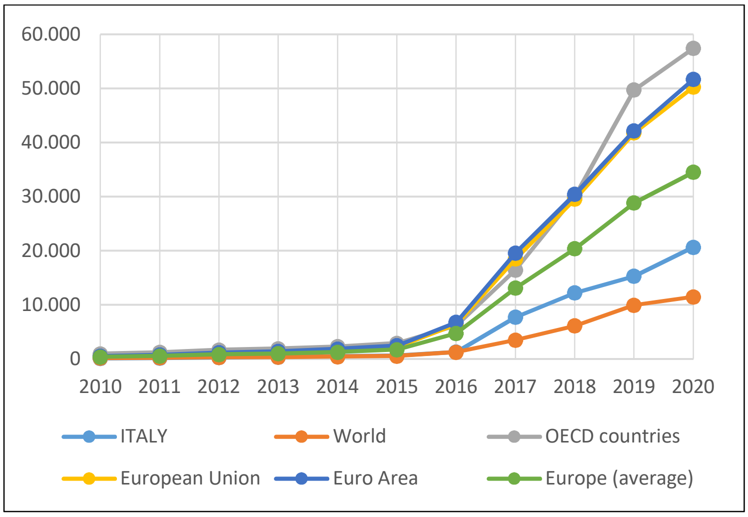


Figure 1.11. ICT investments in OECD countries (measured as a percentage of total non-residential gross fixed capital formation); 1985-2010 (with highlighted year 1991, on which the WWW was born).



Increase factor		
2010 ↓ 2020	2013 ↓ 2019	
162,7	40,8	*Italy*
61,4	26,9	*World*
59,1	26,0	*OECD countries*
103,0	32,4	*European Union*
95,0	29,6	*Euro Area*
86,9	28,6	*Europe (average)*

Figure 1.12 and Table 1.1. Secure internet servers (per 1 million people), 2010-2020.

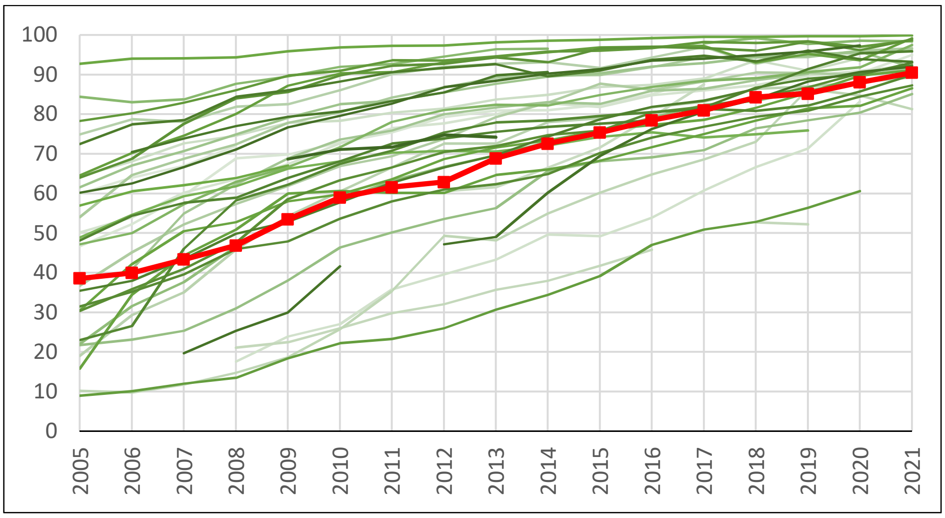


Figure 1.13. Internet access in OECD countries (total, % of all households), 2005-2021 (all available years).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BB Plan for rural areas	■	■	■	■	■	■	■	■						
BB National Plan				■	■	■	■	■						
Ultra broadband Plan					■	■	■							
BUL Strategy							■	■	■	■	■	■	■	■

Table 1.2. Timeline of broadband national programs; 2009-2022.

Country	% of population living in metropolitan areas (> 250.000 inhabitants)	% of population living in the most populated city	% of urban resident population
Italy	16	4	69
Germany	21	4	75
United Kingdom	42	14	83
France	48	18	80

Table 1.3. Urban *vs* rural population among main European countries; 2014, 2014, 2015, respectively.

Municipalities by population		Number of municipalities	% of total municipalities	Cumulated municipalities	% of cumulated municipalities	Associated population	% of total population	Cumulated population	% of cumulated population
Big cities	> 500.000	6	0,07	8.092	100,00	7.197.910	12,60	57.126.202	100,00
	250.000 ÷ 500.000	6	0,07	8.086	99,93	1.878.450	3,29	49.928.292	87,40
Medium cities	100.000 ÷ 250.000	32	0,40	8.080	99,85	4.652.315	8,14	48.049.842	84,11
	80.000 ÷ 100.000	24	0,30	8.048	99,46	2.109.421	3,69	43.397.527	75,97
	50.000 ÷ 80.000	72	0,89	8.024	99,16	4.304.420	7,53	41.288.106	72,28
Small cities	30.000 ÷ 50.000	153	1,89	7.952	98,27	5.831.120	10,21	36.983.686	64,74
	20.000 ÷ 30.000	186	2,30	7.799	96,38	4.495.737	7,87	31.152.566	54,53
	15.000 ÷ 20.000	189	2,34	7.613	94,08	3.273.770	5,73	26.656.829	46,66
	10.000 ÷ 15.000	451	5,57	7.424	91,74	5.522.978	9,67	23.383.059	40,93
	5.000 ÷ 10.000	1.121	13,85	6.973	86,17	7.905.761	13,84	17.860.081	31,26
	4.000 ÷ 5.000	425	5,25	5.852	72,32	1.904.810	3,33	9.954.320	17,43
	3.000 ÷ 4.000	608	7,51	5.427	67,07	2.117.990	3,71	8.049.510	14,09
	2.000 ÷ 3.000	970	11,99	4.819	59,55	2.396.421	4,19	5.931.520	10,38
	1.000 ÷ 2.000	1.623	20,06	3.849	47,57	2.357.935	4,13	3.535.099	6,19
	500 ÷ 1000	1.217	15,04	2.226	27,51	892.947	1,56	1.177.164	2,06
	< 500	1.009	12,47	1.009	12,47	284.217	0,50	284.217	0,50

Municipalities by population		Buildings	% of total buildings	Cumulative buildings	% of cumulative buildings	Real estate units	% of total real estate units	Cumulative real estate units	% of cumulative real estate units
Big cities	> 500.000	241.560	2,14	11.313.761	100,00	302.656	1	25.427.155	100,00
	250.000 ÷ 500.000	525.166	4,64	11.072.201	97,86	691.372	3	25.124.499	98,81
Medium cities	100.000 ÷ 250.000	1.025.362	9,06	10.547.035	93,22	1.415.718	6	24.433.127	96,09
	80.000 ÷ 100.000	850.393	7,52	9.521.673	84,16	1.222.518	5	23.017.409	90,52
	50.000 ÷ 80.000	677.707	5,99	8.671.280	76,64	1.029.950	4	21.794.891	85,72
Small cities	30.000 ÷ 50.000	557.516	4,93	7.993.573	70,65	884.732	3	20.764.941	81,66
	20.000 ÷ 30.000	1.956.661	17,29	7.436.057	65,73	3.411.015	13	19.880.209	78,18
	15.000 ÷ 20.000	1.216.477	10,75	5.479.396	48,43	2.295.233	9	16.469.194	64,77
	10.000 ÷ 15.000	617.841	5,46	4.262.919	37,68	1.309.512	5	14.173.961	55,74
	5.000 ÷ 10.000	820.318	7,25	3.645.078	32,22	1.867.406	7	12.864.449	50,59
	4.000 ÷ 5.000	890.719	7,87	2.824.760	24,97	2.386.667	9	10.997.043	43,25
	3.000 ÷ 4.000	587.717	5,19	1.934.041	17,09	1.754.810	7	8.610.376	33,86
	2.000 ÷ 3.000	293.442	2,59	1.346.324	11,90	874.346	3	6.855.566	26,96
	1.000 ÷ 2.000	522.861	4,62	1.052.882	9,31	1.981.198	8	5.981.220	23,52
	500 ÷ 1000	175.660	1,55	530.021	4,68	868.202	3	4.000.022	15,73
	< 500	354.361	3,13	354.361	3,13	3.131.820	12	3.131.820	12,32

Table 1.4. Italian municipalities, population, buildings and real estate units' breakdown; 2012.

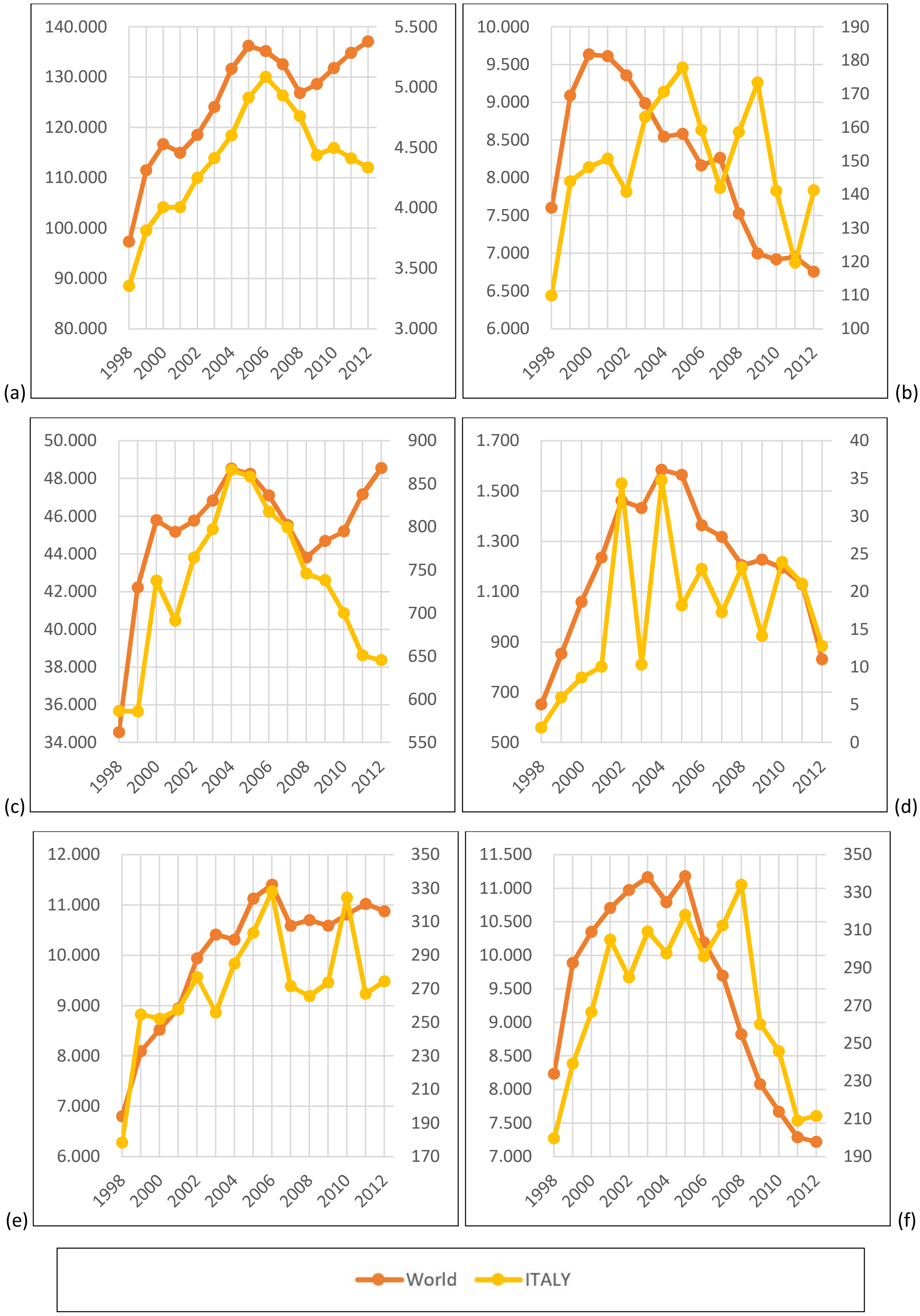


Figure 1.14. Evolution of patent applications at the EPO, (a) considering total counts and split into macro categories ((b) biotechnologies, (c) ICT, (d) nanotechnologies, (e) medical technologies and (f) pharmaceuticals), as filed by inventors from all over the world (left ordinates axis, red splines) and from Italy (right ordinates axis, yellow splines); 1998-2012.

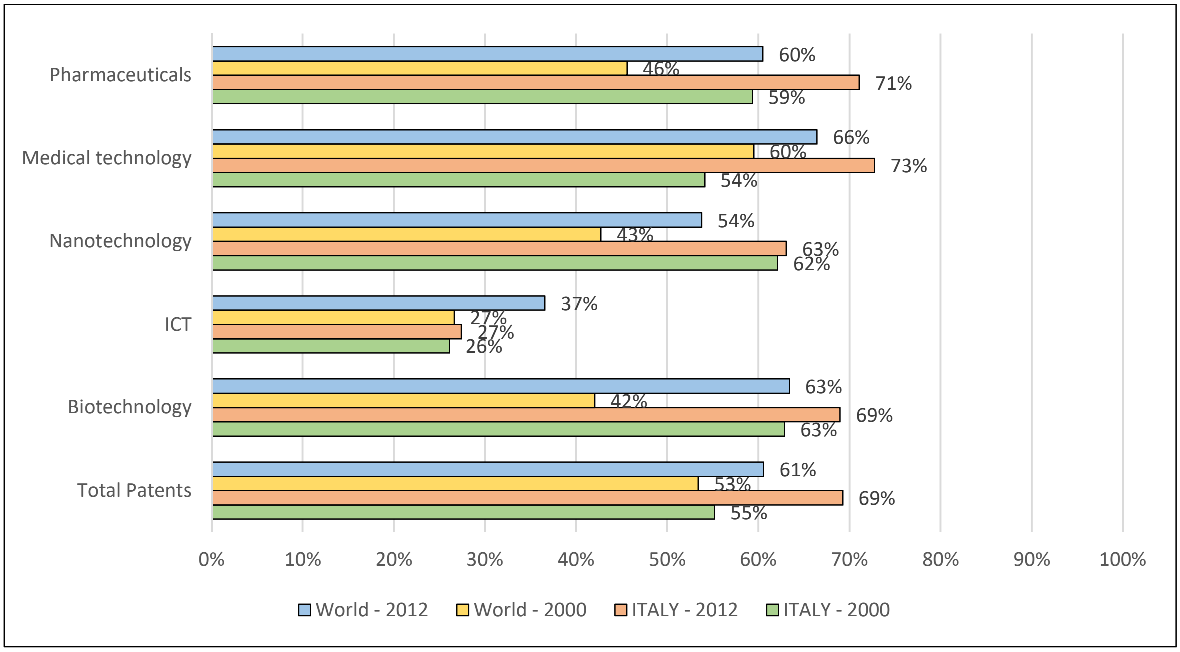


Figure 1.15. Rate of successful patent grants at the EPO (% over total applications by category), Italy and world (considering the inventor's country of residence); 2000 vs 2012.

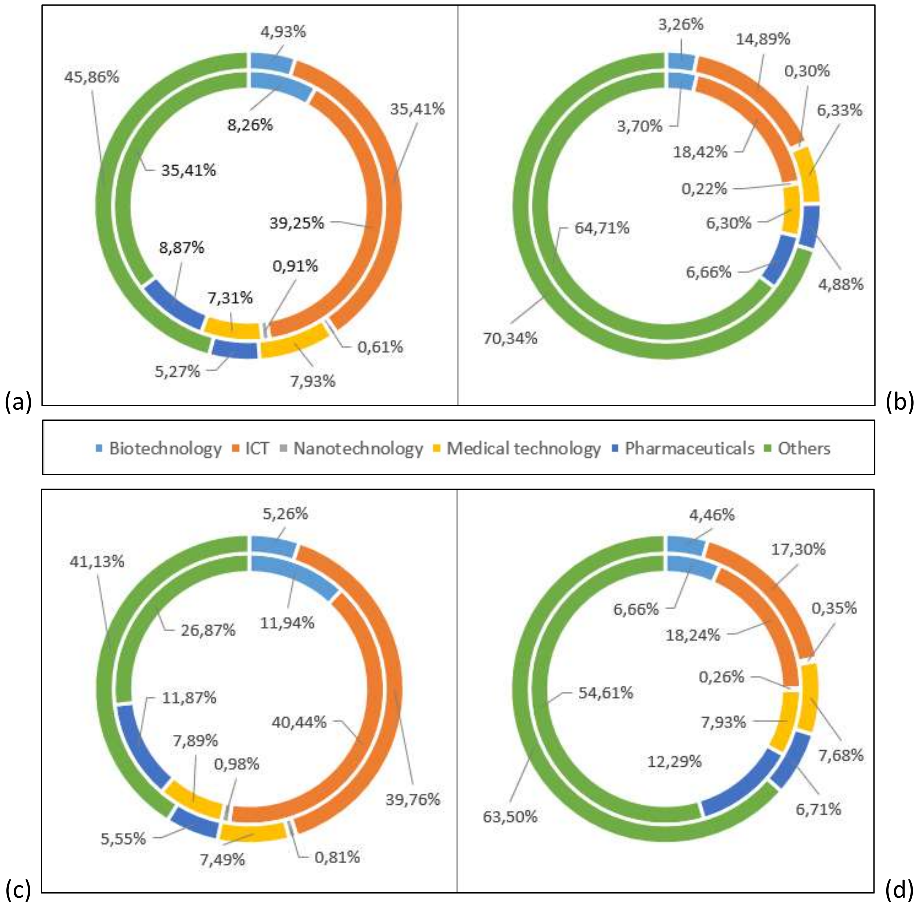


Figure 1.16. Patent applications to the European Patent Office (EPO, a-b) and patent applications filed under the Patent Cooperation Treaty (PCT, c-d) at a world (a-c) and Italian (b-d) level (with respect to the inventor's country of residence); 2000 (internal ring) vs 2012 (external ring).

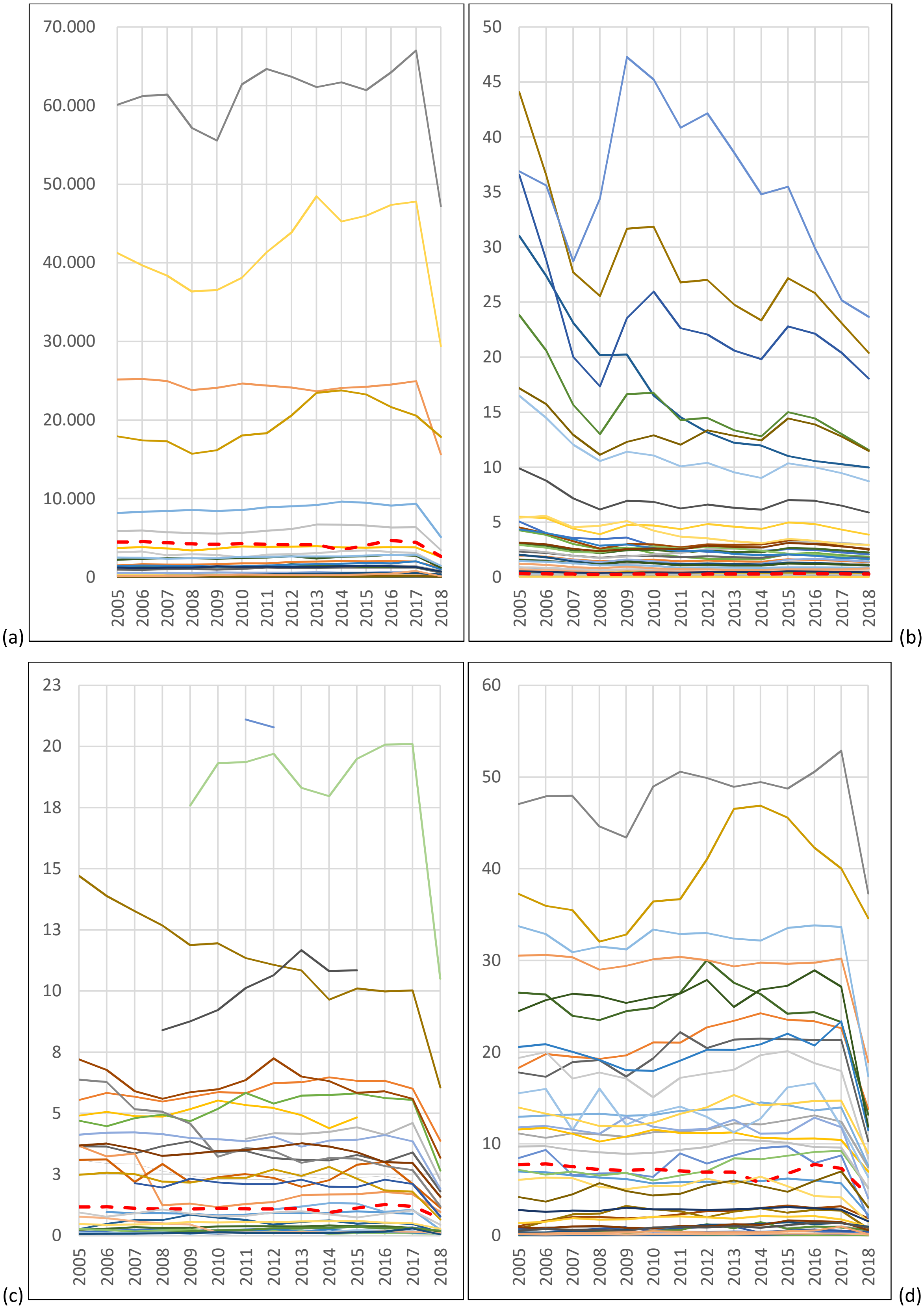


Figure 1.17 a-b-c-d. Patent applications at the EPO for OECD countries: (a) total, (b) per 1 trillion current $ of GDP, (c) per number of country enterprises and (d) per 100.000 country residents; 2005-2018.

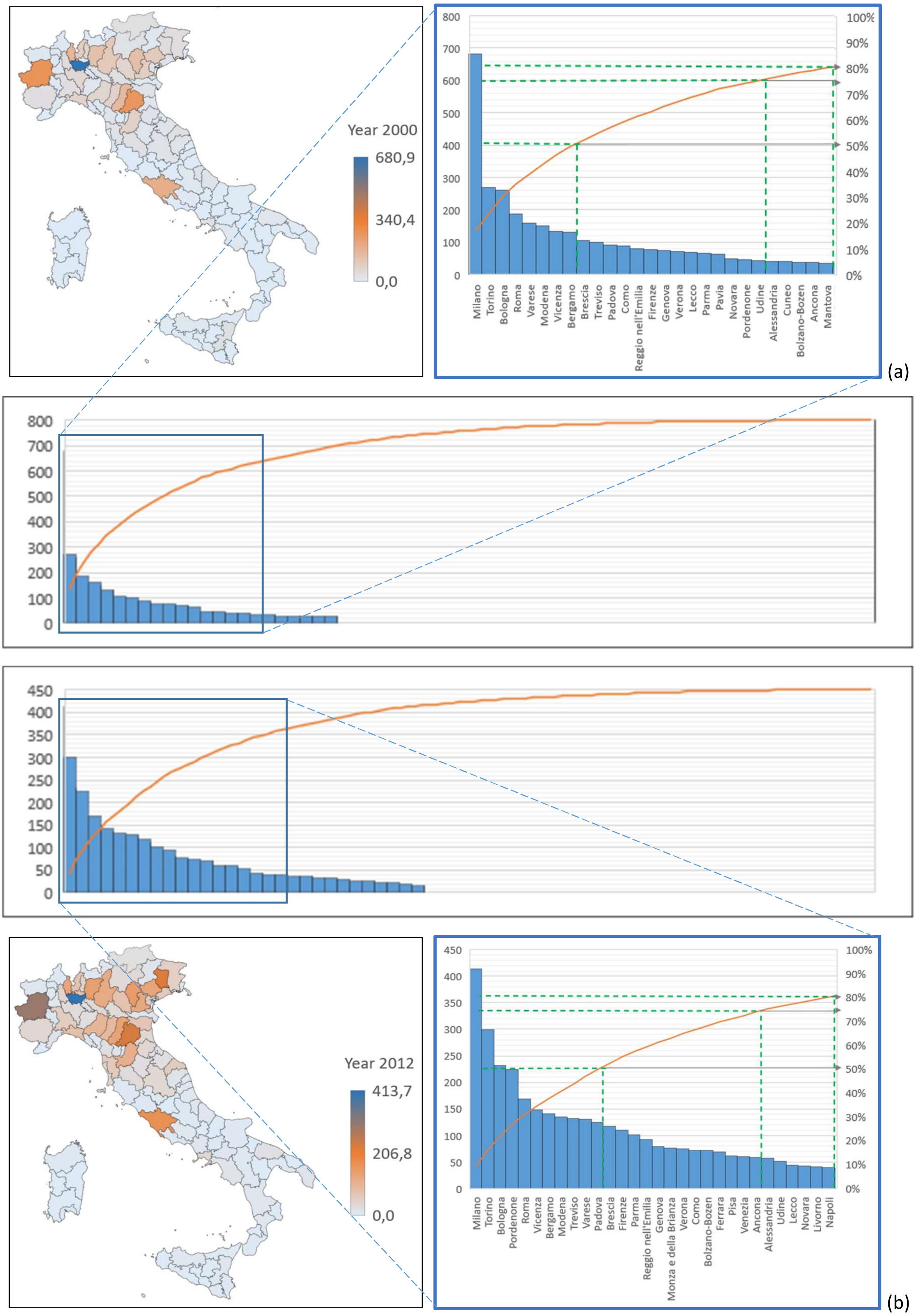


Figure 1.18. Provincial breakdown of Italian patent applications at the EPO (with respect to the inventor(s)' country of reference); 2000 vs 2012 (a-b).

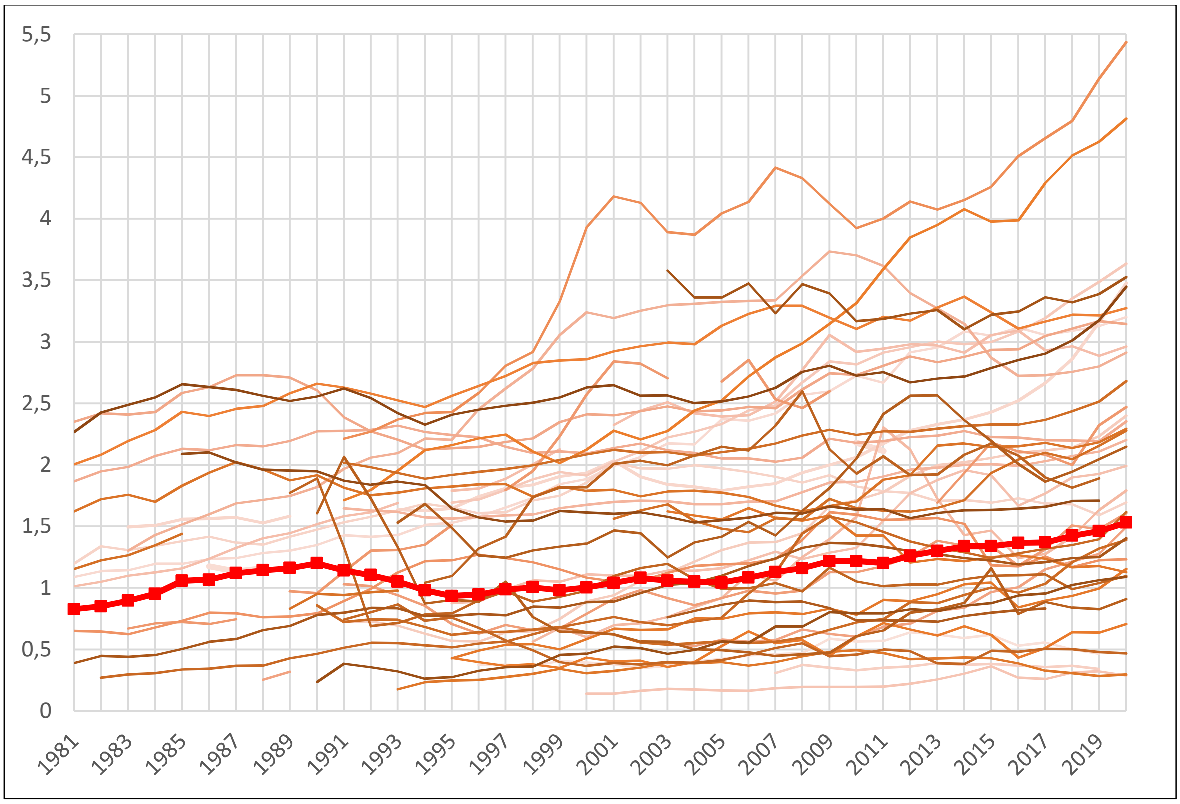


Figure 1.19. Gross domestic spending on R&D (in % of GDP) in OECD countries (Italy highlighted); 1981-2020.

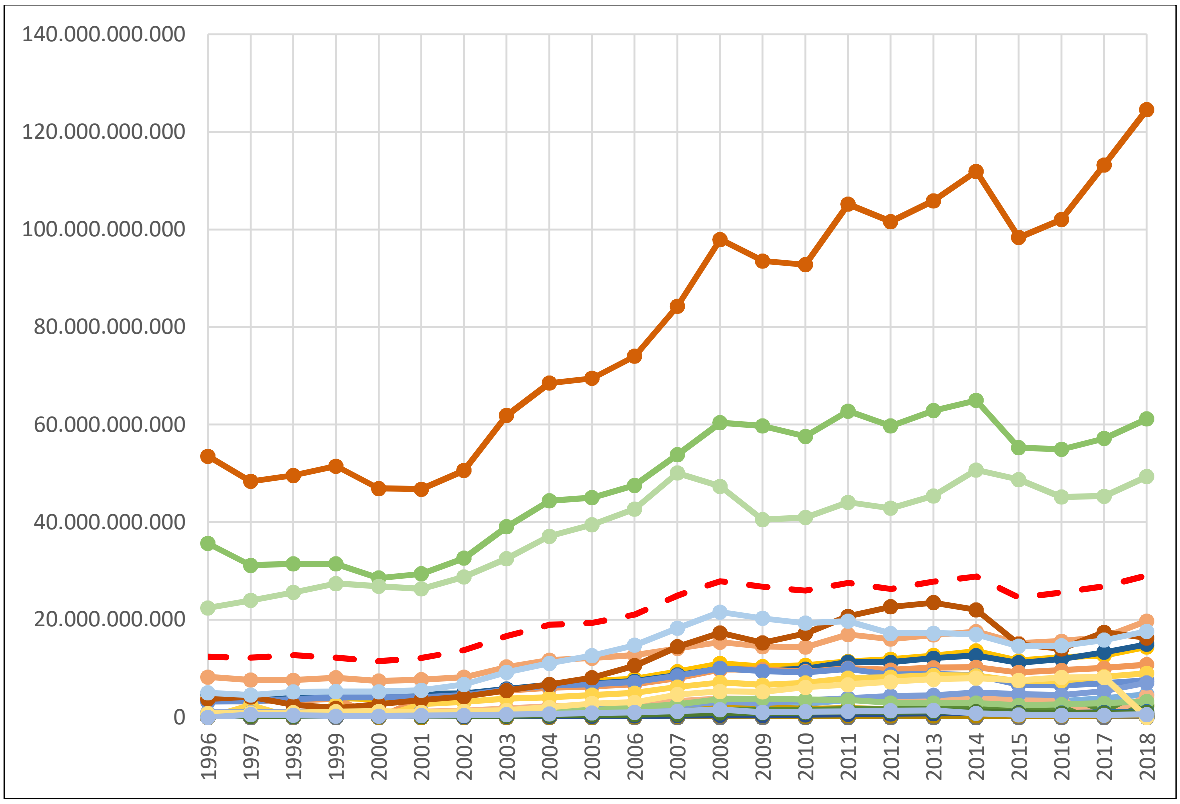


Figure 1.20. Gross domestic spending on R&D (in current $ of GDP) in European countries (Italy highlighted); 1996-2018.

Figure 1.21 a-b-c-d-e-f. (a) Researchers in R&D (per million people); (b) research and development expenditures (% of GDP); (c) firm R&D expenses, by macro-area; (d) firm expenses for in-house R&D, by employee class; (e) breakdown of firm R&D expenses and (f) co-operation deals for innovation projects among firms; 1996-2018; 2012-2019; 2012-2018.

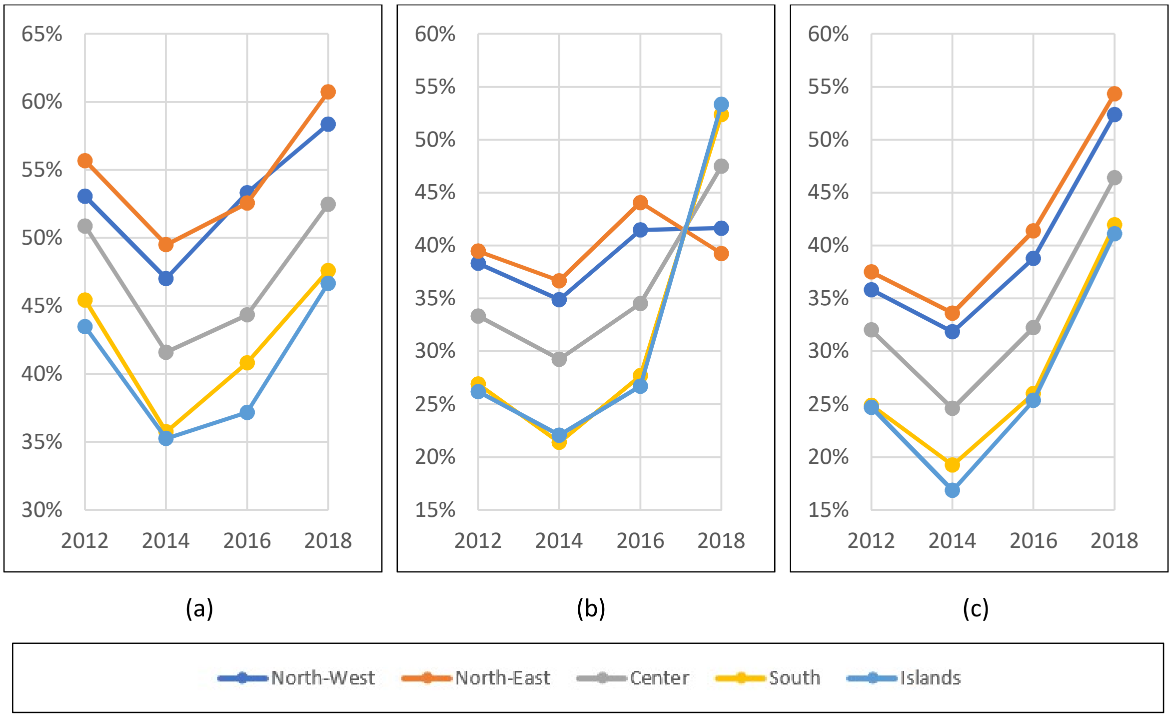


Figure 1.22 a-b-c. (a) Firms with innovative business (according to the Oslo Manual, 2005-2018 editions), (b) firms with product-process innovative business (according to Oslo Manual, 2005-2018 editions) and (c) firms that have effectively introduced product-process innovations, respectively; 2012-2018.

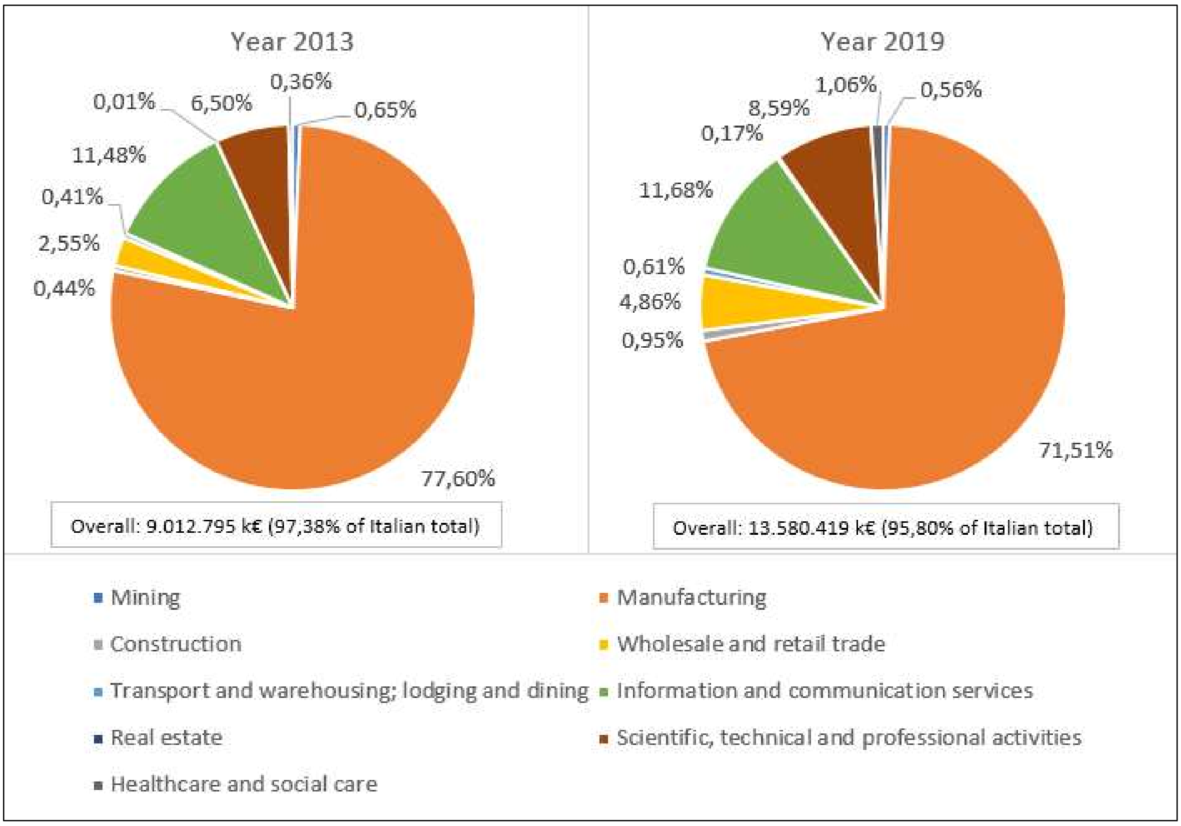


Figure 1.23. Firm expenses for in-house R&D, by industry; 2013 vs 2019.

5.2. Chapter 2

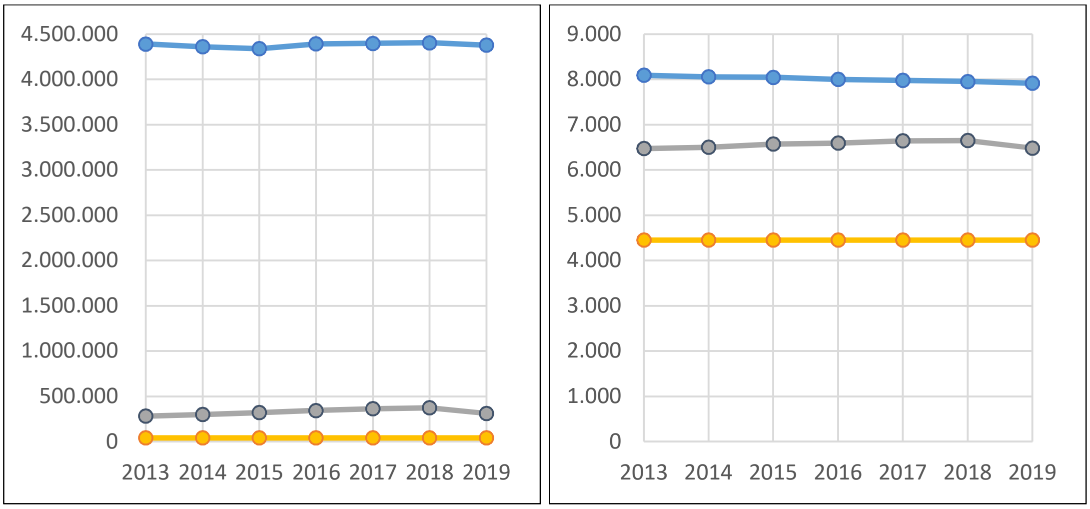
(a)  (b)

Figure 2.1 a-b. Dimensional comparison between the number of firms (a) and municipalities (b) in the panel (yellow spline) and in the dataset (grey spline), with respect to Italian total counts (blue spline); 2013-2019.

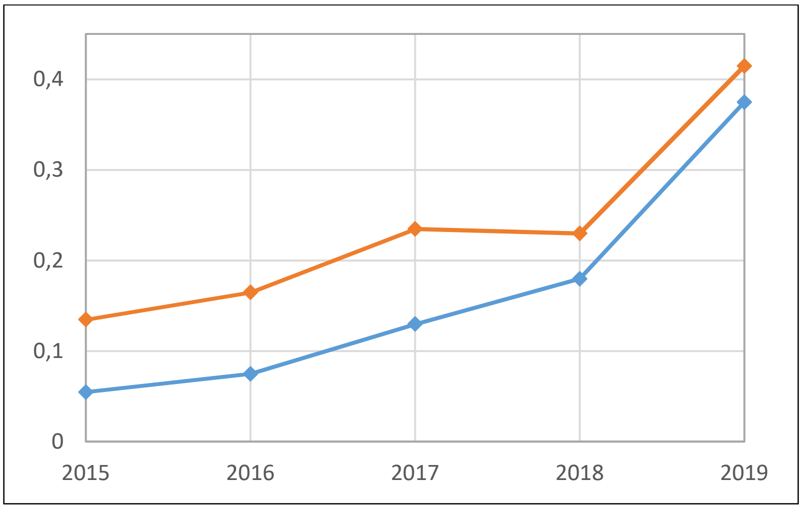


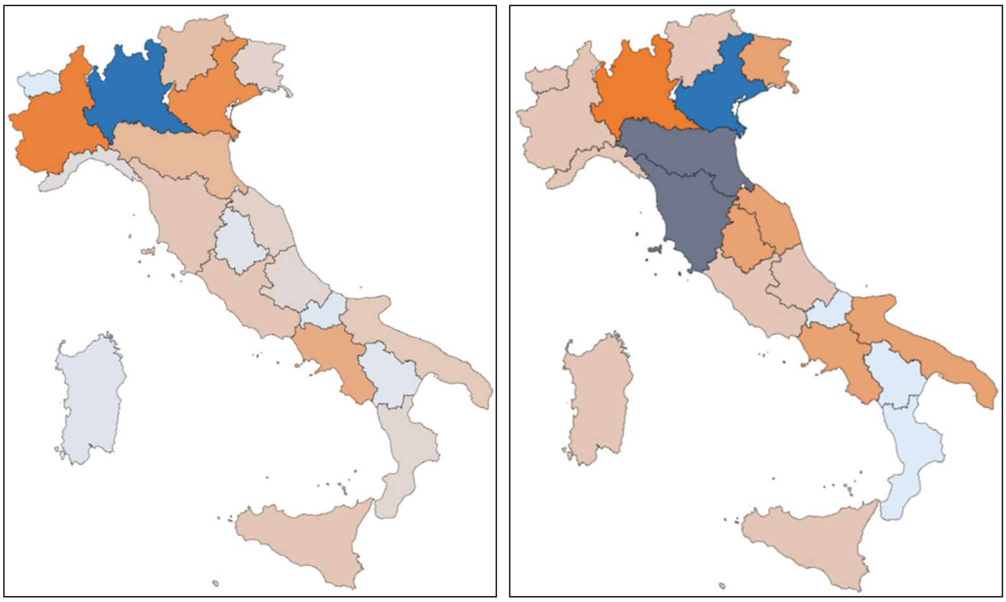
Figure 2.2. UFBb firms (orange path) and households (blue path) adoption by subscription rates, 2015-2019.

Number of municipalities		Whole dataset	Panel-specific
		6.908	4.454
Difference with country overall	2013	-1.182	-3.636
	2019	-1.006	-3.460
Fraction of overall	2013	85,39%	55,06%
	2019	87,29%	56,28%

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Italian municipalities	8.092	8.092	8.090	8.057	8.046	7.998	7.978	7.954	7.914	7.903	7.904

Table 2.1. Municipalities involved in the panel analysis: comparison with Italian overall and with the original dataset for the first and last year of the panel analysis; 2013-2019.

Region	Macro area		Number of municipalities				Firms per municipality	
			Abs. Freq.	Rel. Freq.			*Average*	*Median*
Valle d'Aosta	*North-West*	*North*	25	0,56%	38,12%	61,05%	2,16	2
Piemonte			514	11,54%			6,33	2
Lombardia			1.060	23,80%			11,21	4
Liguria			99	2,22%			9,30	2
Veneto	*North-East*		459	10,31%	22,92%		11,27	7
Friuli Venezia Giulia			141	3,17%			6,66	3
Trentino Alto Adige			155	3,48%			5,37	2
Emilia Romagna			266	5,97%			15,80	6
Marche	*Center*		149	3,35%	16,55%		6,62	3
Umbria			63	1,41%			7,84	3
Toscana			198	4,45%			14,48	6
Lazio			200	4,49%			18,58	2
Abruzzo			127	2,85%			5,83	2
Molise	*Inland South*	*South (mainland and islands)*	42	0,94%	16,52%	22,41%	2,40	1
Campania			325	7,30%			7,97	3
Puglia			188	4,22%			8,50	3
Basilicata			52	1,17%			3,23	1
Calabria			129	2,90%			3,44	1
Sicilia	*Islands*		201	4,51%	5,88%		7,17	2
Sardegna			61	1,37%			7,30	2
		Overall	4.454	100%	100%	100%	9,77	3



(a) (b)

Table 2.2 and Figure 2.3 a-b. Municipalities census in the analyzed panel and corresponding (3 a) heat map, along with average and median number of firms per municipality by region, and associated (3 b) heat map; 2013-2019.

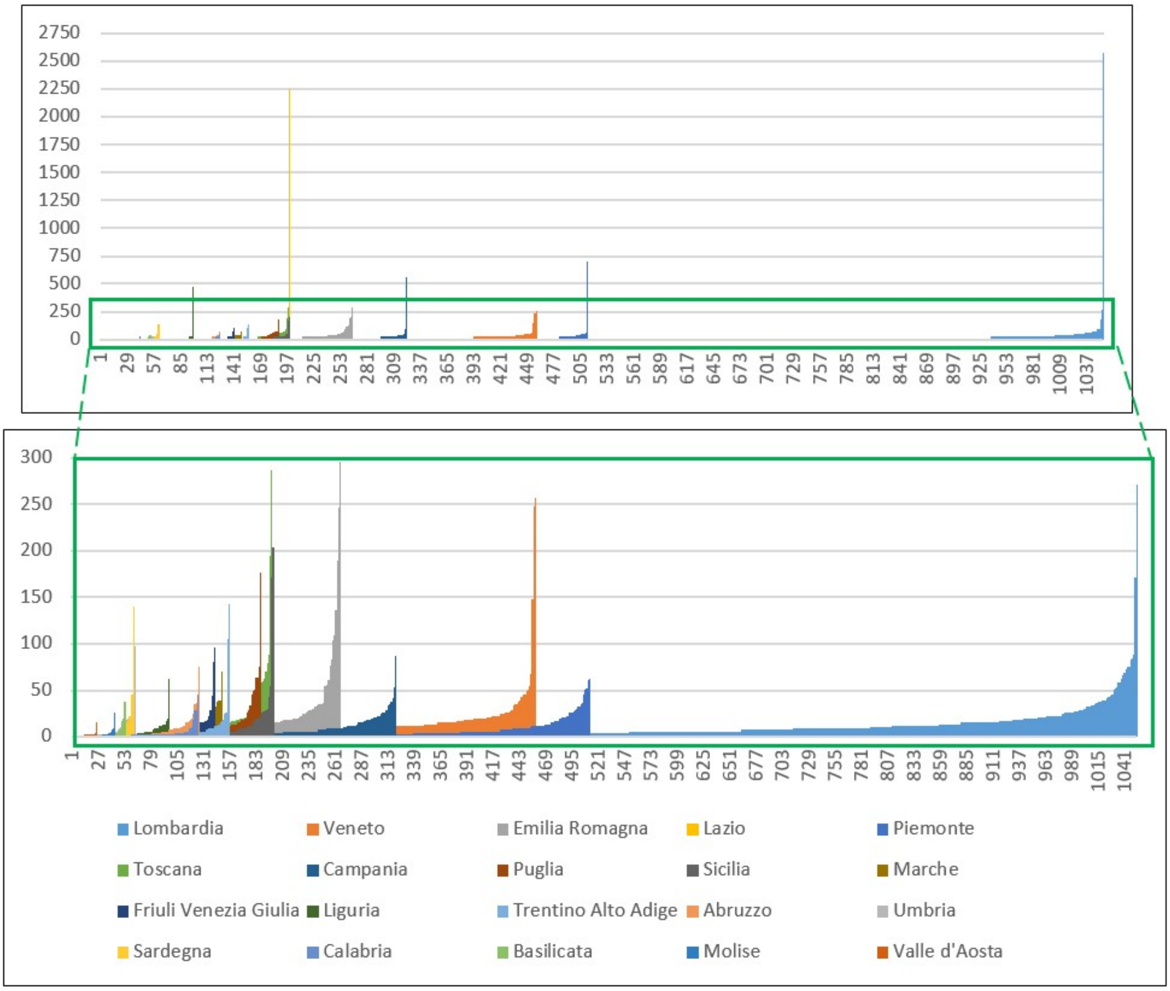


Figure 2.4. Firms geographical distribution (at a municipality and regional level).

Year		2011	2012	2013	2014	2015	2016	2017	2018	2019
Estimated population captured by the panel (as of 2011)		50.275.806								
Italian population (thousands of residents, as of 31st December of each year)		59.394	59.685	60.783	60.796	60.666	60.589	60.484	59.817	59.641
Ratio panel/country		84,6%	84,2%	82,7%	82,7%	82,9%	83,0%	83,1%	84,0%	84,3%
Country change	from 2011	-	0,5%	2,3%	2,4%	2,1%	2,0%	1,8%	0,7%	0,4%
	from previous year	-	0,5%	1,8%	0,0%	-0,2%	-0,1%	-0,2%	-1,1%	-0,3%

Table 2.3. Italian population dynamics, 2011-2019 (in red the years covered by the panel).

Region	Average values									
	Population [#]	Share of residents [%]			University degrees [#]	Surface, 2011 [km^2]	Urbanization degree [1-3]	Altimetric zone [1-5]	Altitude of city center [m asl]	Share of seaside municipalities [%]
		Young	Adult	Old						
Abruzzo	12.268	21	85	23	1.597	44,4	3	3	393,7	12
Basilicata	8.522	23	84	21	892	103,7	3	2	559,4	12
Calabria	35.155	24	83	20	5.618	52,8	3	3	322,1	46
Campania	25.134	24	82	18	3.123	30,3	2	3	248,1	15
Emilia Romagna	15.687	18	84	23	1.777	68,2	3	4	172,9	5
Friuli Venezia Giulia	17.196	18	85	24	2.754	36,5	3	4	139,7	6
Lazio	27.351	22	84	20	3.813	59,6	3	3	313,1	12
Liguria	19.448	17	86	27	2.579	28,2	2	3	127,7	44
Lombardia	9.604	20	82	20	1.040	18,3	2	4	236,8	0
Marche	10.924	20	84	23	1.232	47,3	3	3	275,9	14
Molise	8.892	22	85	23	1.334	47,2	3	2	540,3	15
Piemonte	8.456	18	84	23	1.034	25,2	3	3	329,6	0
Puglia	20.254	23	83	20	1.778	89,6	2	5	154,2	28
Sardegna	12.875	22	85	21	1.584	91,5	3	4	263,4	27
Sicilia	21.939	23	82	20	1.972	87,8	2	3	321,3	44
Toscana	16.920	18	85	24	1.823	86,1	2	3	217,7	15
Trentino Alto Adige	8.615	22	80	18	1.097	55,7	3	1	700,4	0
Umbria	14.303	19	85	24	1.668	122,4	3	3	396,5	0
Valle d'Aosta	3.345	19	83	21	346	54,7	3	1	827,7	0
Veneto	9.733	20	82	20	904	31,6	2	4	116,2	2
Overall	11.899	20	83	21	1.252	43,1	2	3	268,0	10

Region	Median values									
	Population [#]	Share of residents [%]			University degrees [#]	Surface, 2011 [km^2]	Urbanization degree [1-3]	Altimetric zone [1-5]	Altitude of city center [m asl]	Seaside municip. [yes/no]
		Young	Adult	Old						
Abruzzo	4.019	21	85	22	314	30,4	3	3	340,0	No
Basilicata	5.147	23	84	21	389	78,5	3	3	595,0	No
Calabria	4.670	24	83	19	379	30,6	3	3	300,0	No
Campania	7.052	24	82	18	498	17,6	2	3	170,0	No
Emilia Romagna	7.369	19	83	22	540	47,4	3	5	61,5	No
Friuli Venezia Giulia	3.929	18	85	24	258	28,4	3	5	74,0	No
Lazio	1.811	24	83	17	126	20,7	3	3	195,0	No
Liguria	4.968	17	86	27	397	17,0	2	4	39,5	No
Lombardia	4.494	20	82	19	295	11,1	2	5	199,0	No
Marche	4.360	20	84	23	366	28,2	3	4	265,0	No
Molise	2.686	22	85	23	207	43,7	3	1	610,0	No
Piemonte	2.299	18	84	23	161	17,1	3	3	285,0	No
Puglia	12.355	23	83	20	840	50,9	2	5	99,0	No
Sardegna	4.747	22	84	20	270	68,2	3	4	192,5	No
Sicilia	10.796	23	82	20	693	56,6	2	4	275,0	No
Toscana	8.770	18	85	24	670	65,0	2	3	181,0	No
Trentino Alto Adige	2.920	22	80	18	181	38,3	3	1	705,5	No
Umbria	5.659	19	85	24	1.694	123,6	3	3	398,4	No
Valle d'Aosta	1.568	19	84	20	130	25,9	3	1	619,0	No
Veneto	1.501	19	82	19	78	6,1	3	5	3,0	No
Overall	5.050	20	83	21	353	24,0	2	3	211,0	No

Table 2.4. Average (upper part) and median (lower part) statistics about the municipalities involved in the panel analysis; 2011.

Year	Whole dataset (best available proxy for Italy)		Panel-specific		Offset (panel *vs* dataset)			
	Number of municipalities with UBB connectivity (1)	Number of municipalities with FTTH connectivity (2)	(1)	(2)	(1)		(2)	
					#	%	#	%
2013	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0
2015	986	0	810	0	-176	-17,85	0	0
2016	2.006	0	1.659	0	-347	-17,30	0	0
2017	3.539	107	2.859	103	-680	-19,21	-4	-3,74
2018	3.768	174	3.038	170	-730	-19,37	-4	-2,30
2019	3.911	449	3.122	367	-789	-20,17	-82	-18,26

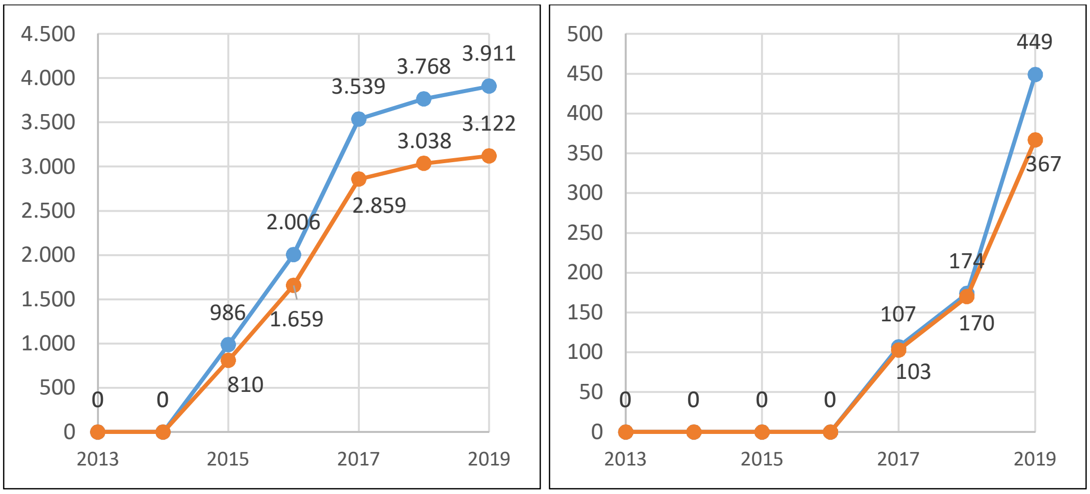
(a)  (b)

Table 2.5 and Figure 2.5 a-b. Municipalities served by different connectivity levels through time: (a) UFBb and (b) FTTH connections. Comparison between original dataset (blue path) and selected panel (orange path), 2013-2019.

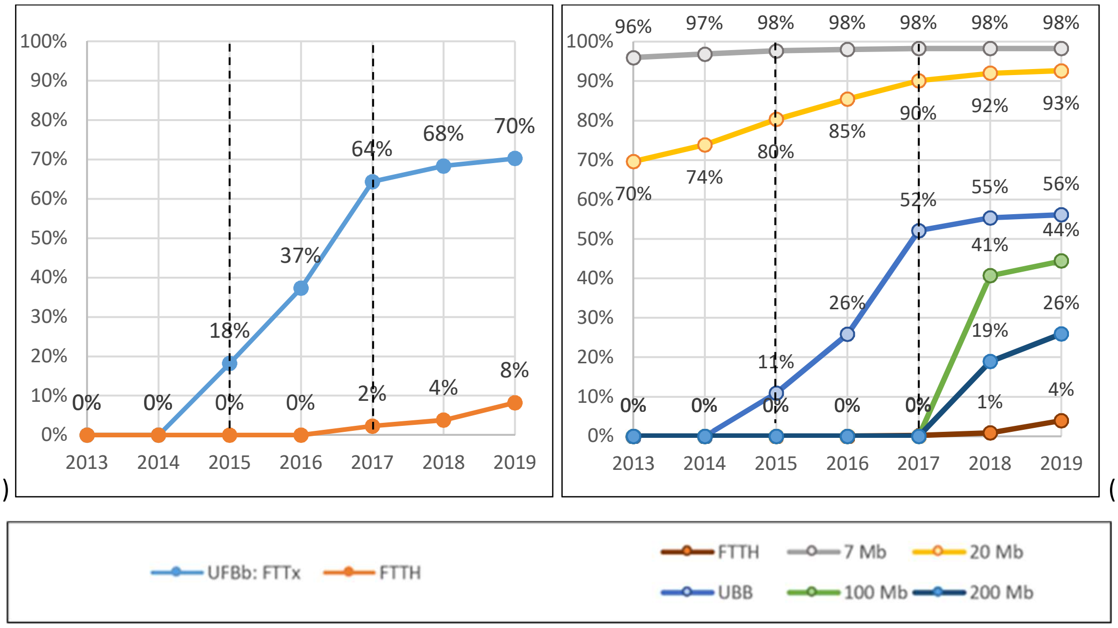
(a)  (b)

Figure 2.6 a-b. (a) Ultra-fast broadband availability and (b) coverages at different bandwidths, both measured at a municipality level within the panel, 2013-2019.

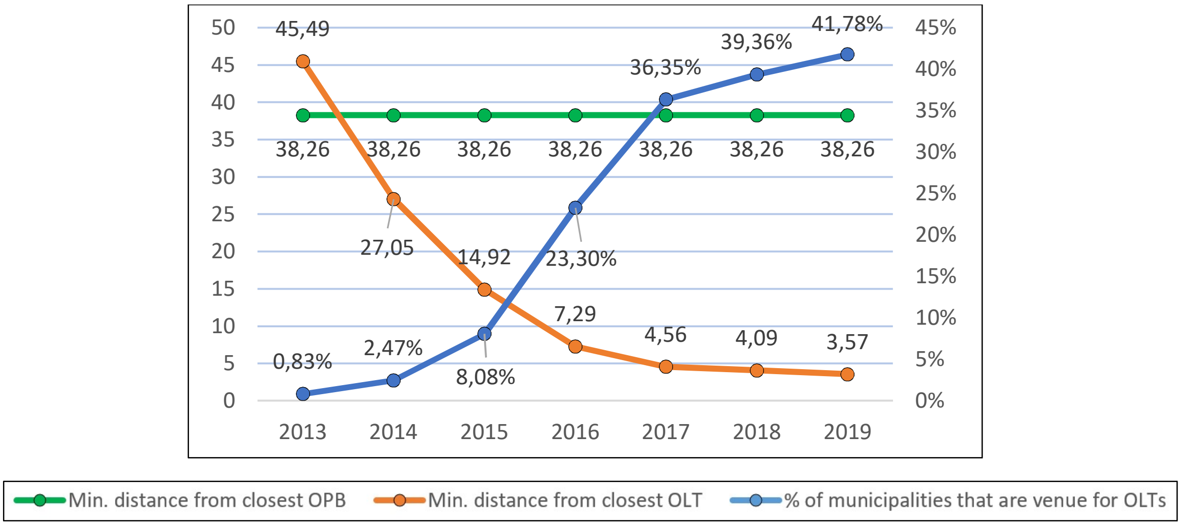


Figure 2.7. Evolution of fiber NGAN along panel years: sample municipalities hosting OLTs and the average shortest distance (in kilometers) between firms and operating OPBs and OLTs, respectively; 2013-2019.

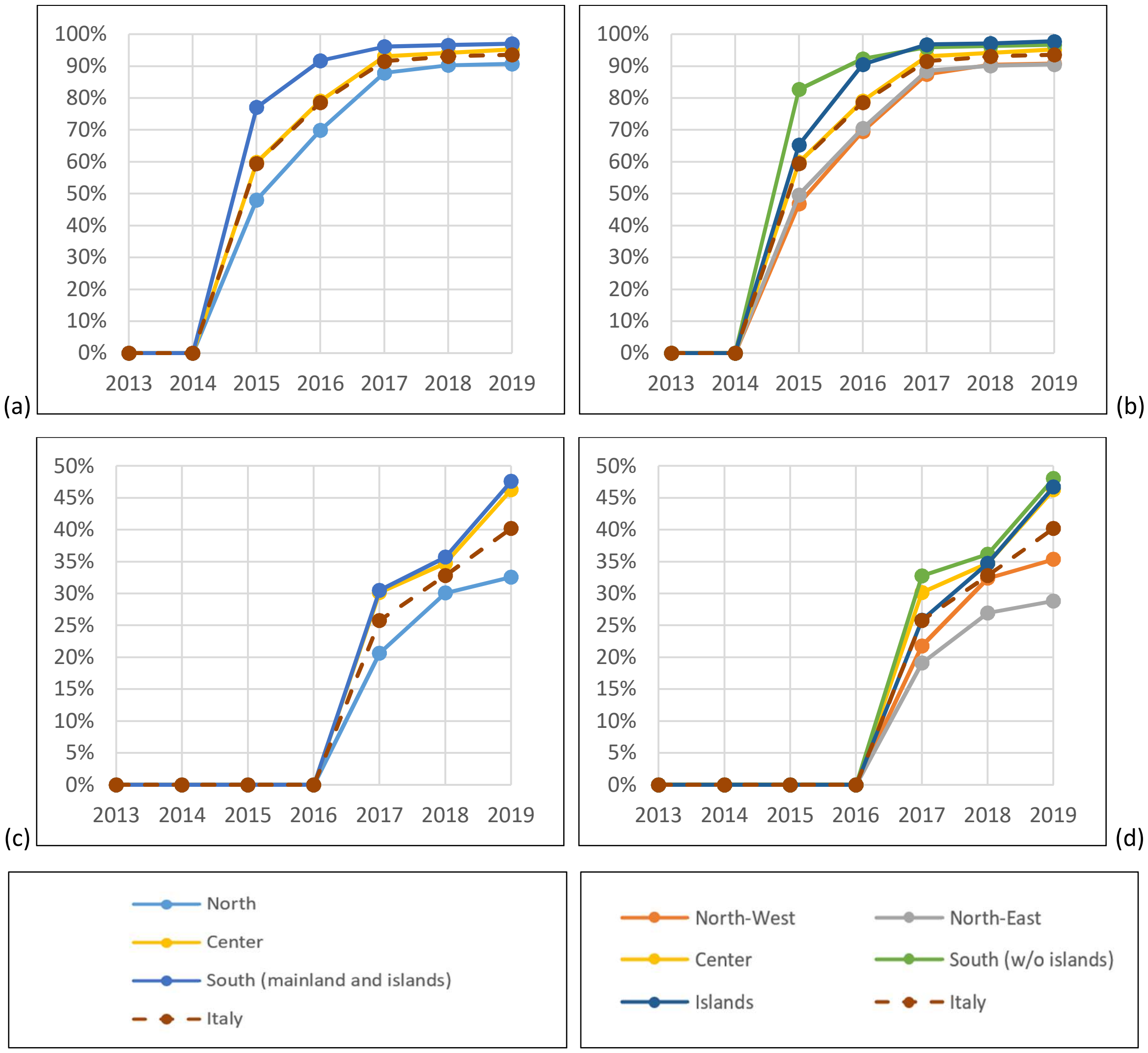


Figure 2.8 a-b-c-d. Estimates of shares of population reached by (a,b) UFBb and (c,d) FTTH, respectively, with respect to the two macro-areas clustering defined (a,c and b,d, as in the legend); 2013-2019.

Region	UFBb: FTTx													
	2013		2014		2015		2016		2017		2018		2019	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Abruzzo	0	0	0	0	5,51	0,15	15,75	0,44	40,16	1,12	43,31	1,21	52,76	1,47
Basilicata	0	0	0	0	42,31	0,48	71,15	0,81	82,69	0,94	84,62	0,97	86,54	0,99
Calabria	0	0	0	0	77,52	2,20	80,62	2,28	85,27	2,42	87,60	2,48	89,92	2,55
Campania	0	0	0	0	46,93	3,36	60,74	4,35	76,07	5,45	78,83	5,65	79,45	5,69
Emilia Romagna	0	0	0	0	12,41	0,72	35,71	2,09	73,68	4,31	76,69	4,48	77,44	4,53
Friuli Venezia Giulia	0	0	0	0	6,34	0,20	24,65	0,77	44,37	1,38	45,07	1,41	51,41	1,60
Lazio	0	0	0	0	16,50	0,72	36,00	1,58	68,50	3,01	72,50	3,19	77,50	3,41
Liguria	0	0	0	0	10,00	0,22	45,00	0,99	80,00	1,76	81,00	1,78	81,00	1,78
Lombardia	0	0	0	0	7,80	1,82	27,63	6,46	59,68	13,95	68,14	15,93	68,98	16,12
Marche	0	0	0	0	7,38	0,24	24,83	0,81	63,09	2,07	64,43	2,11	65,10	2,13
Molise	0	0	0	0	11,90	0,11	11,90	0,11	57,14	0,53	61,90	0,57	61,90	0,57
Piemonte	0	0	0	0	4,44	0,51	13,32	1,52	40,35	4,59	41,70	4,75	42,47	4,83
Puglia	0	0	0	0	49,47	2,04	75,00	3,10	76,60	3,16	78,19	3,23	81,38	3,36
Sardegna	0	0	0	0	13,11	0,18	26,23	0,35	47,54	0,64	47,54	0,64	60,66	0,81
Sicilia	0	0	0	0	37,31	1,65	70,65	3,12	89,05	3,93	91,04	4,02	92,54	4,09
Toscana	0	0	0	0	21,21	0,92	58,08	2,53	90,91	3,95	92,93	4,04	93,43	4,06
Trentino Alto Adige	0	0	0	0	1,27	0,07	6,36	0,33	27,12	1,41	27,97	1,45	27,97	1,45
Umbria	0	0	0	0	7,94	0,11	23,81	0,33	57,14	0,79	68,25	0,94	76,19	1,05
Valle d'Aosta	0	0	0	0	7,14	0,04	10,71	0,07	21,43	0,13	21,43	0,13	32,14	0,20
Veneto	0	0	0	0	20,13	2,04	43,51	4,42	71,65	7,27	76,62	7,78	77,92	7,91

Region	FTTH													
	2013		2014		2015		2016		2017		2018		2019	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Abruzzo	0	0	0	0	0	0	0	0	0,79	0,02	0,79	0,02	7,87	0,22
Basilicata	0	0	0	0	0	0	0	0	0	0	1,92	0,02	7,69	0,09
Calabria	0	0	0	0	0	0	0	0	0,78	0,02	0,78	0,02	2,33	0,07
Campania	0	0	0	0	0	0	0	0	22,09	1,58	22,70	1,63	27,91	2,00
Emilia Romagna	0	0	0	0	0	0	0	0	1,50	0,09	4,51	0,26	7,14	0,42
Friuli Venezia Giulia	0	0	0	0	0	0	0	0	0,70	0,02	1,41	0,04	9,15	0,29
Lazio	0	0	0	0	0	0	0	0	0,50	0,02	1,00	0,04	12,00	0,53
Liguria	0	0	0	0	0	0	0	0	2,00	0,04	4,00	0,09	4,00	0,09
Lombardia	0	0	0	0	0	0	0	0	0,38	0,09	2,35	0,55	5,92	1,38
Marche	0	0	0	0	0	0	0	0	0,67	0,02	0,67	0,02	2,68	0,09
Molise	0	0	0	0	0	0	0	0	0	0	0	0	4,76	0,04
Piemonte	0	0	0	0	0	0	0	0	0,19	0,02	2,51	0,29	3,47	0,40
Puglia	0	0	0	0	0	0	0	0	0,53	0,02	2,66	0,11	6,91	0,29
Sardegna	0	0	0	0	0	0	0	0	1,64	0,02	8,20	0,11	9,84	0,13
Sicilia	0	0	0	0	0	0	0	0	1,49	0,07	3,98	0,18	17,41	0,77
Toscana	0	0	0	0	0	0	0	0	1,52	0,07	3,03	0,13	11,11	0,48
Trentino Alto Adige	0	0	0	0	0	0	0	0	0,42	0,02	0,42	0,02	1,69	0,09
Umbria	0	0	0	0	0	0	0	0	3,17	0,04	4,76	0,07	17,46	0,24
Valle D'Aosta	0	0	0	0	0	0	0	0	0	0	0	0	14,29	0,09
Veneto	0	0	0	0	0	0	0	0	0,87	0,09	1,30	0,13	3,68	0,37

A: Share of municipalities in the region (%)

B: Share of municipalities in the panel (%)

Table 2.6. Municipalities reached by ultra-fast broadband (upper part) and by fiber-to-the-home connectivity (lower part), in particular; 2013-2019.

Region	UFBb: FTTx													
	2013		2014		2015		2016		2017		2018		2019	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D
Abruzzo	0	0	0	0	31,44	0,54	52,63	0,91	74,63	1,29	76,25	1,32	81,11	1,40
Basilicata	0	0	0	0	76,79	0,30	91,07	0,36	94,64	0,37	95,24	0,37	95,83	0,38
Calabria	0	0	0	0	90,09	0,93	91,44	0,95	93,47	0,97	94,14	0,98	95,95	0,99
Campania	0	0	0	0	85,41	5,16	89,46	5,41	94,75	5,73	95,25	5,76	95,41	5,77
Emilia Romagna	0	0	0	0	55,78	5,47	76,20	7,47	94,95	9,31	95,86	9,40	95,98	9,41
Friuli Venezia Giulia	0	0	0	0	31,74	0,70	54,10	1,19	74,65	1,64	74,76	1,64	76,68	1,68
Lazio	0	0	0	0	80,89	7,01	88,72	7,69	96,26	8,34	96,64	8,38	97,60	8,46
Liguria	0	0	0	0	70,47	1,51	86,21	1,85	97,39	2,09	97,50	2,10	97,50	2,10
Lombardia	0	0	0	0	49,68	13,78	72,16	20,01	89,03	24,69	93,00	25,79	93,25	25,86
Marche	0	0	0	0	40,97	0,94	63,69	1,47	87,12	2,00	87,63	2,02	88,34	2,03
Molise	0	0	0	0	50,50	0,12	50,50	0,12	75,25	0,18	78,22	0,18	78,22	0,18
Piemonte	0	0	0	0	44,07	3,35	60,85	4,62	79,72	6,05	80,42	6,11	80,76	6,13
Puglia	0	0	0	0	79,72	2,97	95,43	3,56	95,87	3,57	96,25	3,59	96,62	3,60
Sardegna	0	0	0	0	66,52	0,69	74,38	0,77	86,97	0,90	86,97	0,90	88,76	0,92
Sicilia	0	0	0	0	71,36	2,40	92,79	3,12	97,92	3,29	98,47	3,31	98,68	3,32
Toscana	0	0	0	0	65,31	4,37	84,07	5,63	98,08	6,56	99,06	6,63	99,09	6,63
Trentino Alto Adige	0	0	0	0	33,37	0,65	48,50	0,94	74,55	1,45	74,91	1,46	74,91	1,46
Umbria	0	0	0	0	45,34	0,52	72,27	0,83	91,09	1,05	93,12	1,07	94,13	1,09
Valle D'Aosta	0	0	0	0	27,78	0,04	31,48	0,04	40,74	0,05	40,74	0,05	50,00	0,06
Veneto	0	0	0	0	48,58	5,87	69,89	8,44	87,63	10,58	90,67	10,95	91,05	10,99

Region	FTTH													
	2013		2014		2015		2016		2017		2018		2019	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D
Abruzzo	0	0	0	0	0	0	0	0	10,53	0,18	10,53	0,18	36,98	0,64
Basilicata	0	0	0	0	0	0	0	0	0	0	22,62	0,09	35,12	0,14
Calabria	0	0	0	0	0	0	0	0	6,98	0,07	6,98	0,07	24,77	0,26
Campania	0	0	0	0	0	0	0	0	64,44	3,89	64,32	3,89	68,03	4,11
Emilia Romagna	0	0	0	0	0	0	0	0	22,61	2,22	37,22	3,65	38,39	3,76
Friuli Venezia Giulia	0	0	0	0	0	0	0	0	10,33	0,23	18,96	0,42	21,94	0,48
Lazio	0	0	0	0	0	0	0	0	61,88	5,36	64,71	5,61	71,57	6,20
Liguria	0	0	0	0	0	0	0	0	51,57	1,11	58,85	1,26	58,85	1,26
Lombardia	0	0	0	0	0	0	0	0	27,12	7,52	35,35	9,80	39,39	10,92
Marche	0	0	0	0	0	0	0	0	5,48	0,13	5,48	0,13	12,88	0,30
Molise	0	0	0	0	0	0	0	0	0	0	0	0	26,73	0,06
Piemonte	0	0	0	0	0	0	0	0	21,57	1,64	35,34	2,68	35,74	2,71
Puglia	0	0	0	0	0	0	0	0	11,33	0,42	23,47	0,88	41,49	1,55
Sardegna	0	0	0	0	0	0	0	0	32,13	0,33	51,69	0,54	55,06	0,57
Sicilia	0	0	0	0	0	0	0	0	30,79	1,04	37,03	1,25	51,87	1,75
Toscana	0	0	0	0	0	0	0	0	18,17	1,22	24,65	1,65	41,46	2,77
Trentino Alto Adige	0	0	0	0	0	0	0	0	13,09	0,25	13,09	0,25	13,69	0,27
Umbria	0	0	0	0	0	0	0	0	23,89	0,28	36,03	0,42	41,50	0,48
Valle D'Aosta	0	0	0	0	0	0	0	0	0	0	0	0	35,19	0,04
Veneto	0	0	0	0	0	0	0	0	17,12	2,07	18,72	2,26	20,79	2,51

C: Share of firms in the region (%)

D: Share of firms in the panel (%)

Table 2.7. Firms potentially served by ultra-fast broadband (upper part) and by fiber-to-the-home connectivity (lower part), in particular; 2013-2019.

	UFBb: FTTx											
	Year						Yearly shift					
Region	2015		2016	2017	2018	2019	Average	% of region municip.	Weighted average	% of region municip.	Median	% of region municip.
Abruzzo	+7	+7	+13	+31	+4	+12	+13	+10,55	+12	+9,32	+12	+9,45
Basilicata	+22	+22	+15	+6	+1	+1	+9	+17,31	+4	+8,42	+6	+11,54
Calabria	+100	+100	+4	+6	+3	+3	+23	+17,98	+4	+3,07	+4	+3,10
Campania	+153	+153	+45	+50	+9	+2	+52	+15,89	+23	+7,00	+45	+13,80
Emilia Romagna	+33	+33	+62	+101	+8	+2	+41	+15,49	+26	+9,70	+33	+12,41
Friuli Venezia Giulia	+9	+9	+26	+28	+1	+9	+15	+10,28	+11	+7,63	+9	+6,34
Lazio	+33	+33	+39	+65	+8	+10	+31	+15,50	+22	+11,00	+33	+16,50
Liguria	+10	+10	+35	+35	+1	- - -	+16	+16,20	+9	+9,28	+10	+10,00
Lombardia	+83	+83	+211	+341	+90	+9	+147	+13,80	+104	+9,82	+90	+8,46
Marche	+11	+11	+26	+57	+2	+1	+19	+13,02	+11	+7,55	+11	+7,38
Molise	+5	+5	- - -	+19	+2	- - -	+5	+12,38	+2	+5,67	+2	+4,76
Piemonte	+23	+23	+46	+140	+7	+4	+44	+8,49	+25	+4,87	+23	+4,44
Puglia	+93	+93	+48	+3	+3	+6	+31	+16,28	+12	+6,28	+6	+3,19
Sardegna	+8	+8	+8	+13	- - -	+8	+7	+12,13	+6	+10,08	+8	+13,11
Sicilia	+75	+75	+67	+37	+4	+3	+37	+18,51	+20	+9,92	+37	+18,41
Toscana	+42	+42	+73	+65	+4	+1	+37	+18,69	+22	+11,09	+42	+21,21
Trentino Alto Adige	+3	+3	+12	+49	+2	- - -	+13	+5,59	+6	+2,57	+3	+1,27
Umbria	+5	+5	+10	+21	+7	+5	+10	+15,24	+8	+13,34	+7	+11,11
Valle d'Aosta	+2	+2	+1	+3	- - -	+3	+2	+6,43	+2	+6,09	+2	+7,14
Veneto	+93	+93	+108	+130	+23	+6	+72	+15,58	+47	+10,15	+93	+20,13

	FTTH										
	Year				Yearly shift						
Region	2017		2018	2019	Average	% of region municip.	Weighted average	% of region municip.	Median	% of region municip.
Abruzzo	+1	+1	- - -	+9	+3	+2,62	+3	+2,05	+1	+0,79
Basilicata	- - -	- - -	+1	+3	+1	+2,56	+1	+2,03	+1	+1,92
Calabria	+1	+1	- - -	+2	+1	+0,78	+1	+0,61	+1	+0,78
Campania	+72	+72	+2	+17	+30	+9,30	+12	+3,59	+17	+5,21
Emilia Romagna	+4	+4	+8	+7	+6	+2,38	+5	+2,06	+7	+2,63
Friuli Venezia Giulia	+1	+1	+1	+11	+4	+3,05	+4	+2,57	+1	+0,70
Lazio	+1	+1	+1	+22	+8	+4,00	+7	+3,29	+1	+0,50
Liguria	+2	+2	+2	- - -	+1	+1,33	+1	+0,95	+2	+2,00
Lombardia	+4	+4	+21	+38	+21	+1,97	+24	+2,27	+21	+1,97
Marche	+1	+1	- - -	+3	+1	+0,89	+1	+0,69	+1	+0,67
Molise	- - -	- - -	- - -	+2	+1	+1,59	+1	+1,19	- - -	- - -
Piemonte	+1	+1	+12	+5	+6	+1,16	+5	+0,95	+5	+0,97
Puglia	+1	+1	+4	+8	+4	+2,30	+4	+2,15	+4	+2,13
Sardegna	+1	+1	+4	+1	+2	+3,28	+2	+2,46	+1	+1,64
Sicilia	+3	+3	+5	+27	+12	+5,80	+11	+5,68	+5	+2,49
Toscana	+3	+3	+3	+16	+7	+3,70	+7	+3,30	+3	+1,52
Trentino Alto Adige	+1	+1	- - -	+3	+1	+0,56	+1	+0,46	+1	+0,42
Umbria	+2	+2	+1	+8	+4	+5,82	+3	+4,70	+2	+3,17
Valle d'Aosta	- - -	- - -	- - -	+4	+1	+4,76	+1	+3,57	- - -	- - -
Veneto	+4	+4	+2	+11	+6	+1,23	+5	+1,05	+4	+0,87

Table 2.8. Focus on year-by-year variations of municipalities covered by different connectivity levels (only years with non-null values are exhibited); 2015-2019 for FTTx (upper part), 2017-2019 for FTTH (lower part).

Variable	Mean	Min	Max	Range	Std. Dev.	CV
Employees (#)	72	1	43.122	43.121	471,10	7
Revenues (k€)	25.555,90	100,00	48.215.102	48.215.002	247.539,16	9,69
Total assets (k€)	31.192,42	11,00	85.800.056	85.800.045	586.705,25	18,81
Intangible fixed (k€)	2.888,23	0,00	32.844.716	32.844.786	179.310,20	62,08
Patents (#)	110,03	0,00	1.476.000	1.476.000	6.829,10	62,07
Patents per employee	1,22	0,00	185.547	185.547	339,85	277,71
Capital (k€)	7.397,39	0,02	34.540.992	34.540.992	192.757,29	26,06
Total liabilities (k€)	16.744,93	-563,00	43.528.913	43.529.476	302.288,12	18,05
Value added (k€)	6.093,92	1,00	9.941.521	9.941.520	58.811,54	9,65
Firm age (years)	25,42	0,00	154,00	154,00	15,37	0,60

Variable	10th percentile	25th percentile	Median	75th percentile	90th percentile	Skewness	Kurtosis
Employees (#)	2	5	14	52	128	45,5	2.949,1
Revenues (k€)	324,00	717,00	3.796,00	16.934,00	43.327,00	100,6	13.931,1
Total assets (k€)	317,00	778,00	4.420,00	16.076,00	41.854,00	106,6	13.017,7
Intangible fixed (k€)	0	0	2,00	120,00	792,00	148,9	24.119,8
Patents (#)	0	0	0	0	25,00	169,7	31.937,5
Patents per employee	0	0	0	0	0,43	542,7	296.182,8
Capital (k€)	10,63	49,63	416,77	2.677,26	8.992,90	138,0	22.838,6
Total liabilities (k€)	131,00	373,00	1.990,00	8.568,00	22.796,00	105,4	12.943,3
Value added (k€)	99,00	219,00	892,00	3.818,00	9.946,00	97,2	13.561,5
Firm age (years)	8,00	14,00	23,00	34,00	44,00	1,2	5,7

Table 2.9. Descriptive statistics about some of the main firm characteristics within the panel, 2013-2019.

Region	Macro area		Firms			
			Abs. Freq.	Rel. Freq.		
Valle d'Aosta	*North-West*	*North*	54	0,13%	37,60%	63,62%
Piemonte			3.254	7,59%		
Lombardia			11.886	27,73%		
Liguria			921	2,15%		
Veneto	*North-East*		5.175	12,08%	26,02%	
Friuli Venezia Giulia			939	2,19%		
Trentino Alto Adige			833	1,94%		
Emilia Romagna			4.202	9,80%		
Marche	*Center*		986	2,30%	20,54%	
Umbria			494	1,15%		
Toscana			2.868	6,69%		
Lazio			3.715	8,67%		
Abruzzo			741	1,73%		
Molise	*Inland South*	*South (mainland and islands)*	101	0,24%	11,44%	15,84%
Campania			2.590	6,04%		
Puglia			1.598	3,73%		
Basilicata			168	0,39%		
Calabria			444	1,04%		
Sicilia	*Islands*		1.442	3,36%	4,40%	
Sardegna			445	1,04%		
		Overall	42.856	100%	100%	100%

Table 2.10. Geographical distribution of firms composing the panel, 2013-2019.

Size	Abs. Freq.	Rel. Freq.
Micro	1.938	4,52%
Small	9.279	21,65%
Medium	17.635	41,15%
Large	14.004	32,68%

(a)

To / From	*Micro*	*Small*	*Medium*	*Large*	Total
Micro	10.984 96,44%	378 3,32%	8 0,07%	19 0,17%	11.389 100%
Small	799 1,45%	52.661 95,32%	51 0,09%	1.738 3,15%	55.249 100%
Medium	9 0,01%	61 0,06%	101.792 95,86%	4.328 4,08%	106.190 100%
Large	23 0,03%	3.080 3,65%	3.430 4,07%	77.775 92,25%	84.308 100%
Total	11.815 4,59%	56.180 21,85%	105.281 40,94%	83.860 32,61%	257.136 100%

(b)

Firm size variations	13.924
Downgrade	5.624
Upgrade	8.300

Decrease in number	-637.748
Increase in number	1.048.769
Net variation in the number of employees	411.021

(c)

Table 2.11 a-c. (a) Size, (b) size transitions and (c) employment variations within the panel, 2013-2019.

Legal form	Macro type	Abs. Freq.	Rel. Freq.	
S.A.P.A.	*S.A.P.A.*	2	0,0047%	0,0047%
S.P.A.	*S.P.A.*	9.033	21,08%	25,07%
S.P.A. a socio unico		1.709	3,99%	
S.R.L.	*S.R.L.*	27.671	64,57%	74,93%
S.R.L. a capitale ridotto		1	0,00%	
S.R.L. a socio unico		4.410	10,29%	
S.R.L. semplificata		30	0,07%	

Table 2.12. Legal form distribution of the firms in the panel, 2013-2019.

1	*Lombardia*	8.608.278	1	*Emilia Romagna*	18.098,78
2	*Lazio*	4.912.984	2	*Lombardia*	17.888,96
3	*Campania*	4.907.935	3	*Sicilia*	17.713,36
4	*Veneto*	4.360.401	4	*Puglia*	17.026,56
5	*Sicilia*	4.144.365	5	*Toscana*	16.887,70
6	*Emilia Romagna*	3.902.505	6	*Veneto*	15.118,56
7	*Piemonte*	3.593.224	7	*Trentino Alto Adige*	13.999,61
8	*Puglia*	3.578.185	8	*Piemonte*	12.726,27
9	*Toscana*	3.248.933	9	*Lazio*	11.817,77
10	*Liguria*	1.352.815	10	*Campania*	8.340,37
11	*Marche*	1.324.091	11	*Umbria*	7.292,37
12	*Calabria*	1.164.436	12	*Marche*	6.881,58
13	*Friuli Venezia Giulia*	1.061.107	13	*Sardegna*	5.382,59
14	*Abruzzo*	1.060.650	14	*Abruzzo*	5.344,48
15	*Trentino Alto Adige*	793.794	15	*Calabria*	5.277,22
16	*Umbria*	785.919	16	*Basilicata*	5.238,82
17	*Sardegna*	785.261	17	*Friuli Venezia Giulia*	5.032,21
18	*Basilicata*	404.271	18	*Liguria*	2.540,44
19	*Molise*	206.693	19	*Molise*	1.930,87
20	*Valle d'Aosta*	79.959	20	*Valle d'Aosta*	1.453,78

Table 2.13. Rankings of Italian regions by resident population (left) and surface (right) as described by the panel, 2011.

Year	Firm age (years)							
	0	[1;5)	[5;10)	[10;25)	[25;50)	[50;75)	[75;100)	[100;∞]
2013	234	2.618	6.494	16.342	14.872	1.925	323	48
2014	2	1.890	6.214	16.606	15.717	2.035	342	50
2015	1	1.284	5.469	16.896	16.634	2.159	360	53
2016	1	710	4.733	17.359	17.286	2.339	374	54
2017	1	233	3.921	17.717	17.946	2.598	384	56
2018	1	1	2.850	17.998	18.682	2.876	391	57
2019	0	1	1.891	18.044	19.341	3.119	388	72

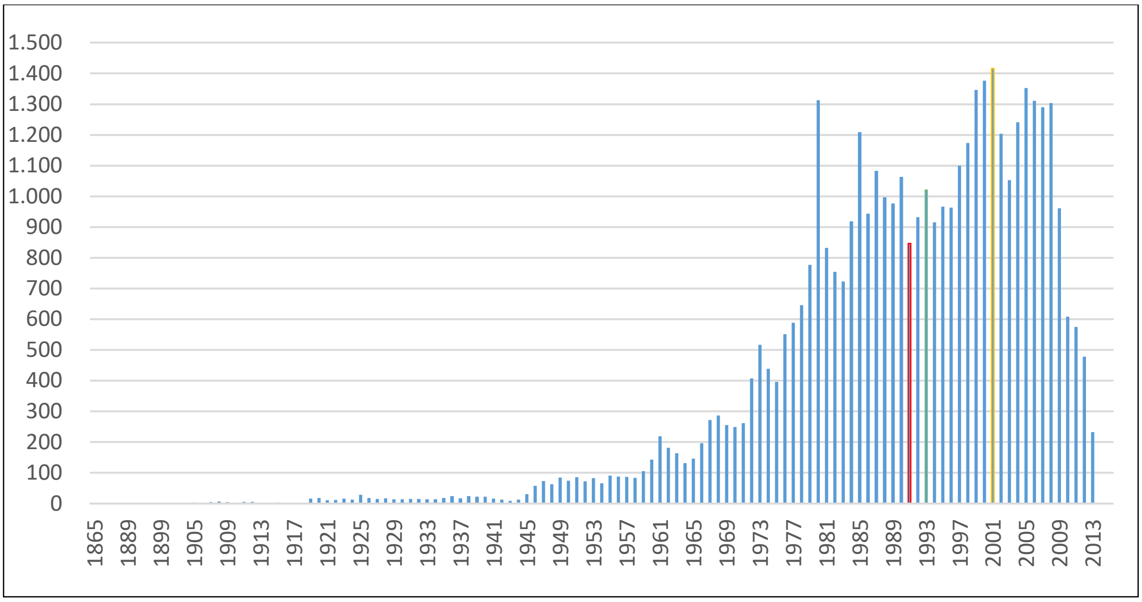


Table 2.14 and Figure 2.9. Firm age and bar-chart of firms in the panel (i.e. active between 2013 and 2019) by year of establishment; 1865-2018.

Industry statistical identificator - Ateco2007 code		Abs. Freq.	Rel. Freq.	Macro industry	Rel. Freq.
B	*Mining*	141	0,33%	mining	0,33%
C	*Manufacturing*	15.690	36,61%	manufacturing	36,61%
F	*Construction*	5.368	12,53%	construction	12,53%
G	*Wholesale and retail trade; cars and motorvehicles restoration*	10.947	25,54%	trade	25,54%
H	*Transport and warehousing*	2.075	4,84%	services	24,99%
I	*Lodging and dining*	1.252	2,92%		
J	*Information and communication service*	1.662	3,88%		
L	*Real estate*	1.229	2,87%		
M	*Scientific, technical and professional activities*	1.705	3,98%		
N	*Rent, travel agencies, enterprise support services*	1.354	3,16%		
P	*Education*	120	0,28%		
Q	*Healthcare and social care*	769	1,79%		
R	*Artistic, entartainment, amusement and sport activities*	286	0,67%		
S	*Other service activities*	258	0,60%		

Table 2.15. Classification of firms and frequency evaluation by industry and macro industry, 2013-2019.

Abruzzo	C	G	F	H	M	I	N	J	Q	L	S	R	B	P
Basilicata	C	G	F	H	I	N	J	B	Q	L	R	M	S	P
Calabria	G	F	C	Q	H	I	N	J	L	M	S	B	R	P
Campania	G	C	F	H	Q	I	N	J	M	L	R	S	P	B
Emilia Romagna	C	G	F	M	H	J	N	L	I	Q	S	R	P	B
Friuli Venezia Giulia	C	G	F	H	M	J	I	L	N	Q	S	R	B	P
Lazio	G	F	C	J	N	M	I	H	L	Q	R	S	B	P
Liguria	G	C	H	F	I	M	J	L	N	R	S	Q	B	P
Lombardia	C	G	F	M	J	L	H	N	I	Q	S	R	P	B
Marche	C	G	F	H	M	J	I	Q	L	N	S	R	B	P
Molise	C	G	F	Q	H	M	I	J	L	N	S	R	B	P
Piemonte	C	G	F	M	J	H	L	N	I	Q	S	P	R	B
Puglia	G	C	F	H	I	Q	N	M	J	L	R	B	S	P
Sardegna	G	F	C	H	I	N	J	M	Q	L	R	B	S	P
Sicilia	G	C	F	H	Q	I	N	M	J	L	B	R	S	P
Toscana	C	G	F	H	I	M	J	N	L	Q	R	B	S	P
Trentino Alto Adige	G	C	F	H	J	I	N	M	L	R	Q	B	S	P
Umbria	C	G	F	H	N	I	M	L	J	Q	R	S	P	B
Valle d'Aosta	G	F	C	H	M	I	J	S	N	L	R	Q	P	B
Veneto	C	G	F	H	J	I	L	M	N	Q	R	S	P	B

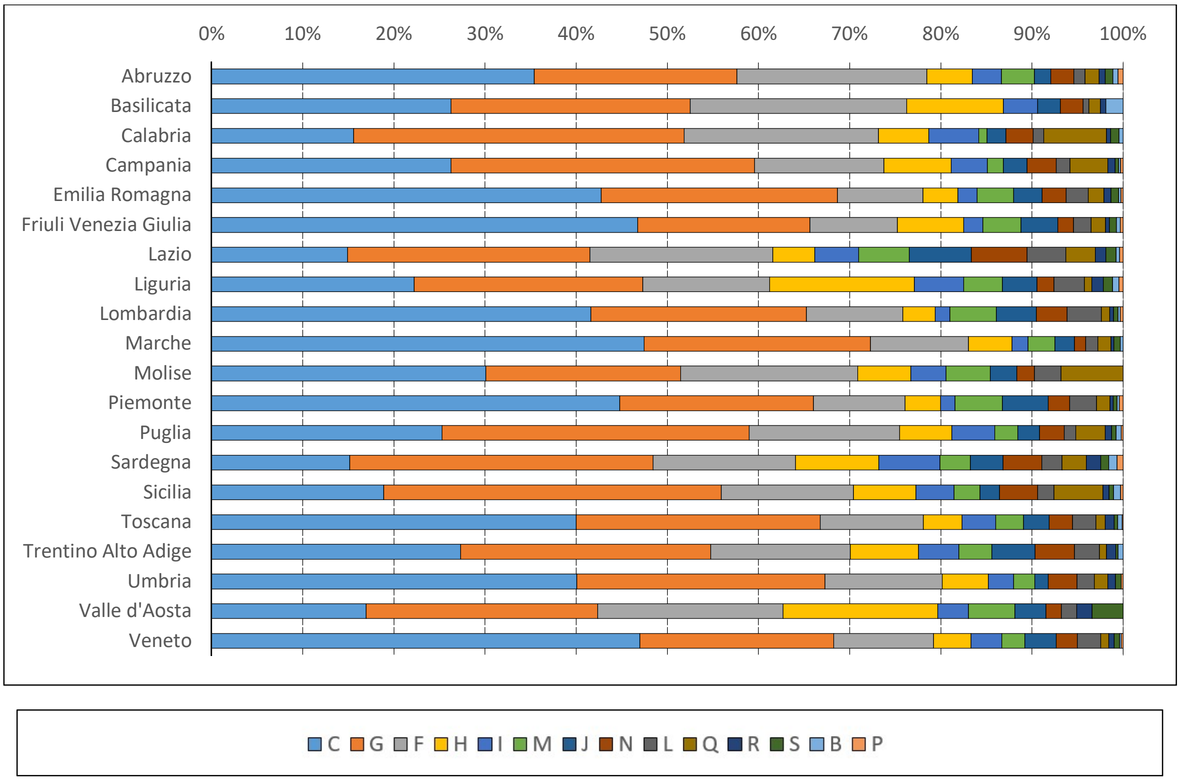


Table 2.16 and Figure 2.10. Industry structure within the panel: ordinal ranking and frequency breakdown by region (legend and ID symbols are referred to Table 15), 2013-2019.

Overall ranking	Ateco 2007 ID	Statistics on ranking			
		Average	Median	Max	Min
1	C	1,55	2	1	2
2	G	1,65	1	1	3
3	F	2,85	3	2	4
4	H	4,55	4	3	8
5	I	6,7	6	4	12
6	M	6,4	6	5	9
7	J	7,55	7	5	10
8	N	6,8	7	4	9
9	L	8,7	10	4	12
10	Q	8,8	9	6	10
11	R	11,65	11,5	8	13
12	S	11,45	11	10	13
13	B	12,75	13	8	14
14	P	13,6	14	12	14

Table 2.17. Global ranking of industries by region within the panel (ID symbols from Table 15), 2013-2019.

Year	Available differences	Average				Median
		Arithmetic	Moving (on D1)			
			2-year bucket	3-year bucket	4-year bucket	
2014	D1	-6				0
2015	D1	-14	-10			0
	D2	-21				0
2016	D1	+21	+3	0		0
	D2	+7				0
	D3	0				0
2017	D1	+3	+12	+3	+1	0
	D2	+24				0
	D3	+10				0
	D4	+3				0
2018	D1	+9	+6	+11	+5	0
	D2	+12				0
	D3	+33				0
	D4	+19				0
	D5	+12				0
2019	D1	+8	+9	+7	+10	0
	D2	+17				0
	D3	+20				0
	D4	+41				0
	D5	+27				0
	D6	+21				0

n-th difference	D1	D2	D3	D4	D5	D6
Average	+3	+8	+16	+21	+20	+21
Median	0	0	0	0	0	0

Table 2.18. Evolution of patents portfolios for panel firms, assessed by means of n-th differences among years; 2014-2019.

.

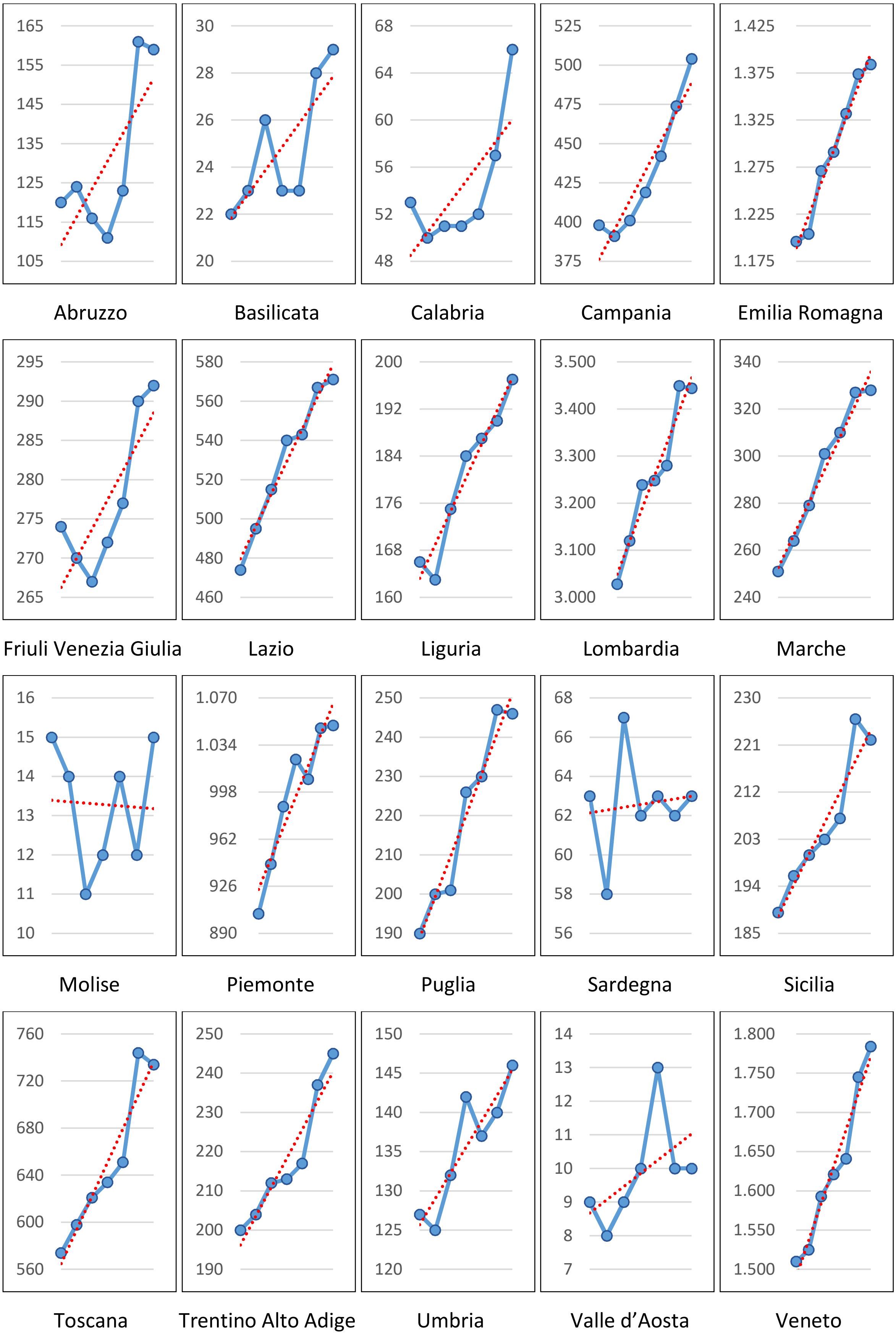


Figure 2.11. Trend within the panel of patents-owning firms number by region, 2013-2019.

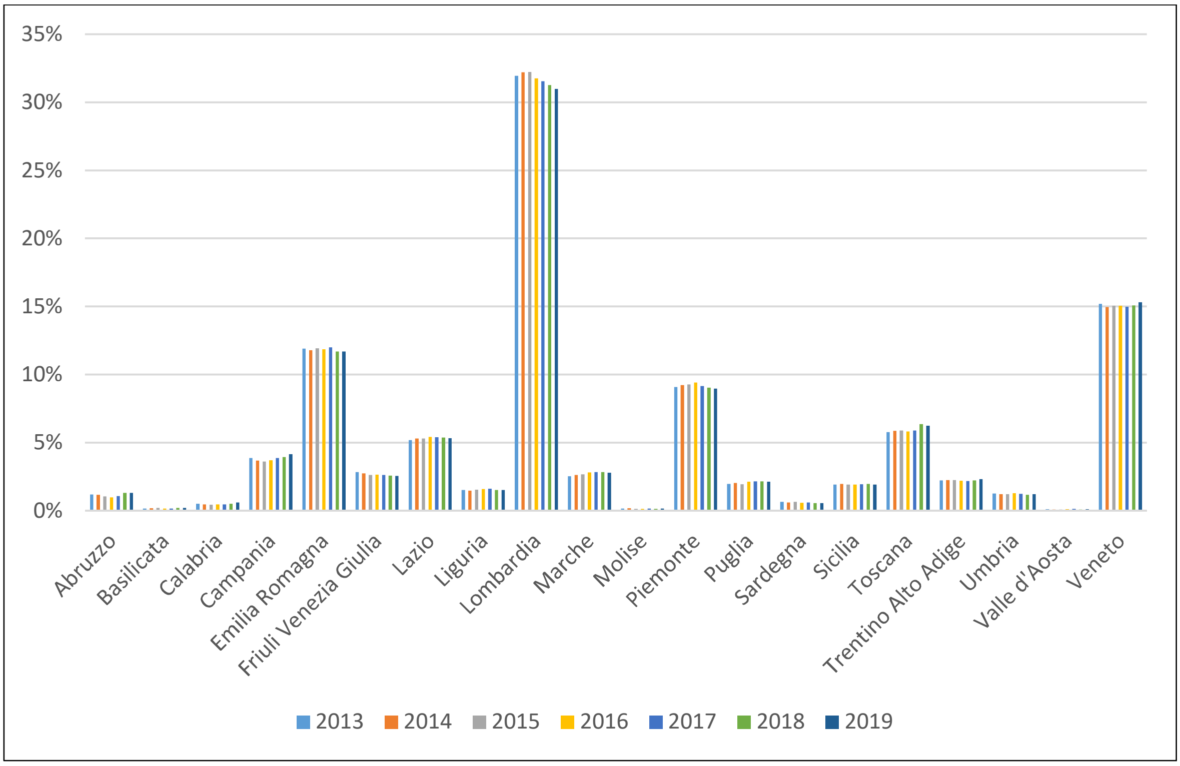


Figure 2.12. Percentage of enterprises investing in patents (i.e., with patents among their assets) over the country total (as included the panel), 2013-2019.

Region	2013	2014	2015	2016	2017	2018	2019
Abruzzo	16,19	16,73	15,65	14,98	16,60	21,73	21,46
Basilicata	13,10	13,69	15,48	13,69	13,69	16,67	17,26
Calabria	11,94	11,26	11,49	11,49	11,71	12,84	14,86
Campania	15,37	15,10	15,48	16,18	17,07	18,30	19,46
Emilia Romagna	28,46	28,65	30,25	30,72	31,70	32,70	32,94
Friuli Venezia Giulia	29,18	28,75	28,43	28,97	29,50	30,88	31,10
Lazio	12,76	13,32	13,86	14,54	14,62	15,26	15,37
Liguria	18,02	17,70	19,00	19,98	20,30	20,63	21,39
Lombardia	25,48	26,25	27,25	27,33	27,60	29,02	28,98
Marche	25,46	26,77	28,30	30,53	31,44	33,16	33,27
Molise	14,85	13,86	10,89	11,88	13,86	11,88	14,85
Piemonte	27,81	28,98	30,33	31,44	30,98	32,18	32,24
Puglia	11,89	12,52	12,58	14,14	14,39	15,46	15,39
Sardegna	14,16	13,03	15,06	13,93	14,16	13,93	14,16
Sicilia	13,11	13,59	13,87	14,08	14,36	15,67	15,40
Toscana	20,01	20,85	21,65	22,11	22,70	25,94	25,59
Trentino Alto Adige	24,01	24,49	25,45	25,57	26,05	28,45	29,41
Umbria	25,71	25,30	26,72	28,74	27,73	28,34	29,55
Valle D'Aosta	16,67	14,81	16,67	18,52	24,07	18,52	18,52
Veneto	29,18	29,47	30,78	31,32	31,71	33,72	34,47

Table 2.19. Panel firms with patents over total panel firms by region, 2013-2019.

Ateco2007	2013	2014	2015	2016	2017	2018	2019
C	5.546	5.675	5.887	6.015	6.104	6.403	6.473
G	2.004	2.035	2.147	2.180	2.209	2.405	2.451
H	416	405	414	421	435	464	477
J	365	379	393	394	403	412	397
M	365	380	366	370	372	385	379
F	324	347	358	383	391	430	433
N	267	270	295	288	298	296	296
Q	147	152	153	156	160	175	178
I	143	147	156	168	166	179	185
L	75	74	79	72	73	83	73
R	57	55	61	67	63	61	58
S	26	26	31	35	40	47	49
P	20	19	20	20	19	26	23
B	9	11	13	17	17	21	16
	9.764	9.975	10.373	10.586	10.750	11.387	11.488

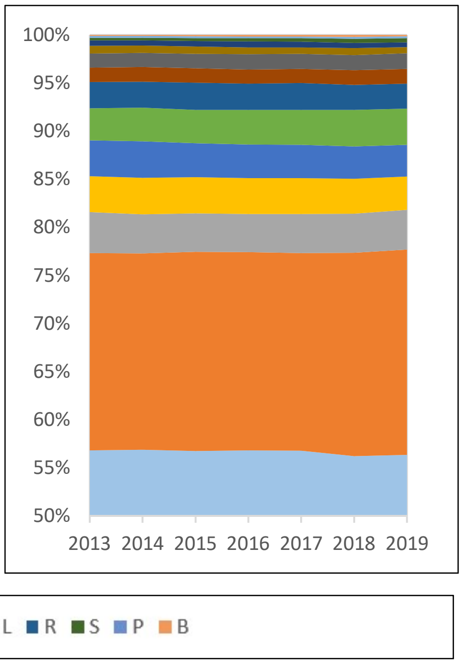


Table 2.20 and Figure 2.13. Trend within the panel of patents-owning firms number by industry, 2013-2019.

5.1. Chapter 3

VARIABLES	(1) Ln(Nr. of patents)	(2) Ln(Nr. of patents)	(3) Ln(Nr. of patents)	(4) Ln(Nr. of patents)
UFBb availability	0,0437** (0,0208) [0,036]	0,0401* (0,0211) [0,058]	0,0377* (0,0216) [0,081]	0,0332 (0,0219) [0,130]
Estimation framework	FE OLS	FE OLS	FE OLS	FE OLS
Observations	44.156	44.156	44.156	44.156
Nr. of municipalities (clusters)	1.984	1.984	1.984	1.984
F: model	368,78	-	103,74	-
R-squared	0,419	0,419	0,810	0,809
Adjusted R-squared	0,391	0,390	0,777	0,777
RMSE	1,438	1,439	0,871	0,870
Fixed effects (FE)	Municipality, Year	Municipality, Region x year	Firm, Year	Firm, Region x year
Municipality controls	Distance from closest OLT [km], Population count		Distance from closest OLT [km], Population count	
Firm controls	Ln(Added value), Employees count		Ln(Added value), Employees count	

Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** p<0.01, ** p<0.05, * p<0.1

F-tests of joint significance

Municipality controls = 0	F_{calc}	6,85	2,65	4,02	2,29
	p-value	0,0011	0,0712	0,0182	0,1016
Firm controls = 0	F_{calc}	719.85	718,71	63,01	63,11
	p-value	≈ 0	≈ 0	≈ 0	≈ 0
FE in time = 0	F_{calc}	3,87		8,48	
	p-value	0,0008		≈ 0	
FE in region x time = 0	F_{calc}		$3,6 \times 10^5$		$9,5 \times 10^4$
	p-value		≈ 0		≈ 0

Table 3.1. Preliminary estimations of UFBb-patents systematic relationship; 2013-2019.

VARIABLES	(5) Ln(No. of patents)	(6) Ln(No. of patents)	(7) Ln(Nr. of patents)	(8) Ln(Nr. of patents)
UFBb availability	0,00511 (0,00700) [0,465]	0,00391 (0,00708) [0,581]	-0,00716 (0,00697) [0,304]	-0,00729 (0,00707) [0,303]
UFBb availability and concurrent high innovation intensity of firms			0,0784*** (0,0175) [7,56 x 10^{-6}]	0,0691*** (0,0178) [0,000108]
Estimation framework	FE OLS	FE OLS	FE OLS	FE OLS
Observations	299.992	299.992	299.992	299.992
Nr. of municipalities (clusters)	4.455	4.455	4.455	4.455
F: model	51,61	10,44	51,67	10,58
R-squared	0,853	0,853	0,853	0,853
Adjusted R-squared	0,828	0,828	0,828	0,828
RMSE	0,654	0,653	0,654	0,653
Fixed effects (FE)	Firm, Year	Firm, Region x year	Firm, Year	Firm, Region x year
Municipality controls	Distance from closest OLT [km], Ln(Population count)		Distance from closest OLT [km], Ln(Population count)	
Firm controls	Intangible fixed assets [k€], Ln(Employees count)		Intangible fixed assets [k€], Ln(Employees count)	

Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** p<0.01, ** p<0.05, * p<0.1

F-tests of joint significance

		(5)	(6)	(7)	(8)
Full factorial = 0	F_{calc} p-value			10,07 ≈ 0	7,55 0,0005
Interaction: UFBb and innovation intensity = 0	F_{calc} p-value			20,09 ≈ 0	15,03 0,0001
Municipality controls = 0	F_{calc} p-value	1,51 0,2213		1,25 0,2861	3,97 0,0189
Firm controls = 0	F_{calc} p-value	133,35 ≈ 0	3,97 0,0130	131,33 ≈ 0	133,49 ≈ 0
FE in time = 0	F_{calc} p-value	40,67 ≈ 0	136,16 ≈ 0	39,58 ≈ 0	
FE in region x time = 0	F_{calc} p-value		6,07 ≈ 0		5,95 ≈ 0

Table 3.2 a-b. Specification development using intensive variable of interest UFBb availability$_{m,t}$; 2013-2019.

VARIABLES	(9a) Ln(Nr. of patents+1)		(10a) Ln(Nr. of patents+1)	
	Main effects of fiber	Differences in effects, matched by innovation intensity	Main effects of fiber	Differences in effects, matched by innovation intensity
Years of UFBb availability				
1 year	-0,00835 (0,00681) [0,220]	0,0307** (0,0147) [0,0369]	-0,00783 (0,00659) [0,235]	0,0268* (0,0145) [0,0644]
2 years	-0,0209** (0,00987) [0,0340]	0,0581*** (0,0174) [0,000812]	-0,0198* (0,0102) [0,0516]	0,0535*** (0,0174) [0,00215]
3 years	-0,0461*** (0,0133) [0,000566]	0,0802*** (0,0206) [0,000101]	-0,0438*** (0,0138) [0,00146]	0,0746*** (0,0208) [0,000349]
4 years	-0,0863*** (0,0179) [1,44 x 10^{-6}]	0,0780*** (0,0229) [0,000672]	-0,0790*** (0,0179) [1,04 x 10^{-5}]	0.0693*** (0,0232) [0,00287]
5 years	-0,125*** (0,0230) [5,88 x 10^{-8}]	0,0605** (0,0254) [0,0171]	-0,115*** (0,0227) [4,47 x 10^{-7}]	0,0516* (0,0268) [0,0548]
Estimation framework	FE OLS		FE OLS	
Observations	257.136		257.136	
Nr. of clusters	4.455		4.455	
F: model	38,68		11,61	
R-squared	0,870		0,870	
Adjusted R-squared	0,844		0,844	
RMSE	0,627		0.627	
Fixed effects (FE)	Firm, Year		Firm, Region x year	
Municipality controls	Distance from closest OLT [km], Ln(Population count)		Distance from closest OLT [km], Ln(Population count)	
Firm controls	Intangible fixed assets [k€], Ln(Employees count)		Intangible fixed assets [k€], Ln(Employees count)	

Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** p<0.01, ** p<0.05, * p<0.1

Table 3.3 a. Additional results using extensive variable Years of UFBb availability$_{m,t}$; 2014-2019.

VARIABLES	(9b) Ln(Nr. of patents+1)	(10b) Ln(Nr. of patents+1)
Fiber absence and high innovation intensity	0,0642* (0,0329) [0,0513]	0,0634** (0,0313) [0,0428]
	Two-way difference in connectivity and innovation among firms	Two-way difference in connectivity and innovation among firms
Years of UFBb availability		
1 year	0,0865*** (0,0315) [0,00608]	0,0824*** (0,0294) [0,00514]
2 years	0,101*** (0,0275) [0,000226]	0,0971*** (0,0252) [0,000116]
3 years	0,0983*** (0,0242) [4,87 x 10^{-5}]	0,0943*** (0,0221) [2,07 x 10^{-5}]
4 years	0,0559*** (0,0192) [0,00356]	0,0537*** (0,0176) [0,00235]
5 years	(omitted)	(omitted)
Estimation framework	FE OLS	FE OLS
Observations	257.136	257.136
Nr. of clusters	4.455	4.455
F: model	38,68	11,61
R-squared	0,870	0,870
Adjusted R-squared	0,844	0,844
RMSE	0,627	0.627
Fixed effects (FE)	Firm, Year	Firm, Region x year
Municipality controls	Distance from closest OLT [km], Ln(Population count)	Distance from closest OLT [km], Ln(Population count)
Firm controls	Intangible fixed assets [k€], Ln(Employees count)	Intangible fixed assets [k€], Ln(Employees count)

Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** p<0.01, ** p<0.05, * p<0.1

Table 3.3 b. Complementary point of view on the contents of output 3 a; 2014-2019.

F-tests of joint significance

Full factorial = 0	F_{calc} p-value	4,74 ≈ 0	4,14 ≈ 0
Interaction: UFBb and innovation intensity = 0	F_{calc} p-value	3,20 0,0069	2,78 0,0164
Municipality controls = 0	F_{calc} p-value	1,03 0,3557	2,32 0,0984
Firm controls = 0	F_{calc} p-value	119,04 ≈ 0	119,72 ≈ 0
FE in time = 0	F_{calc} p-value	36,11 ≈ 0	
FE in region x time = 0	F_{calc} p-value		4,30 ≈ 0

Table 3.3 c. Detail of significance tests for regressions in Table 3 a-b.

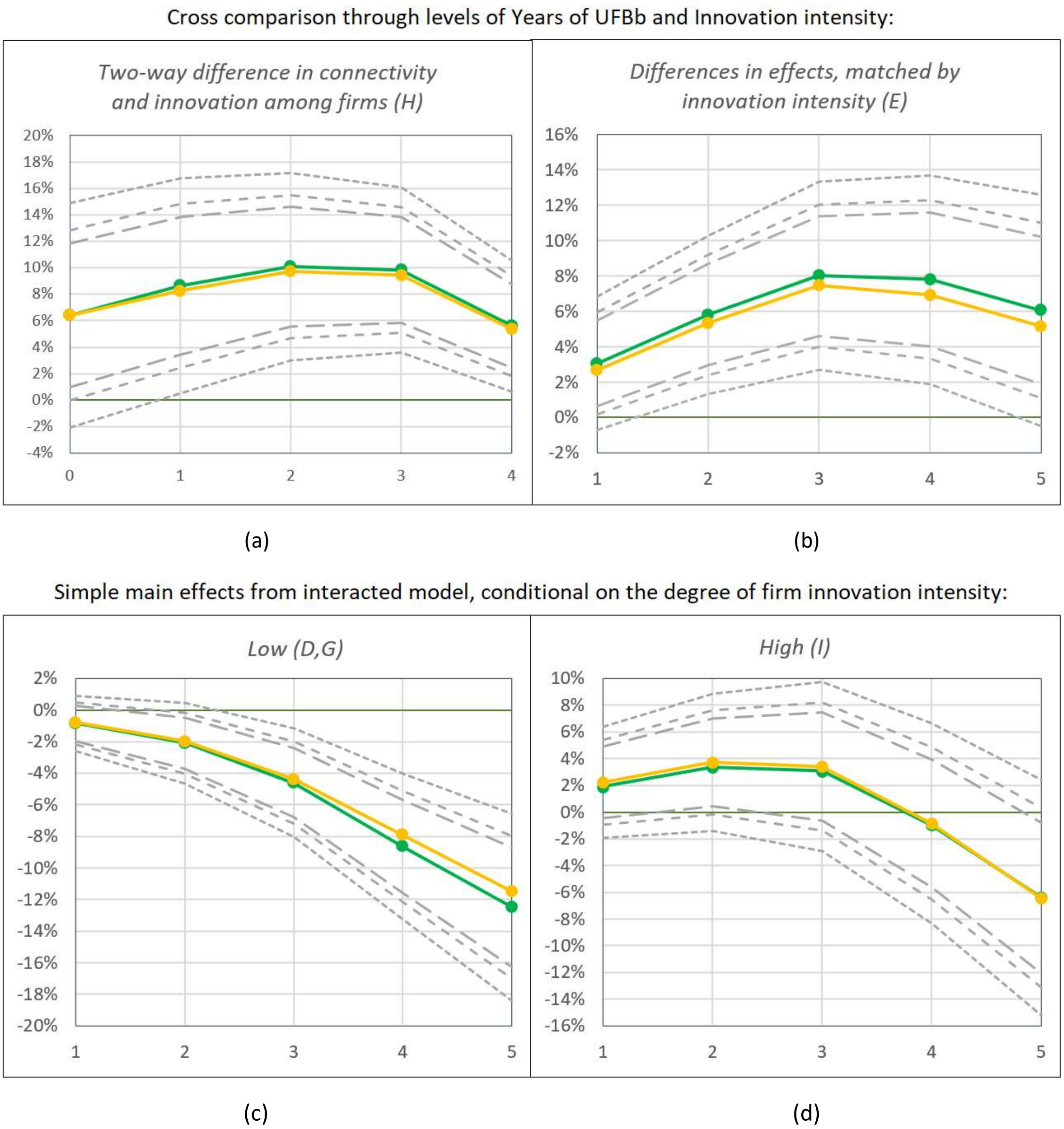


Figure 3.1 a-d. Re-arrangement of estimates to highlight UFBb dynamic influence on business innovation, with the indication of associated pseudo-equations (green splines are derived from specification 9a-b, yellow splines from 10a-b); 2014-2019.

VARIABLES	(11) Ln(Nr. of patents+1)		(12) Ln(Nr. of patents+1)	
	Two-way difference in connectivity and innovation among firms	Main effects of fiber	Two-way difference in connectivity and innovation among firms	Main effects of fiber
Years of FTTH availability				
Absence	0,0510 (0,0368) [0,166]	(baseline)	0,0424 (0,0332) [0,203]	(baseline)
1 year	0,0764** (0,0322) [0,0177]	-0,0350*** (0,00687) [$3,55 \times 10^{-7}$]	0,0703** (0,0285) [0,0137]	-0,0285*** (0,00694) [$4,15 \times 10^{-5}$]
2 years	0,0384 (0,0266) [0,149]	-0,0684*** (0,0120) [$1,30 \times 10^{-8}$]	0,0380 (0,0246) [0,123]	-0,0547*** (0,0112) [$1,19 \times 10^{-6}$]
3 years	(omitted)	-0,0785*** (0,0176) [$7,87 \times 10^{-6}$]	(omitted)	-0,0651*** (0,0166) [$8,68 \times 10^{-5}$]

Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** p<0.01, ** p<0.05, * p<0.1

Estimation setting	FE OLS	FE OLS
Observations	257.136	257.136
Nr. of clusters	4.455	4.455
F: model	59,06	12,04
R-squared	0,870	0,870
Adjusted R-squared	0,844	0,844
RMSE	0,627	0,627
Fixed effects	Firm, Year	Firm, Region x year
Municipality controls	Distance from closest OLT [km], Ln(Population count)	Distance from closest OLT [km], Ln(Population count)
Firm controls	Intangible fixed assets [k€], Ln(Employees count)	Intangible fixed assets [k€], Ln(Employees count)

F-tests of joint significance

Interaction: FTTH and innovation intensity = 0	F_{calc} p-value	6,76 ≈ 0	4,98 ≈ 0
Municipality controls = 0	F_{calc} p-value	1,00 0,3667	1,34 0,2631
Firm controls = 0	F_{calc} p-value	119,55 ≈ 0	120,16 ≈ 0
FE in time = 0	F_{calc} p-value	86,46 ≈ 0	
FE in region x time = 0	F_{calc} p-value		6,77 ≈ 0

Table 3.4. Re-estimation of years of UFBb effects when restricting the scope to FTTH; 2014-2019.

VARIABLES		(13 I) 1^{st} stage: UFBb availability	(13 II) 2^{nd} stage: Ln(Nr. of patents+1)	(14 I) 1^{st} stage: UFBb availability	(14 II) 2^{nd} stage: Ln(Nr. of patents+1)
First-Stage estimates (TSLS): UFBb availability			0,140*** (0,0221) [2,26 x 10^{-10}]		0,106*** (0,0216) [1,06 x 10^{-6}]
Observations		299.992	299.992	299.992	299.992
Nr. of firms (clusters)		42.856	42.856	42.856	42.856
R-squared within		0,795	0,017	0,812	0,017
R-squared between		0,437	0,019	0,432	0,020
R-squared overall		0,143	0,017	0,151	0,018
Fixed effects (FE)		Firm, Year	Firm, Year	Firm, Region x Year	Firm, Region x Year
Municipality controls		Distance from closest OLT [km], Ln(Population count)		Distance from closest OLT [km], Ln(Population count)	
Firm controls		Intangible fixed assets [k€], Ln(Employees count)		Intangible fixed assets [k€], Ln(Employees count)	
Drift controls (exogenous included regressors)	Municipality	Average patents, Average employees, Urbanization degree, Nr. of (panel) firms;		Average patents, Average employees, Urbanization degree, Nr. of (panel) firms;	
	Firm	Sector (mining, construction, services, trade, manufacturing)		Sector (mining, construction, services, trade, manufacturing)	
Trend controls (exogenous included regressors)	Municipality	Average patents, Average employees, Urbanization degree, Nr. of (panel) firms;		Average patents, Average employees, Urbanization degree, Nr. of (panel) firms;	
	Firm	Sector (mining, construction, services, trade, manufacturing)		Sector (mining, construction, services, trade, manufacturing)	
Instruments		Distance from closest OPB [km], Trend controls		Distance from closest OPB [km], Trend controls	

Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3.5 a. Instrumental variable estimations of UFBb-patents relationship; 2013-2019.

F-tests of joint significance

Instruments = 0	F_{calc} p-value	2.815,29 ≈ 0		2.279,86 ≈ 0	
Municipality controls = 0	F_{calc} p-value	523,01 ≈ 0	9,45 0,0001	1.539,83 ≈ 0	1,03 0,3571
Firm controls = 0	F_{calc} p-value	≈ 0 0,9980	201,13 ≈ 0	0,51 0,5979	202,27 ≈ 0
Trend controls = 0	F_{calc} p-value	2.826,16 ≈ 0		1.997,28 ≈ 0	
Drift controls = 0	F_{calc} p-value	391,93 ≈ 0	8,77 ≈ 0	987,66 ≈ 0	5,01 ≈ 0
FE in time = 0	F_{calc} p-value	294,46 ≈ 0	2,80 0,0386		
FE in region x time = 0	F_{calc} p-value			173,36 ≈ 0	2,01 ≈ 0

Table 3.5 b. Detail of model specifications and significance tests for regressions in Table 5 a.

VARIABLES	(15) Portfolio increase		(16) Portfolio increase	
	Main effects	Interaction	Main effects	Interaction
UFBb availability	0,0107*** (0,00257) [$3,03 \times 10^{-5}$]	-0,0310*** (0,00546) [$1,40 \times 10^{-8}$]	0,745*** (0,0436) [0]	-0,989*** (0,0418) [0]
Patents portfolio at t-1	-0,181*** (0,00624) [0]		-0,662*** (0,0383) [0]	
Estimation framework	FE OLS		FE Logit	
Observations	257.136		80.364	
Nr. of firms (clusters)	42.856		13.394	
F: model	207,17			
R-squared	0,391			
Adjusted R-squared	0,269			
RMSE	0,266			
χ^2 (likelihood-ratio test)			2.831	
Pseudo R-squared			0,0494	
Log-likelihood			-30.507	
Log-likelihood, const.-only model			-32.093	
Fixed effects (FE)	Firm, Year		Firm, Year	
Municipality controls	Distance from closest OLT [km], Ln(Population count)		Distance from closest OLT [km], Ln(Population count)	
Firm controls	Intangible fixed assets [k€], Ln(Employees count)		Intangible fixed assets [k€], Ln(Employees count)	

Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** p<0.01, ** p<0.05, * p<0.1

Table 3.6 a. Model expansion: binary evaluation of IP events using UFBb availability$_{m,t}$; 2014-2019.

VARIABLES	(17) Portfolio increase		(18) Portfolio increase	
	Main effects	Interaction with patents portf. at t-1	Main effects	Interaction with patents portf. at t-1
Years of UFBb availability				
1 year	0,00446* (0,00254) [0,0786]	-0,0212*** (0,00664) [0,00140]	0,379*** (0,0512) [0]	-0,503*** (0,0540) [0]
2 years	0,00815** (0,00331) [0,0139]	-0,0297*** (0,00757) [9,07e-05]	0,751*** (0,0597) [0]	-0,931*** (0,0557) [0]
3 years	0,00217 (0,00464) [0,641]	-0,0376*** (0,00742) [4,35e-07]	0,929*** (0,0725) [0]	-1,215*** (0,0602) [0]
4 years	-0,00971* (0,00576) [0,0918]	-0,0341*** (0,00786) [1,44e-05]	1,128*** (0,0885) [0]	-1,548*** (0,0687) [0]
5 years	-0,00768 (0,00710) [0,279]	-0,0452*** (0,00850) [1,09e-07]	1,141*** (0,114) [0]	-1,535*** (0,0895) [0]
Patents portfolio at t-1	-0,180*** (0,00636) [0]	--	-0,626*** (0,00390) [0]	--
Estimation framework	FE OLS		FE Logit	
Observations	257.136		80.364	
Nr. of firms (clusters)	42.856		13.394	
F: model	144,43			
R-squared	0,391			
Adjusted R-squared	0,269			
RMSE	0,266			
χ^2 (likelihood-ratio test)			2.724,73	
Pseudo R-squared			0,0541	
Log-likelihood			-30.358	
Log-likelihood, const.-only model			-32.093	
Fixed effects (FE)	Firm, Year		Firm, Year	
Municipality controls	Distance from closest OLT [km], Ln(Population count)		Distance from closest OLT [km], Ln(Population count)	
Firm controls	Intangible fixed assets [k€], Ln(Employees count)		Intangible fixed assets [k€], Ln(Employees count)	

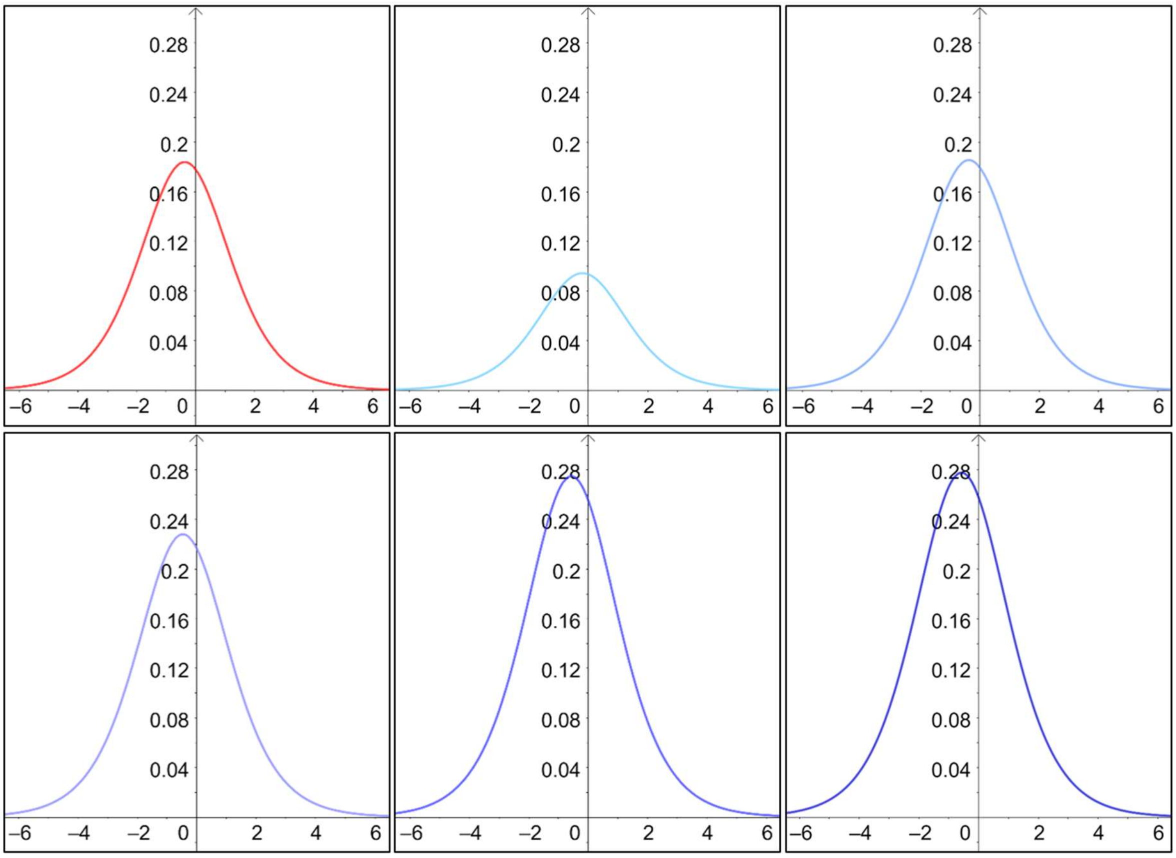
Robust standard errors in round brackets; p-values in squared brackets.
Legend of conventional significance levels:
*** p<0.01, ** p<0.05, * p<0.1

Table 3.6 b. Complementary estimates obtained by using Years of UFBb availability$_{m,t}$; 2014-2019.

F-tests of joint significance		Model specification			
		(15)	(16)	(17)	(18)
Full factorial = 0	F_{calc} p-value	701,73 ≈ 0	205,73 ≈ 0	2.635,42 ≈ 0	2.555,36 ≈ 0
Interaction = 0	F_{calc} p-value	32,31 ≈ 0	7,68 ≈ 0	560,15 ≈ 0	675,08 ≈ 0
Municipality controls = 0	F_{calc} p-value	0,67 0,5097	0,04 0,9611	2,34 0,3111	1,29 0,5241
Firm controls = 0	F_{calc} p-value	52,71 ≈ 0	54,60 ≈ 0	62,78 ≈ 0	64,31 ≈ 0
FE in time = 0	F_{calc} p-value	17,65 ≈ 0	22,96 ≈ 0	221,96 ≈ 0	137,12 ≈ 0

Table 3.6 c. Detail of model specifications and significance tests for regressions in Tables 1 and 2.

(a) (b) (c)



(d) (e) (f)

Figure 3.2. Mathematical area of influence of ultra-fast broadband variables of interest on the probability of portfolio increases; 2014-2019

(7) UFBb availability$_{m,t}$	
2014	0,0161
2015	0,0447
2016	0,0631
2017	0,0824
2018	0,135
2019	0,147

(9) Years of UFBb availability$_{m,t}$	
2014	---
2015	0,0315
2016	0,057
2017	0,092
2018	0,173
2019	0,22

Table 3.7. Year fixed effects from specifications in rounded brackets; 2014-2019, 2015-2019.

(8)

UFBb availability$_{m,t}$

		(8)
Abruzzo	2014	-0,00597
	2015	-0,016
	2016	-0,0361
	2017	0,00256
	2018	0,157
	2019	0,151
Basilicata	2013	-0,0745
	2014	-0,123
	2015	-0,0983
	2016	-0,117
	2017	-0,114
	2018	-0,0461
Calabria	2013	-0,031
	2014	-0,0587
	2015	-0,0547
	2016	-0,0671
	2017	-0,0494
	2018	-0,0299
Campania	2014	-0,0164
	2015	-0,013
	2016	0,00569
	2017	0,0262
	2018	0,0733
	2019	0,102
Emilia Romagna	2013	0,00984
	2014	0,0594
	2015	0,0921
	2016	0,125
	2017	0,175
	2018	0,181
Friuli Venezia Giulia	2013	-0,12
	2014	-0,125
	2015	-0,0963
	2016	-0,0774
	2017	-0,0546
	2018	-0,00483
Lazio	2013	-0,00871
	2014	0,00261
	2015	0,0152
	2016	0,0303
	2017	0,0447
	2018	0,0472
Liguria	2013	-0,111
	2014	-0,132
	2015	-0,0833
	2016	-0,0715
	2017	-0,0413
	2018	-0,0197
Lombardia	2013	-0,0162
	2014	0,0246
	2015	0,0408
	2016	0,0549
	2017	0,105
	2018	0,114
Marche	2013	-0,222
	2014	-0,183
	2015	-0,149
	2016	-0,118
	2017	-0,103
	2018	-0,0221
Molise	2014	-0,0649
	2015	-0,163
	2016	-0,156
	2017	-0,17
	2018	-0,133
	2019	-0,0654
Piemonte	2014	0,0182
	2015	0,0585
	2016	0,0766
	2017	0,0865
	2018	0,142
	2019	0,144
Puglia	2013	-0,0588
	2014	-0,0528
	2015	-0,0461
	2016	-0,018
	2017	-0,0127
	2018	0,0154
Sardegna	2014	-0,176
	2015	-0,189
	2016	-0,218
	2017	-0,231
	2018	-0,217
	2019	-0,179
Sicilia	2013	-0,0267
	2014	-0,0423
	2015	-0,0411
	2016	-0,0464
	2017	-0,0518
	2018	-0,012
Toscana	2014	0,00825
	2015	0,0347
	2016	0,0587
	2017	0,0862
	2018	0,183
	2019	0,179
Trentino Alto Adige	2013	-0,127
	2014	-0,17
	2015	-0,145
	2016	-0,134
	2017	-0,101
	2018	-0,0158
Umbria	2013	-0,172
	2014	-0,154
	2015	-0,0949
	2016	-0,0434
	2017	-0,0327
	2018	-0,0496
Valle d'Aosta	2013	-0,0971
	2014	-0,056
	2015	-0,113
	2016	-0,0245
	2017	0,063
	2018	-0,0461
Veneto	2014	0,0158
	2015	0,0438
	2016	0,0522
	2017	0,0797
	2018	0,15
	2019	0,187

Table 3.8 a. Region-year fixed effects from specification (8); 2013-2019.

(10)

Years of UFBb availability$_{m,t}$

Abruzzo	2015	-0,00409	Friuli Venezia Giulia	2015	0,0344	Molise	2014	-0,0889	Toscana	2014	-0,265
	2016	-0,017		2016	0,0609		2015	-0,172		2015	-0,234
	2017	0,0339		2017	0,0962		2016	-0,158		2016	-0,201
	2018	0,208		2018	0,164		2017	-0,157		2017	-0,157
	2019	0,228		2019	0,194		2018	-0,0963		2018	-0,0312
Basilicata	2014	-0,24	Lazio	2015	0,00514	Piemonte	2015	0,0464	Trentino Alto Adige	2015	0,0267
	2015	-0,199		2016	0,0271		2016	0,0725		2016	0,0404
	2016	-0,207		2017	0,0604		2017	0,0959		2017	0,0815
	2017	-0,184		2018	0,106		2018	0,175		2018	0,182
	2018	-0,0831		2019	0,145		2019	0,207		2019	0,22
Calabria	2014	-0,167	Liguria	2015	0,0564	Puglia	2014	-0,164	Umbria	2014	-0,241
	2015	-0,155		2016	0,0801		2015	-0,151		2015	-0,178
	2016	-0,157		2017	0,13		2016	-0,11		2016	-0,117
	2017	-0,119		2018	0,184		2017	-0,0837		2017	-0,0903
	2018	-0,0658		2019	0,24		2018	-0,0221		2018	-0,0818
Campania	2015	0,00955	Lombardia	2014	-0,187	Sardegna	2014	-0,0941	Valle d'Aosta	2014	-0,12
	2016	0,0381		2015	-0,16		2015	-0,0965		2015	-0,16
	2017	0,0792		2016	-0,138		2016	-0,116		2016	-0,0645
	2018	0,159		2017	-0,111		2017	-0,111		2017	0,0339
	2019	0,225		2018	-0,0388		2018	-0,0704		2018	-0,0612
Emilia Romagna	2015	0,0633	Marche	2015	0,0423	Sicilia	2014	-0,149	Veneto	2014	-0,251
	2016	0,102		2016	0,0824		2015	-0,144		2015	-0,217
	2017	0,15		2017	0,113		2016	-0,137		2016	-0,202
	2018	0,224		2018	0,216		2017	-0,122		2017	-0,161
	2019	0,262		2019	0,269		2018	-0,0493		2018	-0,0668

Table 3.8 b. Region-year fixed effects from specification (10); 2013-2019.

UFBb availability											
0.			I.			II.			III.		
Region	Panel share	Interaction significance	Macro area	Panel share	Interaction significance	Macro area	Panel share	Interaction significance	Macro area	Panel share	Interaction significance
Valle d'Aosta	0,13%	0,5339	Nort-West	37,60%	0,2917	North	63,62%	0,0367	North	63,62%	0,0367
Piemonte	7,59%	0,6126									
Liguria	2,15%	0,3192									
Lombardia	27,73%	0,1826									
Trentino Alto Adige	1,94%	0,953	North-East	26,02%	0,0433						
Emilia Romagna	9,80%	0,2598									
Veneto	12,08%	0,4639									
Friuli Venezia Giulia	2,19%	0,0036									
Toscana	6,69%	0,0671	Center	20,54%	0,0002	Center	20,54%	0,0002	Center	20,54%	0,0002
Umbria	1,15%	0,3891									
Marche	2,30%	0,7429									
Lazio	8,67%	0,0015									
Abruzzo	1,73%	0,6048									
Campania	6,04%	0,052	South (w/o islands)	11,44%	0,0723	South (w/o islands)	11,44%	0,0723	South (mainland and islands)	15,84%	0,2082
Molise	0,24%	0,2703									
Puglia	3,73%	0,5606									
Basilicata	0,39%	0,6199									
Calabria	1,04%	0,6388									
Sicilia	3,36%	0,5095	Islands	4,40%	0,8299	Islands	4,40%	0,8299			
Sardegna	1,04%	0,1512									

Table 3.9 a. Significance of implementation of (8) with regional discrimination; 2013-2019.

Years of UFBb availability											
0.			I.			II.			III.		
Region	Panel share	Interaction significance	Macro area	Panel share	Interaction significance	Macro area	Panel share	Interaction significance	Macro area	Panel share	Interaction significance
Valle d'Aosta	0,13%	0	Nort-West	37,60%	0,005	North	63,62%	0,0132	North	63,62%	0,0132
Piemonte	7,59%	0,8075									
Liguria	2,15%	0,4718									
Lombardia	27,73%	0,0103									
Trentino Alto Adige	1,94%	0,0041	North-East	26,02%	0,1586						
Emilia Romagna	9,80%	0,7717									
Veneto	12,08%	0,1103									
Friuli Venezia Giulia	2,19%	0,3974									
Toscana	6,69%	0,0764	Center	20,54%	0,0003	Center	20,54%	0,0003	Center	20,54%	0,0003
Umbria	1,15%	0,0124									
Marche	2,30%	0,3086									
Lazio	8,67%	0,0005									
Abruzzo	1,73%	0,0811									
Campania	6,04%	0,3975	South (w/o islands)	11,44%	0,4398	South (w/o islands)	11,44%	0,4398	South (mainland and islands)	15,84%	0,3322
Molise	0,24%	0									
Puglia	3,73%	0,5716									
Basilicata	0,39%	0									
Calabria	1,04%	0,5919									
Sicilia	3,36%	0,7622	Islands	4,40%	0,518	Islands	4,40%	0,518			
Sardegna	1,04%	0,0001									

Table 3.9 b. Significance of implementation of (10) along with regional discrimination; 2014-2019.

Years of UFBb availability with yearly FE					
I.			II.		
Industry statistical identificator - ATECO 2007	Panel share	Interaction significance	Macro sector	Panel share	Interaction significance
Mining	0,33%	0	Mining	0,33%	0
Manufacturing	36,61%	0,0378	Manufacturing	36,61%	0,0378
Construction	12,53%	0,0836	Construction	12,53%	0,0836
Wholesale and retail trade; cars and motorvehicles restoration	25,54%	0,6656	Trade	25,54%	0,6656
Transport and warehousing	4,84%	0,4583	Services	25%	0,3563
Lodging and dining	2,92%	0,2473			
Information and communication services	3,88%	0,324			
Real estate	2,87%	0,0201			
Scientific, technical and professional activities	3,98%	0,9243			
Rent, travel agencies, enterprise support services	3,16%	0,13			
Education	0,28%	0,1127			
Healthcare and social care	1,79%	0,1704			
Artistic, entertainment, amusement and sport activities	0,67%	0,8296			
Other service activities	0,60%	0,1518			

Table 3.10 a. Significance of implementation of (8) along with industry discrimination, considering year fixed effects; 2013-2019.

Years of UFBb availability with region-year FE					
I.			II.		
Industry statistical identificator - ATECO 2007	Panel share	Interaction significance	Macro sector	Panel share	Interaction significance
Mining	0,33%	0	Mining	0,33%	0
Manufacturing	36,61%	0,1163	Manufacturing	36,61%	0,1163
Construction	12,53%	0,067	Construction	12,53%	0,067
Wholesale and retail trade; cars and motorvehicles restoration	25,54%	0,4749	Trade	25,54%	0,4749
Transport and warehousing	4,84%	0,4371	Services	25%	0,3043
Lodging and dining	2,92%	0,4432			
Information and communication services	3,88%	0,3394			
Real estate	2,87%	0,0296			
Scientific, technical and professional activities	3,98%	0,7998			
Rent, travel agencies, enterprise support services	3,16%	0,153			
Education	0,28%	0,022			
Healthcare and social care	1,79%	0,1346			
Artistic, entertainment, amusement and sport activities	0,67%	0,4002			
Other service activities	0,60%	0,0399			

Table 3.10 b. Significance of implementation of (8) along with industry discrimination, considering region-year fixed effects; 2013-2019.

Years of UFBb availability					
Size class (Nr. of employees)		With yearly FE		With region-year FE	
		Panel share	Interaction significance	Panel share	Interaction significance
Micro	1-9	41,1%	0,902	41,1%	0,9051
Small	10-49	21,7%	0,0183	21,7%	0,014
Medium	50-249	32,7%	0,0156	32,7%	0,0168
Large	≥ 250	4,5%	0,0296	4,5%	0,077

Table 3.11. Significance of implementation of (8) along with dimensional discrimination of firms; 2013-2019.

6. References

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Technical and regulatory documents:

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    - *ITU-T Liaison Statement SCV-LS13 (2017)*
    - *ITU-T Liaison Statement SCV-TD66 (2017)*
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Relevant contents from academic lectures:

- Slides for the lectures of the course "Tecnologia dei materiali", held by Professor Giulio Malucelli at Politecnico di Torino, A.A. 2018-2019.
- Slides and lecture notes from the course "Economia dei sistemi industriali", held by Professors Carlo Cambini and Luigi Buzzacchi at Politecnico di Torino, A.A. 2019-2020.
- Lecture notes from the course "Diritto commerciale", whose specific part on intellectual property rights was held by Professor Anna Saraceno at Politecnico di Torino, A.A. 2019-2020.
- Slides for the lectures of the course "Strategia e organizzazione aziendale" held by Professors Emilio Paolucci and Paolo Neirotti at Politecnico di Torino, A.A. 2019-2020.
- Lecture notes from the course "Metodi di finanziamento dell'impresa", whose specific part on en-trepreneurial finance was held by Professor Elisa Ughetto at Politecnico di Torino, A.A. 2020-2021.
- Slides and lecture notes from the course "Economia e finanza d'impresa", held by Professors Laura Rondi and Greta Falavigna at Politecnico di Torino, A.A. 2020-2021.
- Lecture notes from the course "Ingegneria della qualità", held by Professor Fiorenzo Franceschini at Politecnico di Torino, A.A. 2020-2021.

6.2. Web sites (*last access in parentheses*)

For historical information on broadband (and fiber optics in particular):

- https://www.sorgenia.it/guida-energia/fibra-ottica-cose-e-come-funziona (20/03/2022)
- https://chetariffa.it/blog/internet-telefonia/fibra-ottica-adsl-e-banda-larga (06/05/2022)
- https://www.treccani.it/enciclopedia/ultrabroadband_%28Lessico-del-XXI-Secolo%29/#:~:text=voce%20ingl.%2C,in%20download%20sia%20in%20upload (06/05/2022)
- https://www.treccani.it/enciclopedia/banda-larga/ (06/05/2022)
- https://www.provincia.bz.it/informatica-digitalizzazione/bandalarga/services/piccolo-glossario-della-banda-larga.asp (06/05/2022)
- https://www.treccani.it/enciclopedia/adsl/ (06/05/2022)
- https://www.treccani.it/enciclopedia/adsl_%28Lessico-del-XXI-Secolo%29/ (06/05/2022)
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- https://it.wikipedia.org/wiki/VDSL (17/07/2022)
- https://fondazionefeltrinelli.it/viaromagnosi-l-era-digitale-e-il-paradosso-della-produttivita-13-01-2016/#top (23/07/2022).

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- http://it.fibresplitter.com/news/passive-and-active-network-fundamentals-24233160.html (20/03/2022)
- https://www.supermoney.it/adsl-internet-casa/guide/come-funziona-la-fibra/ (20/03/2022)
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- https://www.infratelitalia.it/piani-nazionali-e-regionali/piano-nazionale-banda-larga (09/07/2022)
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- https://www.agcom.it/la-neutralita-della-rete (10/07/2022)
- https://www.treccani.it/enciclopedia/le-telecomunicazioni-integrate_%28XXI-Secolo%29/ (17/07/2022)

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- https://st.ilsole24ore.com/art/economia/2012-02-27/aziende-cerca-banda-larga-174427.shtml?uuid=Aa3IZfyE (26/06/2022)
- https://www.corrierecomunicazioni.it/telco/banda-ultralarga/fibra-e-5g-la-ue-avvia-la-consult-azione-pubblica-sugli-aiuti-di-stato/ (26/06/2022)
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- https://www.wipo.int/pct/en/pct_contracting_states.html (14/07/2022)
- https://data.oecd.org/rd/triadic-patent-families.htm (17/07/2022)

For population densities data in different years:

- https://www.istat.it/it/files/2013/03/Noi-Italia-2013.pdf (04/06/2022)
- https://www.tuttitalia.it/italia/ (04/06/2022)

For information on regression models and experimental protocols:

- https://www.publichealth.columbia.edu/research/population-health-methods/difference-difference-estimation (18/09/2022)
- https://dimewiki.worldbank.org/Event_Study (18/09/2022)

- https://journals.sagepub.com/doi/abs/10.1177/009286159603000229?journalCode=dijb (18/09/2022)
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- https://www.stata.com/support/faqs/statistics/instrumental-variables-regression/ (20/09/2022)
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- https://www.stata.com/statalist/archive/2013-01/msg01003.html (20/09/2022)
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- https://www.corsi.univr.it/documenti/OccorrenzaIns/matdid/matdid117036.pdf (22/09/2022)

6.3. Data sources for figures and tables (*last access in parentheses*)

6.3.1. Chapter 1

Figure 1.1 and Figure 1.2 a-b.

Personal elaboration on World Bank data:

- International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database, from World Development Indicators (indicator ID code: IT.NET.BBND) at data.worldbank.org (27/04/2022) made available under CC-BY 4.0.
- (1) United Nations Population Division. World Population Prospects: 2019 Revision. (2) Census reports and other statistical publications from national statistical offices. (3) Eurostat: Demographic Statistics. (4) United Nations Statistical Division. Population and Vital Statistics Report (various years). (5) U.S. Census Bureau: International Database. (6) Secretariat of the Pacific Community: Statistics and Demography Programme; from World Development Indicators (Indicator ID code:

SP.POP.TOTL) at data.worldbank.org (27/04/2022), made available under CC-BY 4.0.

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Figure 1.**3 a-b**.

- Original dataset

Figure 1.4 and Figure 1.5.

Personal elaboration on OECD data:

- OECD (2022), "Broadband database", *OECD Telecommunications and Internet Statistics* (database), https://doi.org/10.1787/data-00682-en (29/05/2022).

Figure 1.**6 a-b-c-d**.

Personal elaboration on World Bank data:

- International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database, from World Development Indicators (indicator ID code: IT.NET.BBND) at data.worldbank.org (27/04/2022), made available under CC-BY 4.0.

Figure 1.7, Figure 1.8 and Figure 1.9.

Personal elaboration on OECD data:

- OECD (2022), “Business use of broadband” (indicator), https//doi.org/10.1787/6e2e8a67-en (18/05/2022).

Figure 1.10 a-b-c.

Personal elaboration on ISTAT data:

- dati.istat.it/#, exploiting the dataset: “ICT nelle imprese con almeno 10 addetti” (18/05/2022), made available under CC BY 3.0 IT.

Figure 1.11.

- OECD (2022), “ICT investment” (indicator), https//doi.org/10.1787/b23ec1da-en (18/05/2022).

Figure 1.**12**.

Personal elaboration on World Bank data:

- Netcraft (netcraft.com) and World Bank population estimates, from World Development Indicators (IT.NET.SECR.P6) at data.worldbank.org (27/04/2022), made available under CC-BY 4.0.

Figure 1.13 and Table 1.1.

- OECD (2022), "Internet access" (indicator), https://doi.org/10.1787/69c2b997-en (18/05/2022).

Table 1.2 and Table 1.3.

- Adapted from “Strategia italiana per la banda ultralarga – Piano d’investimenti per la diffusione della banda ultralarga”, Presidenza del Consiglio dei Ministri, https://www.mise.gov.it/images/stories/documenti/ITALIA_Strategia_BUL-Piano_di_investimenti_fin.pdf (09/07/2022).

Table 1.4.

Personal elaboration of data extracted from:

- “Strategia italiana per la banda ultralarga – Piano d’investimenti per la diffusione della banda ultralarga", Presidenza del Consiglio dei Ministri, https://www.mise.gov.it/images/stories/documenti/ITALIA_Strategia_BUL-Piano_di_investimenti_fin.pdf (09/07/2022).

Figure from 1.14 to 1.16.

Personal elaboration on OECD data:

- OECD (2022), "Patents by regions", *OECD Patent Statistics* (database), https://doi.org/10.1787/data-00509-en (28/05/2022).

Figure 1.17 a-b-c-d.

Personal elaboration on OECD and World Bank data:

- OECD (2022), "Structural business statistics ISIC Rev. 4", Structural and Demographic Business Statistics (database), https://doi.org/10.1787/8e34f7e7-en (29/05/2022).
- OECD (2022), "Patents by main technology and by International Patent Classification (IPC)", OECD Patent Statistics (database), https://doi.org/10.1787/data-00508-en (29/05/2022).
- (1) United Nations Population Division. World Population Prospects: 2019 Revision. (2) Census reports and other statistical publications from national statistical offices. (3) Eurostat: Demographic Statistics. (4) United Nations Statistical Division. Population and Vital Statistics Report (various years). (5) U.S. Census Bureau: International Database. (6) Secretariat of the Pacific Community: Statistics and Demography Programme; from World Development Indicators (indicator ID code: SP.POP.TOTL) at data.worldbank.org (accessed on 27 april 2022), made available under CC-BY 4.0.
- World Bank national accounts data and OECD National Accounts data files, from World Development Indicators (indicator ID code: NY.GDP.MKTP.CD) at data.worldbank.org (27/04/2022), made available under CC-BY 4.0.

Figure 1.18.

Personal elaboration on OECD data:

- OECD (2022), "Patents by regions", *OECD Patent Statistics* (database), https://doi.org/10.1787/data-00509-en (28/05/2022).

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Figure 1.19.

- OECD (2022), "Gross domestic spending on R&D" (indicator), https//doi.org/10.1787/d8b068b4-en (18/05/2022).

Figure 1.20.

- OECD (2022), "Gross domestic spending on R&D" (indicator), https//doi.org/10.1787/d8b068b4-en (18/05/2022).
- World Bank national accounts data and OECD National Accounts data files, from World Development Indicators (indicator ID code: NY.GDP.MKTP.CD) at data.worldbank.org (27/04/2022), made available under CC-BY 4.0.

Figure 1.21 a-b-c-d-e-f.

Personal elaboration on World Bank and ISTAT data:

- UNESCO Institute for Statistics (uis.unesco.org), Data as of September 2021, from World Development Indicators (indicators ID codes: SP.POP.SCIE.RD.P6, GB.XPD.RSDV.GD.ZS) at data.worldbank.org (27/04/2022).
- World Bank national accounts data and OECD National Accounts data files, from World Development Indicators (indicator ID code: NY.GDP.MKTP.CD) at data.worldbank.org (27/04/2022), made available under CC-BY 4.0.
- dati.istat.it/#, exploiting the datasets: "Innovazione nelle imprese con almeno 10 addetti" and "Ricerca e sviluppo" (18/05/2022), made available under CC BY 3.0 IT.

Figure 1.**22 a-b-c**.

Personal elaboration on ISTAT data:

- dati.istat.it/#, exploiting the dataset: "Ricerca e sviluppo" (18/05/2022), made available under CC BY 3.0 IT.

Figure 1.**23**.

Personal elaboration on ISTAT data:

- dati.istat.it/#, exploiting the dataset: "Ricerca e sviluppo" (18/05/2022), made available under CC BY 3.0 IT.

6.3.2. Chapter 2

Original dataset (and, subsequently, panel) sources:

- Data base AIDA (Analisi Informatizzata delle imprese italiane) by Bureau van Dijk Electronic Publishing Ltd. and/or its licensors, affiliates and information providers.
- TIM and OpenFiber data, as cited in the paper by C. Cambini, E. Grinza, L. Sabatino, "*Ultra-fast broadband access and productivity: evidence from Italian firms*" (2021):
    - courtesy of Mario Mirabelli (TIM-LAB) and Francesco Nonno (OpenFiber), who provided with access to and guidance on broadband data used in the cited paper.
- ISTAT archive for 2011 Census municipality data.

Figure 2.1 a.

Personal elaboration on:

- ISTAT data from I.Stat, CensimentoIndustriaServizi, at http://dati-censimentoindustriaeservizi.istat.it/Index.aspx, through Dati strutturali sulle imprese 2011 >> Imprese e risorse umane >> Dati di sintesi: Registro Statistico Imprese Attive (ASIA), section Asia-imprese, "Imprese e addetti: Imprese attive % per classe di addetti luglio 2020" (05/06/2022), made available under CC BY 3.0 IT.
- Original dataset and operating panel.

Figure 2.1 b.

Personal elaboration on:

- ISTAT classification "Codici statistici delle unità amministrative territoriali: comuni, città metropolitane, province e regioni", published on 30/03/2022 at https://www.istat.it/it/archivio/6789, with the attached file "Comuni-per-regione-e-ripartizione-geografica-Anni-1991-2022", Tavola 6 – "Comuni per regione e ripartizione geografica, per anno censuario (2011) e al 31 dicembre, Anni 2011-2021, valori assoluti e percentuali" (05/06/2022), made available under CC BY 3.0 IT.

- Original dataset and operating panel.

Figure 2.2.

- Adapted from C. Cambini, E. Grinza, L. Sabatino, "*Ultra-fast broadband access and productivity: evidence from Italian firms*" (2021) (from European Council and ISTAT data, in turn).

Table 2.1.

Personal elaboration on:

- ISTAT data:
    - Classification "Codici statistici delle unità amministrative territoriali: comuni, città metropolitane, province e regioni", published on 30/03/2022 at https://www.istat.it/it/archivio/6789, with the attached file "Comuni-per-regione-e-ripartizione-geografica-Anni-1991-2022", Tavola 6 – "Comuni per regione e ripartizione geografica, per anno censuario (2011) e al 31 dicembre, Anni 2011-2021, valori assoluti e percentuali" (05/06/2022), made available under CC BY 3.0 IT.
- National geopolitical data from https://www.tuttitalia.it/variazioni-amministrative/nuovi-comuni-2021/ (29/05/2022).
- Original dataset and operating panel.

Table 2.2, Table 2.4 and Tables from 2.6 to 2.20

- Operating panel.

Figure 2.3.

- Operating panel.

Realized with Bing technology © GeoNames, Microsoft, TomTom.

Figure 2.4 and Figures from 2.6 to 2.13.

- Operating panel.

Table 2.3.

- Operating panel.
- National demographic data from https://www.tuttitalia.it/statistiche/popolazione-andamento-demografico/ (27/05/2022).

Table 2.5 and Figure 2.5 a-b.

- Original dataset.
- Operating panel.

6.3.3. Chapter 3

Figures from 3.1 to 3.2

- Operating panel

Tables from 3.1 to 3.11

- Operating panel

6.3.4. Concluding remarks and development prospects

Figure 4.1: created by means of XMind Zen, a software for mind mapping.

لا تستسلم.

ستخاطر بفعل ذلك قبل ساعة

من حدوث المعجزة.

Non arrenderti.
Rischieresti di farlo
un'ora prima del miracolo.

(Proverbio arabo)

يمكنك العيش بدون إخوة ،

لكن ليس بدون أصدقاء.

Si può vivere senza fratelli,
ma non si può vivere senza amici.

(Proverbio arabo)

7. Acknowledgments and final thanksgivings

È incredibile pensare a quante cose siano successe, a quante vite sembra che siano trascorse dalla prima (e ultima) volta in cui mi sono ritrovato a scrivere le mie riflessioni al fondo di una tesi di laurea. In soli tre anni, mentre percorrevo la strada che mi ha portato a queste parole, la Vita ci ha fatto davvero assaggiare tutte le possibili sfaccettature del suo sapore: la fine e l'inizio; la paura, e la serenità; la prigionia, la libertà, il dolore con la gioia; la solitudine, per poi apprezzare l'amicizia; la delusione, che prepara il trionfo.

Oggi è un giorno speciale. Tutti i giorni lo sono, per qualcosa, per qualcuno; ogni giorno è un evento decisivo, per una battaglia che vi ha luogo, per ciascuna storia che in esso viene scritta; e nel mio piccolo, so già che questo è uno di quelli che non dimenticherò più. Perché in questo giorno si tocca una cascata di cerchi concentrici, che raccontano di vite, di mondi, di persone che si incontrano, rimescolati nel mazzo delle opportunità, e che trovandosi in un punto fanno tanta, tanta luce.
Proprio in questo giorno, mi fa quasi tremare il ricordo di quando, un anno esatto indietro nel tempo, mi sono trovato all'improvviso davanti al Mondo, all'apertura dei cancelli che spalancavano un evento unico, l'Esposizione Universale; mettendo il mio messaggio in una bottiglia da consegnare alle onde, alla folla, non potevo ancora sapere quali e quante meravigliose sfide avrei affrontato, mentre rappresentavo il mio Paese, mentre diventavo qualcun altro. Non potevo neanche immaginare, quanto fosse proprio ciò di cui avevo bisogno; ero benzina, che si avvicinava al fiammifero. Quella scintilla, quella fiamma mi hanno insegnato che non esiste sconfitta, se si impara sempre qualcosa; che non c'è problema, che non celi anche, almeno un'opportunità; che c'è sempre un motivo, per il quale essere grati. Ed io ho una gran voglia, viva, sincera, di poter ringraziare, di far risaltare il contributo di tutti i protagonisti di un percorso molto più lungo di questi tre anni, e molto più ampio della fetta di terra e mare in cui si è svolto; un'avventura, di cui questa tesi e questa laurea non sono altro che le ultime ambasciatrici.

Voglio partire dalle file accademiche, ringraziando tutti i miei docenti di questi semestri per l'impulso al domani che mi hanno trasmesso, dandomi così l'occasione di arricchirmi in maniera esponenziale attraverso le tante prospettive di sensibilità e pensiero che hanno condiviso con noi studenti. Nello specifico, ci tengo a testimoniare tutta la mia riconoscenza verso il mio tutor di laurea e di tirocinio all'estero, il professor Carlo Cambini, per me un mentore nel suo essere esempio di puntualità, cordialità ed efficacia, che con semplicità e spirito mi ha accompagnato nei corsi da lui tenuti ed in queste due esperienze straordinarie facendomi sentire sempre seguito, compreso e supportato: senza nessuna retorica, sono convinto che non avrei potuto trovare guida migliore.

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Usciamo dunque dalle aule e dai locali dell'ateneo, e veniamo alla famiglia, per me un punto di riferimento imprescindibile lungo tutta la durata del viaggio. Ai miei genitori, che hanno portato insieme a me il peso di questi anni rari, mettendo le loro mani sulle mie nel tenere la barra del timone, per condurre la nave ad ogni meritato porto; ai miei zii e nonni, presenze necessarie per definire un significato di casa, regalo della vita per le lezioni che sanno darmi, sempre e comunque: a tutti loro, il merito di aver contribuito a creare, ciascuno a modo suo, l'ambiente di idee in cui poter costruire tutto ciò che oggi ho d'importante.

Passando dalle radici del mio albero ai suoi rami più verdeggianti, è ora il turno di tutte quelle persone che ho avuto la fortuna di incontrare (e soprattutto di tenermi stretto) attraverso le mille traiettorie dei giorni che hanno portato a questo bellissimo traguardo.

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Gioele Biagiotti

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