Three essays on profits, technology, and economic change

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Three essays on profits, technology, and economic change

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To my mum, Dad and my sister

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I declare myself the only one responsible for any mistake or omission of this work.

Introduction

This thesis aims to study from a broad perspective the recent wave of capitalist development driven by the neoliberal revolution that occurred after the 1980s. In each stage of capitalist development, according to Marxian analysis, the search for profits drives the process of capital accumulation and the evolution of the economy. Therefore, an analysis of the accumulation patterns in capitalism requires a deep understanding of profit.

In a dynamic perspective, the search for profits shapes technological competition of firms and industries to develop innovative breakthroughs aiming to gain "Schumpeterian profits". This turbulent and uneven process of technological competition determines long-run economic growth (Pianta, 2020).

Therefore, this work tries to understand the relationships between profit, technological development, and economic change by looking at how capital accumulation and innovation proceeds, shaping long-run economic growth.

The first chapter explores the relationship between finance, profits, and capital accumulation, focusing on the financialization of the economy that occurred since the 1980s. I review the recent literature about the financialization process in which profits accrue primarily throughout financial deals and speculative transactions.

The rise of financial profits as a leading economic activity has major implications for the economic system. I examine the drivers of these dynamics, including the long-term cycles of capitalist development, in which phases of material accumulation alters periods driven by financial expansion. Some stylized evidence about the recent financialization is provided, showing the expansion of financial actors' activities, the increasing involvement of non-financial corporations in financial investments, the multiple ways households are drawn into financial deals, and the long-term boom of financial assets. These developments change the dominant accumulation patterns by moving resources from material and technological activities to financial deals. The rise of finance changes the nature of capital accumulation, leading to important transformations in capitalism itself.

The second chapter focus on the relationship between profit search, capital accumulation, and technological development across industries in six major European countries. Profit growth in this model is linked to two different innovation strategies and to different orientations of investments pursuing alternatively technological or cost competitiveness. Profits are driven by two alternative cumulative and self-reinforcing patterns. The first is based on the introduction of product innovations. The second is fed by capital investments, productivity gains, and wage reduction. The empirical evidence confirms the coexistence of different technological and accumulation regimes in both manufacturing and services. In high-tech sectors, profits are linked to the introduction of product innovation and on the complementarity between capital accumulation and disembodied technological change. Conversely, in low-tech industries, profits and investment growth are linked to introducing process and labor-saving innovations.

The third chapter This paper contributes to the literature of evolutionary economic geography and innovation studies by analyzing the trends of population, technological and economic changes in Italian metropolitan areas from 2000 to 2018.

The rise of the population in a few metropolitan zones shrinks the demography of the peripheries. The growth of income concentrates in large cities along with the decline of old manufacturing centers.

High-profit corporate services cluster in few places, enlarging the disparities in wealth and opportunities. Moreover, innovation activities gather in a few urban zones, expanding geographical structural imbalances.
Two are the roots of this stage of development. First, knowledge-intensive services such as Finance and ICT benefit from agglomeration externalities and concentrate in large metropolitan cities (Balland et al., 2020, Diodato et al., 2019, Sassen, 2018). Second, innovation activities take place in a few metropolitan hubs where the accumulation of capital, researchers, and firms creates an especially innovative environment (Crescenzi et al., 2019). These two developments created a new spatial order featured by a few rich urban agglomerations –"superstars cities"-, and declining territories –"places that do not matter" (Rodríguez-Pose, 2018), overlooked by the world economy.
The work finds geographical polarisation across Italian Metropolitan Areas concerning GDP per capita and value-added growth, as well as for the sectoral composition of metropolitan economies, focusing on three key economic sectors: Financial and Insurance Services, ICT services, and the manufacturing industry. Likewise, we witness evidence of the concentration of innovation activity in a few metropolitan cities. Indeed, the development of one global city and a few middle-sized metropolitan areas coexists with the decline of old manufacturing territories. These results suggest a structural divergent growth path among Italian metropolitan zones, increasing the country's geographical imbalances.
We performed a factor and cluster analysis to grasp the evolution of Italian metropolitan areas between 2000-2018 according to economic, sectoral, and technological variables. We witness a process of polarisation fed by the growing relevance of the metropolitan area of Milan, where the advancements in ICT and Financial industries concentrate, while the other metropolitan zones achieved very barely improvements. These developments augment the gap across metropolitan economies. Moreover, cluster analysis results indicate no substantial modification in the group formed between the two periods, mirroring the absence of a process of convergence among the Italian metropolitan economies. Instead, we found that cluster score differences enlarged in 2018, suggesting a growing polarisation across metropolitan economies in terms of technological and economic trajectories of these cycles of accumulation.

Chapter 1:

Finance, profits, and accumulation.

Concepts, surveys, and trends

Abstract

This paper explores the relationship between finance, profits, and capital accumulation, focusing on the relevant concepts, on the different approaches that have emerged in economic studies, and on the major trends in the last 40 years. The recent literature about financialization and the rise of financial profits as a leading economic activity is reviewed, and its drivers are examined, including the long-term cycles of capitalist development, the role of technological change, and the extended reach of financial activities. Some stylized evidence about the recent developments of financialization is provided, showing the expansion of financial actors' activities, the increasing involvement of non-financial corporations in financial investment, the multiple ways households are drawn into financial deals, and the long-term boom of financial assets. These dynamics have major implications for the economic system. Production is constrained by lower resources available for real investment. Income distribution experiences a rise in the capital share of growing inequalities in incomes and wealth. The rise of finance changes the nature of capital accumulation, leading to important transformations in capitalism itself.

1. Introduction

There is a broad consensus regarding the increasing role of financial activities in the economic system. Both, mainstream and heterodox literature agree on the prominent role of financial activities in the recent Great Recession. Despite the canonical role of intermediation and efficient allocation of financing opportunities, many authors (Stockhammer, 2004, Epstein, 2005, among others) pointed out the expanding role of finance as the gravitational center of the current phase of economic growth. Since the 1980s, the growing power of finance has constrained productive investments and material accumulation and has boosted financial speculation and monetary transactions in what Vercelli called a "financial production system" (Vercelli, 2019).

This development path has led to a growing literature about the financialization of the economy, where profits accrue primarily through financial activities. The term financialization, thus, refers to "a self-reinforcing socio-economic process, which manifests itself in the growing prominence of behaviors derived from the functioning of the financial sector "(Tori & Onaran, 2018:3).

Two sets of drivers are at the root of the current financial accumulation. First, in terms of economic flows, there is an expansion in the quantity and quality of financial transactions, that involve not only banks and financial institutions, but increasingly also non-financial corporations and households. Second, in terms of stocks of assets, the huge rise of financial assets values has changed the nature of capital accumulation, the composition of individual wealth, and the capital/output ratios (Piketty, 2014).

Non-financial corporations are more and more involved in financial transactions through the activity of borrowing and lending, the 'shareholder value' orientation of corporate management aiming to maximize short-term gains, and the increasing size of distributed profits.

Households are involved in financial markets primarily through the mortgage market for housing, with large interests paid to the financial sector, but debt financing of health expenditure, student loans and consumption are also increasing rapidly in many countries.

Second, the long-term boom in the price of stocks and financial assets has been driven by financial speculation searching for capital gains, by global financial flows expanding investment in the major stock markets – Wall Street and the City in particular - and has been made easier by the expansionary monetary policy that followed the 2008 financial crisis.

These patterns have wide-ranging economic implications, increasing imbalances between production and finance, in the distribution between capital and labour, in the polarisation of social conditions.

The paper discusses the literature concerning the long-run development of capitalism, and the role played by finance. An important reference is the work of Arrighi (1994) on systemic cycles of accumulation in which phases of financial accumulation follows phases of material expansion. In each long cycle, the first phase of economic growth is driven by productive activities and trade in which profitability is high and financial capital supports investments and material expansion. However, when the profitability of these activities falls, due to increasing competition among capitals, capital moves from productive activities to financial ones, boosting speculation and financial deals. This search for higher financial profits allows a new phase of capital accumulation, but expands instability, leading to crises, decline, and the eventual end of a given cycle of accumulation cycle.

Financial capital is also crucial in the process of technological change by supporting innovative breakthroughs, as pointed out by Schumpeter and neo-Schumpeterian approaches (Perez, 2002).

During the generation phase of new technologies, profitability in these sectors is high and financial capital provides resources for innovative efforts and the diffusion of technologies across the economy. However, after the spread of innovative technologies across the economy, the process of imitation and catching up by competitors leads to lower profitability, and financial capital moves toward speculative deals and new financial tools, which allow to maintain high profits and increase capital value.

So that, according to the cyclical view of economic development, phases of financial accumulation recur in the capitalism history, when profitability in leading productive activities and leading technological industries halt. Therefore, capital moves toward financial deals and speculative transactions, which increase profits and financial assets value at the cost of the material and technological accumulation. The work sketches a conceptual framework encompassing these two perspectives of the long-run cyclical economic growth.

Moreover, the paper depicts some stylized facts concerning the phase of financial accumulation shaped by the 1980s, by showing the increasing weight of financial profits, the orientation of corporate management to increase stock value at the cost of material investment, the increasing weight of debt-led consumption of households in some selected advanced country, and the effects of these dynamics on the rise of capital income.

The paper proceeds as follows. Section 2 discusses studies on the financialization of the economy and reviews key concepts and definitions. Section 3 describes the key role played by the search for profits for capital accumulation and technological change, examining Marxist and Neo-Schumpeterian perspectives. Section 4 focuses on the role of finance in the current phase, considering the approaches based on systemic cycles of accumulation perspective and on the importance of technological change. Section 5 provides some descriptive evidence of the current phase of financial expansion, focusing on major drivers and patterns. Section 6 draws some concluding lessons on how finance, profits, and accumulation could be addressed in a coherent framework.

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2. How can we understand the rise of finance?

Even if there is a relevant increasing number of publications regarding financialization, it is difficult to find a unique definition of the term. According to Meder et al., (2020), it is possible to distinguish three phases of the development of financialization studies. A first phase between 1980-2000, with a scarce use of the term, followed by a substantial first increase in the number of contributions between 2000-2008. A new rise in publications on the field occurred after the Great Financial crisis of 2008.
A first wave of publications about the "financialization of markets" emerged in the 1990s, when scholars started to study several aspects of the link between financial power and behavior of institutional investors, such as real estate market cycles and household debt, the markets for natural resources, and the effect of financial concentration on the geography of development (Arrighi 1994; Harvey, 1982; Sassen, 1991;).
A second, stronger diffusion of researches on the theme started in parallel to globalisation after 2000. In the 2000-2008 period some of the most influential studies about the increasing power of finance on the economy provided the theoretical background to a more systematic and empirical approach. Some pivotal contributions developed in this period, particularly regarding the increase of financial profits in non-financial corporations (Lazonick and O'Sullivan, 2000), the macroeconomic trend of financial accumulation (Krippner, 2005; Stockhammer, 2004), and the Marxian perspective on the financial power as last stage of capitalism development (Foster, 2007; 2008), which constitute the building block of heterodox approach to the issues.
The third phase of studies developed in the aftermath of the Great Financial Crisis of 2008, when the number of articles on adopting the term financialization boomed, that this approach became a central point of the public debate regarding economic growth and financial instability. Most contributions of this period emphasized the pervasiveness of financial markets in the economy (Dodig et al., 2016; Epstein, 2015; Lapavitsas, 2013; Shaikh, 2016; Stockhammer, 2013; Vercelli, 2019). The renewed interest on the impact of financialization on society expanded the scale of analysis, including the effects on developing and emerging countries (FESSUD, 2013; Karwowski and Stockhammer, 2017), the impact of financialization on inequality (Dávila Fernández and Punzo, 2021), the increasing financial intermediation in cultural and social matters (Aalbers, 2008) such as student-loans, housing, cities' financing structure, leading to an interdisciplinary stream of researches. Moreover, during this phase, an interesting theoretical debate among economic schools concerning the phenomena arise (see Dünhaupt, 2016 for a review).
Financialization is a complex issue involving many economic and social dimensions, inspiring research from very different fields. We, therefore, need to discuss the origin of the concept and its main diffused definitions.
In Marx's analysis of capitalism, monetary capital is "fictitious capital" in the sense that it is not based on an existing value, but it depends on the monetary equivalent of future dividends. In this sense, the conceptual distinction between industrial capitalist and finance capitalist is based on the difference between money-capital and commodity-capital understood as a different form of capital. Financial capital, in this sense, encompasses the monopolization of the operations of the money-capital circuit by a special category of businesses: banking and non-banking financial institutions, such as banks, insurance companies, stock exchanges, and so forth.

A seminal inspiring study of this line of research regards the work of Hilferding. In “Financial Capital” (1910), the author investigated the close link between banking activities and industrial development in what has been called “first financialization” at the start of the XX century (Vercelli, 2017). His view was that financialization reflected the ‘last’ stage of capitalist development, in which oligopolies of banks and corporations drove the process of accumulation, searching for imperial expansion to enlarge markets, profits and political domination. These dynamics foster inter-state competition and imperial policies, leading to instability and intra-capitalist wars, such as the first world war.

Another influential work on the issue is the analysis of Magdoff and Sweezy (1987) on the role of financial capital in the post-second world war boom. The authors, building on a Marxian perspective, strongly recognized the role of financial capital in shaping the growth of post-war Western countries. In particular, they emphasize the rapid diffusion of “new innovative financial instruments” such as securitization and derivatives as tools to foster financial profits at the cost of the traditional productive activities.

The concept of financialization plays a key role in the analysis of Giovanni Arrighi (1994). The Italian economist and sociologist defines in this way the declining phase of the cycle of accumulation, when activities shift from production to finance, searching for speculative profits. According to the author, each accumulation cycle in capitalist history is paralleled by a cycle of hegemony; when financial activities become the leading economic activity, they drain funds from production activities, resulting in weaker international power and profitability of the hegemonic center. Financial accumulation increases the instability of the system leading to major crises, after which a new phase of accumulation develops, with a new hegemonic center and a new system of international relations. Arrighi (1994) explained financialization as part of the decline of the US power in the ’90s, as well as for the British Empire at the beginning of the 20th century, when the increasing power of the financial industry boosted the instability of the system.

Nowadays, the most influential definitions of financialization draw on a few seminal works developed during the second wave of financialization studies, emphasizing the broad range of matters involved. Table 1 reports the most diffused definition of financialization according to Mader et al., (2020:9).

Table 1: the definition of financialization

Autor	Definition
Epstein (2005)	“increased activity of non-financial businesses on financial markets, [...] measured by the corresponding income streams”
Stockhammer (2004:2)	“a pattern of accumulation in which profits accrue primarily through financial channels rather than through trade and commodity production”
Krippner (2005)	“a pattern of accumulation in which profits accrue primarily through financial channels rather than through trade and commodity production”

Source: Autor’s elaboration on Mader, Mertens, and van der Zwan (2020:9)

Epstein's definition (2005:3) identifies the broad mechanisms in which financialization affects economic development, suggesting the growing relevance of financial power in the economy. On the one side, globalization and the spread of the global value chains augment capital flow and financial transactions around the globe, augmenting the volume and the geographical extension of the financial activities. On the other side, these dynamics feed the growing dependence of national economies and domestic firms on international capital flows.
Stockhammer's (2004:2) definition underlines the stream of income generated throughout financial activities by non-financial businesses. The growing relevance of financial returns and liabilities of many non-financial companies increasingly enlarge the relevance of the financial market for firms. This led to a considerable shift of the "business core" from material production to financial activities, augmenting the relevance of the management for financial governance. This pattern is a core block of the earlier financialization studies, emphasizing the growth of financial motive for non-financial corporations' activities leading to the "shareholder value orientation" of the firms' management (Lazonick and O'Sullivan, 2000; Lazonick, 2015; Orhangazi, 2008).
Krippner's definition (2005:175) looks more systematically at how the economy developed, highlighting the prominent role of finance in the modern accumulation cycle. In this view, the massive growth of financial profits mirrors the shift of accumulation from material activities and trade to financial ones. In this view, capital accumulation and profits accrue primarily throughout financial dynamics and speculation at the cost of material accumulation and commercial exchanges.
With the third phase of studies on financialization, the number of empirical specifications and econometric exercises increased, making the definitions more operative. Tori and Onaran (2018) consider financialization as a "self-reinforcing socio-economic process, which manifests itself in the growing prominence of behaviors derived from the functioning of the financial sector" (Tori, Onaran, 2018:3). They test the influence of financial income on investment with econometric tools by using firm disaggregated data. In this line of research, they study the "increasing orientation towards external financing, shareholder value orientation and the internal substitution of fixed investment by financial activity" (Tori and Onaran, 2018: 18) empirically as a part of the broader trend of internationalization of production and profits into global value chains.
More recent contributions, such as Vercelli (2019), pointed out the monetary nature of the financialization process. Financialization, in this approach, is a "process of evolution of money that progressively increases its influence in the economy and society" (Vercelli, 2019:91). Money is not only a quantity or a means of exchange but constitutes a massive liquid and free form of capital. Therefore, inspired by the evolutionary approach, the Author underlines the increasing role of the profits from the money-capital circuit M-M' rather than other production processes such as M-C-M'. Hence, financialization refers to the "increasingly crucial role of money capital in the circulation of commodities" (Vercelli, 2013: 34), expanding its power over other forms of capital.
Despite the wide definitions of financialization and the wide significance of the term, it is possible to cluster three broad macro-area in which financialization studies developed. According to the work of Van der Zwan (2014), financial studies involve a macro approach, centering on accumulation dynamics and on how financial transactions drive economic growth nowadays, increasing the instability of the system. A meso-level of analysis regarding the economic actors involved in financial activities by looking at how industries and non-financial enterprises expand financial gains. A third

cluster regards the micro-level, where the research agenda feels mainly the household choices of saving and borrowing and the advance of finance into the realms of everyday life.
As discussed briefly in the paragraph, it is difficult to find a univocal definition of financialization. Despite the differences, it will be helpful to find some common features. Mainly, scholars in the field consider the increasing role of financial activities in the economic process as a central matter. The growing expansion of financial profits in the economy is a further central point in this perspective, shaping a new and different accumulation dynamic. Then, it involves not only the traditional financial actors but also the increasing "connect changes in finance with other shifts in politics, economics, social relations, and culture, and articulate these as causes and consequences" (Mader, Mertens, and Van der Zwan, 2020:8).

3.Capitalism and profits

The search for profit guides economic decisions in the market economy, driving the process of capital accumulation and the evolution of capitalism (Shaikh, 2016). Therefore, an analysis of the accumulation patterns in capitalism requires a deep understanding of profit dynamics. A starting point of the profit analysis is Marx's identification of two functional circuits. The circuit of the capital and the circuit of the revenue. In the first, which is schematized by M-C-M' formula, the essential component is the capital used in the profit-making process. Money (M) is invested in commodities (C), usually capital goods, which can start a production process, such as labor force, plants, technologies, and raw materials. At the end of the process, capitalists gain a quantity of money (M') greater than M, the capital invested. Each component of the capital circuit is used to increase the initial amount of money. In each stage, capital appears in a different form: money-capital (M), commodity-capital (C), aiming to generate greater returns (M') respect the amount invested.
Marx has also described the circuit of revenue. This is different from the previous since the money is utilized to buy consumption commodities or savings. The circuit of the revenue can be described by the schema C-M-C. Here, a worker sells him labor forces (C) to hire a wage (M), used to buy goods for consumption or increase savings. What is worthy to note in this scheme is that the two circuits are necessarily interdependent in the capitalist production process. "Wages received by employees are part of the capital expenditures of firms, while the consumer goods and financial assets purchased by employees are part of the profit-motivated sales of firms" (Shaikh, 2016:211).
The classical analysis of profits claims that the source of profits is the exploitation of the workers in the production process, which is made basically by the length of the working day. What Shaikh explained is that "there can be no positive profit without a surplus of labour" (Shaikh, 2016: 212). The crucial variable in this setting is the length of working-day. Workers are constrained to work more than what Marx calls necessary labor time, the quantity needed to guarantee the survival of the labor force. After the time of work required to ensure the means of subsistence of the workers, they generate a surplus of labor, which is the origin of the surplus produced. In this view, the sale of surplus produced is the source of profit for capitalists. According to the classical economic analysis then," at any given set of relative prices within a given technology, real profit will be a positive function of surplus labour time" from a microeconomics point of view (Shaikh, 2016: 217).

A further step is to consider two distinct sources of aggregate profit, *positive profits* and *relative profits,* as pointed out by John Stuart Mill, at the base of the Marxian distinction between *profits from surplus* and *profits from transfers*.
Profits from transfers are typical of merchant capitalism and, more generally, of any form of a trade relationship based on the exchange between commodities with unequal values. In this sense, they are called *relative profit;* in such, they do not relate to the production of any commodities or services. Actually, they are based on the exchange of monetary values based on the existing stock of wealth produced but do not increase or produce it.
Instead, the second and most important source of profit in the capitalist accumulation process relies on *positive profits*, or industrial profits, which are built on the sales of the surplus generated throughout the production process. These profits derive from the output produced exceeding the inputs involved in the production; therefore, they are the primary source of aggregate profits.
As pointed out by Shaikh (2016), the production of a surplus is the condition to have any form of profits, and the exploitation of workers is crucial to enlarging the output obtained.
Therefore, in capitalism, production is a social process rooted in the conflictual relation between actors involved concerning the working conditions: the length of the working day, the intensity of the production, and the level of wages for working hours which are indispensable to enlarge surplus and increase profits.
Conversely, profits gained from the exchange activity are a mere transfer of value from the circuit of capital to the circuit of the revenue and can be considered a secondary source of profits; they are based on the exchange of surplus produced and depending on price and value from it.
From this standpoint, financial profits have a gloomy nature since they can contribute to the production process by providing initial capital to finance productive activities and enlarge surplus, but they can also be based on a mere transfer towards speculative activities. In this scheme, too, financial profits are a secondary form of profits since they depend directly on the surplus sold, deriving essentially from an excess of saving, retained profits, and expected future production.

3.2 Profit and capital accumulation

In capitalism, capital accumulation is achieved through the reinvestment of profits that expands the capital stock (Louçã, 2021, Kotz and Basu, 2019). Indeed, profitability - the net returns on investment - is crucial in shaping the capital accumulation dynamics and affects investment decisions. Periods of strong economic growth have been driven, historically, by a high level of profitability, in which, high expected returns fostered investments aiming to catch profitable opportunities (Duménil and Levy, 2021).
Investments in fixed capital are essentially driven by retained profits and net borrowing. These two sources of capital accumulation are substitutes, meaning that during the phases of low retained profits, net borrowing increases, providing the fund necessary to invest. The converse mechanism also holds, guaranteeing the substitution effects between the two variables to support expenditure in fixed capital. However, by exploring the components of profits, Duménil and Levy (2021) found a rise in the profits paid to financial gains, dividends, and share buybacks since the mid of 1980s, which drained funds from capital accumulation and lowered the level of financing resources for the production. Moreover,

the greater tendency to use borrowing and landings activities to sustain share repurchase and enlarge stock market gains further diminishes the resources to support economic activities.

These dynamics, therefore, may explain the falling rate of capital accumulation and economic development that occurred since the second phase of the last century due to the increasing orientation toward financial activities of firms and industries. Hence, they conclude that "The eagerness of the upper classes in neoliberal managerial capitalism to increase their incomes reached such degrees that the correction could not be thoroughly accomplished, but it was very large. This "greediness" is the pivotal root of the diminished rates of accumulation in neoliberalism. Human psychology is not at issue, but class struggle" (Duménil and Lévy, 2020, p. 22).

Therefore, during periods of material accumulation and output growth, capital accumulation enlarges profits, supporting increasing demand for employment, particularly in leading technological industries. However, the modern development path shaped by the crisis of the 80s boosts financial profits in the form of interests, dividends, and shareholders returns at the cost of material investments, increasing the weight of speculative economic activities at the cost of the production and technological-oriented development. Actually, many empirical contributions pointed out the negative link between fixed assets investments and financial income, both, in the form of financial profits and liabilities. Tori and Onaran (2018) find robust evidence of an adverse effect of interests, dividends, and financial gains on the accumulation rate for a sample of UK firms and many developing countries (Tori and Onaran, 2022). Therefore, the shift of capital accumulation from material activities to financial income also exerts a considerable effect on development dynamics, leading to the enlargement of capital gains at the expense of work and technological development.

3.3 Profits and technological change

In a dynamic perspective the search for profits shapes technological competition of firms and industries to develop innovative breakthroughs aiming to gain "extra-profits". This turbulent and uneven process of technological competition determines long-run economic growth (Pianta, 2020).

Classical economists recognized the crucial role of innovations to boost profits and economic evolution (Evangelista, 1999). They connect capital accumulation to technological change, highlighting two main features. First, innovative productions require higher capital-intensity. So, investments in machines and capital assets spread innovations across the economy. Second, technological development is a capital-deepening process with labour-substituting dynamics. This is particularly clear across industries where automatization and mechanization aim to reduce production costs by diminishing salaries.

In the analysis of Schumpeter (1995), entrepreneurs' efforts to introduce innovations aim to escape market competition and gain "extra-returns" determine the evolution of economic cycle. The development/adoption of innovations guarantees monopolistic positions and market power to the leading technological firms, which realize "Schumpeterian profits" at the cost of competitors. Successful innovative outcomes impact on the market structure, generating a concentration of gains and financial resources in some large oligopolistic companies, able to produce or adopt the leading technologies available. These dynamics boost the expansionary phase of the economic cycle, stimulating employment, consumption, trade, and fostering optimistic exaptation of the future.

However, when innovations spread across the economy, returns of leading firms decline, and profitability fall. International catching-up, the process of imitation of competitors, and the spread of the new innovative techniques across the economy level off the productivity premium of the leading innovators (Pianta, 2020). In this way, the economy upgrades technologically, but "extra-profit" dynamics halt, shaping the downward phase of the economic cycle. During this phase, profits decreases, profitability diminish, and investment slows down, smoothing the overall growth. Hence, in this approach, innovation efforts are the engine of competition, aiming to obtain Schumpeterian "monopolistic-profits" and escape from market dynamics.
Furthermore, profits play an essential role also in sustaining innovative efforts realized by firms and industries, as in the Schumpeterian Mark II model of innovation (Schumpeter, 1995). Retained profits of thriving high-tech industries spur technological accumulation and R&D expenditure to maintain their leading position and market power. Conversely, declining periods are featured by low-profit gains, which in turn determine smaller available found to finance accumulation.
Long cycles of strong economic growth are rooted in industrial revolutions whose innovative discoveries changed the entire mode of production and consumption across the economy (Freeman and Louçã, 2001). The application of revolutionary technologies in some sectors increases productivity, investments, and profits, boosting overall economic growth.
If steam power, iron machines, and textiles production shaped the development in the first industrial revolution, economic growth in the first part of the 20th century was built on the vast industrialization of heavy chemistry and civil engineering, electrical equipment, and automotive sectors based on the massive use of the of steam, oil, and petrochemicals (Freeman and Louçã, 2001). Fixed capital stock of advanced technological inputs has been a fundamental source of productivity gains and spread of knowledge across industries, sustaining economic growth.
Each long cycle of economic growth is built on a set of social power relations, institutional, legislative facilities, and international hierarchical systems, which allow guaranteeing a stable accumulation race by entirely ensuring the diffusion of technological breakthroughs (Louçã and Freeman, 2001; Louçã, 2019; Kotz and Basu, 2019). Evolutionary theorists elaborated four theoretical tools to study in a systematic way long cycles of economic development.
The first is the *techno-economic paradigm* (Dosi, 1982; Perez, 2002; Freeman and Louçã, 2001). It describes the relationship between the mode of production and the technology available in each historical period (Louçã, 2019). It consists of a cluster of innovations rooted in a dominant technological branch and leading productive sectors. If automotive and heavy manufacturing foster economic growth in the first 20th century, information technologies and the digital economy drive the current development phase.
The second is the *accumulation regime*. It describes the patterns of production and distribution in each long cycle. Production dynamics are moved by the productivity pace and surplus accumulation; distribution depends upon the power relationships across classes and by the hierarchies of production between industrial and financial capital, management orientation, and banking system.
The third is *the socio-institutional regulation*, which regards wage determination from a broader perspective, including the welfare system, social security, and working conditions. In a nutshell, it is the legislative structure that determines the organization of the work in each historical context. During economic breakdowns, social regulation becomes an impediment to accumulation dynamics and the conflict between capital and labour augments. News mode of production requires different forms of work organization and working conditions that evolve with the relations across the economy.

The fourth aspect is *the international hierarchy* that corresponds to the organization of the world economy and the international relations across actors. It involves the international structure and the material and immaterial facilities which drive accumulation. In the current phase, globalization and the global value chain allow the process spread production and trade globally. It is well described by the "World System" concept developed by Giovanni Arrighi (1994).
These four dimensions can systematically describe the feature of each growth cycle. As argued by Louçã (2019), among others, the actual pattern of accumulation is driven by financial profits and can be identified as contraction phase B of the fourth long wave beginning after WWII. The main insight regards the turning point of the 1970s and the contradiction between the new techno-economic paradigm and the socio-institutional system.
The new accumulation regime is oriented toward financial profits by the diffusion of ICT technologies, the decline of labour's share, and the low-interest policies inaugurated by the "asymmetric monetarism" in response to the decline of profitability rate in the early 1970s. "In the current case, this Phase B has been shaped by structural changes imposed through three processes: the neoliberal reconfiguration of institutions, the financialization of surplus extraction, namely through rentism, and accumulation via intensified inequality" (Louçã, 2019:3).

4. Capitalism and finance

4.1 The rise of financial profits

The novelty of the modern economy driven by financial accumulation is the increasing and predominant role of financial gains on the overall profits, which drain resources from the material and technological activities to enlarge bubbles and speculative operations. Two are the crucial mechanisms that drive these dynamics, expanding the power of finance in the recent development phase.
The first is the even more increasing involvement in financial operations of material economic activities such as production and consumption, which generate a massive flow of income from non-financial corporations and households towards financial deals.
On the one hand, shareholder value maximization becomes the leading corporate management goal, draining profit and resources from material accumulation to financial operations (Lazonick and O'Sullivan, 2000, Lazonick 2017). According to this view, the increasing stock-owner influence directly affects managerial preferences by linking individual payoff to the firm stock performances and distributed profits. Indeed, shareholders' short-run returns become the primary source of evaluation for business management.
The maximization of dividends along with the increase of stock prices are nowadays the first objective of firm management. In this way, profits moved away from the productive "retain and reinvest" goal toward the "downsize and distribute" paradigm (Lazonick and O'Sullivan, 2000:18). Likewise, the remuneration of the managers based on the stock options increases the preference of the overall governance for the short-run value maximization, weakening long-run investments. Duménil and Lévy (2011) describe the right-side compromise between shareholders and managers based upon the

high returns from capital gains and financial income in what they called “Managerial Capitalism”. The new form of the social contract is based on the maximization of the upper-class income through financial wealth. This process enlarges capital share and at the cost of labour income by increasing the flow of investment and profits from material and productive activities to the accumulation of financial capital stock, which is mainly held by managers, the banking sector, and financial rentiers.
On the other hand, debt-led consumption massively increases the weight of financial debt for the private sector, increasing the flow of interests and commissions paid to institutional investors. The expropriation of wages is driven primarily by the mortgage market and housing, connecting consumption patterns and financial investments. Moreover, wages feed financial profits by augmenting interest payments, speculative operations, and loans to support consumption in new markets, such as student loans, health insurance, and welfare services (Stockhammer, 2019). These dynamics accrue the flow of income from the circuit of revenue and consumption to the financial circuit, enlarging the weight of financial profits and opening the door to new forms of speculation such as derivative contracts and composed insurances.
A second mechanism, that enormously enlarged financial profits, is the massive increase in the value of the stock of financial assets, leading to the boom of financial rent (Franzini and Pianta, 2016).
An essential ingredient of the answer to the crisis of profits during the 70s and 80s was a monetary policy inspired to stimulate cheap capital and halt the salary dynamics, reshaping the balance of power between wages and profits (mainly financial); the “asymmetric monetarism” promoted monetary and financial deals, cheapening the price of capital at the cost of labour. In response to the Stagflation Crisis, the Volcker shock between 1974-1981, when interest rates moved from around 4% in 1975 to a peak of 14% in 1981, broke the link between productivity and salary dynamics, aiming to halt wages growth. However, the abundance of easy and cheap credit renews capital accumulation race by stimulating financial transactions rather than physical investments.
Vercelli (2020) pointed out the far-reaching consequences of this policy. First, it prevented inflationary pressures in the real economy but not in the financial activities, where asset bubbles developed cyclically. Furthermore, it stimulated cheap indebtedness in the economic system, both for firms and households. Third, it produced a distortional effect, supporting financial transactions with relatively low prices and risk as compared to productive investment. Low economic growth and scarce demand, in turn, further debt-led consumption via wealth effect, augmenting the dependence of private sectors from financial markets. Additionally, the diffusion of ICT technologies boosted the circulation of capital, mainly the financial one. Indeed, financial innovations developed since the 1970s- the “securitization” and the derivates boom - massively feed liquidity, favoring financial trade and capital gains.
In a nutshell, economic growth driven by the crisis of the 1970s and 80s has been sustained by a low-interest rate, pushing the relative profitability of financial activities with respect to the physical investment and technological activities, and low wages, moving income from labor to capital. Furthermore, the spread of the ICT revolution enormously increased capital flows and favored financial transactions and speculative gains.
Indeed, as Pianta and Franzini (2015) evinced, financial wealth and assets are held mainly by the capital earners. These dynamics accrue wealth accumulation through financial rent, enlarging inequality in what they labelled “Oligarch capitalism”. Indeed, the rise in the concentration of income in the upper side of the distribution enlarges social power and political influence of the richests. In

this way, the primary form of accumulation became inheritance and legacy at the cost of technological development and market opportunities.

4.2 The source of financial profits

As Lapavitsas (2013) explained, from public debt to interest gains, financial profits are crucially based on future expected output. Indeed, these profits are rooted in the exchanges of the surplus realized throughout production, but do not generate it, moving the monetary value from material production to the circuit of capital. Therefore, it is helpful to distinguish analytically between a primary and secondary form of financial profits.

The former accrues to the monetary capital owners, such as loanable funds or financial exchanges. They are returns from leading money, gains from holding equities, and profits from financial assets trade. The secondary form of financial profits can be recognized in the returns generated from the intermediation of financial institutions. Financial payoffs of this kind are manly fees and commissions paid to the financial intermediaries.

From an empirical point of view, three are the major sources of financial profits nowadays, which drive the process of financialization nowadays by enlarging the weight of financial transactions in the production and consumption spheres and increasing the value of the monetary assets.

The first regards the increasing role of liabilities held by the non-financial corporations, with a rise in the activity of borrowing/lending along with an expanding orientation towards share buybacks. As Davis (2017) noted for the US stock market, the rising turnover mirrors the new role of financial activities in corporate governance, oriented toward short-term profit maximization and a fall in long-term investment.

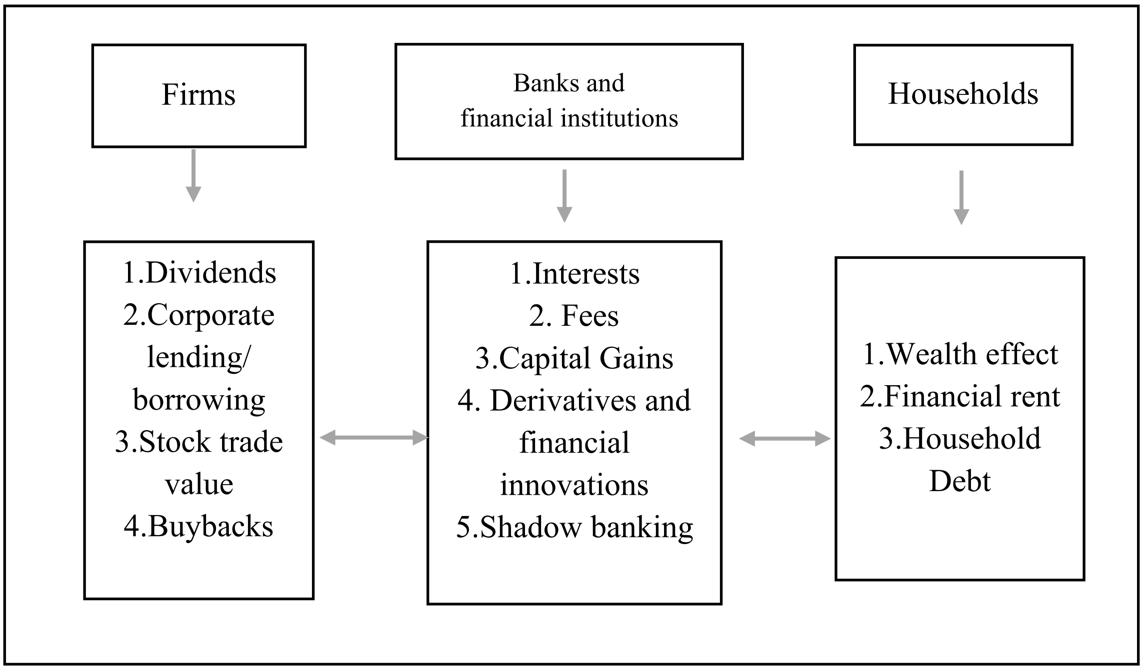
Duménil & Lévy (2011) found that during the financial era, the issuing activity of non-financial corporations is aimed to increase the purchase of their own shares and enlarge their price via buybacks. At the same time, the net borrowing operations are used to finance the acquisition of shares and the enlargement of the stock market indexes without connection with the productive accumulation. Moreover, the weight of interests paid and received witnessed the increasing weight of activities far from the production process across firms. In this view, the aim of corporate management in the financialization era is to distribute profits that heavily come back into productive investment.

The second source of financial gains regards the role of commercial banks. The monetary policy inspired by the low-interest rate largely supported the operative margins of banks (Lapavitsas, 2013, Shaikh, 2016). Banks, actually, are more and more involved in open-market operations and household landings, away from the investment in productive projects, and increasingly oriented to creating sophisticated financial instruments for trade. These patterns are witnessed by the sharp exchange of over-the-counter derivatives among a few leading global banks (Lagoarde-Segot,2017) and the development of shadow systems aimed to enlarge trading activities between institutional investors and commercial banks.

The third source of profits during financialization regards the increasing indebtedness of the households driven by easy credit and wealth effect dynamics (Stockhammer 2013). This driver of financial profits is qualitatively different from the first two, which involve profit-making institutions

such as banks and corporations, and regard mainly the consumption of welfare and life-based commodities. Actually, households are committed into financial transactions mainly to acquire goods or services, leading to what Marxists define as a form of "financial expropriation" due to the <<non-capitalist character of personal income>> (Lapavitsas, 2013:145).
The main field of financial expropriation is the real estate and mortgage market, providing a striking source of interest payments (Shaikh, 2016, Mian, Sufi, Verner, 2017). Too, the increasing value of the homes and the cheap cost of the debt shaped the wealth effect for the consumers, allowing them to further increase debt-led expenditures. Other non-exhaustive fields in which the households are involved in financial activities are education loans (Eaton et al., 2017), commodity markets (Henderson et al., 2015), and insurance services, along with many growing aspects of "everyday life" (Mader et al., 2020).
We depict an analytical framework in figure 1 to sketch the different types of financial activities and the way in which economic actors increasingly participate in finance in modern economies. Actors engage in finance as both lenders and borrowers; activities include both expanding economic flows and increases in the value of the stock of financial assets.

Figure 1: The dynamics of finance



Source: Author's elaboration on Lapavitsas (2013) insights

Summing up, the expansion of finance is rooted in the involvement of many actors. Non-financial corporations, commercial banks, and households are increasingly engaged in financial operations.

4.2 Material and financial accumulation in the world-economy

World economy proceeds throughout long economic cycles rooted in a political center of power that drives capital accumulation (Arrighi, 1994; Braudel, 1984; Kondratiev, 1984). Systemic accumulation cycles present some recurrent features.
In the first phase of the cycle, profits and capital accumulation are high, driving strong economic growth. After some periods, however, growth halt, profits decline, and capital accumulation drop. Competition among capitals enlarges, augmenting economic and political instability. Capitals require profitable opportunities and new investment. Financial expansion substitutes material and commercial accumulation, becoming the leading economic sector. However, financial accumulation increases the fragility of the system leading to a massive financial meltdown and the terminal phase of the accumulation cycle.
According to Arrighi (1994), four systematic cycles of accumulation boosted capitalist development, each characterized by an internal block of institutional facilities and a worldwide structure of capital accumulation: a Genoese cycle, from the fifteenth to the early seventeenth centuries; a Dutch cycle, from the late sixteenth century through most of the eighteenth century; a British cycle, from the latter half of the eighteenth century through the early twentieth century; and a US cycle, began in the late nineteenth century and reaching the current phase of financialization.
Each long cycle is composed of a phase of material expansion and a period of financial accumulation. At the beginning of the cycle, profits are driven by a period of material expansion, in which material activities and trade produce high gains. Investment profitability is very high, guaranteeing high returns and allowing further capital expansion. However, after a period of more or less stable economic growth, profitability falls due to the increasing competition among capitals and an extreme search for further profits; the accumulation process slackens, determining periods of turbulence and instability. These dynamics halter economic growth, driving the search for a new pace of capital accumulation.
The excess of capital and the search for high profit shift the accumulation process from trade and production to financial operations, guaranteeing a renewed capital enlargement. These patterns recurred in each long cycle: Dutch escaped from commerce in the middle of the eighteenth century to become “the bankers of Europe (Arrighi, 1994:5)”. The same happened in the sixteen-century in Italy, when the Genoese capitalist oligarchy, leaving commercial affairs, became the main financers of Kings and States.
After that, the English empire, too, in the late 19th century, when the end of “the fantastic venture of the industrial revolution”, created an oversupply of money capital in the national financial global centers such as London (Braudel 1984: 242–3). The current phase of financialization, centered in a few US financial global cities (Sassen, 1991), followed the period of material accumulation shaped by economic conditions and international hierarchies born after the second world war.
However, financial-led growth augments turbulence and instability in the system, fostering economic collapse and financial bursts, determining definitely the crisis of the accumulation system << when bubbles burst, the accumulated debt of firms and governments become unsustainable, banks fail and the economic crash may turn into a protracted depression – the ‘terminal crisis’ of the accumulation cycle>> (Pianta and Franzini, 2015: 61). These periods are characterized by the abundance of free monetary capital and a new international hierarchy, which place the conditions for starting a novel

cycle centered in a new hegemonic center by ensuring a stable path of capital accumulation and elevated profits.

Therefore, in the analysis of the world economy of Arrighi (1994), current financialization mirrors the maturity stage of the US systemic accumulation cycle, driven by financial expansion due to the falling profitability of material activities in the 80s.

In this perspective, the Marxian general view of the circuit of production (MCM′) << can therefore be interpreted as depicting not just the logic of individual capitalist investments, but also a recurrent pattern of historical capitalism as world system (Arrighi, 1994: 6)>>. Economic long cycles of growth mirror two contrasting systems of accumulation.

In the first part, M-C, monetary capitals drive material expansion by investing even more resources in productive activities, leading to a period of massive profits and capital boost. In this phase, it is profitable for capitalists to invest in economic activities and trade, which allow increasing returns.

In the second system, depicted by the formula C-M', capital accumulation is driven by financial expansion, mirroring the descendent phase of the cycle. Financial deals become the leading profitable activities, causing the shift of large funds from the production and trade to speculative activities and monetary transactions, which renews hugely capital gains. These patterns, however, massively augment the instability of the accumulation process, driving toward the collapse of the cycle.

According to Arrighi (1994) and Braudel (1984), the shift from material to financial accumulation resembles the maturity stage of each systemic accumulation cycle.

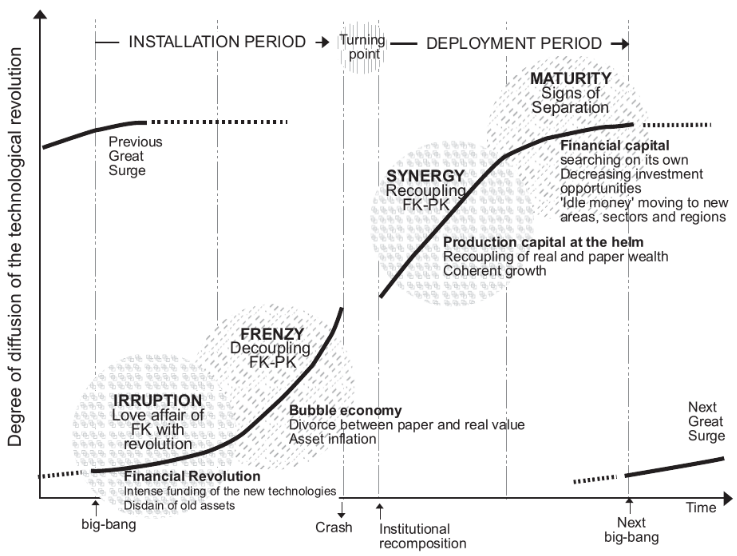
These dynamics are driven by the natural tendency of capital to expand itself, searching continuously to secure larger future profits. During material expansions, money capital M is invested in some particular combination of input-output C to obtain a future enlargement of money M'. Monetary capital allows the loss of flexibility and liquid form due to the profitable expected opportunities. However, when profitability falls along with the expectations to obtain future returns, capital tends to remain into the more "flexible forms of investment – above all, to its money form" (Arrighi,1994:5), which allows grasping each new possible investment. So that, the preference for liquidity, along with the fall in expected profits, moves capital accumulation from material to financial deals.

The fall in profitability between the 70s and 80s, along with the renewed accumulation race throughout monetary operations at the root of the boom in financial profits and the current financialization. As Shaikh pointed out indeed: <<The historical solution to this crisis was an attack on labor and a great reduction in the interest rate. Both of these worked to substantially increase profitability, making the real average and incremental rates rise dramatically. This is the real secret of the great boom that began in the 1980s: cheapened labor and cheapened finance (Shaikh, 2016:735)>>.

4.3 Finance and technological change

Technological change is closely linked to financial dynamics. Technological breakthroughs generate high profitability and massive gains, attracting investments and financial capital. Moreover, the development and spread of a new technological cluster of innovations require massively financial resources to fund innovative efforts.
Perez (2002) pointed out the connection between the development/spread of radical innovations and financial cycles. The historical development of the leading technological revolutions presents some recurrent phases which connect financial capital accumulation and technological change, as shown in figure 2.

Figure 2: financial capital and innovation



Note: the link between financial cycle and technological change. Source: Perez (2002:74)

In the period of generation of radical innovations, which Perez (2009) defined as "installation", financial capital attracted by the profitability of the new technology massive fund its development, supporting innovative efforts of firms and industries that adopt it. In the first periods, financial capital primarily encourages the creation and the diffusion of innovations, shaping the process of technological upgrade across the economy. This is motivated by "irrational exuberance" (Perez, 2009) of finance, moved by great investment opportunities and high expected returns.
Moreover, the financial sector itself is a leading innovator, "providing venture capital, of attracting new investors and new capital to the market and of leveraging, handling, hedging and spreading risk" by developing financial innovations (Perez, 2009:781). These dynamics drive the "Majors technological Bubble" centered on the massive search for investment in the new innovations which

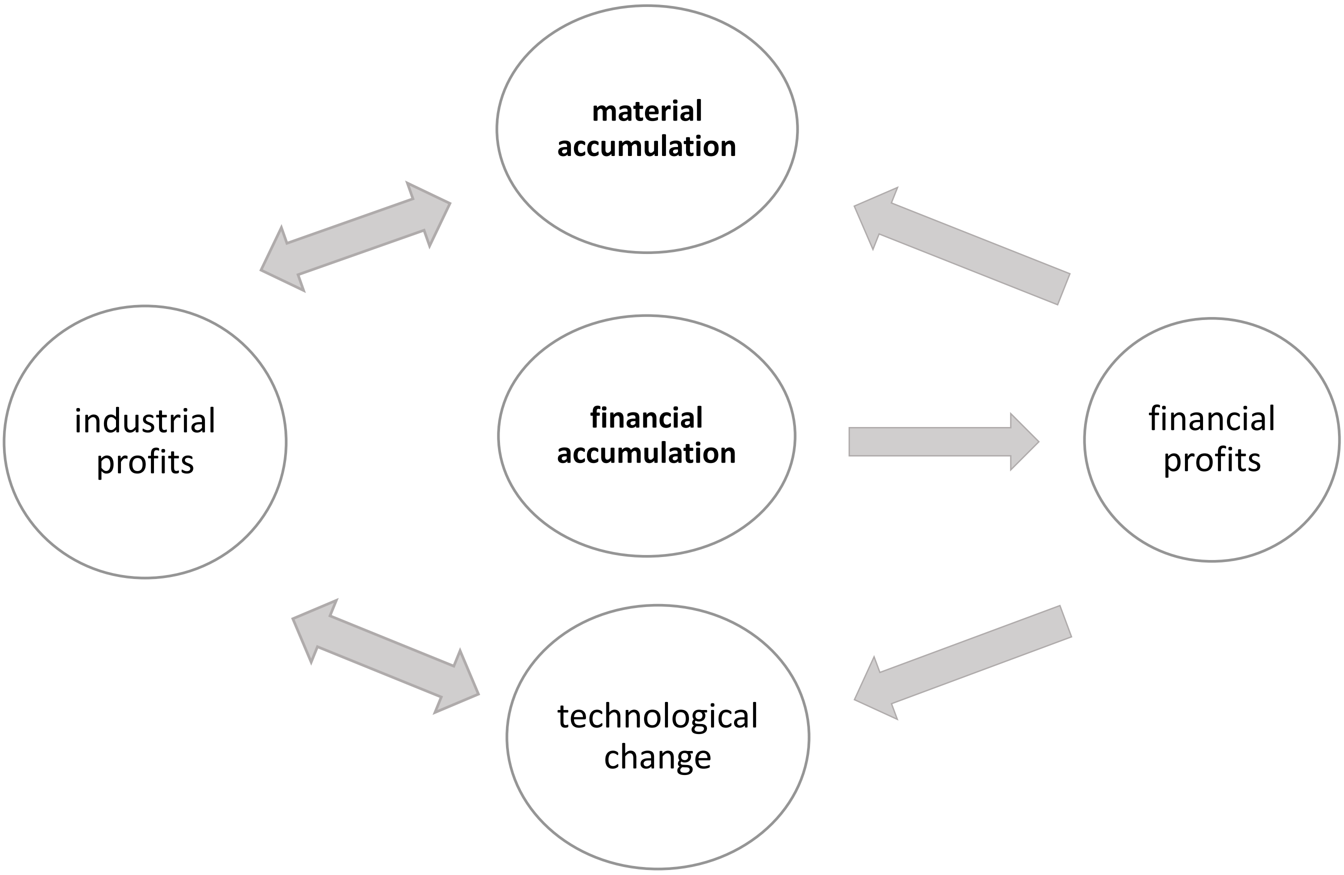
led to the end of the installation period when innovations entirely developed, and the new technological paradigm is diffused across industries.
But, after the diffusion of the new technology, there is too much capital in search of an investment than innovative projects, and the profitability in the technological branch declines along with expected profits. The search for high returns and new higher profitable opportunities moves financial capitals toward speculative operations and financial assets, mainly driven by financial innovations.
Hence, the object of speculation turns to financial deals, and it is raised by financial innovations that encourage new forms of financial exchanges. The Easy liquidity bubble is "driven by the availability of abundant cheap credit searching for whatever object of speculation is on hand or can be created by financial innovation (Perez, 2009:792)".
Therefore, financial capital plays a fundamental role in driving the process of technological change, boosting the first phase of development of innovations, and guaranteeing necessary funds for its diffusion. Then, financial accumulation divorce from technological development, when profitability drops, moving toward bubbles and speculative deals.

4.4 Sketching the two accumulation cycles

In the analysis of systemic cycles of accumulation by Arrighi (1994), phases of material financial expansion follow periods where accumulation proceeds throughout material activities and trade. These patterns recur across the economic history of capitalism, from Genoese commercial supremacy until the current phase of economic growth under US hegemony. The turning point in the analysis of Arrighi is the fall in the profitability of the material production and trade due to the increasing and persistent search of capital accumulation to enlarge profits. Intense competition, physical barriers, and monopolistic power limit the accumulation process, favoring the shift from material to financial deals.
Moreover, as Perez (2009) shows, financial cycles follow the creation and the spread of technological paradigms, providing the necessary funds to finance innovative efforts in the new technological branches and in novel economic sectors. During the period of "installation", when innovations generate high Schumpeterian profits, financial capital largely invested in these sectors and supported the spread of the radical technologies across the economy. However, when the new technological paradigm is diffused, through the process of imitation and catching-up, profits in these technologies fall, shaping the downward phase of the cycle (Pianta, 2020). Financial capital, however, tries to maintain high returns and profitability in financial markets, boosting the creation of innovative financial instruments and speculative dealing; in this way, financial capital recklessness the innovation process, moving towards bubbles mechanism and enlargement of financial returns.
As suggested by Pianta in the preface of the Italian version of Arrighi's book (2016), in the study of the systematic accumulation cycles, very low attention is depicted to technological progress. Following this intuition, we try to sketch the two phases of accumulation in a conceptual framework by integrating the connection between financial cycles and technological change into Arrighi's analysis. This matter may help to stress the link, in an integrated way, between material, financial, and technological accumulation during the long cycle of economic growth.

Figure 3 depicts the initial phase of material accumulation, where capital expands mainly through production and trade, evinced by the Marxian formula M-C.
During the phases of material accumulation, industrial profits are driven by capital accumulation and technological activities, as well described by Neo-Schumpeterian theories of economic growth (Pianta, 2020). Leading innovators, along with capital-intensive industries, increase profits, particularly in high-tech sectors where demand for labor is high.
Moreover, due to the high profitability of these activities and the growing demand dynamics, retained profits are invested in fostering capital and technological accumulation, shaping economic growth in the upward phase of the cycle.
During the material accumulation phases, due to the high profitability of technological activities and material accumulation, financial profits provide the crucial support to expand accumulation and spread innovations across the economy, definitively shaping the new techno-economic paradigm. These periods are featured by high economic growth, where financial accumulation proceeds along with material accumulation supporting capital expansion and technological evolution.

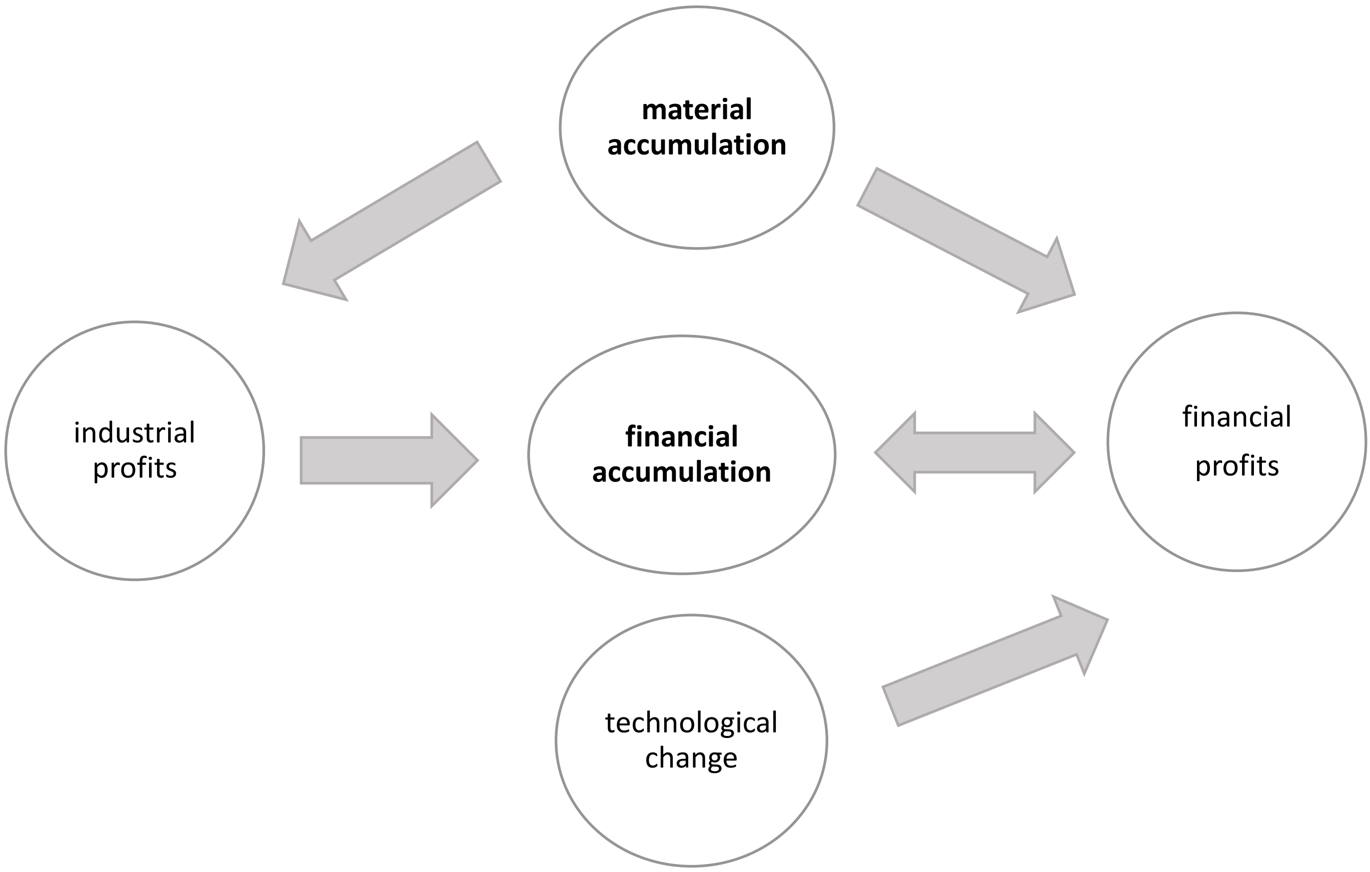
Figure 3: the cycles of material and financial accumulation



Source: Author's elaboration

the turning point, economic growth halts and profitability falls due to the excessive competition among capitals, the diffusion of innovation across the economy reduces "Schumpeterian-profits" of the leading innovators, interrupting the stable accumulation race.
These developments lead to a more or less huge economic crisis, boosting the declining phase of the systematic accumulation cycle. The turning point shifts the accumulation dynamics from material to financial one depicted by the formula C-M', renewing capital expansion and profits throughout monetary transactions and financial deals. These phases require free and liquid monetary capital able to grasp profitable financial opportunities.
Figure 4 sketches these dynamics by considering the different roles of financial profits in relation to material activities and total profits.

Figure 4: The phase of financial accumulation



Source: Author's elaboration

Industrial profits, coming from production, trade, and innovation, are now directed to increase financial accumulation, which become the leading profitable activity. Financial innovations on the one side, and aggressive foreign policies on the other, searches for new markets by increasing competition among States. These patterns mirror what Hilferding (1910) identified as the oligopolistic block of power between financial capital and political power. In the new accumulation dynamics, top technological firms participate in financial deals by increasing stock market turnover and increasing dividends and buybacks due to their market and knowledge monopolistic position (Pagano and Rossi, 2008; Rikap, 2021). Financial profits, in turn, are invested throughout monetary markets, expanding the value of financial capital and rents throughout bubble mechanisms. The accumulation process, therefore, can be depicted by the Marxian formula, M-M', in which monetary capital increases its value primarily throughout financial accumulation.

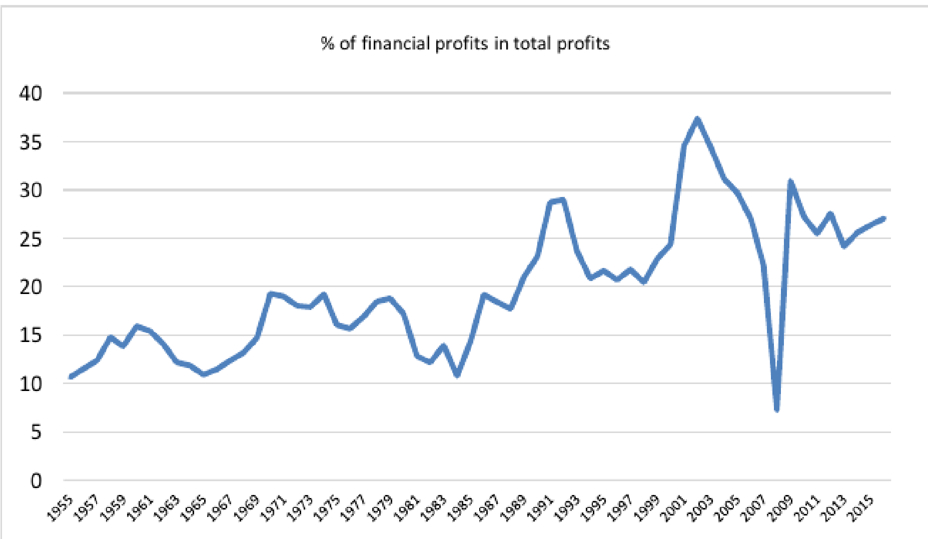
However, this phase of economic growth is highly unstable, leading to the increasing development of Ponzi schemes and risky operations. Moreover, as Franzini and Pianta (2015) suggested, this accumulation process increases inequality, favoring financial wealth holders at the cost of workers; these dynamics further social and political imbalances by increasing financial rent and capital assets value at the cost of productive processes.

Both in Arrighi's systematic accumulation cycles (1994) and in Perez's (2002) long period analysis of financial capital and innovation process, the phases of financial accumulation accrue the availability of free capital, shape a new phase of economic growth by financing technological and material investments in a new hegemonic center of accumulation, able to guarantee high profits and a renewed stable accumulation path.

5. Some stylized facts about financialization

Krippner (2005) reported the massive growth of the weight of financial industry on the total GDP of the US economy. Also, Greenwood and Scharfstein (2013) found a substantial rise of the financial sector across the US economy by measuring the financial industry's growth over the total production, the number of employees, and the sectoral average wage. Too, Philippon and Reshel (2013) pointed out a similar increase of financial industry for several OECD countries, although with different intensities.

Figure 5: the rise of financial profits



Source: Louçã (2019:30)

According to Louçã (2019), financial profits have increased since 1985 in the US, reaching 35% in 2003, as depicted in figure 5. During 1955-1985 the share of financial profits on the total moved between 10% and 20%. After 1985 instead, financial profits massively increased until 2007, reaching a value more than 3 times than in 1955. Not surprisingly, after a massive drop during the Great Financial Crisis of 2007-2010, financial profits recovered very hastily (Epstein, 2015, among others), up to 30% again.

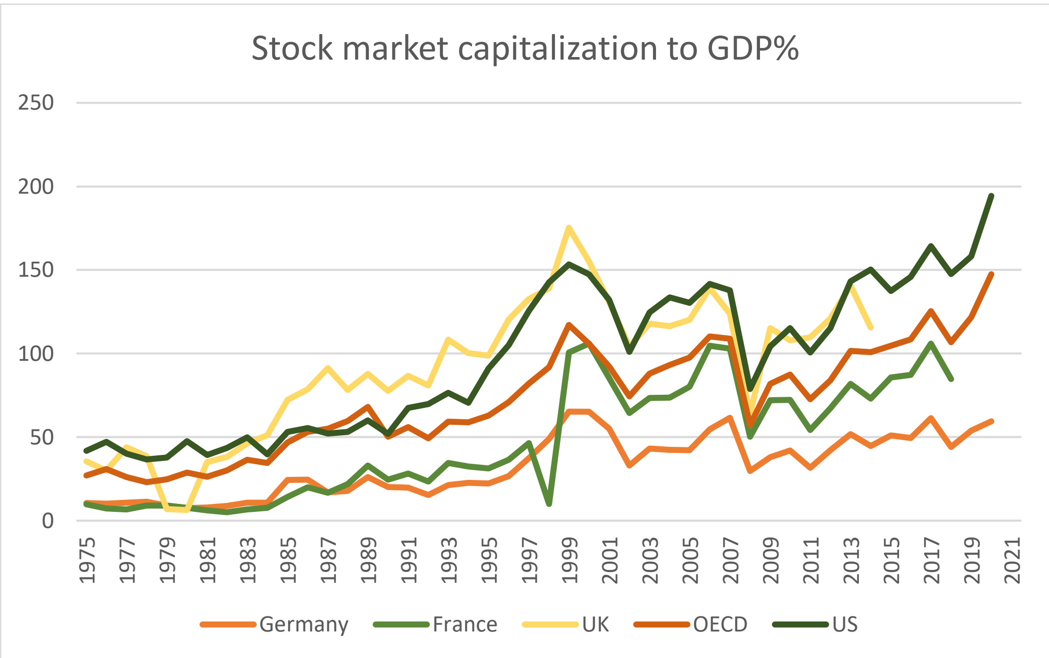
The same dynamics can be seen in other OECD countries. Dünhaupt (2016) calculated a peak of 37% of the financial profit on the total in 2002 for some OECD countries. Lapavitsas (2013:209) pointed out a similar trend in the leading European nations.

The rise of the financial sector is also witnessed by the boom in the value of financial activities compared to the output produced, measured by GDP (Stockhammer 2013). Figure 6 shows the stock market capitalization as a share of GDP for Germany, France, the UK, the USA, and the OECD countries average, from 1975 to 2021.

Stock market capitalization has overgrown in all countries starting in the mid-1980s and even more so by the mid-1990s. In the UK and in the USA, since the early/mid-1990s, stock market capitalization has outstripped GDP significantly. Moreover, in 2007, before the Great Financial Crisis, stock market capitalization overcame GDP in all countries considered except Germany.

These dynamics mirror the increasing value of financial assets compared to economic activities. The rise of financial assets price and bubble mechanisms largely contributes to the increase of capital share at the cost of labour share. Indeed, financial assets are mainly held by the upper-side part of the income distribution, contributing to increased financial rents and capital gains (Franzini and Pianta, 2015).

Figure 6: the boom of the stock market values



Source: Author’s elaboration on World Bank data

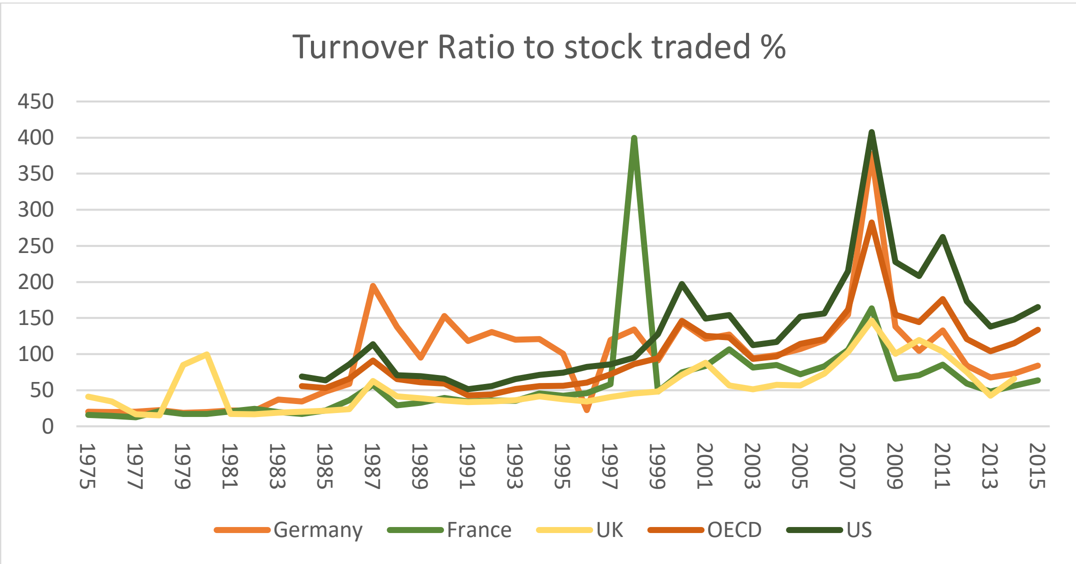
The so strong difference between the market value of companies with respect to their book value may indicate a market overvaluation of the business, a general pattern in financialized capitalism where stock trade and financial evaluations aiming to boost financial deals and far from the productive structure of firms.

Furthermore, many studies using firms' data witnessed the increasing involvement of non-financial corporations in financial operations both on liabilities and on the assets side, which shift the growing weight of the financial management in the corporate governance of firms (Davis, 2017; Orhangazi,2008; Tori and Onaran, 2018 among others).

As Davis (2017) has noted for the US, an increasing Stock Market Turnover can be seen as a symptom of a new role of the stock market in corporate governance, oriented toward a short-term value of the management.

In Figure 7, it is reported the same ratio for other countries, witnessing very similar tendencies. The index is calculated by the value of domestic shares traded divided by market capitalization. A higher stock market turnover among institutional investors can change the goals of the firms' management. The short-run ownership can increase the shareholder orientation of the management, in contrast with the medium and long-run accumulation goals. Indeed, "together with the expansion in institutional investors, increased turnover reflects a marked departure from the pre-1980 period – dominated by long-term household-level stockholding – towards increasingly 'impatient' stock market finance" (Davis, 2017:16).

Figure 7: the turnover ratio of the stock market

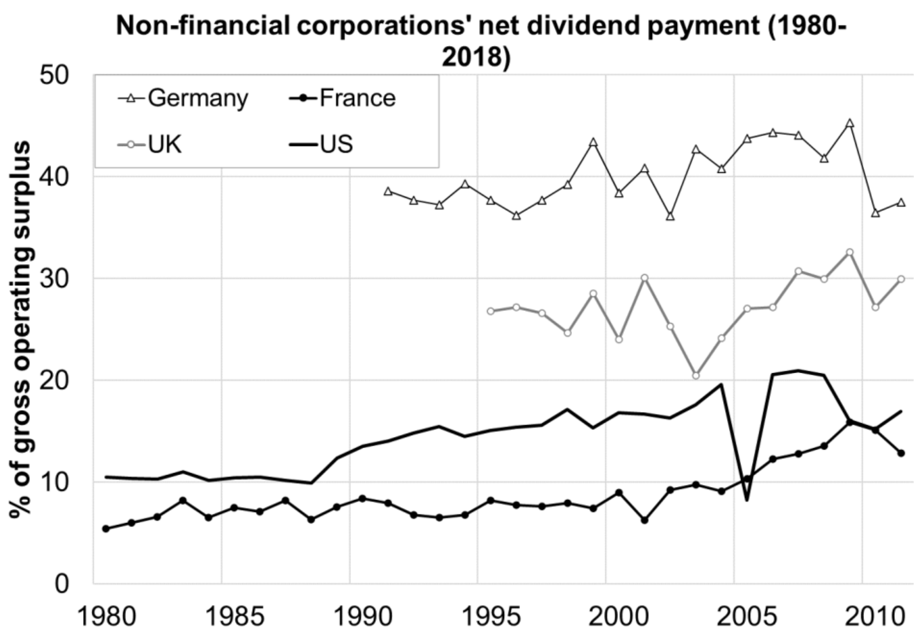


Source: Author's elaboration on World Bank data

The increasing turnover ratio of the domestic share, as seen in figure 7, mirrors the tendency of using the activity of issuing shares commonly to increase the volume of exchanges and not as a source of finance productive investment. The climbing of stock market price witnesses a clear orientation to enlarge financial capital value with respect to its use in material investment (Pianta and Franzini, 2015).

Davis (2017) has shown an increasing trend in gross stock repurchase relative to outstanding equity from 1983, the year of the law reforms in the US that open the chances to the stock-repurchase for non-financial corporations. The same path is described by Duménil and Lévy (2011). The authors studied the difference between share buyback and the new issuances of stock shares as a percent of the net stock of fixed capital of non-financial corporations in the US. The issuing activity is aimed at sustaining higher share prices by the repurchase of their own shares. From 1985 a positive cyclical path witnessed this common strategy of the non-financial corporations in the US.
Another aspect of financialization is the increasing flow of financial income, which moves from non-financial corporations to financial markets. Duménil and Lévy (2004) found a growing presence of financial income in US non-financial firms. Krippner (2011) evinced a massive rise of interests, dividends, and capital gains among non-financial corporations. Orhangazi's seminal work (2008) pointed out an increase in financial payment to shareholders. Moreover, the vast study made by Lapavitsas (2013) on German, Japan, the UK, and the US, maintain an increasing role of the market and bank funding in the composition of the enterprise's liabilities.
Figure 8 depicts the rise of net dividend payments as a share of the gross operating surplus of non-financial corporations for Germany, France, the UK, and the US. Despite the case of Germany, the ratio between profits and dividends increased in all countries considered. In the US, the ratio doubled between 1980 and 2010, whit a huge drop after 2005. A similar pattern can be seen in the UK, where the line shows an increasing trend, depicting the growing relevance in the current corporate management to enlarging distributed profits.

Figure 8: The dividends race

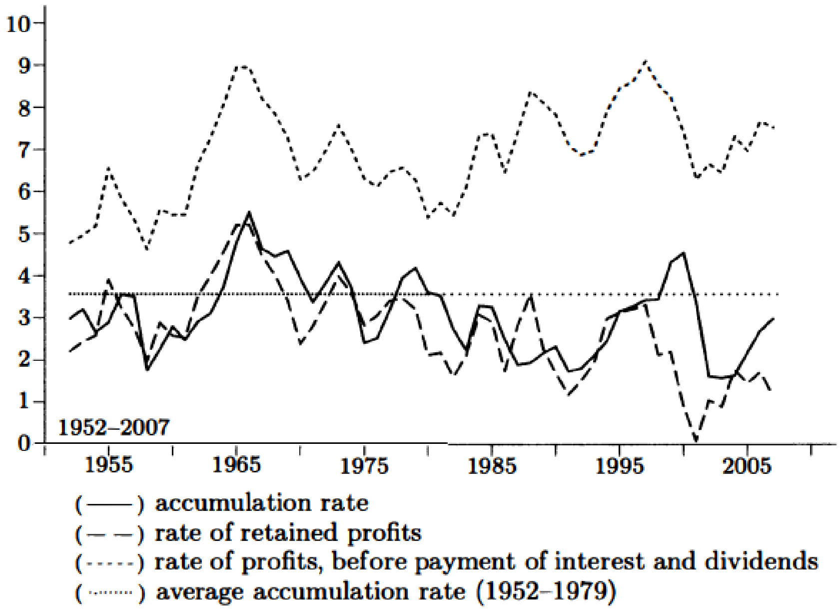


Source: Auvray et al., (2021: appendix material)

The increasing flow of resources which moved towards financial activities is at the root of the declining trend in accumulation that started in the 1980s. Retained profits are crucial to funding new innovative activities and fixed asset expenditures. Corporate management oriented toward short-term returns maximization aims to increase the market value of firms, increasing financial income flow at the cost of material accumulation. This is the clear pattern described in the phases of financial accumulation by Arrighi (1994), in which profits accrue primarily throughout monetary operations and financial deals.

Figure 9 points out the connection between capital accumulation, total profit, and retained profits witnessing the increasing weight of interest and dividends on total profits calculated by Duménil and Lévy (2011) for the US economy.

Figure 9: Rate of accumulation and rate of profit in the US.

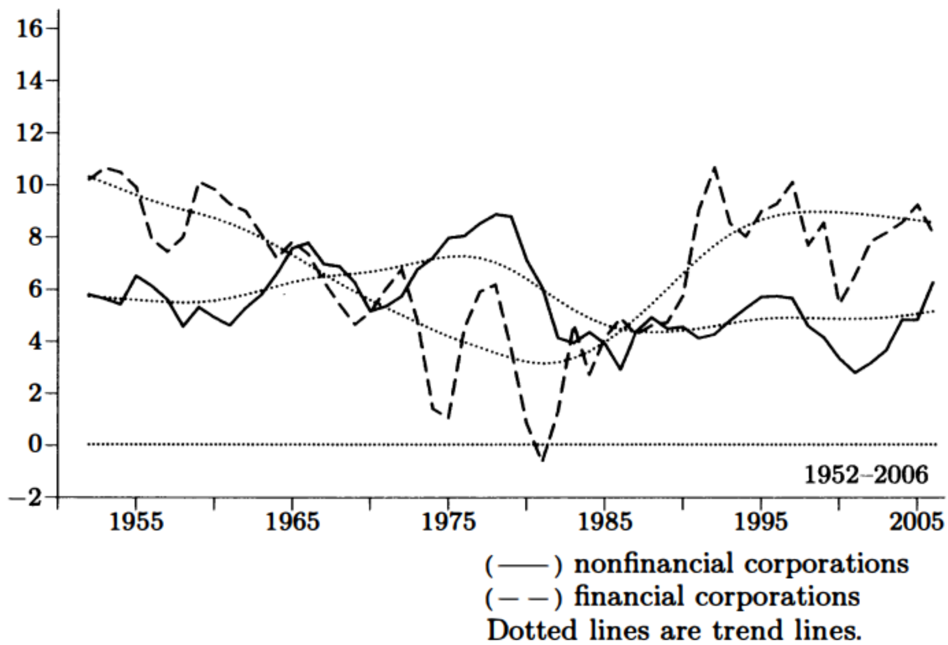


Source: Duménil, Lévy (2011:152)

The rate of accumulation is the growth rate of the net stock of fixed capital computed by the ratio of net investment to the net capital stock. Some interesting issues emerge. First, there has been a declining tendency in the accumulation rate since 1980. From the peak in fixed capital accumulation in 2000, it reached 3% after a sharp decline between 2001 and 2004. The second meaningful aspect of the picture regards the strict tendency of the accumulation rate to follow the rate of profit after payments of interest and dividends. As the authors explained, this suggests that the primary source of investments in fixed capital are retained profits, the profits that are not distributed to shareholders. A third worthy aspect is an increasing spread between the rate of retained profits, again connected with the accumulation of the net stock of capital, and the profit rate before the payment of interest and dividend. This distance declined between 1965 and 1980 when it touched the lowest point of 2 points percent. Then it increased until 2001, the year of the dot-com bubble in the US, which signed a harsh fall in interest and dividend returns. These dynamics mirror the increasing role of the distributed

profits during financialized capitalism and the divergence between increasing returns of financial activities and the material accumulation path. Overall, the authors underline a drop in the accumulation of fixed capital of 32% with respect to the earlier average rate in twenty years, from 1985 to 2005.
The evidence of profits without investment is not limited to Anglo-Saxon capitalism, but is also diffused in the most advanced countries and, hence, can be considered a core tendency of the accumulation process started in the 1980s. Stockhammer (2004) found an empirical validation of the negative effect of what he called "Rentiers income", namely dividends and interest payments in non-financial enterprises, on the accumulation of the fixed stock of capital for many OECD countries, but not for Germany. However, in a more recent investigation, Detzer (2019) also found patterns of financialization in the German industrial network.
At the root of the shift from material to financial accumulation, according to Arrighi (1994), there is the fall in profitability of material activities, which moves investment toward financial markets.
Figure 10 shows the long-run profit rate calculated by Duménil and Levy (2011:67) for financial and non-financial corporations.

Figure 10: the shift in profitability



Source: Duménil and Levy (2011:67)

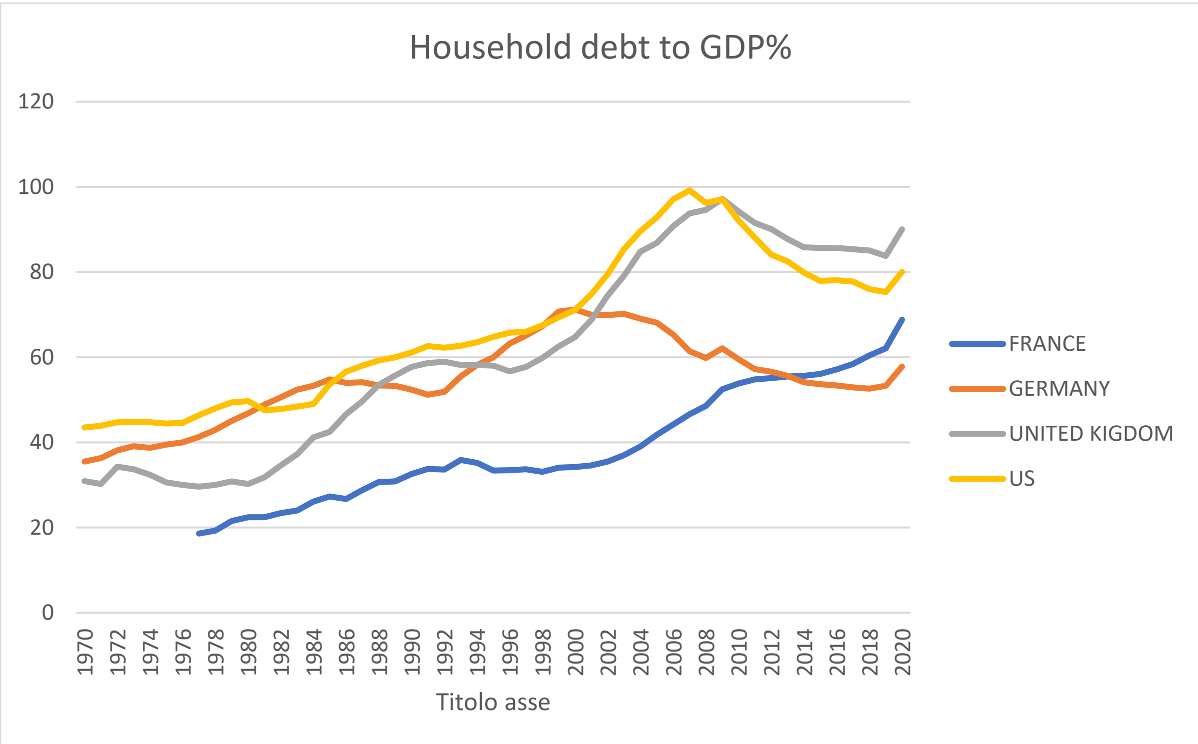
Between 1980-1985 the sharp fall of the non-financial corporation rate of profits augments instability of the system, leading to economic crisis and high inflation. The answer in terms of monetary policy was the huge interest rate rise. These dynamics renew the accumulation boosted by cheap labour and cheap finance, restoring high profits in financial sectors.
After 1985, the hierarchy in favor of the non-financial sector was inverted, boosting the expansion of financial accumulation. During this phase, the profit rate of non-financial corporations fluctuated around 4% in an almost horizontal trend, while the profit rate of financial corporations increased. The

increasing relevance of interest paid, the new profit flows linked to financial innovation, and capital gains in the stock market increase the power of financial corporations.

Why does the shift arise?

From one side, an explanation recalls the Marxian insight regarding the rate of profits. In particular, Shaikh contends that at the roots of the neoliberal shift between the 1970s and 1980s, there was a crisis of profitability of capital. The answer was a strong reduction of the real wages through the "Volcker shock", the harsh increase of interest rate that broke the link between the productivity and real wages growth and reduced the bargaining power of the workers. At the same time, the recovery of profit rate follows the monetary policy of low-interest rates that enlarge the financial profitability. On the same line, Brenner (2012) considers the crisis of profitability caused by the strong competition in the manufacturing sector among the late-developed country, particularly Germany and Japan, and the US producers that decrease the profitability of investment and the overall profits. Also, among Marxist tradition, Duménil & Lévy (2004, 2011) found a decline in profit rate due to the capital-bias technological change direction of capitalism. In this line of research, the response to the crisis of profitability was the shift to the financial activities for firms and non-financial corporate sectors and the increasing role of debt to sustain household consumption. In other words, the low profitability of productive activities, caused by high competition (Brenner, 2012), recurrent and cyclical factors (Shaikh, 2016), decrease in productivity of capital (Duménil & Lévy, 2004, 2011), shaped a new form of accumulation in which financial profits and low capital accumulation drive the growth of the economy, with lower wages, low productive investment, and great capital income share.

Figure 11: the debt-led consumption



Source: Author's elaboration on BIS data

A further ingredient of the financial accumulation path that occurred since the 80s has been the increasing concession of credit and loans to maintain high consumption levels in the advanced core countries. As depicted in figure 11, the upwards consistent trend of the household debt to GDP in the advanced countries mirrors the increasing involvement of consumers in financial activities by mortgage market and consumption patterns, which become a relevant part of the financial profits made by banks through interest and derivatives insurance instruments. Households debt shows a constant increase over time in many advanced countries (Lapavitsas, 2013; Stockhammer, 2019).

There is a broad consensus on the role of the house price and mortgage market in the Sub-Prime crisis of 2007. The same dynamics are found in the Eurozone. Stockhammer (2019) explained the strong connection between the export-driven macroeconomic regime and the debt-led growth. Here, the main point regards the complementarity between the imbalances among northern countries, mainly oriented to export of capital funds and goods, and Southern-East country, where household indebtedness is driven by consumption needed and persistently low wages. The same argument is supported by a structural change point of view, where trade imbalances create divergent income dynamics in the eurozone (Celi et al., 2017).

These dynamics are at the roots of the increasing shift of income distribution among capital and labour witnessed in many advanced countries. Capital gains and financial profits benefit the upper side of the distribution. Moreover, the growing value of financial assets and scarce growth of real wages increase capital share at the cost of labor income.

As pointed out by Pianta and Franzini (2015), there has been a reduction of about 10% points of the labor share of GDP in the most advanced countries since the 1980s, a trend still decreasing. The decline in the wage share is even more prominent if the top-income workers are excluded from the overall wage share.

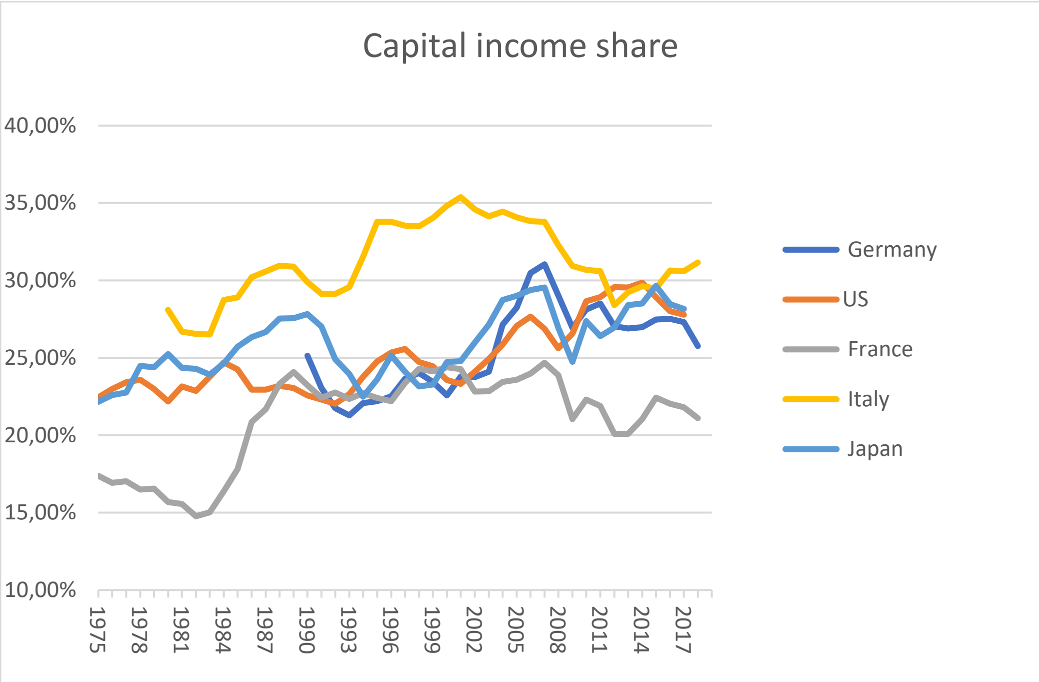
The analysis of the distribution of the wages indeed witnessed the polarization of income among workers, with an increase in remuneration for the 1% of the richest workers- managers and high skilled- and a generalized decline for the rest of the distribution. Indeed, the formers earn part of their income in shares, stock option, and other financial assets, which have increased in quantity and value since the 1980s. Conversely, as illustrated in figure 12, financial accumulation favors financial rents and capital gains at the cost of labour income.

Since 1970, we can find three main movements of the capital income share. First, a declining tendency of capital share from 1970 to the end of the 1970s; second, a recovery occurred during the 80s; third, a more generalized upward trend from 1990. The drop in the capital income share of the 1970s is due to what Duménil and Lévy (2011) called the "coup", the persistently high inflation that started in 1970 and culminated with the Volcker shock of 1979, the harsh increase of nominal interest rate operated by the Fed to stop inflation.

After this period, capital share rise during the 1980s, signing a season of increasing profit share on GDP for all the advanced countries. Moreover, as we can see from the graph, after the GFC, the capital income share of GDP varies from 25% to 30%, with the only exception of France, which is just below the minimum range.

The rise of capital over labor is a key process in the increasing inequality dynamics that occurred in the last decades. Financial accumulation drained resources from productive investment and enlarged the profits share through bubble inflation and speculative operations. Moreover, financial wealth, held by the top of the income distribution, contributes to the rise of financial rent and political influence (Franzini and Pianta, 2015). On the other side, labor market institutions and the unemployment rate are crucial determinants of the labor share. Both phenomena indeed are self-reinforcing both parts of a large process started with the shape of the neoliberal cycle of accumulation.

Figure 12. Capital income share in selected economies.



Source: Author's elaboration on WID Database.

6. conclusion

This paper discusses the recent wave of studies regarding the growing power of finance over the material economic activities shaped since the 1980s. These dynamics have led many authors to speak about a process of financialization of the economy: “a pattern of accumulation in which profits accrue primarily through financial channels rather than through trade and commodity production” (Krippner, 2005). In financialized capitalism, new economic actors are more and more involved in financial deals.

Two mechanisms shaped the current financial accumulation. First, in terms of economic flows, there is an expansion in the quantity and quality of financial transactions, that involve not only banks and financial institutions, but increasingly also non-financial corporations and households. As pointed out by Sassen (1991), few leading global centers largely concentrate massively financial flows. Second, concerning stocks, the huge rise of financial assets values has changed the nature of capital accumulation, the composition of individual wealth, and the capital/output ratios (Piketty, 2014).

Non-financial corporations are engaged in financial transactions by the shareholder value orientation of corporate management, which increases financial transactions and distributed profits at the cost of material production.

Household debt-led entails a growing relevance of financial markets for consumption patterns such as housing, health expenditure, and student loans.

These dynamics led to considerable effects on the economy in terms of declining investments in material and technological activities, the growing inequality among capital and labor, and relevant political and social outcomes.

The paper provides a picture of the development of financialization studies, discussing also the most diffused definitions of the issue.

Moreover, it emphasizes the literature concerning the role of profits as a driver of long-run development. Capital accumulation is achieved by reinvesting profits that expand the capital stock (Louçã, 2021, Kotz and Basu, 2019). Indeed, profitability - the net returns on investment - is crucial in shaping the capital accumulation dynamics and affects investment decisions.

In a dynamic perspective, the search for profits shapes technological competition of firms and industries to develop innovative breakthroughs aiming to gain “extra-profits”. This turbulent and uneven process of technological competition determines long-run economic growth (Pianta, 2020).

Furthermore, the paper discusses the literature on the long-run development of capitalism, and the role played by finance in such dynamics.

The seminal work of Arrighi (1994) on systemic cycles of accumulation in which phases of financial accumulation follow phases of material expansion is reviewed. In each long cycle, the first phase of economic growth is driven by productive activities and trade in which profitability is high and financial capital supports investments and material expansion. Due to fierce competition among capitals, these activities tend to become less profitable. In turn, capital moves from productive to financial activities, which in turn boosts speculation and financial deals.

Financial capital is also crucial in the process of technological change by supporting innovative breakthroughs, as pointed out by Schumpeter and neo-Schumpeterian approaches (Perez, 2002).

In the first periods, financial capital primarily encourages the creation and the diffusion of innovations, shaping the process of technological upgrade across the economy. Profitability of new technologies is high, and investments in these sectors provide high returns to financial capital. However, after the spread of innovative technologies across the economy, profitability in these technological branches drops, and financial capital moves toward speculative deals driven by financial innovations.

So that, in the cyclical analysis of economic long-run economic growth, phases of financial accumulation recur in the capitalism history, when profitability in leading productive activities and leading technological industries halt. In turn, capital moves toward financial deals and speculative transactions, which increase profits and financial assets value at the cost of the material and technological accumulation.

This work outlines these two perspectives on long-run cyclical economic growth in an integrated conceptual framework.

Moreover, I provide some empirical insights on the recent economic dynamics of financialized capitalism. The boom of stock value capitalization, the massive stock turnover ratio, the increasing weight of distributed profits, the growing profitability of the financial sector, and the huge rise of household debt to GDP, characterize economic development since the 1980s. These patterns increase capital income at the cost of labour and technological accumulation.

In the next chapter, we are going to analyze in a systematic way the relationship between material accumulation- measured as fixed assets capital investment-, technological development-dividing for different types of innovation performed- and profits growth at the industrial level.

Furthermore, the conclusive work will study the effect of the concentration of leading profitable sectors, such as Finance and Insurance, and ICT services, on the recent development of the Italian Metropolitan areas. According to the recent literature on regional and local development (Harvey, 1982; Sassen, 1991), financial capital and high-tech activities tend to gather in a few places, attracting investment, income, and technology. These dynamics, however, contribute to the increasing territorial imbalances in advanced countries, further an uneven geographical development as witnessed by the Italian Metropolitan Areas recent economic path.

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Chapter 2:

Profits, investments, and Innovation: exploring the virtuous cycle

Abstract

The article explores the link between profits, product innovation and capital investments by looking at their systematic and looping relationships across industries in six major European countries. Profit growth in our model is determined by two growth strategies: technological and cost competitiveness. Moreover, lagged profits are the major driver of further innovative expenditures in innovation and in capital accumulation.

We show that, profits are driven by the introduction of product innovations, the growth of capital investments, productivity gains and wages reduction. However, investments are negatively linked with the introduction of product innovation, suggesting a trade-off between capital accumulation and innovative activities.

Additionally, we divide the sample according to the technological regime of industries, by testing the model in high-tech and low-tech sectors. In technology-oriented industries, the introduction of product innovation fosters investments, witnessing a complementary between capital accumulation and technological change. Conversely, in low-tech industries, investment growth and product innovation are negatively related, suggesting the idea that expenditures in fixed assets are a substitute of internal innovative efforts. In these sectors, capital accumulation seems to be more related to the acquisition of advanced productive tools from other industries aiming to introduce process innovation. These results point out the different roles of capital accumulation in the process of technological change across industries.

1. Introduction

Technological change and capital accumulation are the drivers of economic development. They allow leading innovative firms and industries to gain "monopolistic profits", providing financing resources to further boost a new cycle of accumulation. Starting from the seminal contribution of Evangelista (1999), the link between innovation activities and capital investments has received renewed attention feeding many recent contributions (Barbieri et al., 2019; Medda and Carboni, 2018¸ Spescha and Woerter, 2021). These works emphasise a causal positive relationship between innovative efforts realized by firms and subsequent investment in fixed assets using micro-data. However, very few contributions explore the link between innovation activities and capital accumulation at the industrial level. Dosi et al. (2021) provide empirical evidence on the different impacts of innovation and expansionary investments on employment but do not connect technological change and capital expenditures with industrial economic performances.

The paper would fill this gap in the literature, by analysing in a systematic and integrated way the link between profit growth, type of innovation introduced and capital accumulation across industries of the six major European countries. Following the evolutionary approach to the study of innovation, we adopt the distinction proposed by Pianta (2005) between technological and cost competitiveness to analyze the role of capital accumulation by looking at the heterogeneous technological industrial dynamics. Indeed, capital investments in our framework have a twofold function. On the one hand, they are a major source of embodied technological change in traditional sectors, spreading productive tools and technologically advanced machines and equipment across the economy (Kaldor, 1957). In low-tech industries, capital investments may "crowd out" internal innovative activities, fostering process innovation and labour-saving strategies aiming to sustain cost competitiveness. Conversely, in advanced industries, they allow for expanding the production of innovative commodities and services, sustaining technological competitiveness and innovation. Therefore, using the Revised Pavitt's taxonomy (Bogliacino and Pianta, 2010, 2016), we explore these relations by considering heterogeneous industrial patterns (Freeman and Louçã, 2001; Nelson and Winter, 1973).

According to the Neo-Schumpeterian and Marxian views of economic growth, profits are the primary source of a new cycle of expansion, financing further expenditure in innovative activities and fixed investment (Duménil and Levy, 2020; Schumpeter,1975). Following these insights, in our model, product innovation and capital accumulation drive profits, but previous profits are primary drivers of new investment and new innovative expenditures. We sketch the conflictual nature of distribution between capital and labour by considering wage reduction and the growth of flexible work as a further determinants of profit increases. Technological development, in this framework, is proxied by the introduction of product innovation, which is the result of the previous level of workers with a high educational degree, lagged profits, and R&D expenditures, reflecting the cumulative nature of innovation. Investment growth is the result of the type of innovation introduced, of the rate of growth of labour compensation at the industrial level, and of the rate of growth of lagged profits. In this way, we look at the correlation between innovative patterns and capital accumulation.

We test the model equation by equation and using the system of simultaneous equations. In this way, we explore the causal relationship among the variables, but also the cyclical way in which they work. Indeed, adopting the perspective of the "virtuous cycle" allowing to grasp the reinforcement mechanisms and the looping effects across variables, considering also as endogenously determined the lag effects of profits on product innovation and investments growth. This approach is fruitful to depict in a systematic way the relationship considered as witnessed in many works (Bogliacino and Pianta 2013a, 2013b; Bogliacino et al. 2016; Guarascio et al. 2015, 2016; Guarascio and Pianta, 2017; Pianta and Reljic, 2021).

This work provides a few interesting novelties. First, it is the first attempt to study in a systematic way the link between profit growth, product innovation and investment using an integrated approach and a modern econometric technique. Second, very few analyses connect product innovation and investment dynamics at the industrial level. Building on the analytical distinction proposed by Pianta (2000) we test the relationship between the introduction of product and process innovation and capital accumulation, considering contrasting competitiveness strategies and their impact on profits.

Third, if we do not account for the industrial technological heterogeneity, results evince that the introduction of product innovation harms investment growth. So that, innovation activities and technological competition seem to be negatively linked with capital accumulation. Conversely, process innovation and wages dynamics foster investment growth, witnessing a closer relationship between cost competitiveness and capital accumulation.

Fourth, we show that technological industrial patterns matter in regards to capital accumulation dynamics. In high-tech industries, product innovation and investment seem to be positively related, suggesting that investment provides further support to technological development. In low-tech instead, the introduction of product innovation exerts a negative effect on investment growth, witnessing a trade-off between internal innovative efforts and disembodied technological change. The answer lies in the fact that the acquisition of intermediate inputs and productive tools is the main source of technological upgrades in traditional industries. These results expand and reinforce the finding of Pavitt (1984) and Evangelista (1999) on the link between embodied and disembodied technological change and industrial dynamics.

The rest of the paper proceeds as follows. Section 2 describes the conceptual framework on which our approach builds, highlighting the major conceptual insights and providing a review of the literature. Section 3 describes the data and sketches some descriptive evidence on a few determinants considered in the model. Section 4 describes analytically the model and explains the relationship among the variables. Section 5 pointed out the econometric exercise realized, with the explanation of the specification strategy adopted. Section 6 concludes the work, highlighting the main results and summing up some relevant insights.

2. The conceptual framework

The dynamic of capitalism is based on the accumulation of profits through the use of labour in production and their reinvestment into expanded capital stock. Investment decisions are driven by profitability - the net returns over the capital invested - which is the ultimate criteria for determining the success or the failure of an investment decision: "the profit motive always remains the central regulator of the system because both supply and demand are ultimately rooted in profitability" (Shaikh, 2016, p. 50).

The diversity of profit rates in the different sectors of the economy is a key driver of the evolution of the economy, as capital leaves activities with high competition and lower profits and goes into new activities promising higher returns. This dynamic is affected by uncertainty, risk and bounded rationality, as well as by the institutional setting of national economies and the policies affecting income distribution, profits and capital assets. In this way, the search for higher profits drives structural change across the economy, determining the success and decline of industries. Post-Keynesian structural change approaches pointed out that "free-market competition inevitably drives capital funds out of low-profit sectors and into high-profit sectors" (Pasinetti, 1981, p. 175), generating turbulence and disequilibrium process. This is associated to short-term business cycles and to the longer-term "long waves" of accumulation (Freeman and Louçã, 2001; Pianta, 2020) that characterise the evolution of capitalism.

In the XX century, the dynamics of capitalism had been characterised by the contribution of science and technology in shaping new areas of economic activity. Schumpeter (building on Marx's insights) has pointed out that firms compete not just by lowering prices, but through the introduction of new products based on superior technologies; in this case, they obtain extra profits due to the temporary monopoly they have in an emerging new market niche, stimulating the entry of imitators that aim at capturing part of such gains. Technological change is, therefore, at the root of dynamic competition, and innovation is a driver of 'Schumpeterian profits' (Schumpeter, 1995). Firms that introduce innovations achieve better performances than the others, increasing productivity and profits, which, in turn, allows financing for further technological efforts to maintain their leading returns. In this way, technologically advanced industries realize higher returns, meanwhile, others decline. Neo-Schumpeterian perspectives have explored how technological change and innovation guide the economic dynamics at the firm and industry levels by looking at the technological regimes they belong to (Dosi, 1982; Freeman and Louçã, 2001; Malerba, 2002). In this view, technological features and market conditions affect the technological trajectories of firms. The work adopts an industry-level perspective that summarises technological and economic trajectories of economic sectors, softening specificities related to firm-level analysis. We group industries according to the Revised Pavitt's Taxonomy (Bogliacino and Pianta, 2010, 2016), which is a powerful tool to catch the different competitiveness strategies adopted by low-tech and high-tech industries, resulting in different employment, technological and economic performances. Two possible growth strategies are considered, with contrasting outcomes in terms of distributional gains among wages and profits, further technological development, demand dynamics, and employment patterns (Pianta, 2020); the first one is based on the *cost competitiveness* strategy driven by process-oriented technological progress, mainly aimed to reduce labour cost and optimize the production process. Investments in this setting have the fundamental role of spurring embodied knowledge in the economy, particularly among sectors that buy technology and advanced machinery from other industries (Evangelista, 1999). The second relies on a *technological competitiveness* strategy, in which industries and firms finance innovative efforts to introduce new products, expand the market, and catch growing demand (Pianta, 2001, 2020). Investments across these industries can be complementary to innovative efforts and sustain the expansion of productive capacity in firms and industries by catching growing demand for innovative commodities.

2.1 The analysis of profits

Profits are the principal indicator of the economic success of a firm or an industry and can be used as a crude proxy to measure the overall performance of the economic actors (Bogliacino and Pianta, 2013b, Guarascio and Pianta, 2017). We consider few analytical distinct, but in practice often complementary, substantial factors that increase profits: the introduction of innovations, market power, the demand-pull mechanism, the accumulation of capital, and labour-saving strategies aiming to reduce production costs.

A fundamental driver of profits across firms and industries is technological change (see, for example Bogliacino and Pianta, 2013a, 2013b; Bogliacino et al. 2018; Cefis and Ciccarelli, 2005; Coveri and Pianta, 2022; Guarascio and Pianta, 2017; Klepper, 1997; Pianta and Tancioni, 2008; Teece, 1986). Following the Schumpeterian perspective, profits growth is crucially the result of the "*creative destruction*" (Schumpeter, 1995) process undertaken by firms and industries to gain market power and increase sales. The introduction of innovations allows for generating greater profits at the cost of the competitors. This led technological advanced firms and industries to obtain market power and gain "monopolistic profits". This is the case, for example, of the monopolistic power and massive profits earned by ICT high-tech corporations nowadays as well explained by Rikap (2021). Monopolistic profits, driven by market power and successful technological sales, are also key drivers of accumulation, financing further expenditure in innovative efforts and technology-embodied capital. Hence, in Schumpeterian analysis, the introduction of innovations allows profits to increase, and these are a crucial source to boost further innovative activities undertaken by large oligopolistic firms, specialized in technology-oriented development (Schumpeter, 1975).

Bogliacino and Pianta (2013a), following such an approach, test an empirical model in which aggregate sectoral profits are driven by the introduction of innovative products, which are the result of R&D efforts performed by industries. The authors found that profit growth is positively related to the turnover share of innovative sales, which are based on the previous innovative expenditures in R&D performed by industries. In turn, past profits increase the quote of innovative expenditure realized across industries, boosting a further cycle of technological accumulation. Therefore, these results led the authors to conclude that "R&D efforts are cumulative; profits are the outcome of previous innovative efforts, and they provide the necessary financial resources for subsequent R&D activities (Bogliacino and Pianta, 2013a, p. 5)."

Bogliacino et al. (2016) adopted a similar framework to analyse the economic performance of a panel of Italian manufacturing firms. The work analyses the link between innovative sales, innovation inputs and innovative output depicting a "virtuous cycle" of technological growth. Firms realize expenditures in innovative inputs by looking at the total sales, which is a key source of funds for innovation, lessening financial constraints. Innovative inputs lead to an increase in the turnover share of new products. Demand-pull effect, proxied by export, boosts the sales of innovative products. This,

in turn, increases total sales, enlarging profits and improving overall performance. In this way, a looping and reinforcement mechanism has been found, witnessing the link between economic performances, firm's efforts in innovative activities and innovative outputs.
Furthermore, Bogliacino and Pianta (2013b) explicitly consider the different innovation patterns that allow for profits to rise. In their setting, profits are positively linked with industries that introduce a higher share of innovative products and realize a greater amount of expenditures for acquiring new machines. Both types of innovative outcomes affect profits significantly along with the growth of the total value-added.
A further driver of profits relates to capital investments in fixed assets, which have been a key component of firms' ability to expand sales and outcompete rivals, enlarging firms' productivity and allowing them to exploit scales economies (Evangelista, 1999). Investments in fixed assets are strongly connected with profit growth, but not in a straightforward way, depicting heterogeneous patterns across industries. Here we stress at least three of them. First, acquiring advanced technological intermediate inputs may increase labour productivity in lagged sectors, upgrading productive techniques and leading to increasing output produced. Capital investments spread advanced technological machines and other means of production across industries, fostering embodied technological change (Kaldor, 1957) and modernizing the production process.
Second, investments in technological assets and machines spur the capital-deepening nature of the process of technological change, fostering the automatization of production and labour-saving processes. These patterns are at the root of the well-known "technological unemployment" process related to the capital-intensity nature of production, which has been a crucial feature of technological development. In this way, capital accumulation increases profits by reducing the amount of labour required in the production process.
Third, capital investments may result from the commercialization of new products and increasing market opportunities, enlarging the productive capacity of firms and industries with growing sales (Coad and Rao, 2019). This is the complementarity between technological change and capital investments found by Spescha and Woerter (2021) in a panel of Swiss companies. These authors witnessed a positive and statistically significant link between the introduction of innovative commodities or services and the successive investments in fixed capital aiming to expand the productive capacity of innovators.
A further way to increase profit is to shrink wages, which are the major variable cost of production. This pattern witnesses the contraposition between capital and labour as inputs of production (Shaikh, 2016), mirroring the conflicting nature of the distribution across wages and profits at the roots of the growing functional inequality that has occurred since the last quarter of the century. Indeed, according to Franzini and Pianta (2016), the massive rise of capital gains along with the considerable reduction of the worker's share remuneration is a key driver of the increasing personal inequality of the 21st century.
Coveri and Pianta (2022) develop and test empirically a model in which profit growth is driven by the capital-labour conflict, the expansion of value-added per hour worked, different technological strategies and offshoring of production. According to these authors, profits growth is substantially fostered by increasing labour productivity. This can be sustained by different technological trajectories. On the one side, introducing product innovations, boosting sales and gaining market power, increases profits, without exerting downward pressure on wages. On the other side, introducing process innovation aiming to restructure the production process and cut labour costs is a

different way to sustain profit growth. Moreover, offshoring and strategies of internationalization of production support profit gains but exert negative pressure on wages. So that, in this model, inequality across profits and wages is explained by the different growth strategies undertaken by industries. Profits increase by introducing new products may positively affect wages, stimulating technological effort and R&D, which requires upgrading workers' skills. Conversely, process innovations, the automatization of production and labour-saving strategies, along with a lower unionization rate across workers, enlarge profit by reducing wages. Moreover, the internalization of production and offshoring, particularly for low-tech inputs, seem to << intensifies worldwide competition amongst workers and is associated to various forms of social dumping (Coveri and Pianta, 2022, p. 238).>>
The determinants of profits are in the quantity and quality of the capital stock, in the technological characteristics, in market power as well as in the balance of power between capital and labour and in the conflict over functional income distribution between profits and wages (Coveri and Pianta 2022; Duménil and Lévy, 1993; Kotz and Basu, 2019; Louçã, 2021). Coveri and Pianta (2022) pointed out the technological roots of the capital-labour conflict, highlighting the impact of different technological strategies in terms of distributive patterns between profits and wages. Bogliacino and Pianta(2013a, 2013b) highlight the technological-driven nature of profit accumulation by connecting innovative efforts and profit growth. Shaikh (2016), building on the classical framework, argued that the primary source of profit relies on the surplus produced throughout labour exploitation. Duménil and Lévy (1993), Kotz and Basu (2019) and Louçã (2021) maintained that the dynamic of profit rate is the crucial variable to study the long period cycle of economic growth. For the simplicity of the analysis, we focus on real economic activities and leave aside financial profits and speculative gains through financial rents. Yet, the vast growth of financial profits in the form of interests, dividends and shareholders returns shift investments from material and productive capital to financial ones, increasing the weight of speculative economic activities at the cost of the production and technological-oriented development. In this way, financial investments enlarge the gains of capital holders at the expense of work.

2.2 The analysis of investment

Capital accumulation is a central matter in the dynamics of capitalism (Robinson; 1962). New and old models of long-run economic growth depict capital accumulation as the main source of development (Kaldor,1957; Solow, 1957). We consider here the link between capital investments, technological change, and profits.
First, investments are crucial to increasing profits. The use of more technological advanced machines and assets increases productivity and expands output. A greater quantity of capital leads to a substitution effect on labour, reducing production costs and halting wages expenditures. Large investments in plants and equipment allow exploiting scale economies by expanding output along with diminishing production costs (Evangelista, 1999). Furthermore, high capital immobilization may lift barriers to entry into the market due to the high sunk costs required to enhance certain productions, guaranteeing market power to a few large companies and oligopolistic industrial structures.
Second, profits are the fundamental source to finance investment in profitable opportunities, boosting further a cycle of economic growth. Duménil and Levy (1993;2020) maintained the strong association between retained profits and capital accumulation as a central factor in explaining long-run economic

dynamics. Moreover, in the Schumpeterian mark II innovation model (Schumpeter, 1975), previous profits of big industrial companies finance innovative investments and R&D expenditures to sustain new accumulation trajectories.

Third, despite the growing relevance of intangible assets and knowledge in the production process nowadays (Orhangazi, 2019; Rikap, 2021), investments in fixed capital are still a core source of innovation and technology widespread across the economy (Evangelista, 1999). Building on the conceptual distinction between embodied and disembodied knowledge, it is helpful to shed light on the puzzling link between investments in fixed capital and technological change. Embodied knowledge denotes technical, productive assets and devices, which are yet involved in the sphere of production. In this view, embodied technological change relies on the accumulation of new technologically advanced machines and equipment, intangible assets, and innovative intermediate inputs to upgrade the production process (Evangelista, 1999, p.6). Conversely, disembodied knowledge refers to the stock of codified or tacit knowledge available before it has been incorporated into the production process. From the disembodied perspective, technological change is related to the efforts to develop new technological knowledge throughout activities such as R&D expenditures, education, patents, applied research and learning by doing.

2.3 Investment and innovation

Classical economists stressed the embodied nature of technological change, broadly recognizing the role of capital investments as a source of technology diffusion across the economy (Evangelista, 1999). They connect capital accumulation to technological development, highlighting two main features. First, technologically advanced productions require higher capital-intensity. So, investments in machines and capital assets spread innovations across the economy. Second, technological development is a capital-deepening process with labour-substituting dynamics. This is particularly clear across industries where automatization and mechanization aim to reduce production costs by diminishing salaries.

Schumpeter (1995) underlines the disembodied nature of the process of technological change. In this perspective, efforts undertaken by firms to generate new technical knowledge are the primary source of technological development. Indeed, R&D expenditures aiming to introduce new processes or products, innovative organizational arrangements, and open new market segments are the roots of economic growth. So, in the disembodied perspective, knowledge accumulation by R&D, human capital, and innovative activities of firms and industries are the crucial sources of economic growth.

More recently, following Post-Keynesian framework, Kaldor (1957) elaborated a model in which explicitly capital investments spread technological change across the economy, but also considered the relevance played by disembodied knowledge to foster technological advancements. The combination of capital investments and new knowledge are the sources of economic growth, driven by demand-pull and the technological-push mechanisms.

On the one side, capital-intensity foster the diffusion of more technological production techniques across the industries. Hence, mechanization and capital-deepening are crucial features of technological change and innovation activities. On the other side, the development of higher innovative tools of production- machines, equipment, innovative capital- is driven by the dynamism to generate and incorporate new technological knowledge (Evangelista, 1999). Therefore, disembodied perspective and the development of new knowledge are not denied but are strictly connected with the embodied view of technological change.

Building on the evolutionary perspective of innovation analysis, Pavitt's taxonomy (1984) considers the role of capital investments in the process of technological change by looking at the innovation patterns of the industries. Low-technological sectors acquire machinery and intermediate inputs from high-tech producers to absorb innovation and upgrade production, performing barely expenditures to generate new knowledge. Therefore, investments are a core source of innovation activities across low-tech industries, which use new technological capital developed by high-tech sectors to boost process innovations and embodied technological change. Conversely, high-tech sectors rely more on within-industry innovative efforts to generate new-disembodied knowledge and introduce product innovations, meanwhile, capital investments play a minor role in innovative activities.

Evangelista (1999) elaborates a new taxonomy considering the connection between innovation activities and capital investments, the relevance of process and product innovations realized in the sector and the market structure. The work presents some novelties concerning Pavitt's taxonomy. Overall, high tech-sectors perform innovation by relying more on the generation of disembodied knowledge, R&D expenditures, and product innovation, which seem to substitute for expenditure in capital investments (Evangelista, p.168). Conversely, low-tech sectors perform more fixed investments and process innovation with lower R&D efforts, suggesting a straight connection between capital accumulation and innovative activities in these industries. In other words, in advanced technological sectors, innovation is based on efforts to generate new products, improve the old ones, and expand markets, with low expenditures in fixed capital. In contrast, in lagged technological industries, capital investments are the dominant form of technological acquisition related to organizational and process innovations, improving production by using advanced machines and new capital assets. However, some technology-oriented industries largely complement product innovations and disembodied knowledge with fixed capital investments (Evangelista, p.181). This is the case of sectors such as aerospace, office machinery, and telecommunication, in which the capital-intensity of the production is very high.

Further studies at the firm level analysed the link between innovation activities and capital investment, underlining some interesting matters. Carboni and Medda (2018), by using a panel of European firms, found a positive link between R&D expenditures and investment in capital in firms with a higher propensity to export to international markets. Spescha and Woerter (2021), instead, by focusing on a Swiss sample of firms, found that R&D expenditure and the introduction of product innovations cause a subsequent rise of capital investments, meanwhile, there isn't empirical evidence of the reverse link from capital investments to innovative activities.

Furthermore, Pianta and Reljic (2021) consider the connection between fixed investment growth and productivity rises in a "virtuous cycle" perspective at the industrial level. In their model, indeed, fixed capital increases generate productivity gains, which in turn are able to increase wages and good-quality jobs, sustaining the introduction of innovative products and supporting technological competitiveness strategies. These further evidences suggest a connection between a growth strategy driven by technological upgrading and capital investments in innovative firms.

Following this approach, in this work, we shed light on the different use of investment across high-tech and low-tech industries disentangling the "undifferenced" view of investment as a source of development across economic sectors. While in high-tech industries, investments may support product innovation, expanding production capacity to enlarge the output of new or improved products and services, in low-tech sectors, accumulation of gross fixed capital formation may be more related to labour-saving process, aiming to the reduction of labour cost, replacement of workers and reorganisation of production. These matters should be integrated with the study of technological change and its outcome in terms of labour dynamics, growth trajectories and distribution patterns in the economy.

2.4 The analysis of innovation

Technological change and innovations have driven the development of capitalism (Freeman and Louçã, 2001). The Schumpeterian theory of the business cycle (Schumpeter, 1975) greatly emphasises the role of innovative breakthroughs as the elements that drive the development stages of capitalism. In Schumpeter's view, the introduction of innovations allows obtaining extra-profits which, in turn, spurs economic growth as well as further investments by the mass of potential imitators; this drives the upswing phase of the economic cycle. Nonetheless, once the previously introduced technological innovation has been diffused across the economy, the most intense competition reduces monopolistic profits, resulting in less investment, employment reduction and demand drop, fuelling the downswing of the economic cycle (Pianta et al., 2021). However, the catch-up process performed by competitors along with the spread of advanced technological inputs of production across industries allows for upgrading the productive techniques of production, boosting overall productivity and economic development. So that, technological change is the dynamic engine of economic growth, which proceed across turbulence and uneven patterns. This dynamic and cyclical process is at the roots of the structural change of the economy in which some industries gain higher returns, attracting capital and investments, meanwhile, others disappear, facing lower demand and old productive techniques.
The introduction of innovations is the result of technological-push and demand-pull factors. Evolutionary perspective emphasizes the role of the technological opportunities undertaken by industries and firms to gain high returns as an incentive to introduce innovations. According to this view, innovative outputs result from the cumulative and path-dependency nature of the investments that led to the production of new technologies. Retained profits, and R&D expenditures realized by firms are key drivers of the technological development of the industries. Previous profits are fundamental to overcoming financial constraints and supporting innovative activities (Bogliacino and Pianta, 2013a; Guarascio and Pianta, 2017). High R&D expenditures are the core inputs to generate new products and new processes, allowing to enlarge sales and improve productivity (Bogliacino and Pianta,2013a,2013b; Reljic and Pianta, 2021). Also, market structure is a central matter affecting technological development. High expenditure in innovative efforts in a sector can be seen as high sunk costs for competitors, generating what Evangelista (1999) defined as dynamic barriers to entry into the market, guaranteeing a leading monopolistic position due to the high knowledge required for the production process.
Guarascio and Pianta (2017) analyse how demand factors, profits growth and product innovations are related, underlying the looping reinforcement mechanism across these variables. In their model, previous profits and expenditure in R&D are the crucial drivers of the development of product innovations. Industries with a higher share of product innovation export more than the others, exploiting the possibility related to foreign markets and the most dynamic component of the demand.

In turn, profits growth is fostered by export, while they are not affected by internal demand. These results mirror the extensive role of the demand-pull mechanism to incentive the introduction of product innovations, boosting sales and profits. Also Coad and Rao (2019), by analysing the causal determinant of the R&D expenditures performed by a sample of leading innovators, found that sales growth is the core variable that affects investment in R&D, supporting the idea that the demand-pull mechanism is essential to spur technological development.

Phases of strong economic growth have been rooted in industrial revolutions whose innovative discoveries have changed the entire mode of production and consumption across the economy. Neo-Schumpeterian perspective has elaborated the analytical concept of techno-economic paradigms (Dosi, 1982; Freeman and Louçã, 2001; Perez, 2002) to describe the clusters of new technologies and dominant branches of production at the roots of cycles of economic development. The application of radical new technologies in some sectors increases productivity, investments, and profits, boosting overall economic growth. If steam power, iron machines, and textiles production fostered development in the first industrial revolution, economic growth in the first part of the 20th century was built on the wide industrialization of heavy chemistry and civil engineering, electrical equipment and automotive sectors based on the massive use of the of steam, oil and petrochemicals

Nowadays techno-economic paradigm is built on the development of information and communications technologies (ICT), enhancing the extensive use of computers and software, "Big data", Cloud Computing and algorithms. These technologies accelerate the digitalisation and automatization of production in both manufacturing and services (Pianta,2020). Human capital and intangible assets are crucial drivers of accumulation, while fixed assets seem to play a minor role.

Reljic et al. (2020), by differencing the use of digital technologies, found significant heterogeneity in economic performances and employment results across sectors. The authors distinguish between the acquisition of intermediate inputs by digital-intensive sectors and the amount of investments realised in tangible and intangible ICT assets. On the one side, the spread of intermediate digital inputs allows upgrading the production process, leading to better economic performances and improving the quality of output realized. Digital inputs are often incorporated in product innovations, increasing sectoral employment (Pianta, 2020). On the other side, growing investments in ICT assets per employee seem to be related to the introduction of process innovation aiming to restructure productive processes and increase capital-intensity of the production, with shrinking effects on employment. In turn, this work sheds light on the different dimensions of digitalization and its relative impact on sectoral employment and economic performance.

2.5 Profits, investment, innovation: an integrated approach

Building on such literature, this paper depicts two patterns of capital accumulation; the first one is driven by the expansion of investment to enlarge activities using existing production systems; the second one is rooted in technological change and in the development of new products and new markets, as well as of new processes of production. Profits are driven by some major factors in our approach. First, the conflicting nature of the production process between capital and labour is mirrored in the contraposition among profits and wages. Second, labour productivity is a crucial driver of profits growth. This can be pursued by two growth trajectories. On the one hand, introducing product innovations results from innovative internal activities aiming to commercialise innovative goods and services to overcome competitors and gain market power and monopolistic profits. Capital investments may support this growth strategy by expanding productive capacity. On the other hand, labour-saving strategies aiming to shrink wages and improve labour productivity can be supported by fixed capital investments and increased workers' share with unstable employment conditions. In this way, the acquisition of advanced capital assets fosters the capital-deepening process contributing to labour-saving strategies and labour exploitation, and less rigid employment conditions allow for flexible and pro-cyclical utilization of workers.

The explanation of profits requires consideration for the conflictual nature of the production and for the role of technological development. As in Coveri and Pianta (2020), productivity gains are the major driver of profit growth. This can be realized by reducing wages, increasing the flexibility of work and investing in fixed capital, aiming to perform labour-saving strategies and augment the capital-intensity of the production. Or it can be driven by innovative efforts, which lead to the introduction of new products and services which expand output, allowing for the increase of the productive capacity of industries and upgrading labour skills required in the production.

The explanation of innovation requires attention to the path-dependency and cumulative nature of the production process. We connect demand-pull and technological-push mechanisms. R&D expenditures and previous profits provide the fundamental factors to generate product innovations. Moreover, technological efforts require a high stock of human capital available, measured in the lagged quote of high educated workers. We consider the total value-added as a proxy of demand to mirror the demand-pull incentive to technological change.

The explanation of investment requires attention to the link between technological change and capital accumulation and, more specifically, understanding how gross fixed capital investments affect the introduction of product and process innovations. We will explore the link between capital investments and technological strategies adopted by industries by testing the substitution hypothesis among capital investment and product innovations. Furthermore, we look at the sectoral heterogeneity concerning capital accumulation by dividing industries according to the technological regime they belong to, testing both, simultaneous and single equations for high-tech and low-tech sectors. Additionally, investments may be related to wages growth, inspiring labour-saving processes to reduce costs and halt wage dynamics. Exports and growing demand should positively affect the capital-intensity of the production, supporting the expansion of the productive structure of industries.

The complex nature of the relationships between profits, innovation and investment requires a novel conceptual and methodological framework able to understand in a systematic way the causal determinants and the reinforcement links across technological trajectories and capital accumulation.

We adopt here the "virtuous cycle'" perspective, building on the seminal work of Myrdal (1957) regards the cumulative causation patterns of economic development. Rather than being isolated from the others, variables affecting economic development are interlinked; changes in one variable cause cumulative effects on the others, which in turn affects the first one and the development of the entire system, mirroring how economic development proceeds in a complex circular way. Kaldor (1967) has applied the same idea to point out the circular relationship between supply and demand. Manufacturing productivity increases output produced and growing economic production, in turn, incentives manufacturing sector productivity by exploiting scale economies. Moreover, by improving resource allocation across sectors, the manufacturing sector makes other sectors also more productive. More recently, Pianta (2020) contends the need to grasp in a systematic way the relationships across technological patterns and economic developments by looking at the looping effects among innovation and economic performances, whereby a continuous and cumulative process of development can be identified (Pianta and Reljic, 2021). The request for a systematic understanding of innovation patterns and economic dynamics fed the spread of similar approaches in the field and enriched the variety of the empirical strategies adopted (Coad and Grassano,2019).

This approach meshes very well with our framework due to the looping and cumulative nature of the linkage across profit growth, capital accumulation and technological developments. Retained profits are crucial to sustaining capital investments and innovative activities, which, in turn, are aimed at increasing future profits. Furthermore, investment and innovative activities are interlinked and substantially shaped by the technological trajectories undertaken by industries.

A large stand of the literature has adopted the "virtuous cycle" perspective to study the link between technological change and economic development. Bogliacino and Pianta (2013a, 2013b) and Bogliacino et al. (2016) found a positive association between R&D efforts, profit dynamics and the introduction of product innovations. Guarascio et al. (2015, 2016) analysed the relationship between R&D expenditures, profits and internalization strategies of firms and industries; Guarascio and Pianta (2017) consider the role of export dynamics to foster product innovation and profits growth. More recently, Bogliacino et al. (2018) analysed the complex patterns across technology, offshoring and wages, also looking at the different impacts on workers' skill categories of the offshoring strategy. Carboni and Medda (2018) analyse the link between internalization dynamics, R&D expenditures, and investment decisions, finding a positive relationship among the variables. Spescha and Woerter (2021) observed a positive and consistent effect of R&D expenditures on capital stock investments for a sample of Swiss companies but did not find empirical evidence of an inverse linkage. Furthermore, Pianta and Reljic (2021) model the" virtuous cycle" of *good jobs-high innovation,* considering the interdependencies between labour quality, wages dynamics, innovative efforts, and productivity increases. Relying upon these works, we adopted the "virtuous cycle" approach. This allows us to study in a more integrated way, considering lags, feedback and temporal loops among the variables, the process of development shaped by these key drivers of the capitalist accumulation, accounting for their interdependences. So that, in our "virtuous cycle" of accumulation, past profits sustain a new accumulation cycle, driving both decisions of expenditure in new investments and in innovative efforts aimed at product innovations. However, these two growth strategies have different economic outcomes. Product innovation is positively spurred by R&D efforts and the share of high-skilled workers, augmenting knowledge stock of economy technology-oriented competition. Conversely, investments occur mainly in sectors with high labour compensation and process innovation, suggesting a growth trajectory inspired by labour-saving dynamics and wages reduction. In this work, we consider as a crude proxy for the capital accumulation the investments in gross fixed capital defined as the acquisition of produced assets (including purchases of second-hand assets), comprising the production of such assets by producers for their own use, minus disposals, provided by OECD Structural Analysis Database (STAN).

Virtuous circles have been modelled with sets of simultaneous equations, including cumulative, temporal and feedback effects. Models of Three Stages Least Squares (3SLS) have been used since they seem to be the most appropriate for exploring simultaneous relationships and feedback loops among variables; additionally, the 3SLS explicitly allows for controlling for most of the potential sources of endogeneity which may impact these relationships (Guarascio and Pianta, 2017).

In the following sections, we highlight the literature related to profits, type of innovation realized, investments in fixed capital, also looking at the sectoral features of these relationships, highlighting the economic outcomes related to the different growth trajectories undertaken by industries.

3 Data and descriptive evidence

3.1The SID database

The empirical analysis draws on the Sectoral Innovation Database (SID). This dataset was developed at the University of Urbino (Pianta et al. 2021) by merging different data sources from several datasets and referring to industries' total activities covering the time span 1994-2015. Many are the empirical works that rely on the valuable information contained in this database concerning structural change, technology adoption and employment outcomes, competitive strategies undertaken by industries, offshoring dynamics and distributive matters, such as Bogliacino and Pianta (2013a, 2013b), Bogliacino et al., (2018), Cirillo (2017), Coveri and Pianta (2022), Guarascio, and Pianta, (2017), Reljic et al., (2021a, 2021b) Pianta and Reljic (2021) among others.
The database includes data for six major European countries - France (FR), Germany (DE), Italy (IT), the Netherlands (NL), Spain (ES) and the United Kingdom (UK), which together covers a substantial share of European GDP (75%). Variables related to innovation activities, are collected using the Community Innovation Survey (CIS) firm-level data – CIS 2 (1994–1996), CIS 3 (1998–2000), CIS 4 (2002–2004), CIS 7 (2008–2010), CIS 9 (2012–2014), CIS 10 (2014–2016) and subsequently aggregated to industry-level data. Economic variables are drawn by OECD's Structural Analysis Database (STAN) of Eurostat and World Input-Output Tables (WIOT) provided by WIOD. Moreover, variables regarding labour market are constructed from the EU Labour Force Survey (EU LFS) of Eurostat.

Table 1: List of variables

Variable	Unit	Source
Profits	Compound average growth rate	OECD-STAN
Investments	Compound average growth rate	OECD-STAN
Productivity per employee	Compound average growth rate	OECD-STAN
Distance from technological frontier	Percentage difference	SID
Product innovation	Share of firms	CIS
Process innovation	Share of firms	CIS
Internal expenditure in R&D	Thousand euro/employee	CIS
Total expenditure in R&D	Thousand euro/employee	CIS
Average firm size	Number of employees	CIS
Value Added	Compound average growth rate	OECD-STAN
Export	Compound average growth rate	WIOT
Wage per w/h	Compound average growth rate	OECD-STAN
Wage per employee	Compound average growth rate	OECD-STAN
Non-standard work	Compound average growth rate	EU LF
High-education workers	Share of employee	EU LF
Low-education workers	Compound average growth rate	EU LF
Manual workers	Compound average growth rate	EU LF

Source: author's elaboration

The detailed list of variables employed in this work, their sources and unit of measurements is depicted in table 1, while a detailed description can be found in table A.2 of the appendix.
Data are available for the two-digit NACE Rev. 2 classification for 18 manufacturing (from 10 to 33 NACE Rev. 2) and 23 service sectors (from 45 to 82 NACE Rev. 2) (see table A.3 in appendix). Each monetary variable is expressed in constant price with the base year 2000, has been deflated, converted to euros, and adjusted for parity price index guaranteeing full comparability over time and across countries. Data before 2008 have been converted into NACE Rev. 2 using the conversion matrix elaborated by Perani and Cirillo (2015).
The time structure of the dataset is a panel covering five periods from 1994 to 2016, accounting for the different phases of the business cycle. This allows studying how the interrelationships among output growth, innovation regimes, demand dynamics, and offshoring strategies change during upswings and downswings (Cirillo et al., 2017; Guarascio et al., 2015; Lucchese and Pianta 2012). This time structure has two advantages. First, it allows to link structural analysis to the dynamics of the economic aggregates, examining together the changes in the productive structure and the overall economic performances; Second, considering the role of the business cycle at industry level, it allows to better capture the different technological and structural trajectories of the economies. On this ground, the Schumpeterian theory of the business cycle (Schumpeter, 1995) greatly emphasises the role of investments in technological innovation as the elements that drive the development stages of capitalism, generating uneven development and structural change in the economy. Each historical phase is shaped by the technological breakthroughs available and by the degree of development of the productive forces, which determine different rates of growth across industries (Pianta et al., 2021); In Schumpeter's view, the introduction of innovations allows to obtain extra-profits which, in turn, spurs economic growth as well as further investments by the mass of potential imitators; this drive the upswing phase of the economic cycle. Nonetheless, once the previously introduced technological innovation has been diffused across the economy, the most intense competition reduces monopolistic profits, resulting in less investment, employment reduction and demand drop, fuelling the downswing of the economic cycle. This dynamics and cyclical process produces structural asymmetries that result in different growth rates of sectors, favouring the expansion of certain industries and the decline of others (Pianta,2020).
Moreover, relying on the evolutionary approach to the innovation studies, in each period, innovation variables refer to previous years respect to the economic variables, accounting for the time needed for innovative activities to deploy its effect on the economic process (see time structure of SID in table A.4 in the appendix). Economic variables used in this work-gross operating surplus per employee, gross fixed capital formation per employee, total value-added, productivity per employee, export, wage per working hour and wage per employee - are compound average annual growth rates for the periods:1996-2000, 2000-2003, 2003- 2008, 2008-2012, 2012-2015, while labour market variables: manual workers, non-standard work employment, high-skilled workers, low-skilled workers, refer to the first year of each of the five periods, i.e. 1996, 2000, 2003, 2008, 2012; Innovation variables, i.e. internal R&D expenditure for employee, total R&D expenditure for employee, the share of firm introducing a new process innovation, the share of firms introducing a new product or service innovation, and the average firm size, refer to the following five periods: 1994-1998, 1998-2000, 2002-2004, 2008-2010, 2012-2014.
So that, all explanatory economic variables in the product innovation equation are lagged, referring to the average annual compound growth rate of the previous period, as well as labour market variables

which are computed for the first year of the previous time span. Likewise, in the equation of profit and investment, dependent variables are computed over the years 1996-2000, 2000-2003, 2003- 2008, 2008-2012, 2012-2015, while explanatory variables related to innovation refers to 1994-1998, 1998-2000, 2002-2004, 2008-2010, 2012-2014, ensuring the time needed to deploy their effect and lightening simultaneity-related endogeneity bias.

3.2 The industry level of analysis

Studies regarding the link between innovation activities, technological performances and economic outcomes have been conducted using both industry and firm-level; Each unit of analysis has its own pros and cons. A long list of work carried out using firm-level data has addressed valuable novelties regarding the wide heterogeneity in the technological adoption across firms and industries and the causality between technological efforts and economic performances.

Notwithstanding the relevance of theoretical and empirical matters discovered by such type of analysis, some concerns emerge with regard to the chance of capturing and generalise in a systemic way industrial heterogeneity concerning the relationship between structural change, technological dynamics and overall economic cycle using firm-level analysis (Bogliacino and Pianta, 2013a, 2013b). First, most firm-level studies are based on panels consisting of relatively few firms, unable of being representative of all firms. Further, when the study is based on a panel followed over time, by definition, it excludes firms exiting and entering the market, key drivers of technological change from the evolutionary perspective (Pianta et al., 2021). Given these limitations, generalising the findings beyond the sample to the whole economy is somewhat challenging (Bogliacino and Pianta, 2013a). Conversely, industry-level studies, smoothing gains and losses that affect firms, better capture the economic activity of a given sector, linking the changes in the economic structure to overall macroeconomic patterns. Second, there is a clear cut-off between industry and firm-level analysis considering the role of demand. While an individual firm can always grow and gain market share in the face of competitors – the 'business stealing' issue –the industry's demand has a downward slope, consisting of a portion of aggregate demand directed to the products and services of a particular sector (Pianta et al., 2021). Thus, while at the firm level, innovation can easily lead to improved economic performance, at the industry level, it can only happen when also industry's demand expands, compared to the others.

Third, firm-level studies are incapable of accounting for the heterogeneity of sectors effectively, considering only in a limited way for industries' specificities.

Industry-based analysis instead, grouping together firms belonging to the same technological regimes -defined as shared technological opportunities, appropriability conditions of technological advances, type of predominant knowledge used, and similar market structure (Bogliacino and Pianta, 2016, Breschi et al., 2000; Dosi, 1982, 1988; Dosi et al. 2006; Evangelista, 1999; Malerba, 2004; Pavitt, 1984) - achieves a better understanding of the evolution of the innovative industrial trajectories.

Following the evolutionary perspective, many authors have elaborated taxonomies to group industries according to shared features to capture the variety of technological trajectories across sectors.

Pavitt (1984), focusing on the market structure and on the nature, sources and appropriability of innovation, classified manufacturing industries according to four different technology-based classes. Bogliacino and Pianta (2010, 2016), extending the original Pavitt classification, renewed this work, focusing on the relationships between innovation patterns and economic performances of service industries. They provide the Revised Pavitt Taxonomy, which is a fundamental step to study technological trajectories, including the relevance of the service sector; the list of technology-based clusters can be found in table A.1 in the appendix, while their brief description, drawn by Pianta et al. (2021), is the following:

- Science-Based industries (SB) include sectors where innovation is based on advances in science and R&D (such as the pharmaceuticals, electronics, computer services) where research laboratories are important, leading to intense product innovation and a high propensity to patent. (high-tech)

- Specialised Supplier industries (SS) include the sectors producing machinery and equipment; their products are new processes for other industries. R&D is present, but an important innovative input comes from tacit knowledge and design skills embodied in the labour force. Average firm size is small, and innovation is carried out in close relation with customers. (high-tech)

- Scale and Information Intensive industries (SI) include sectors (such as the automotive sector and financial services) characterised by large economies of scale and oligopolistic markets where technological change is usually incremental. New processes (often related to information technology) shape the organisation of production and coexist with new product development. (low-tech)

- Supplier Dominated industries (SD) include traditional sectors (such as food, textile, retail services) where internal innovative activities are less relevant, small firms are prevalent and technological change is mainly introduced through the inputs and machinery provided by suppliers from other industries. Firms in this group do not carry out much R&D or other innovative activities. (low-tech)

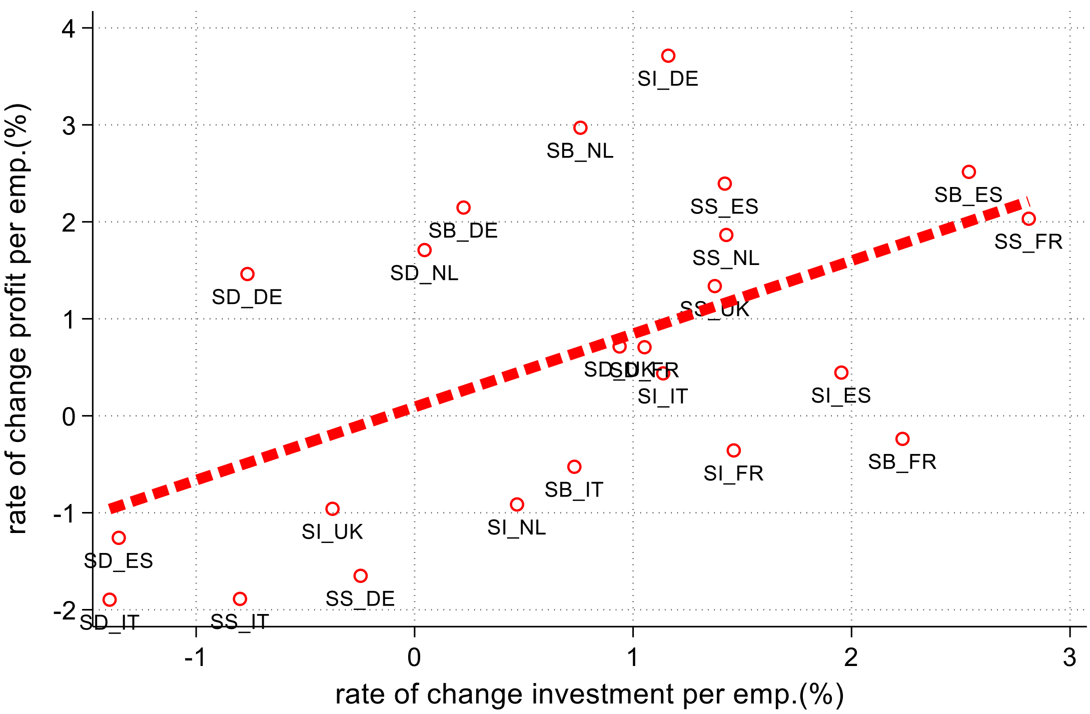
This classification helps to consider the different technological trajectories undertaken by industries in light of the prevalent type of innovation introduced, type of knowledge used, and driver of accumulation exploited, which have contrasting impacts on the economic development.

3.3 Descriptive evidence

In this section, we provide descriptive evidence on the key relationships of our interest. In the graphs, we group variables according to technological classes identified by Pavitt taxonomy (Pavitt, 1984; Bogliacino and Pianta, 2010). The variables are the weighted average -based on the number of employees- by technological class of the six countries and five periods taken into account. This effort helps us to understand the relationship among variables considering the technological features of industries.

Figure 1 plots the complex and twofold relationship between investment in gross fixed capital formation per employee, profits, and previous profits, proxied by gross operating surplus per employee.

Figure 1: the relation between profits and investments



Source: own elaboration on SID (Pianta et al., 2021). Notes: The figure plots the mean of the compound average growth of gross operating surplus and investment in gross fixed capital formation by Pavitt class and country of the periods 1996-2000,2000-2003, 2003-2008, 2008-2012, 2012-2015.

Pavitt class: SB stands for Science-Based industries, SS for Supplier Specialized, SI for Scale and Information Intensive and SD for Supplier Dominated. The country acronyms are DE (Germany), NL (Netherlands), FR (France), IT (Italy), SP (Spain) and UK (United Kingdom). SB_UK is excluded from the graphical inspection because it is an outliner within its Pavitt group.

On the one hand, investments are a core driver of the rate of growth of profits in technological driven industries across advanced countries; capital-intensity is a source of competitiveness among sectors that rely on scale economies and a fundamental source to acquire embodied technology in process-oriented industries (Evangelista, 1999; Pianta, 2001). On the other hand, previous profits are a determinant source to finance productive expenditure and investment as maintained by the Neo-Schumpeterian literature. According to this approach, indeed, industries with high past profits have higher investment growth due to their lower financial constraint and greater economic availability to use internal funds to finance the expenditure for productive investment and expand production capacity. This pattern is a core driver of growth, particularly in high-tech industries, where expenditures in innovation and in embodied technological breakthroughs are complementary (Evangelista, 1999).

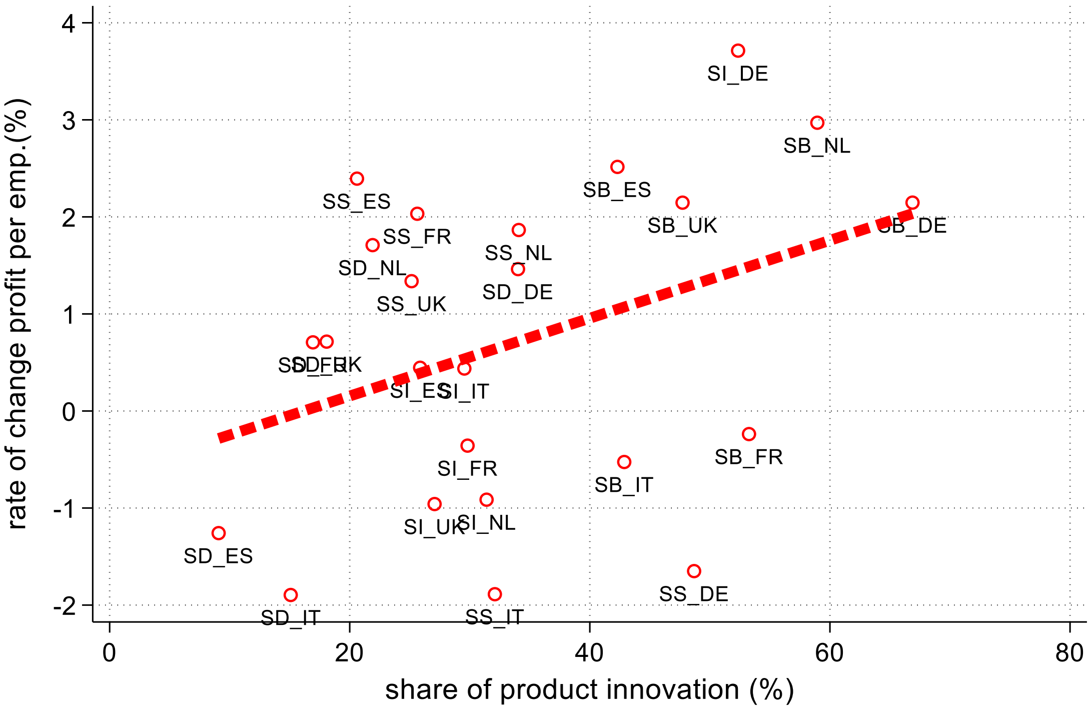
In Figure 1, profits and investments are expressed as compound annual growth rate average over 1995-2015 computed by Pavitt class for each country. We witness a positive link between the rate of change of profits and investments over the period. That is, investment growth seems to be a core component of the growth rate of profits across European industries, resulting in a substantial correlation of 0.367 between the two variables. Overall, high-tech classes, such as Science-Based and Supplier Specialized industries, have a higher growth rate of both, profits and investments. For the most, Supplier-Specialized industries seem to associate a considerable growth of profits to a remarkable increase of investments, except for Italian and German industries of this group. Indeed, they realized the highest investment increase among the technological classes, witnessing the considerable role of investment in gross fixed capital in their growth strategy. Additionally, Science-Based industries experienced profits growth linked to investments increase, but slightly smaller than the other high-tech class. A more pronounced geographical heterogeneity also emerges among the Science-Based group; Italian and French industries increase in terms of investment but decline slightly in profits. This pattern seems to suggest a lower role of capital-intensity growth strategy among industries belonging to this group.

Looking at the low-tech classes, it evinces a lower increase of profits and a more complex relationship to investment patterns. Concerning the Scale and Information Intensive industries, they realized a strong growth of investment in gross fixed capital along with a modest rise of profits, suggesting a considerable role of investment in machines and equipment and capital assets across these industries. German industries outperformed in profit growth with respect to the others; meanwhile, Spanish industries belonging to this group have the highest growth of investments. Conversely, Scale and Information Intensive English industries decrease in both variables. Finally, considering Suppliers Dominated industries, they performed the lowest growth of both investments and profits, with the worst performances of Italian and Spanish industries, performing the strongest reduction of both.

Figure 2 shows the link between the average growth rate of profits and the average share of product innovation by Pavitt class and country over 1994-2015. Evolutionary approaches (Nelson and Winter 1982; Dosi 1988) have shown that the economic performances of firms and industries should be properly understood by an adequate consideration of innovative processes rooted in different technological trajectories. Following this approach, Bogliacino and Pianta (2013b), Pianta and Tancioni (2008) show a positive link between product innovation and profits. Similar results, considering the relationship between innovative input -R&D expenditure per employee- and profit growth rate, has been found in Bogliacino and Pianta (2013a), while Pianta and Reljic (2021) witnessed an increase in productivity in industries introducing more product innovations.

The correlation of 0.365 and the positive linear prediction line between the two variables seem to confirm the findings of the literature, suggesting that product innovation is a core growth strategy across the more innovative technological industries. Looking at the different industrial classes, high-tech industries introduce a considerably higher share of product innovation. Science-Based sectors, in particular, performed the higher share of product innovation along with a considerable growth of the profit over the period, followed by Specialized Suppliers and Scale and Information Intensive groups. Supplied dominated industries instead, seem to lag behind, with a low average share of new products and very barely advancements in profits.

Figure 2: the relation between product innovation and profits

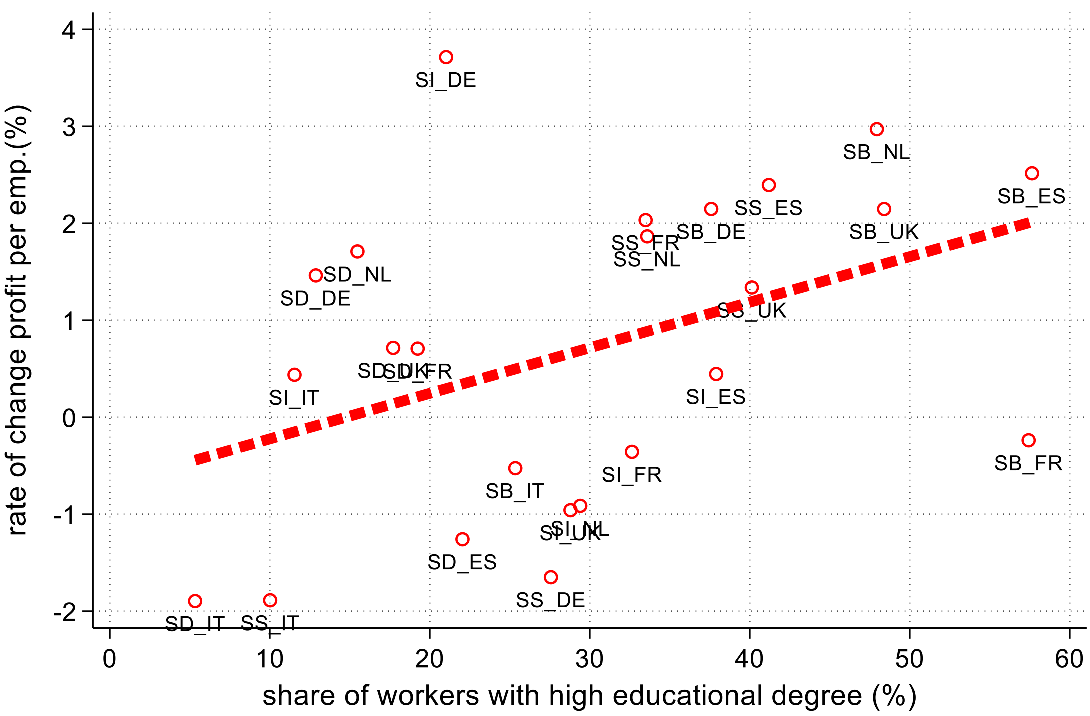


Source: own elaboration on SID (Pianta et al., 2021). Notes: the figure plots the mean of the compound average growth of gross operating surplus of the periods 1996-2000,2000-2003, 2003-2008, 2008-2012, 2012-2015. The share of product innovation is the average share of firms introducing product innovation by Pavitt class and country of periods: 1994-1998, 1998-2000, 2002-2004, 2008-2010, 2012-2014.
Pavitt class: SB stands for Science-Based industries, SS for Supplier Specialized, SI for Scale and Information Intensive and SD for Supplier Dominated. The country acronyms are DE (Germany), NL (Netherlands), FR (France), IT (Italy), SP (Spain) and UK (United Kingdom).

In addition, it can be evinced a quite interesting geographical heterogeneity within the groups that overcomes the technological patterns. Germany's industries, in each Pavitt class, perform better than the others, highlighting the strong technological propensity of this economy. This can be seen from the relatively strong performance of the German Supplier Dominated and Scale and Information Intensive industries, those realized a higher share of innovative new products introduced with consistent growth of profits compared to the other countries.
The right-side graph plots the relationship between lagged profits and product innovation. According to evolutionary economic literature, indeed, lagged profits are a fundamental tool to sustain expenditure in innovation and innovative efforts of firms and industries. Due to the 'radically uncertain' nature of the innovation process, internal resources, mainly Schumpeterian profits, represent a vital driver for firms' and sectors' innovative outcomes (Guarascio and Pianta, 2017). Indeed, they found a positive link between past profit per employee and the introduction of new products. Our graphical inspection seems to be consistent with these insights.
According to Schumpeterian view of development, introducing innovations is the major drivers of economic growth. In this perspective profit growth is largely determined by the technological evolution of firm and industries that realize R&D to generate and use new technical knowledge. High

level labour force education and lifelong learning are crucial components of the innovation activities, allowing to use the most productive technologies and upgrade continuously the production process. These matters are the roots of the idea of “knowledge-economy” (Lundvall,2016), in which modern economic activity is mainly based on the generation, distribution and use of knowledge (Evangelista, 1999). Figure 3 plots the growth rate of profits according to the average share of workers with high educational degree. High-tech Pavitt’s class performed a higher growth of profits and have a considerably high share of high-degree employment. The exceptions regard the Italian high-technological class which underperforms in both variables, and the Science-Based French industries, which realized a slight decrease of profits. Conversely, low-tech classes seem to rely very less on a high educational degree work force. These patters underline the relevance of the technological industrial technological patterns. While technology-based sectors perform a growth trajectory based on the use and development of disembodied knowledge and human capital, lagged-technological sectors improve economic performances without employing human knowledge and educational advancements.

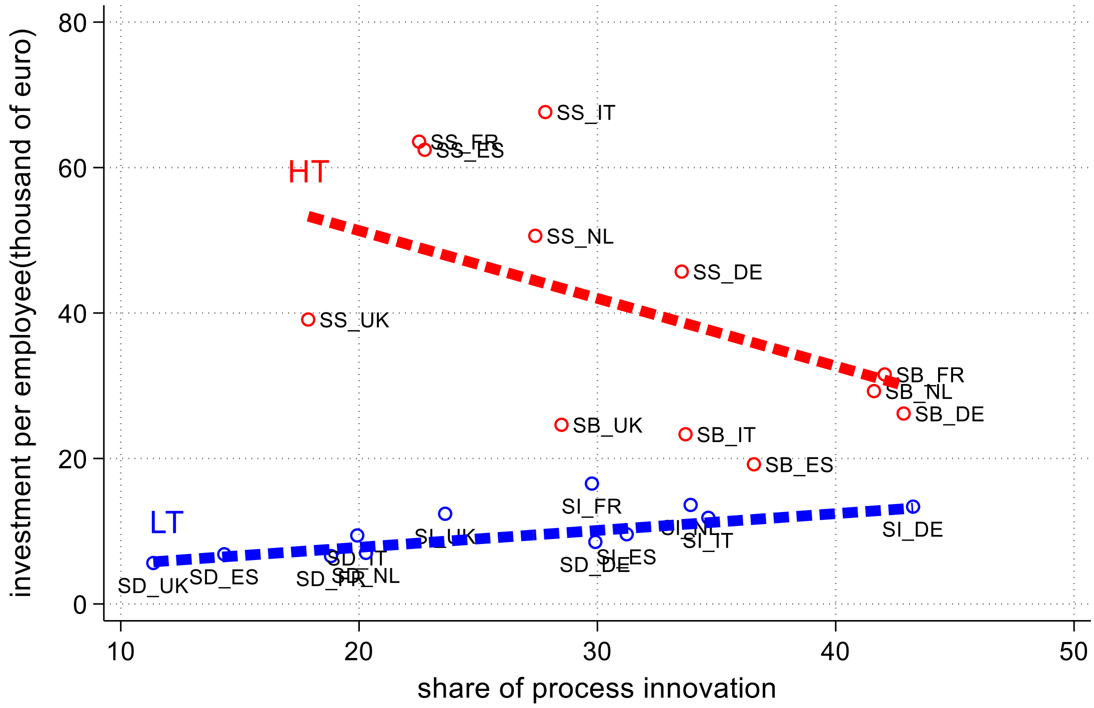
Figure 3: Profits growth and high-educated employment



Source: own elaboration on SID (Pianta et al., 2021). Notes: the figure plots the rate of change of gross operating surplus - calculated as mean over the periods 1996-2000,2000-2003, 2003-2008, 2008-2012, 2012-2015 by Country and Pavitt class and the average share of high-skilled workers as mean over the periods 1996-2000,2000-2003, 2003-2008, 2008-2012, 2012-2015.Pavitt class: SB stands for Science-Based industries, SS for Supplier Specialized, SI for Scale and Information Intensive and SD for Supplier Dominated. The country acronyms are DE (Germany), NL (Netherlands), FR (France), IT (Italy), SP (Spain) and UK (United Kingdom).

Figures 4 depicts a graphical inspection of the relationship between the share of industries introducing process innovation and investment in gross fixed capital formation measured in thousands of euros per employee. Following the original Schumpeterian division between product and process innovation, Pianta (2001) pointed out the analytical relevance of the difference between these two modes of innovation. Although often complementary, these innovation patterns have a contrasting effect on growth, employment and distribution and are usually associated with different growth strategies (Bogliacino and Pianta 2010, 2012; Crespi and Pianta 2008a, 2008b; Pianta and Tancioni 2008;). Product innovation is usually more related to *technological competitiveness* strategy, which leads to the introduction of new products or services and to the creation of new markets; process innovation is mainly supported by the acquisition of embodied technology in new machinery and plants, driving *cost competitiveness* and reorganization of the production chains. Moreover, Evangelista (1999) explored the role played by investments among sectors according to different technological trajectories. One the one side, investments in new machines and machinery are relevant among low-tech sectors with low expenditure in R&D to acquire technological breakthroughs and exploit scale economies, minimizing the cost of production. On the other side, in many high-tech industries, they are complementary to innovative efforts and high-skills tasks to expand production capabilities and sales of new products. Figure 4 illustrates the relation between investments and process innovation by grouping sectors according to technological industrial trajectories.

Figure 4: investments and process innovations



Source: own elaboration on SID (Pianta et al., 2021). Notes: the figure plots the average of the gross fixed capital investment per employee- in thousand millions of euro- calculated as mean over the periods 1996-2000,2000-2003, 2003-2008, 2008-2012, 2012-2015 by Country and Pavitt class. The share of process innovation is the average share of sectors introducing product innovation by Pavitt class and country of periods: 1994-1998, 1998-2000, 2002-2004, 2008-2010, 2012-2014.

Pavitt class: SB stands for Science-Based industries, SS for Supplier Specialized, SI for Scale and Information Intensive and SD for Supplier Dominated. The country acronyms are DE (Germany), NL (Netherlands), FR (France), IT (Italy), SP (Spain) and UK (United Kingdom).

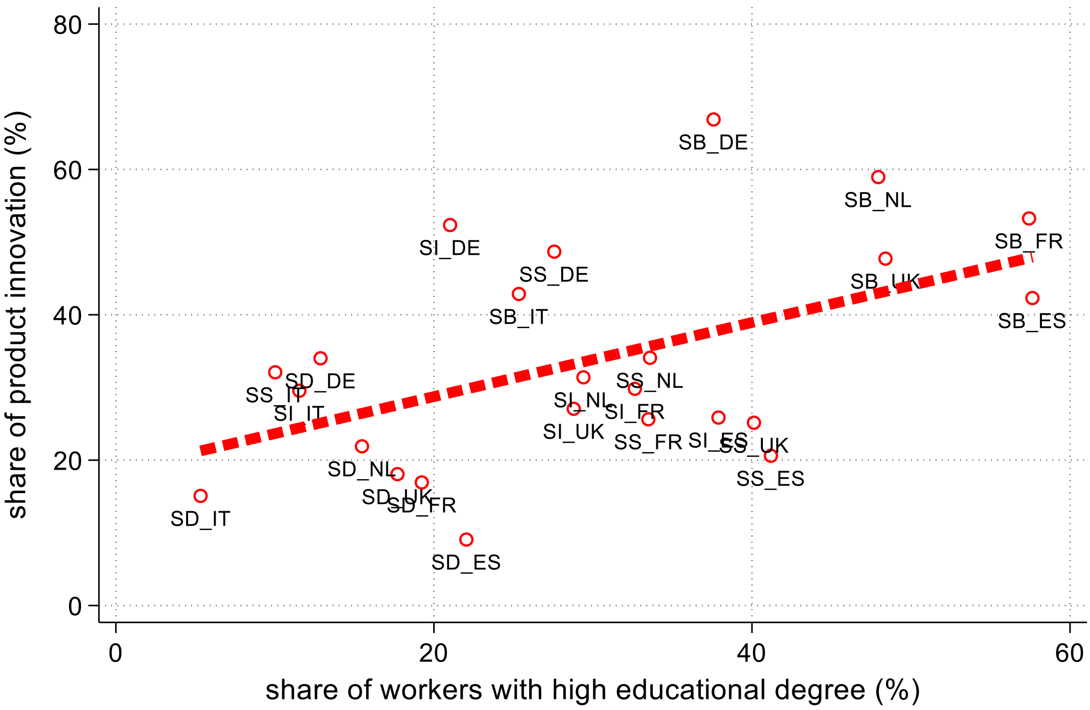
The red line, associated with the high-tech cluster, indicates a negative relationship between the two variables driven mainly by the consistent weight of process innovation of Science-Based industries and this group's relatively low investment expenditures. This pattern shows the massive complementarity between process and product innovation across technological driven industries, which links the production of sophisticated goods and services with complex production processes. Investments, instead, seem to be not a key technological driver within Science-Based industries, due to the decreasing capital-intensity in the top observations, compared to the other high-tech group.

Conversely, Specialized-Suppliers industries are featured by a consistent investment weight and a moderate share of process innovation. In this group, investments are an essential technological source of innovation due to the capital-intensity nature of the production process. However, the moderate share of process innovation seems to indicate a low relevance of process-related technological innovations. These findings align with Evangelista (1999), who found similar patterns across industries producing machinery and equipment and intermediate inputs for other industries. Therefore, this result may depict a sort of trade off between capital investments and process innovations across high-tech industries. Specialized suppliers have a capital-intensive production process but perform a relatively process innovation. Conversely, Science-Based industries, highly combine product and process innovation, but invest barely in fixed assets.

The blue line, instead, shows a straight relationship across investments and process innovation in low-tech industries. This may indicate that, widely in low-tech sectors, process innovation is driven by the acquisition of new technological artefacts that optimize production and foster organizational improvements.

Figure 5 suggest the positive relationship between the knowledge accumulation of disembodied technology- measured as the quote of educated workers- across industries grouped in Pavitt class and the share of product innovation. A large stand of literature stresses the relevance of knowledge accumulation as a key source of innovation in technology-oriented industries. Guarascio and Pianta (2017) found that a higher share of high skilled workers positively affects the introduction of new products. Similar results are found in Pianta and Reljic (2021), where the introduction of product innovation is positively correlated with the lagged share of workers with a university degree, while no effect has been found for workers with secondary education or below degree of instruction. These patterns are mirrored in the positive correlation found in figure 4. Science-Based industries far overperformed the rest of industries with a higher share of both variables. A close performance evinces for Science Suppliers and Scale and Information Intensive sectors, with consistent growth of both the variables. Among the latter, it is worth noting the lower average share of the UK and Spanish industries compared to the rest of their group. Supplier-Dominated industries lagging behind, focusing basically on different drivers of innovation and knowledge. Looking at the geographical point of view, Italian industries seem to have the worst performance in each technological class, mirroring the low propensity of the country to knowledge-base and technological driven economic trajectory.

Figure 5: knowledge accumulation and innovation outcome



Source: own elaboration on SID (Pianta et al., 2021). Notes: The figure plots the average share of product innovation by Pavitt class and country calculated over the mean of the periods: 1994-1998, 1998-2000, 2002-2004, 2008-2010, 2012-2014 and the average share of high-skilled workers as mean over the periods 1996-2000,2000-2003, 2003-2008, 2008-2012, 2012-2015. Pavitt class: SB stands for Science-Based industries, SS for Supplier Specialized, SI for Scale and Information Intensive and SD for Supplier Dominated. The country acronyms are DE (Germany), NL (Netherlands), FR (France), IT (Italy), SP (Spain) and UK (United Kingdom).

Summing up some worthy issues emerge from this graphical inspection. (i) Investment and profits have a twofold relation. Investment drive profits, and lagged profits finance investments, particularly in technologically oriented sectors. (ii) Industries with a higher share of product innovations realized higher profits. (iii) In low-tech industries, process innovations seem to be driven by expenditure in investments, so that, disembodied technological change is related to capital investment. Across high-tech industries the relation is more puzzling. Specialized-Suppliers have a strong capital-intensity of the production, but introduce modest process innovations. Conversely, Science-Based industries have a lower level of investment per employee, but combine product and process innovation. (iiii) Industries oriented to more product innovation employee a higher level of educated workers.

4. The model

4.1 The profit equation

The rate of growth of profits per employee is a useful indicator to grasp the economic performance of firms and industries for many reasons. First, it allows understanding the different technological strategies undertaken by industries to improve their economic performances, overcoming problems related to firm's peculiarities of micro-level data (Bogliacino and Pianta, 2013b). Second, using industry-data and a large time span like ours allows us to control for the different phases of the business cycle. Third, profits per employee depict a comparable measure of the profitability across industries, weighting profits for the number of employees of the industries.

Our profit equation is ground on the work of Bogliacino and Pianta (2013a, 2013b), Bogliacino et al. (2017), Coveri and Pianta (2022), Guarascio and Pianta (2017), Pianta and Tancioni (2008) in which the growth of profits is driven by technological and market factors accounting for the conflicting nature of the production process. In Bogliacino and Pianta (2013a), aggregate industry profits are driven by technological innovation, particularly by the increase in turnover share of innovative sales, and by demand, proxied with the value-added growth. Bogliacino and Pianta (2013b) explicitly consider cost and technological competitiveness strategies in the profit equation. The first is proxied by the share of innovative products, and the second by the expenditure in new machinery realized by industries. Both strategies have been found significantly related to profit growth along with the demand-pull mechanism. Bogliacino et al. (2017) found that the rate of change of investments and demand - both internal and external- positively affects the annual growth rate of aggregated industrial profits, while the market size and wages growth exert a negative impact. Coveri and Pianta (2022) explain the rise of inequality among European countries showing the conflictual link between profits and wages. Profits are driven by process and product innovation, which foster gross operating surplus increases throughout productivity gains. However, while product innovation has strong statistical significance, scarce relevance has been found for the expenditure in machinery realized. Likewise, all types of offshoring strategies lead to a profits rise. In contrast, the growth rate of wage per working hour and the share unionization of the labour force depress profits, mirroring the conflictual nature of the distribution. Guarascio and Pianta (2017) found that new product innovation fosters the growth rate of profit per employee. Exports are the principal component of demand to push industries to generate innovative products. Pianta and Tancioni (2008) explain the distributive conflict among salaries and profits in light of different growth trajectories undertaken by European industries. Product innovation increases profits with a positive effect on employment, while process innovation, boosting profits, lowers wages and reduces employment.

Our profit equation allows us to consider two main sources at the roots of profit accumulation, mirroring the inverse relationship between profit and wage growth. Higher profits are driven by the rise of productivity per employee, which can be realized by augmenting total value-added or improving the production process. We account for both growth strategies discussed below. On the one side, technological competitiveness is driven by introducing new products that increase sales and the value-added of the industries. This strategy is clearly also driven by the demand rise, which is indirectly considered in the productivity measure in our framework. On the other side, profit can result from the cost competitiveness strategy in which industries reduce production costs, decreasing wage for working hour, fuelling capital investments to pursue labour-saving strategies. Furthermore, an increasing number of unstable workers should foster profits, allowing more control over the labour force, lowering union requests, and adapting labour flexibility to the business cycle fluctuations. The profit equation is the following:

$$(1)\ \Delta\pi_{i,j,t} = \alpha_0 + \alpha_1 NP_{i,j,t} + \alpha_2 \Delta\, productivity_{i,j,t} + \alpha_3 \Delta K_{i,j,t} - \alpha_4 \Delta W_{i,j,t} + \alpha_5 \Delta unstable_{i,j,t} + \mu_i + \tau_i + \delta_i + \varepsilon_{i,j,t}$$

So that, in our empirical specification, we consider market and technological factors. i, j, t indices indicate respectively: industry, country and periods. Summing up our model, the rate of growth of the profit per employee $\Delta\pi$, is related to the increase of the share of new product introduced, NP, by the rate of change of productivity per employee $\Delta\, productivity$, by the rate of growth of investments in gross fixed capital formation, ΔK and by the rate of growth of workers with unstable working contract $\Delta unstable$. Conversely, accounting for distributive conflict between labour and capital, the growth rate of wage per working hour ΔW , lowers profits per employee. It is worth noting that NP refers to previous periods with respect to the economic variables, accounting for the time needed for innovation to entirely affect the economic process, as evolutionary economics largely explained.
μ_i stands for the industry effects, for which we control, including a series of dummy variables for the Revised Pavitt classes; this is necessary to account for different technological trajectories pursued by industries. δ_i accounts for country fixed effect, allowing to consider the national institutional setting and the peculiarities of each national system of innovation. Finally, τ_i , are a series of time dummies that allow considering in the equation the effect of the different phases of the business cycle, while $\varepsilon_{i,j,t}$ is the error term.

4.2 The equation of product innovation

Economic theory largely recognises technological change as the main driver of economic development. Innovation is at the root of the process of technological change and is the principal source of positive economic performances of industries and firms. According to Crépon (1998), the process of innovation and its impact on economic performance can be divided analytically by a few fundamental stages. A first stage regards the decision of economic agents to perform expenditure in innovation inputs; the second is centred on the relation between innovative input (R&D) and successful outputs; the third, on the impact of innovation output on the economic performances of economic actors (Bogliacino and Pianta, 2013a). Following this approach and distinguishing between innovation *inputs* and innovation *outputs*, we consider the introduction of product innovation as a measure of the successful efforts (*innovative input)* to develop new commodities (*Innovative outputs)*. Many recent studies build on these insights, considering in a systematic view the process shaped by the innovative efforts to generate innovative outcomes and their impact on the industry's performances. These works, linking the evolutionary approach to the study of innovation with post-Keynesian structural change literature, consider innovation as a cumulative and uncertain process, in which technological efforts and markets conditions are fundamental ingredients (Pianta, 2020; Pasinetti, 1981). R&D expenditure, and the stock of knowledge available, are essential to generate innovative products or services. Moreover, both supply-side and demand-side patterns matter for the introduction of innovations. On the one side, the demand-pull mechanism incentive firms to innovate. Indeed, the growing demand for commodities in high-tech sectors boosts the expansion of production. However, on the other side, high demand may represent a source of rent for firms and industries, guaranteeing positive economic performances to less innovative businesses. This, in turn, may lighten or delay the incentive to undertake technology-oriented growth strategies. Additionally, profits are a fundamental source to overcome the financial constraints of the economic agents, providing new resources to boost innovative cycles, as well as understood in the Schumpeterian mark II innovation model.

Bogliacino and Pianta (2013a,b) connect R&D efforts to the successful introduction of product innovation in a circle that fosters profit accumulation. Past profits in these models have the fundamental role of sustaining R&D and product innovation expenditures, boosting the new innovation process. Guarascio and Pianta (2017) witnessed that product innovation is driven by higher growth of previous profits, export, and innovative expenditure in R&D. Pianta and Reljic (2021) found a virtuous cycle of growth between R&D expenditures, product innovation and productivity gains, connecting these patterns to the quality of employment and a higher level of wages.

Following these works, our product equation function is built considering market and technological matters. A higher share of product innovation is shaped by innovative efforts in R&D expenditure per employee, a larger stock of past *disembodied* knowledge, and greater availability of past profits. Moreover, we control for demand patterns, considering as in Bogliacino and Pianta (2013a) valued-added as a good proxy for demand. Our empirical estimation is the following:

$$(2) \quad NP_{i,j,t} = \beta_0 + \beta_1 R\&D_{i,j,t} + \beta_2 \Delta \pi_{i,j,t-1} + \beta_3 knowledge_{i,j,t-1} + \beta_5 \Delta D_{i,j,t-1} + \mu_i + \tau_i + \delta_i + \varepsilon_{i,j,t}$$

In our model, the share of new products, NP , is driven by the R&D expenditures per employee to create technological knowledge performed by firms and industries, $R\&D$, by the rate of growth of lagged profit per employee, a fundamental to overcome financial constraints, $\Delta\pi$, and by the previous disembodied technical knowledge stock of the industries, $knowledge$, proxied by the share of workers with at least a university degree. Moreover, we control the different stages of development of sectors accounting for the growth rate of total lagged demand ΔD measured by the rate of change of value-added. As in the previous equation, we consider industry, country and time dummies in order to capture peculiarities related to these patterns.

4.3 The investment equation

Although evolutionary economics has overlooked for a long time the role of capital expenditures in the process of innovation,

Our model builds on the insights described below and models investment as a function of the type of innovation introduced. We use the gross fixed capital formation as a proxy of innovative investment. Evangelista (1999) found a very high correlation between these two variables, even if not unitary. In our framework, capital investments are explained by the competitiveness strategy undertaken by industries. In this setting, process innovation fosters capital accumulation, mirroring the well-known pattern of capital-deepening driven by technology. So that, we expect a positive link between the rate of growth of labour compensation per hour worked and growth of investment; high wages may incentive labour-saving dynamics aiming at the reduction of the production costs across industries where it is possible to automate the production chain.

More puzzling considerations evince for product innovation. Indeed, on the one side, capital accumulation can increase the productive capacity in firm industries growing the sales boosted by innovative products. On the other side, there may be a trade-off between investment in capital and technology-oriented growth-trajectory. This can be due to the limited amount of financial resources. Therefore, in our model, lagged past profits are a fundamental source to boost capital accumulation. Finally, as it is well known in the literature (Bogliacino et al., 2018; Coveri and Pianta, 2022; Guarascio and Pianta, 2017), the dynamism of demand affects the growth of investments. For this reason, we control the different phases of the business cycle, inserting the export growth among explanatory variables. We prefer this proxy of demand since it may soften endogeneity bias with the lagged profits with respect to other demand proxies such as total value-added.

$$(3) \qquad \Delta K_{i,j,t} = \gamma_0 + \beta_1 \Delta\, \pi_{i,j,t-1} + \gamma_2 NP_{i,j,t} + \gamma_3 Process_{i,j,t} + \gamma_4 \Delta\, exp_{i,j,t-1} + \gamma_5 \Delta W_{i,j,t} + \mu_i + \tau_i + \delta_i + \theta_i + \varepsilon_{i,j,t}$$

Summing up, our empirical equation estimates the rate of growth of gross fixed capital formation per employee, ΔK, which is driven by the rate of change of lagged profits per employee $\Delta\pi_{t-1}$, by the share of product innovation of the industries, NP, and process innovation, $process$, by the lagged rate of growth of exports, Δexp_{t-1} and by the rate of growth of wages per working hour, ΔW. It is worth noting that, innovation variables refer to previous period respect to investments, so they must be read as lagged with regard to investment decisions; industries undertake innovative processes and *then* decide to invest or not in gross fixed capital.

The details of the equation are the same as discussed in (1). However, considering the substantial heterogeneity across services and manufacturing industries in the use of gross fixed capital, particularly relevant with the development of digital technologies (Cainelli et al.,2004; Pianta, 2020), here we account also for a manufacturing dummy θ_i.

4.4 The "virtuous cycle" model

Summing up, in our "cycle" of accumulation, in equation (1), profits per employee are driven by productivity per employee gains which can be realized throughout cost and technological competitiveness. The latter leads to introducing the new products, while the former increases capital investments per employee, decreases wages per working hour, and employs more unstable workers.

$$(1) \quad \Delta\pi_{i,j,t} = \alpha_0 + \alpha_1 NP_{i,j,t} + \alpha_2 \Delta\, productivity_{i,j,t} + \alpha_3 \Delta K_{i,j,t} - \alpha_4 \Delta W_{i,j,t} + \alpha_5 \Delta unstable_{i,j,t} + \mu_i + \tau_i + \delta_i + \varepsilon_{i,j,t}$$

In (2), product innovation is driven by efforts to develop disembodied knowledge measure as R&D expenditure per employee, by the lagged stock of accumulated human knowledge across industries, measured as the share of workers with at least university degree and by the rate of growth of lagged profits per employee, which are a fundamental drive to boost innovative efforts of firms and industries.

$$(2) \quad NP_{i,j,t} = \beta_0 + \beta_1 R\&D_{i,j,t} + \beta_2 \Delta\, \pi_{i,j,t-1} + \beta_3 knowledge_{i,j,t-1} + \beta_5 \Delta D_{i,j,t-1} + \mu_i + \tau_i + \delta_i + \varepsilon_{i,j,t}$$

In (3), investments in gross fixed capita per employee are related to the kind of innovative patterns prevalent across industries. They are supported by process innovation while having a more complex relationship with product innovation. Overall, we consider product innovation as a substitute for capital accumulation. Additionally, an increase in labour compensation- measured as the rate of change of wage per working hour-, may foster investment aimed at boosting labour-saving processes. Finally, a growth rate of export may support sales, feeding the need for the productive expansion of industries and increasing investment in gross fixed capital.

$$(3) \quad \Delta K_{i,j,t} = \gamma_0 + \beta_1 \Delta\, \pi_{i,j,t-1} + \gamma_2 NP_{i,j,t} + \gamma_3 Process_{i,j,t} + \gamma_4 \Delta\, exp_{i,j,t-1} + \gamma_5 \Delta W_{i,j,t} + \mu_i + \tau_i + \delta_i + \theta_i + \varepsilon_{i,j,t}$$

5. Econometric analysis and results

5.1 Econometric analysis

In terms of econometric strategy, we follow the approach proposed by Bogliacino and Pianta (2013a, 2013b), Guarascio and Pianta (2017), Pianta and Reljic (2021). We test the validity of the hypothesized relationships equation-by-equation, estimating separately the model described in Section 3. Second, we test the model simultaneously, explicitly considering lags, feedbacks and loops across the variables shaping our "virtuous cycle" of accumulation.

Regarding the single equations, we adopt the following identification strategy. First, we carry out each equation using a weighted least squares estimator (WLS). According to Wooldridge (2002, Ch. 17), the use of this method should be preferred when data are grouped in unequal size; industry-data are clearly the case. This allows avoiding the risk that very small-sized sectors explain the same effect as large ones (Pianta and Reljic, 2021). We use the number of employees of each industry as a weight adopted in the regressions. According to Pianta and Bogliacino (2013a, b) and many other authors, it should be the preferred weight to group industry-level data since it is not subject to monetary fluctuations.

Second, we test each single equation considering different specifications and using various control variables. Results change very barely, suggesting the robustness of our estimations. Among the various specifications, a critical role regards the use of the average firm size as a control variable. Indeed, average firm size is strictly linked with technological and structural factors - degree of competitiveness, firm dynamics, sectoral technological trajectories (Guarascio and Pianta, 2017, p.792). - that can affect our estimations. Moreover, average firm size is also more relevant in analysing the link between investment and innovation, as maintained by Evangelista (1999). Indeed, the author shows that firm size crucially affects both the degree of fixed assets and capital accumulated and the process of technological change, shaping sector-specific barriers to entry and economies of scale. He identifies three different patterns in which economies of scale affect both variables. The first regard the barriers to entry related to the high level of disembodied knowledge accumulated in technology-oriented sectors. The second regards the scales economies connected with the vast amount of fixed assets and capital intensity of the production process, guaranteeing rent positions to large firms. And a third in which tacit and cumulative knowledge related to the production process can be seen as barriers to entry into the market due to the high level of less formalized and tacit knowledge required. So that, we consider this control as a crucial indication of the robustness of our results.

Third, in each equation and in the simultaneous model, we insert time, country and Pavitt dummies to account for heterogeneity bias and to grasp technological and country fixed effects, also controlling for time dynamics that may affect our coefficients. Time dummies are fundamental tools to capture the different phases of the business cycle and catch time-effects that may bias the estimations and enlarge the error term. We insert dummies for each country to capture national specificities. Indeed, institutional setting, such as the one related to market labour, or the one associated with the national system of innovation (Breschi,2002; Malerba, 2004), are country-specific and may bias the estimation of the relationships. Furthermore, Pavitt dummies depicts the heterogeneity of the technological regimes of the industries, accounting for the different technology-related patterns of accumulation. In the investment equation, additionally, we account for the different use of gross fixed capital across

the manufacturing and services industry. This allows a more precise specification of the rate of growth of the investment, underling macro-sectorial differences.
Fourth, to grasp the technological heterogeneity that occurs across high-tech and low-tech sectors, each equation is performed by splitting the sample according to these macro-tech classes. Despite the obvious different results highlighting technological-related accumulation patterns, it is a further indirect robustness check of our empirical specification. As a result, the inclusion of average size along with different control variables, the estimation performed on different samples, together with a complete set of dummies, provides a consistent signal of the validity of our econometric specification.
Five, we use Huber and Whites robust standard errors, softening the heteroscedasticity problem and providing a more precise measure of the variance and covariance matrix as suggested in Wooldridge (2002), which should make more accurate our tests and statistical significance. This method is particularly useful to grasp heterogeneity within the sample, which is the case of industry data, since it should be able to assess with the parameter variability even when the model is misspecified.
Six, given the time structure of our panel, all economic variables are compound average rate of variation over three to four years, which approximate log differences, while innovation variables report information referring to two years average CIS waves for different periods.
This time structure and the use of long lags strongly softens simultaneous related bias and endogeneity of the variables. Indeed, regarding the former point, the different time span between innovation and economic variables should greatly alleviate the risk of simultaneous bias across innovation and economic variables. On the latter point, it is worth noting that since our time lags are between 3 and 5 years, the autoregressive character of variables should almost be eliminated(Van Reenen, 1996). This is particularly true for the lagged structure of product equation (2) and for the investment equation (3), as for innovation variables in (1).
Lastly, we use a system of equations model in order to identify feedbacks and self-reinforcing loops among variables. We performed analysis using a three Stage Least Squares model (3SLS) since it fits for the estimation of simultaneous systems allowing, at the same time, to deal with the endogeneity issues. The 3SLS estimator, indeed, will enable the estimation of a system of equations in which some variables are endogenous to the system and disturbances correlated with them. Further, because some of the explanatory variables are the dependent variables of other equations in the system, we expect to have positive cross-correlation of the error terms. The estimator uses instrumental-variables to consistently estimate endogenous variables and the generalized least squares (GLS) method to account for the cross-correlation structure of error terms across the equations. It is performed by three steps. In the first, it regresses each endogenous variable on all other exogenous explanatory variables, providing in such a way instruments resulting from the predicted values for each endogenous variable. The second provides a consistent estimate for the covariance matrix of the cross-equation disturbances using two-stage least squares regression residuals. In the third, it estimates through the GLS method equations using the fitted values from the first stage in place of the right-hand-side endogenous dependent variables and the covariance matrix estimated resulting from the second stage. Therefore, it allows to explicitly consider simultaneity across variables.
Finally, we replicate the 3SLS estimation separating low-tech and high-tech groups of industries, assessing the presence of divergent dynamics of accumulation across these groups. We use the interaction terms technique following the work of Guarascio and Pianta (2017) and Lucchese and

Pianta (2012) since it accounts for intercepts and coefficient heterogeneity among different subsamples.

5.1 Results

This section provides results for the profit accumulation equation, the product innovation equation, and the capital accumulation equation, respectively. In each section, we split the sample across macro technological classes elaborated by the revised Pavitt taxonomy (Bogliacino and Pianta, 2010, 2016) to capture the different accumulation patterns. Moreover, in the appendix, we show other specifications of each equation, provided as further controls. Then we show the estimations of the simultaneous model performed over the sample and by using interaction terms for technological classes.

5.1.1 The result of profits analysis

Results of the profit equation are provided in table 2. They largely confirm expected insights as discussed in section 3. The growth rate of profit per employee is driven by technological and market factors. Productivity increases are the main driver of profit accumulation. This can be fostered by two accumulation patterns. First, technological competitiveness strategy, here proxied by the share of product innovation introduced by industries, positively affects profits in all specifications. These results confirm consistently the finding of the literature, particularly of the works of Bogliacino and Pianta(2013a,b), Guarascio and Pianta (2017), Pianta and Tancioni (2008). Second, the cost competitiveness strategy also increases the rate of change of profits. Capital investment per employee foster profit growth along with the growth of workers with unstable employment contracts.

Table 2: The profit equation results

	(1)	(2)	(3)	(4)
	Δ profit per emp.	Δ profit per emp.	Δ profit per emp.	Δ profit per emp.
Q product innovation	.0560**	.0590**	.0670**	.071***
	(.026)	(.025)	(.026)	(.027)
Δ Investment per emp.	.138**	.149**	.143**	.143**
	(.061)	(.061)	(.066)	(.066)
Δ product. per emp.	1.187***	1.224***	1.289***	1.304***
	(.14)	(.141)	(.147)	(.15)
Δ Wage for w/h.		-.299**	-.377***	-.383***
		(.134)	(.143)	(.147)
Δ unstable workers			.032	.035
			(.024)	(.025)
Average firm size				-.067
				(1.036)
_cons	-5.705***	-5.077***	-5.529***	-5.901***
	(1.704)	(1.683)	(1.735)	(1.847)
Observations	914	914	775	757
R-squared	.280	.285	.323	.325
Pavitt Dummy	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES
Country Dummy	YES	YES	YES	YES

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*
Source: author elaboration.
Note: Q stands for share. Δ stand for compound average growth rate

This latter, however, is not statistically significant in our sample. Conversely, an increase in wages depresses profits, evincing the conflicting nature of the distribution between capital and salary. This result is in accordance with the finding of Coveri and Pianta (2022) and Pianta and Tancioni (2008). Controlling for the average firm size and market structure does not consistently alter our results. Statistical significance and the coefficient of the share of product innovation improved scarcely along with the estimation of the productivity growth. No substantial modifications occurred regarding the impact of investment growth on profits. Instead, the rate of change of the wage per working hour coefficient increases, highlighting the relevance of the contrasting nature of the division of surplus produced, regardless of sectoral peculiarities, market structure and degree of competition. Overall, the results confirm that different growth trajectories can pursue profits gains and economic development, besides structural, market and technological heterogeneity. On the one side, technological development foster profit accumulation. On the other side, labour-saving and cost competition also are relevant strategies to increase profits. This latter is oriented toward the reduction of production expenses, and, particularly, of wages. Table A.5 in the appendix show different specifications of the profit equation. Inserting the share of process innovation, which is positive but not significant over all the specifications, we control for possible omitted variables. Then, we use the rate of change of wage per employee instead of the wage per working hour; the results are pretty the same. Additionally, we use the difference between one period and another in the share of unstable workers instead of the rate of change. Finally, we consider the rate of change of high skilled workers to capture the knowledge accumulation patterns across industries. All the main relationships proposed hold to the different specifications.

Table 3 looks at the technological heterogeneity across the sample by running estimations for high-tech and low-tech industries.

Table 2: The profit equation results by macro tech-class

	(1) HT	(2) LT
Q product innovation	.101***	.071**
	(.037)	(.035)
Δ Investment per emp.	.175***	.122
	(.061)	(.08)
Δ product. per emp.	.939***	1.356***
	(.175)	(.173)
Δ Wage for w/h.	-.335	-.297*
	(.26)	(.176)
Δ unstable workers	.034	.054
	(.031)	(.036)
_cons	-7.095***	-6.265***
	(2.546)	(1.952)
Obs.,	298	477
R-squared	.369	.349
Pavitt Dummy	YES	YES
Time Dummy	YES	YES
Country Dummy	YES	YES

Standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

Source: author elaboration

Note: Q stands for share. Δ stands for compound average growth rate

The product innovation coefficient has a strong statistical significance and a greater weight across high-tech industries. Surprisingly, capital accumulation seems to impact profits across high-tech industries more, while it lost significance in low-tech sectors. Productivity gains affect more low-tech classes, in which the coefficient is greater. The inverse relationship between wage growth and profit is not significant in high-tech industries, indicating lower relevance of the *cost competitiveness* strategy among technology-oriented sectors. Overall, these results provide relevant issues on the growth strategies undertaken by industries to increase profits.

5.1.2 The results of product innovation analysis

The results of the product innovation equation are collected in table 3. Product innovation is our proxy to grasp technology-oriented growth strategy. It is the innovative outcome provided by the internal effort in internal R&D expenditures

Table 3: The product innovation equation results

	(1) Q prod inn	(2) Q prod inn	(3) Q prod inn
Internal ReD per emp.	2.627***	1.782***	1.761***
	(.276)	(.22)	(.226)
Δ Profit per emp., lag	.309***	.109*	.110*
	(.084)	(.065)	(.064)
Δ VA, lag	-.555***	-.443***	-.457***
	(.204)	(.165)	(.163)
Q high-skilled workers, lag		.131***	.102**
		(.045)	(.045)
Average firm size			3.405**
			(1.344)
_cons	32.258***	27.43***	27.616***
	(2.407)	(2.161)	(2.156)
Observations	703	702	696
R-squared	.538	.717	.722
Pavitt Dummy	YES	YES	YES
Time Dummy	YES	YES	YES
Country Dummy	NO	YES	YES

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*
Source: author elaboration
Note: Q stands for share. Δ stands for compound average growth rate

. Indeed, the coefficient of the latter is strongly significant in all the specifications, offering further proof of the connection between innovation inputs and innovative outputs. This result is in line with a long stand of literature, such as Bogliacino and Pianta (2013b), Bogliacino et al (2018) Guarascio and Pianta (2017) , Pianta and Reljic (2021) among others. The lagged profits have a strong and significant impact on industries introducing more innovative products. Our findings evince the central role of profits, as found in Guarascio and Pianta (2017), aiming to sustain a new innovative cycle, driving a new accumulation path. This result is in accordance with idea drawn by the Schumpeterian model II of innovation, in which large enterprises with high profits finance R&D activities to maintain technological leadership in the market.

Additionally, the lagged stock of knowledge, proxied by the previous share of workers with at least a university degree, positively affect industries with a higher share of product innovations. This result mirrors the growing idea that in technological-oriented growth strategy, the spread of knowledge across the economy is a fundamental source of economic development, as well as echoes by the literature concerning the "knowledge-based economy" (Lundvall, 2016).
Remarkably, the lagged value-added growth rate has a negative and significant coefficient. This may have a few explanations. First, this result suggests that product innovation is greater in markets with lower demand. So that, in our model, innovation activities aim to increase sales and generate new products in markets with low dynamism. Conversely, markets with higher demand can guarantee positive economic performances and the survival of low technological firms, lowering the incentive to introduce new products. Profits in these markets are driven by positional rents and market power, ensuring consistent murk-up margins without innovating. Second, it is worth noting that the panel's time structure depends on periods with a relatively long-time span, in which the demand-pull effect may be substantially softened.
In (2), we control for average firm size. The coefficients of the R&D expenditure and of the high-skilled workers share decrease, but only barely modification can be evinced. Average firm size, reflecting market structure, has a robust significative impact on the introduction of product innovation. Evangelista (1999) widely analyse this point. Market structure, related to the size of firms, affect innovation patterns. Indeed, a large firm size mirrors consistent barriers to entry linked to the high weight of "intangible" assets due to the presence of extensive accumulated knowledge. That is, what he defined as "dynamic" barriers to entry. These are particularly relevant in science-based and technology-oriented industries, in which, nonetheless low immobilization of fixed capitals, a sort of economies of scales are connected to the massive relevance of tacit knowledge concerning the production process and the quantity of expenditure in R&D realized.
In table A.6, we provide further specifications of the product innovation equation. We use total R&D expenditure per employee instead of the only internal expenditures, confirming the relevance of the innovative efforts undertaken by industries to perform product innovation. The distance from the technological frontier is measured as the percentage difference between an industry and the leading productive industry, for each period and country. Bogliacino and Pianta (2013) found that a wider distance from the technological frontier should allow a process of imitation and depress the introduction of innovative products. Conversely, our result finds a positive and robust effect of the distance from the technological frontier across industries with higher product innovation share. Moreover, we use the lagged rate of growth of low-skilled workers as a measure to account for the link between innovation and disembodied knowledge accumulation. The variable negatively affects the introduction of product innovation, even if it is not statistically significant. In the last two equations, we control for the effect of the occupational structure considering the rate of change of manual workers. The impact of this variable is ambiguous but not statistically significant in both specifications. Overall, the core explanatory variables considered- lagged profits, R&D expenditure, and stock of human knowledge of the industries- are essentially robust across the different specifications and using additional controls.
Table 4 witness the differences between high-tech and low-tech classes related to the determinants of product innovation. A few interesting issues may be worth it. First, R&D internal expenditure per employee affects both groups with a strong and significative coefficient. It is higher in high-tech classes, indicating the relevance of the innovative inputs for technological-related accumulation

patterns. Lagged profits per employee are positive but not significant anymore across high-tech classes, while matter for low-tech industries. This may suggest that, while in low-tech industries, the availably of financial resources is fundamental to drive product innovation, in high-tech sectors, innovation is crucial to economic development, therefore innovation activities depend less on financial resources.
The demand growth negatively affects product innovation in the low-tech group, while is not statistically significant in high-tech. This result, as discussed below, may indicate that high demand in low-tech sectors may disincentive innovative efforts and technological development, guaranteeing relatively good economic performances and positional-rent gains. As expected, the previous share of high-skilled workers in an industry positively impacts the development of product innovation. This effect is higher, as largely projected, in the high-tech Pavitt class.

Table 4: The product innovation equation results by technological class

	(1) HT	(2) LT
Internal ReD per emp.	1.896***	1.518***
	(.408)	(.251)
Δ Profit per emp., lag	.031	.151**
	(.184)	(.066)
Δ VA, lag	-.431	-.449**
	(.346)	(.187)
Q high-skilled workers, lag	.193***	.132**
	(.073)	(.057)
	(3.849)	(1.934)
Obs.,	247	455
R-squared	.664	.649
Pavitt Dummy	YES	YES
Time Dummy	YES	YES
Country Dummy	YES	YES

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*
Source: author elaboration
Note: Q stands for share. Δ stands for compound average growth rate

Overall, these results confirm (i) the role of R&D expenditure per employee as crucial innovation input to generate product innovation and technology-driven growth strategy. (ii) The importance of previous profits, particularly in low-tech industries, assures the financial resource needed to foster innovative processes. (iii) The crucial relevance of the stock of disembodied knowledge and human capital to spur technological-oriented growth.

5.1.3 The results of innovation analysis

Table 5 shows the results from the investment equation. Lagged profits are a crucial source to foster capital investments. Moreover, the growth rate of investment in gross fixed capital is affected differently according to industry innovation patterns. Product and process innovation proxies technological and cost competitiveness, respectively. While process innovation appears to be complementary with capital investments, product innovation negatively impacts capital accumulation. Moreover, we control for the more dynamic component of demand, namely the growth rate of exports, which has scarce statistical significance. Conversely, the dynamic of the labour cost has a strong impact on capital investments. In sectors that experienced growing labour cost, measured as wage per working hour, the increase of investments is higher, mirroring the capital-deepening effect of the capital accumulation as maintained by classical economists. In (4), we control for the educational attainment of industries, inserting the rate of growth of high-skilled workers, which is not statistically significant.

Table 5: The investment equation results

	(1) Δ Investment per emp.	(2) Δ Investment per emp.	(3) Δ Investment per emp.	(4) Δ Investment per emp.
Δ profit per emp., lag	.094**	.094**	.093**	.091**
	(.04)	(.04)	(.04)	(.04)
Q process inn	.018	.011	.011	.016
	(.048)	(.054)	(.053)	(.053)
Q product inn	-.069*	-.070*	-.070*	-.067*
	(.038)	(.038)	(.038)	(.036)
Δ export, lag	-.026	-.025	-.023	-.019
	(.037)	(.037)	(.037)	(.037)
Δ Wage for w/h.	.739***	.727***	.738***	
	(.273)	(.271)	(.27)	
Average firm size		.646	.698	.401
		(1.227)	(1.231)	(1.273)
Δ high skilled workers			.033	.028
			(.05)	(.05)
Δ Wage per emp.				1.043***
				(.274)
_cons	2.827**	2.856**	2.624*	2.422*
	(1.389)	(1.396)	(1.467)	(1.454)
Observations	591	590	585	585
R-squared	.188	.189	.189	.218
Pavitt Dummy	YES	YES	YES	YES
Manufacturing Dummy	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES
Country Dummy	YES	YES	YES	YES

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*
Source: author elaboration
Note: Q stands for share. Δ stands for compound average growth rate

Results provide hardly surprising issues, confirming the trade-off between capital accumulation and technological competitiveness and the consistent role of lagged profits in financing expansion of gross fixed capital.

The growth rate of lagged profit per employee is positive and significative across all the specifications. Capital investments are higher in industries with a higher share of process innovation, although the coefficient is not significant. Contrariwise, a higher percentage of product innovation negatively affects investment growth across industries. The demand component, measured through the rate of change of exports, is not significant across all the specifications, probably due to the long-time span of our lags. Instead, the rate of growth of wage per working hour has a strong positive impact on capital accumulation, witnessing those industries with higher growth of labour compensation realize more capital investment aiming at labour-saving patterns.

In (2), we control for the average firm size, but the coefficients are very similar to the specification (1). In (3), we estimate the impact of the rate of change of high-skilled workers on investment growth, controlling for educational characteristics of labour force, but the results are pretty the same, and coefficient is not statistically significative. In (4), we substitute the growth rate of wages per working hour with the wage per employee. The coefficient increases and is still positive, remarking the role of labour compensation in investment patterns.

In table A.7, we provide further controls of the equation, but the main relationships do not change in sign and statistical significance. We use the differences between periods of the share of product on process innovation performed by industries. Moreover, we control for the value-added growth rate instead of export, which coefficient is negative and significant. Issues regard the Schumpeterian rule of demand as an incentive to innovation, and the considerations about the panel's time structure discussed for the product equation, also hold in this case. Finally, we control for the growth rate of workers with unstable contract conditions, but we do not find any interesting changes in results.

Table 6 provides the results running the equation on the low-tech and high-tech subsamples. Despite the general decreases in the significance of the coefficients due to the lower and unbalanced sample setting, some results are worth to be mentioned.

Table 6: The investment equation results by technological class

	(1)	(2)
	HT	LT
Δ profit per emp., lag	-.005	.109**
	(.057)	(.047)
Q process inn	-.025	.025
	(.08)	(.063)
Q product inn	.013	-.109**
	(.051)	(.052)
Δ export, lag	.022	-.036
	(.049)	(.046)
Δ Wage for w/h.	.452	.831**
	(.305)	(.336)
_cons	2.24	3.887*
	(1.443)	(2.033)
Obs.,	224	367
R-squared	.168	.217
Pavitt Dummy	YES	YES
Time Dummy	YES	YES
Manufacturing Dummy	YES	YES
Country Dummy	YES	YES

Standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

Source: author elaboration

Note: Q stands for share. Δ stands for compound average growth rate

The growth rate of lagged profit is a core component in low-tech industries to finance capital accumulation, while it is not significant in high-tech industries. This may suggest that, remarkably, low-tech industries needed previous high profits to perform investment decisions. There seems to be a different role of investments in the process of technological change across high-tech and low-tech sectors, as in the result of Evangelista (1999). Indeed, while process innovation is positively correlated in low-tech industries to investment growth, it has a negative impact in high-tech. The opposite is true for product innovation, which positively affects investments in high-tech sectors and negatively in low tech. Although only the negative effect of product innovation in low-tech industries is statistically significant, these results may imply interesting issues. In low-tech sectors, where cost competitiveness is the primary growth strategy, investments are strictly linked with the acquisition of embodied technological capital and intermediate goods to reduce production costs and reorganize production. While there is a trade-off between product innovation and capital investment. Contrastingly, in high-tech sectors, product innovation and technological competitiveness positively affect investments growth. This may indicate that expansion of fixed assets and capitals across high-tech sectors is linked with the need to increase productive structure fed by introducing new products and services. Process innovation, instead, is negatively correlated with investment across these industries. Additionally, the strong and positive significance of the coefficient related to wage growth across low-tech industries suggests a consistent use of investment to pursue labour-saving strategies, while the coefficient is not significant in high-tech.

Overall, this analysis confirms some interesting issues regarding the relevance of lagged profits in the process of capital accumulation performed by industries and the different role investment in the innovation process across industries belonging to diverse technological trajectories. (i) Lagged profits are a fundamental source to enlarge gross fixed capital across industries and is particularly relevant in low-tech industries. (ii) There seems to be a trade-off between product innovation and capital investments, witnessing the relevance of cost and technological competitiveness strategies. However, in high-tech industries, investments may support the expansion of productive capacity boosted by introducing innovative products and services. Conversely, in low-tech, investments fuels process innovation and cost competitiveness. (iii) Investment growth is higher in the industries in which capital compensation grows more, indicating the labour-substituting nature of the capital accumulation. However, this relationship in our data holds mainly for low-tech industries.

5.2 The results of "virtuous cycle" model

Table 7 presents the results from the simultaneous equation model using the three Stage Least Squares model. In our model, cost and technological competitiveness strategies drive profits accumulation. The first is performed by industries through wages reduction, the rise of the number of unstable workers, and capital investments. The second is proxied by the introduction of product innovations, which is supported by R&D expenditures per employee.

Additionally, previous profits are a fundamental source to shape a new cycle of accumulation. Indeed, they finance both growth strategies, supporting product innovations and investments growth. However, these growth trajectories have different economic outcomes. Product innovation increased with the stock of disembodied knowledge available, measured as R&D expenditure per employee and by the share of workers with high education, driving technological-oriented competitiveness. Conversely, investments are fostered by process innovation and the growth of wages per employee, shaping labour-saving processes to reduce production costs. Moreover, investments are negatively correlated with product innovations, indicating an inverse relationship between capital accumulation and disembodied technological change and technological oriented growth strategy.

The result seems to support this theoretical framework. Regarding the profit equation, productivity gains and a higher share of product innovation positively and significantly impact profits growth. Besides the positive and strong coefficient estimated, capital investments are not significative in the

simultaneous model. Wage per employee growth has a negative but not statistically significant effect on profits in this model.
Regarding product innovation and investment equation, an increase in lagged profits has a substantial positive impact on both. Regarding the former equation, the lagged stock of workers with high educational attainments and R&D expenditure per employee raise the share of the product innovation introduced by industries. Concerning the latter equation, process innovation positively affects the growth of investments in fixed capital, even if it is not statically significant. This suggests a straight connection between capital accumulation and cost competitiveness strategy. Instead, the negative and significative coefficient of the product innovation over the growth rate of investments witnesses an inverse relationship between the decision to introduce product innovations and to perform investments in the sample. This mirror the fact that capital investments are a substitute to technological competitiveness strategy in most cases.

Table 7: the "virtuous cycle" 3SLS estimation results

	(1) Δ profit per emp.	(2) Q prod inn	(3) Δ Investment per emp.
Q prod inn	0.110***		-0.762***
	(0.0412)		(0.284)
Δ Investment per emp.	0.125		
	(0.442)		
Δ productivity per emp.	1.046***		
	(0.212)		
Δ Wage for w/h.	-0.0707		
	(0.216)		
Δ profit per emp., lag		7.948**	5.553***
		(3.173)	(1.364)
R&D per emp.		-0.665	
		(0.836)	
Q high-skilled workers, lag		0.227***	
		(0.0835)	
Q process inn			0.186
			(0.226)
Δ export, lag			0.0194
			(0.0515)
Constant	-2.249	6.244	9.443*
	(1.828)	(10.80)	(5.420)
Observations	521	521	521
R-squared	0.261	-15.576	-37.987
Time Dummy	YES	YES	YES
Country Dummy	YES	YES	YES
Pavitt Dummy	YES	YES	YES

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*
Source: author elaboration.
Endogenous variables: Δ profit per employee, Q product innovation, Δ investment per employee, Δ profit per employee, lag
Exogenous variables: dependent variables, included Time, Country, and Pavitt dummy.
Note: Q stands for share. Δ stands for compound average growth rate

Overall, it seems that two cycles of accumulation have been depicted. In the first, profits are driven by product innovation via technological competitiveness, incrementing disembodied knowledge and human capital, leading to a technological upgrading of the production process. In this cycle, lagged profits finance the innovative efforts undertaken by industries to introduce innovative breakthroughs,

expand or generate new markets, supply new products and services, and pursue new demand segments.
In the second cycle, profits accumulation is driven by capital investments. This cycle is grounded on cost competitiveness strategy, in which restructuring production process and capital-deepening are fed by process innovation and capital investments. However, in the simultaneous estimations, investments do not have statistical significance over the profits rise. In this accumulation pattern, process innovations and wage growth incentive capital investments, shaping dynamics of labour-saving. Additionally, we found an inverse link between product innovation and capital investments, mirroring the contrasting relationship across these two growth trajectories. Finally, lagged profits also boost this cycle of accumulation, affecting positively capital investment growth too. This result provides evidence of the consistent role of previous profits as a tool to finance capital investments and innovative expenditures, extending the Schumpeterian idea of profits as a booster of the innovative activities to the accumulation of capital as explained by Marxian insights.

5.2 The results of "virtuous cycle" model by technological classes

The interaction method allows us to test the role of investments in innovation activities according to the technological regime to which industries belong. We follow in this technique the work of Guarascio and Pianta (2017), which found consistent differences across southern and northern European countries regarding the link among international competitiveness, technological performances, and profits growth. Moreover, Lucchese and Pianta (2012) use this method to study the effect of innovation on employment by looking at the different phases of the business cycle. We divided industries between high-tech, Science-Based and Specialized-Suppliers, and low-tech, Supplier-Dominated and Scale and Information Intensive, following the Revised Pavitt taxonomy (Bogliacino and Pianta, 2010, 2016).
This exercise aims at discovering the different roles played by capital investments in the spread of technologies across sectors and in the process of technological change undertaken by industries.
Following the work of Evangelista (1999), capital investments are not only a way in which low-tech acquires technological assets and advanced intermediate goods by technological-specialized sectors to improve the production process. But, they are also a fundamental tool to technological-upgrade in some high-tech industries by complementing innovative activities.
Table 8 depict the result of the simultaneous model using interaction method across high-tech and low-tech classes. In the first and second equations presented in table 8 related to profit accumulation and product innovation, trivial differences emerge across the two groups, remarking the results of the previous estimations. The patterns evince by the third equation related to investment growth are more worthy. As in the single investment equation split by high-tech and low-tech industries, here we found different effects of product and process innovation across sectors on the dynamic of capital accumulation. A higher share of product innovation positively affects the capital investment growth rate in the high-tech group, while process innovation has a negative and significant coefficient. Conversely, product innovation has an inverse relation across low-tech industries with investment growth, which is positively related to process innovation. These patterns may hint that, across high-tech industries, product innovation and gross fixed capital investment are complementary, boosting productive capabilities and enlarging the productive structure of these industries. Instead, process

innovation within this group is negatively related to capital investments. The opposite is true in the low-tech, even if the coefficients are not statistically significant. Capital investments in low-tech industries relate to enhancing the production process but are substitutes with respect to the efforts to develop product innovations. These results are in line with the work of Evangelista (1999), witnessing the not straightforward relationship between investments and technological change in industry belonging to different technological regimes.

Table 8: the "virtuous cycle" 3SLS estimation by technological class

	Tech Class	Δ profit per emp.	Q prod inn	Δ Investment per emp.
Q prod inn	HT	0.0501**		0.157***
		(0.0241)		(0.0490)
	LT	0.0739**		-0.00176
		(0.0311)		(0.0445)
Δ Investment per emp.	HT	0.0721		
		(0.0909)		
	LT	0.0396		
		(0.0519)		
Δ product. per emp.	HT	0.766***		
		(0.171)		
	LT	0.995***		
		(0.135)		
Δ Wage for w/h.	HT	-0.0909		
		(0.273)		
	LT	0.0229		
		(0.192)		
Δ profit per emp., lag	HT		-0.0448	-0.0456
			(0.106)	(0.0718)
	LT		0.0194	0.124***
			(0.0612)	(0.0410)
R&D per emp.	HT		1.909***	
			(0.223)	
	LT		1.219***	
			(0.309)	
Q high-skilled worker, lag	HT		0.511***	
			(0.0434)	
	LT		0.495***	
			(0.0574)	
Q process inn	HT			-0.199***
				(0.0701)
	LT			0.000833
				(0.0517)
Δ export, lag	HT			0.0696
				(0.0599)
	LT			-0.0273
				(0.0517)
Constant		-1.122	9.892***	1.143
		(1.128)	(1.867)	(1.118)
Observations		521	521	521
R-squared		0.243	0.618	0.152
Time Dummy		YES	YES	YES
Country Dummy		YES	YES	YES
Manufacturing Dummy		YES	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1*
Source: author elaboration.
Endogenous variables: Δ profit per employee, Q product innovation, Δ investment per employee
Exogenous variables: dependent variables, included Time, Country, and manufacturing dummy.
Note: Q stands for share. Δ stands for compound average growth rate

6. Conclusion

Technological change and capital accumulation are key drivers of the development of capitalism, raising profits which boosts a further cycle of economic growth. The work analyses the relationship between profits, product innovation and investment across European industries by employing an integrated and systematic approach, allowing to take into account looping effects and lagged relationships among variables.

In our model profits growth is driven by productivity gains. This can be realized by two contrasting competitiveness strategies. On the one hand, the introduction of product innovations mirrors technology-related industrial growth, in which the creation of improved or sophisticated commodities or services, the search for new market segments and new consumer habits allow for increasing sales and productivity. Capital accumulation, in this framework, may support technological advancements by expanding productive capacity of innovative industries. This growth strategy may have positive or barely effects on employment, upgrading educational attainments required by labour market and leading to high-paid and good quality work (Pianta, 2020; Pinata and Reljic, 2021). Product innovation, in our framework, is explained by innovative efforts in R&D realized by industries and by the share of workers with high educational degrees, which reflects the accumulation of disembodied knowledge necessary to boost technological advancements.

On the other hand, competition on prices may sustain profits growth and productivity gains by cutting the cost of production. The reduction of wages, the expansion of fixed investments and the use of more flexible and unstable employment are the determinants of the cost competitiveness strategy. These patterns echo the classical contraposition between profits and wages (Shaikh, 2016). Process innovation and capital accumulation aiming to restructure the production process fed the labour-saving effect of technological change on employment, expanding also precarious and bad-paid jobs.

In this model, investments in fixed assets are explained by the wage dynamics, product and process innovation, and the rate of growth of export realized in the sector. Following the work of Evangelista (1999) we look beyond the "undifferentiated" view of fixed investments. Investment may be complementary to the process of innovation across sectors which combine capital-intensity and technological development. But they can be a substitute to the internal innovation activities in low-tech sectors, which acquire advanced production tools as source of disembodied technological change. Therefore, we test the hypothesis of complementarity or substitution between fixed capital investment and product innovation to explore the relationship among technological development and capital accumulation.

Furthermore, past profits are the key booster of the new development cycle. Indeed, lagged profits are the determinant of both, fixed investment and product innovation, providing financial resources to capital accumulation and innovation activities. This matter depicts the cyclical view of economic development as pointed out by Neo-Schumpeterian and Marxist analysis, in which profits are not only the motive of accumulation, but also determine the development of a new economic cycle.

The work presents some novelties respect to the existing literature. First, it studies in an integrated way the relation between profits, innovation and capital investments by using a modern econometric technique, which let to consider systematically these links. The 3SLS model, indeed, allow studying these variables as endogenously determined in the system, catching the cyclical way in which technological and capital accumulation raise profits and profits finance further development.

Second, to the best of our knowledge, this model is the first attempt to study these relationships at the industrial level, allowing us to explore the connection between investment and technological change across sectors. Furthermore, we account for the different technological trajectories of industries, by testing the model among high-tech and low-tech industries, witnessing interesting heterogeneous dynamics.
Third, many studies use R&D as a proxy for disembodied technological change (Barbieri et al., 2019; Dosi et al., 2019; Medda and Carboni, 2018). We use, instead, following the work of Bogliacino and Pianta (2013) and Spescha and Woerter (2021), the outcome of innovation activities, the introduction of product innovation as a proxy to innovation, allowing us to point out the link between the successful introduction of advanced breakthroughs in the market and capital investments.
Fourth, we expand the work of Evangelista (1999) on the link between embodied and disembodied technological change, by looking at the industries of the major European countries and connecting innovation patterns and embodied technological change with profit growth.
Results confirm the links depicted by the model enough. Profits are driven by product innovation and productivity. Moreover, they increase with the reduction of wages, mirroring the conflictual nature of the distribution as witnessed by Coveri and Pianta (2021). Product innovation is supported by past profits and R&D expenditures, which along with a higher share of educated workers are the inputs to sustain technology-oriented development. Investment growth seems to be related positively to process innovation and export. Moreover, they are higher in sectors with high wage growth, inspiring the idea of capital-deepening and labour-substitution nature of capital accumulation to halt salary dynamics. Instead, we find a negative and statistically significant relationship between capital investment and product innovation, which reflect a trade-off between innovative activities and investments in fixed assets. Lagged profits strongly support both, product innovation and investment expenditures.
Additionally, we look at the different technological trajectories undertaken by industries, by exploiting The Revised Pavitt's Taxonomy (Pianta and Bogliacino, 2010, 2016). We cluster industries according to their technological features by dividing high-tech and low-tech industries. This exercise is very useful to catch the different use of investment and embodied technological change across economic sectors. Indeed, while in high-tech industries, the introduction of product innovation is complementary to the investment in fixed assets, in low-tech industries we find a negative relationship between the two variables. In high-tech sectors investments in fixed assets are associated with technological efforts to develop new products. So, capital accumulation expands the productive capacity of the technological-oriented industries, allowing to enlarge innovative sales. Evangelista (1999) found that some very innovation-based sectors such as telecommunication, aerospace or machinery production realize high product innovation and high investments. This result aligns with the firm-level studies such as Spescha and Woerter (2021), which found that introducing new products and R&D expenditures are responsible for a subsequent rise in capital expenditures.
In contrast, in low tech-sectors, investments are found to substitute to the introduction of product innovation but seem to be positively linked to the introduction of process innovations. These matters suggest that embodied technological change, realized by the acquisition of modern vintages, machines and equipment is the principal source of technological development across these industries aiming to cost competitiveness growth. This latter is oriented to increase profits by minimizing costs of production, augmenting capital-intensity and performing labour-saving management strategies.

This evidence echoes the result of Dosi et al. (2021) that emphasised the negative impact on employment of capital investment in downstream industries.

We test the model equation by equation and in an integrated way, using a system of equations model, allowing to account for endogeneity bias and looping effect across variables. Moreover, this approach lets to consider lagged effects across variables, i.e., the effect of past profits on the growth of fixed investments and the share of product innovation introduced.

This work provides some theoretical implications. Capital accumulation is strictly linked with technological change, but investments have different effects in light of the industrial patterns. In high-tech sectors, capital accumulation and product innovation are linked to boosting technological competitiveness, which results in improved consumption dynamics, employment increases and knowledge accumulation.

In low-tech sectors, instead, capital accumulation and product innovation are negatively linked, suggesting that investments across these sectors have the role of acquiring intermediate inputs of production and advanced tools aiming to the cost competitiveness strategy. This development trajectory, actually, led to replacing capital with labour, fostering mechanization and capital-deepening of production with the negative consequences in terms of employment.

From a policy point of view, these results suggest that an undifferentiated incentive to investment in fixed assets, without considering the puzzling way in which these relate to technological industrial trajectories may be wordy. Actually, industrial policies should link investment incentives with the support for technological upgrades, particularly in low tech sectors, to shape a virtuous cycle of economic development. Moreover, financing the spread of public and private R&D activities may become a strong incentive even across technological lagged sectors to connect capital accumulation to technology-oriented growth.

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Appendix A: Tables

Table A.1: The Revised Pavitt class

List of Sectors	NACE Rev. 2 codes
SCIENCE BASED	
Manufacture of chemicals and chemical products	C20
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21
Manufacture of computer, electronic and optical products	C26
Telecommunications	J61
Computer programming, consultancy and related activities; information service activities	J62-J63
Scientific research and development	M72
SPECIALISED SUPPLIERS	
Manufacture of electrical equipment	C27
Manufacture of machinery and equipment n.e.c.	C28
Manufacture of other transport equipment	C30
Repair and installation of machinery and equipment	C33
Real estate activities	L68
Legal and accounting activities; management consultancy activities	M69-M70
Architectural and engineering activities; technical testing and analysis	M71
Advertising and market research	M73
Other professional, scientific and technical activities; veterinary activities	M74-M75
SCALE AND INFORMATION INTENSIVE	
Manufacture of paper and paper products	C17
Printing and reproduction of recorded media	C18
Manufacture of rubber and plastic products	C22
Manufacture of other non-metallic mineral products	C23
Manufacture of basic metals	C24
Manufacture of motor vehicles, trailers and semi-trailers	C29
Publishing activities	J58
Audiovisual and broadcasting activities	J59-J60
Financial service activities, except insurance and pension funding	K64
Insurance, reinsurance and pension funding, except compulsory social security	K65
Activities auxiliary to financial services and insurance activities	K66
SUPPLIER DOMINATED	
Manufacture of food products, beverages and tobacco products	C10-C12
Manufacture of textiles, wearing apparel and leather products	C13-C15
Manufacture of wood and of products of wood and cork, except furniture	C16
Manufacture of fabricated metal products, except machinery and equipment	C25
Manufacture of furniture; other manufacturing	C31-C32
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45
Wholesale trade, except of motor vehicles and motorcycles	G46
Retail trade, except of motor vehicles and motorcycles	G47
Land transport and transport via pipelines	H49
Water transport	H50
Air transport	H51
Warehousing and support activities for transportation	H52
Postal and courier activities	H53
Accommodation and food service activities	I55-I56
Administrative and support service activities	N

Source: Pianta et al., (2021)

Table A.2: the description of variables

Variable	Description
Profits	The compound average annual rate of the growth of the gross operating surplus deflated by country value-added deflators. Source OECD STAN.
Investments	The compound average annual rate of the growth gross fixed capital formation deflated by country value-added deflators. Source OECD STAN.
Productivity per employee	The compound average annual rate of growth of the value-added per hour worked. Source OECD STAN.
Distance from technological frontier	Percentage difference distance of industry labour productivity from the highest value for the same industry in the period in each country. Source: SID
Product innovation	Share of firms that significantly improved their goods and services in the observed period, regardless of any other type of innovation. Source: CIS
Process innovation	Share of firms that implemented a new or significantly improved production or delivery method in the observed period, regardless of any other type of innovation. Source: CIS
Internal expenditure in R&D	In-house research and development expenditure per employee. Source: CIS
Total expenditure in R&D	Total research and development expenditure per employee. Source: CIS
Average firm size	Average firm size is computed as the ratio between the total number of employees over the number of firms in the sector. Source: CIS
Value Added	Value added is expressed as the compound average annual growth rate deflated by country-industry specific value-added deflators. Source: OECD-STAN
Export	Exports are computed as the sum of both intermediate and final flows of goods (expressed in monetary terms) produced by that industry and directed abroad, expressed as the compound average annual growth rate. Source: WIOT
Wage per w/h	Average sectoral labour compensation per working hour is computed as compound average growth rate. Source OECD STAN
Wage per employee	Average sectoral labour compensation per employee is computed as compound average growth rate. Source OECD STAN
Non-standard work	Computed as compound average growth rate of workers who have a non-standard type of employment contract over the total number of employees. Source: EU LFS
High-skilled workers	Computed as the share of employees holding at least a bachelor's degree (ISCED 6-ISCED 8) over the total number of employees. Source: EU LFS.
Low-skilled workers	Computed as compound average growth rate of employees holding less than secondary education (ISCED 1- ISCED 3) over the total number of employees. Source: EU LFS.
Manual workers	Computed as compound average growth rate of employees in occupations ISCO8 (Plant and machine operators and assemblers) and ISCO9 (Elementary occupations). Source: EU LFS.

Source: author's elaboration

Table A.3: The list of sectors

Nr.	Sectors (NACE Rev. 2 classification)	NACE codes	Revised Pavitt class	High-tech / Low-tech
	Manufacturing sectors			
1	Manufacture of food products, beverages and tobacco products	C10-C12	SD	LT
2	Manufacture of textiles, wearing apparel and leather products	C13-C15	SD	LT
3	Manufacture of wood and of products of wood and cork, except furniture	C16	SD	LT
4	Manufacture of paper and paper products	C17	SI	LT
5	Printing and reproduction of recorded media	C18	SI	LT
6	Manufacture of chemicals and chemical products	C20	SB	HT
7	Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	SB	HT
8	Manufacture of rubber and plastic products	C22	SI	LT
9	Manufacture of other non-metallic mineral products	C23	SI	LT
10	Manufacture of basic metals	C24	SI	LT
11	Manufacture of fabricated metal products, except machinery and equipment	C25	SD	LT
12	Manufacture of computer, electronic and optical products	C26	SB	HT
13	Manufacture of electrical equipment	C27	SS	HT
14	Manufacture of machinery and equipment n.e.c.	C28	SS	HT
15	Manufacture of motor vehicles, trailers and semi-trailers	C29	SI	LT
16	Manufacture of other transport equipment	C30	SS	HT
17	Manufacture of furniture; other manufacturing	C31-C32	SD	LT
18	Repair and installation of machinery and equipment	C33	SS	HT
	Service sectors			
19	Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	SD	LT
20	Wholesale trade, except of motor vehicles and motorcycles	G46	SD	LT
21	Retail trade, except of motor vehicles and motorcycles	G47	SD	LT
22	Land transport and transport via pipelines	H49	SD	LT
23	Water transport	H50	SD	LT
24	Air transport	H51	SD	LT
25	Warehousing and support activities for transportation	H52	SD	LT
26	Postal and courier activities	H53	SD	LT
27	Accommodation and food service activities	I55-I56	SD	LT
28	Publishing activities	J58	SI	LT
29	Audiovisual and broadcasting activities	J59-J60	SI	LT
30	Telecommunications	J61	SB	HT
31	Computer programming, consultancy and related activities; information service a	J62-J63	SB	HT
32	Financial service activities, except insurance and pension funding	K64	SI	LT
33	Insurance, reinsurance and pension funding, except compulsory social security	K65	SI	LT
34	Activities auxiliary to financial services and insurance activities	K66	SI	LT
35	Real estate activities	L68	SS	HT
36	Legal and accounting activities; management consultancy activities	M69-M70	SS	HT
37	Architectural and engineering activities; technical testing and analysis	M71	SS	HT
38	Scientific research and development	M72	SB	HT
39	Advertising and market research	M73	SS	HT
40	Other professional, scientific and technical activities; veterinary activities	M74-M75	SS	HT
41	Administrative and support service activities	N	SD	LT

Source: Pianta et al., (2021)

Table A.4: The time structure of SID

	CIS 2	*CIS 3*	*CIS 4*	*CIS 7*	*CIS 9*	*CIS 10*
CIS variables	1994-1996	1998-2000	2002-2004	2008-2010	2012-2014	2014-2016
ICT investment	1996	2000	2004	2008	2012	2014
ICT intermediate inputs	x	2000	2004	2008	2012	2014
Offshoring	1996-2000	2000-2003	2003-2008	2008-2012	2012-2014	x
Unionization	1996-2000	2000-2003	2003-2008	2008-2012	2012-2014	x
Labour market variables						
***Contract type**	1996-2000	2000-2003	2003-2008	2009-2012	2012-2015	2015-2017
***ISCO**	x	2000-2003	2003-2008	2008-2010	2012-2015	2015-2017
***Education**	1996-2000	2000-2003	2003-2008	2008-2012	2012-2015	2015-2017
Economic variables	1996-2000	2000-2003	2003-2008	2008-2012	2012-2015	x
	First period	*Second period*	*Third period*	*Fourth period*	*Fifth period*	*Sixth period*

Source: Pianta et al., (2021)

Table A.5: The profit equation- other specifications

	(1) Δ profit per emp.	(2) Δ profit per emp.	(3) Δ profit per emp.	(4) Δ profit per emp.	(1) Δ profit per emp.
Q process inn	.031	.034	.042	.035	.039
	(.046)	(.049)	(.049)	(.049)	(.05)
Q product inn	.058*	.061*	.058*	.059*	.07**
	(.034)	(.034)	(.034)	(.034)	(.036)
Δ Investment per emp.	.136**	.135**	.131**	.141**	.123*
	(.066)	(.066)	(.065)	(.068)	(.072)
Δ product. per emp.	1.291***	1.304***	1.313***	1.316***	1.245***
	(.147)	(.149)	(.151)	(.152)	(.155)
Δ Wage for w/h.	-.318**	-.319**	-.301**		
	(.141)	(.144)	(.145)		
Δ unstable workers	.035	.036	.027	.036	
	(.025)	(.026)	(.028)	(.026)	
Average firm size		-.105	-.116	-.065	
		(1.106)	(1.104)	(1.118)	
Δ high-skilled workers			.041		
			(.033)		
Δ Wage per emp.				-.329*	-.093
				(.172)	(.191)
Q unstable work, first diff					-.023
					(.055)
_cons	-6.546***	-7.091***	-7.365***	-7.258***	-2.345*
	(1.796)	(1.892)	(1.924)	(1.897)	(1.314)
Observations	756	746	734	746	691
R-squared	.327	.329	.328	.328	.327
Pavitt Dummy	YES	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES	YES
Country Dummy	YES	YES	YES	YES	YES

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*
Source: author elaboration
Note: Q stands for share. Δ stands for compound average growth rate

Table A.6: The product innovation equation- other specifications

	(1)	(2)	(3)
	Q prod inn	Q prod inn	Q prod inn
Total ReD per emp.	.782***	.605***	.759***
	(.112)	(.109)	(.114)
Δ Profit per emp, lag	.111*	.134**	.134**
	(.066)	(.062)	(.065)
Average firm size	4.039***	3.295**	3.436**
	(1.281)	(1.277)	(1.353)
Tech. frontier distance		.049***	
		(.007)	
Δ VA, lag	-.385**	-.396**	-.454***
	(.162)	(.154)	(.16)
Δ low-skill workers, lag	-.057		
	(.095)		
Δ manual workers		.018	-.031
		(.054)	(.052)
_cons	30.672***	39.183***	32.631***
	(2.086)	(1.999)	(2.043)
Observations	706	631	631
R-squared	.718	.762	.734
Pavitt Dummy	YES	YES	YES
Time Dummy	YES	YES	YES
Country Dummy	YES	YES	YES

Robust standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

Source: author elaboration

Note: Q stands for share. Δ stands for compound average growth rate

Table A.7: The innovation equation- other specifications

	(1) Δ Investment per emp.	(2) Δ Investment per emp.	(3) Δ Investment per emp.
Δ profit per emp., lag	.08*	.086*	.085*
	(.042)	(.052)	(.051)
Q process inn, first diff.	.010	.049	.050
	(.045)	(.049)	(.049)
Q product inn, first diff.	-.072*	-.064*	-.067*
	(.042)	(.038)	(.037)
Δ Wage for h.	1.091***	.912***	.914***
	(.294)	(.295)	(.29)
Δ Manual workers	-.042	-.043	-.045
	(.043)	(.043)	(.043)
Δ export, lag	.009		
	(.042)		
Average firm size		-.299	
		(.926)	
Δ value-added, lag		-.309**	-.295**
		(.142)	(.136)
Δ unstable workers		.016	.011
		(.029)	(.027)
_cons	1.55	-.569	-.679
	(1.517)	(2.052)	(2.005)
Observations	458	457	466
R-squared	.209	.201	.205
Pavitt Dummy	YES	YES	YES
Time Dummy	YES	YES	YES
Country Dummy	YES	YES	YES

Robust standard errors are in parentheses

*** $p<.01$, ** $p<.05$, * $p<.1$

Source: author elaboration

Note: Q stands for share. Δ stands for compound average growth rate

Chapter 3:

The polarisation of Italian metropolitan areas between 2000-2018: structural change, technology and growth

Abstract

Large cities are a key driver of technological innovation and economic growth. This paper investigates the developments of Italian metropolitan areas, building on insights from economic geography and innovation studies. The key questions to be investigated are the following:

a) Which trajectories of population and economic change can be identified for Italian metropolitan areas? Are we facing a process of economic and technological polarisation that may worsen the country's imbalances?

b) What is the role played in such developments by technological and structural change, and in particular by digital technologies and the rise of finance?

The empirical analysis investigates the patterns of technological and economic indicators for the period 2000-2018 for 14 Italian metropolitan areas – proxied by their provinces -, providing evidence of growing polarization between Milan, where most positive developments are concentrated, and the other metropolitan zones. Rome has been losing ground in most fields; Venice and Genoa are characterised by industrial decline. Few mid-sized cities show some economic dynamism – including Bologna and Cagliari - while most southern and insular Italian cities increase their gap relative to the performances of leading metropolitan areas.

1. Introduction

This paper contributes to the literature of economic geography and innovation studies analysing the trends of population, technological and economic changes of Italian metropolitan areas from 2000 to 2018. The rise of the population in metropolitan zones shrinks the demography of the peripheries. The growth of income concentrates in large cities along with the decline of old manufacturing centres and southern and insular metropolitan zones. High-profits corporate services cluster in few places, enlarging the disparities in wealth and opportunities. Moreover, innovation activities gather in urban zones expanding geographical structural imbalances. These patterns indicate divergent growth trajectories among Italian metropolitan territories over the last two decades. Two are the features at the roots of these developments. First, knowledge-intensive services such as Finance and ICT benefit from agglomeration externalities and concentrate in large metropolitan cities (Diodato et al., 2019, Glaeser, 2020). Second, innovation activities take place in a few metropolitan hubs where the accumulation of capital, researchers and firms creates an especially innovative environment (Crescenzi et al., 2019, Moretti, 2012). These two developments created a new spatial order featured by a few rich urban agglomerations –"Superstars Cities"-, and declining territories –"places that do not matter".

Are these developments affecting also Italian metropolitan areas? Do technology and corporate services polarize among Italian metropolitan zones?

The relevance of such processes in Italy has received less attention. Viesti (2021) illustrates the divergent growth of the aggregated value-added of industry and services among Italian provinces. In particular, he emphasises the strong gap between the leading provinces and the southern ones. Moreover, he witnessed a negligible weight of market-oriented services outside of a few top areas. There is, still, scarce evidence regarding the concentration of innovation and services sector among the Italian metropolitan territories due to their recent institution in 2014. The paper will fill this gap in the literature analysing Italian metropolitan areas- proxied by their provinces- from 2000 to 2018 in terms of innovation, income, and sectoral dynamics. Policymakers created these urban zones to stress the strong linkage between the principal city and the close commuting zones regarding economic activity, social services, and labour market pooling. Italian government considered the metropolitan territories a key tool to foster the development of the entire country and guaranteed innovative governance instruments and specific resources. Italian metropolitan cities in 2016 accounted for 36,2% of the country's population, 41 % of total value added (ISTAT, 2020), and 35% of total employment (Start City, 2016).

The work finds geographical polarization in the country concerning GDP per capita and value-added growth, as well as for the sectoral composition of metropolitan economies, focusing on three key economic sectors: Financial and Insurance Services, ICT services, and the Manufacturing Industry. Likewise, we witness evidence of the polarisation of innovation activity in a few metropolitan cities. Indeed, the development of one global city and a few middle-sized metropolitan areas coexists with the decline of old manufacturing territories. The under-developed southern and insular metropolitan areas have not gained from the technological breakthroughs of the third technological revolution due to weak economic structure and scarce innovation capabilities (Viesti, 2021). These results suggest a structural divergent growth path among Italian metropolitan zones, increasing the country's geographical imbalances.

We then performed a factor and cluster analysis to grasp the evolution of Italian metropolitan areas between 2000-2018 according to economic and technological factors. We witness a process of polarisation feed by the growing relevance of the metropolitan area of Milan, where the advancements concentrate, meanwhile the other metropolitan zones achieved very barely improvements. Moreover, cluster analysis results indicate a non-substantial modification in the group formed between the two periods, mirroring the absence of a process of convergence among the Italian metropolitan economies. Instead, we found that cluster score differences enlarged in 2018, suggesting a growing polarisation between groups due to divergent growth trajectories.
The remainder of the paper proceeds as follow. Section two concentrates on the relevance of metropolitan areas from the economic point of view. Section three reviews the international literature concerning the concentration of innovation and economic dynamism in large cities as drivers of divergent regional growth. Section four reviews the main drivers of technological and economic polarisation among cities following an evolutionary point of view. Section five investigates the Italian case, with a brief survey of the country's urban structure and evolution and the definition of metropolitan cities as the focus of the analysis. Section six documents the trends of the last 18 years in key economic and technological variables – such as GDP per capita, growth of sectoral value-added and patents, exploring the links between such variables and identifying the main clusters that emerge from factor analysis exercise. Finally, section 7 will conclude by summing up the developments of Italian metropolitan areas, affecting by technological and economic polarisation.

2 The dynamics of metropolitan growth

Around the world, largest cities are the geographical centre of capitalist economic growth, fostering the accumulation process and technological development (Sassen 1991, Glaeser 2020). They hold the major portion of the population, wealth, and technologies. In advanced countries, cities and their commuting zone accommodate 55% of the total OECD population, 59% of employed, and around 60% of the total GDP in 2016 (OECD, 2018, p. 102). In European countries, metropolitan areas are home to 59% of the population and grew more than rural and small-medium cities between 2000 and 2015. In 2013, they accounted for 68% of total GDP produced and 62% of total employment (EC, 2016, p. 58).
Today, large urban agglomerations are the crucial physical infrastructure of the world economy, fostering unequal geographical development within countries (Harvey, 2018). They draw technology, capital, advanced services, and finance, providing essential intermediate inputs to spread production globally (Sassen 2018, p. 6). Knowledge-intensive services, such as corporate, financial, legal, and accounting consulting, marketing and communication, advertising, gather in large urban zones where high-skilled workers and new technologies flow (Glaeser, 2020). ICT services are deeply localised in large metropolitan centres where the demand for their functions is high. Financial industry locates in a few wealthy cities accumulating large inflows of global capital, profits, and investments (Ascani and Iammarino, 2019, Ioannou and Wójcik, 2021). The structural shift towards a service-led economy driven by information technologies and the global spread of financial markets changed the geography of production. The specialisation in services of the advanced countries, indeed, is highly correlated

with the massive growth of large metropolitan areas (OECD/EC, 2020, p. 79), fostering territorial inequality and uneven geographical development (Harvey, 2018).

On the one hand, the spread of production worldwide enlarges the demand of firms for management, control, and servicing activities that are highly clustered in metropolitan zones. Actually, these knowledge-intensive and creative occupations are still partially place-bound and hugely require face-to-face interaction and social connectivity, concentrating high-skilled workers and new technologies (Glaeser, 2020, p 7, Sassen, 2018). Market-oriented services production require a multiplicity of inputs and feedbacks from different services activities, gaining enormously from the agglomeration externalities. Moreover, the complementarity between high-tech manufacturing productions and these activities accumulates sophisticated industries in metropolitan zones (Ascani and Iammarino, 2019, Bogliacino et al., 2013, Glaeser, 2020, Gervais et al., 2021), causing increasing geographical inequality (Ehrlich and Overman, 2020).

On the other hand, information and telecommunication technologies allow remote control of factories and production globally dispersed, but require massive physical and social infrastructures, located in the cities. Indeed, alongside the global spread of the production process and the new knowledge-economy, cities and their commuting zones became core centres of the global economy, providing <<material facilities and organisational arrangements necessary for the implementation of the global network of factories, services, and markets >>(Sassen, 2018, p. 6). These technologies, indeed, require vast material structures and dense urban environments to fully develop their potential.

The geography of innovation activities is also highly urban-centred. Between 2011-13, 70% of all patent applications were granted in metropolitan areas for the 19 OECD countries (OECD, 2016, p. 92). The concentration of innovation activities in large urban agglomerations has led many authors to speak about a “concentrated dispersion” system (Crescenzi et al., 2020). The concentration of innovation activity and technologies in a few zones mirrors the structural imbalances among territories (Iammarino et al., 2018, Sassen, 2018). Technologies, capital, and wealth concentrate in some urban territories, neglecting many others. The socio-economic performances of these areas determine the development of the overall region, generating geographical disparities within high-income countries (Clark et al., 2018, Crescenzi et al., 2020, OECD/EC, 2020, Viesti, 2021, p. 139).

These patterns have led to a divergence in economic growth, skills, and life opportunity among a few “superstars cities“ and the “places that do not matter” (Kenemy and Storper, 2020, Sassen, 1991). The firsts are global trade networks, financial and economic centres, key nodes of knowledge-intensive production and players of globalisation and knowledge-economy. The seconds are “Left Behind places”, declining territories with weak economic structure and low economic growth (Crescenzi et al., 2020, Rodríguez-Pose, 2018, Viesti, 2021). This issue is known as “the great inversion”, the divergent developments that occurred since 1980 among prosper centres and declining peripheries (Iammarino et al. 2018, Kenemy and Storper, 2020, Rosés and Wolf, 2019, Viesti, 2021). These tendencies have critical socio-economic consequences boosting housing costs, skilled-bias geographical allocation of workers, uneven educational and learning opportunities between metropolitan territories and inequality within them (De la Roca and Puga, 2017, Sassen, 2018). Moreover, growing inequality makes the population of the “places that do not matter” unsatisfied of the current cycle of accumulation, increasing differences and segregation in what has been called a “new urban crisis” (Di Matteo, Mariotti, 2021, Florida, 2017, Rodríguez-Pose, 2018, Viesti, 2021).

3 . A survey of the literature

The growing territorial inequality is a leading issue of economic debates today due to its huge social, political, and economic consequences (Iammarino et al., 2018, OECD, 2018, OECD/EC, 2020, Rodríguez-Pose, 2018, Rosés and Wolf, 2019, 2021, Viesti, 2021). Rising regional concentration of income, advanced productions and skilled occupations increase the disparities within advanced countries, shrinking overall development and polarising economic growth (OECD/EC, 2020). The most profitable industries, namely knowledge-intensive services, concentrate in large metropolitan zones, fostering regional imbalances (Sassen, 2018, Viesti, 2020). These patterns, moreover, augment geographical and socio-economic gaps, such as in the access to basic services, in the accumulation of human capital, in job and learning opportunities, leading to the resurgence of regional cleavages (Rodríguez-Pose, 2018).

Since 1980 wealthier regions grew more than others, engendering huge structural imbalances among territories in Europe (Iammarino et al., 2018, Rosés and Wolf, 2019, 2021). These features also involve many advanced countries outside Europe. Between 2000 and 2018, the territorial gaps in GDP per capita among small regions (TL3) constantly increased in all OECD countries (OECD, 2020, p. 54). Moreover, the concentration of technological productions in a few growing regions deeply modify the demography of territories (Moretti, 2012). Leading regions attract talents, accumulating a young and educated population. In contrast, poorer regions suffer from an outflow population, affecting by a concerning demographic dynamic (Iammarino et al., 2018, Viesti, 2021).

These results are particularly striking in light of the convergence occurred from 1950 to the second half of the 1970s, suggesting a massive shift of long-run development path. The reversal trajectory has led many authors to speak about a process of "great inversion" (Iammarino et al., 2018, Kenemy and Storper, 2020, Viesti, 2021). The inversion regards the shift from a period of regional convergence in growth towards an increasing uneven development that arose since the 1980s. Top regions gather the advances in demography, technological productions, and wealth. Rural and small regions grow less than the national average and increase their gap with the leading territories. Old manufacturing areas are declining, suffering from high unemployment and a negative demographic balance (Iammarino et al., 2018, Viesti, 2021). The economic structure of these territories highly ground on low-technological productions and low-wages occupations, causing massive emigration of young and high-skilled workers. This, in turn, enlarges structural imbalances and aggravate territorial inequality.

The geographical distribution of innovative activities is also territorially polarised, leading to a system of "concentrated dispersion" (Crescenzi et al., 2020). The new technological poles born in Eastern countries changed the geography of innovation. But, these innovative hubs draw in specialised metropolitan areas more connected with the global network of knowledge-users such as global firms, multinational enterprises, and other innovative hubs than home countries (Sassen, 2018, Crescenzi et al., 2020). Hence, the geography of innovation activity reflects the concentration of wealth creation, soaring disparities in life and learning opportunities among territories (Crescenzi et al., 2020). These patterns occurred due to the progress of the service-led economy and information technologies that allow the diffusion of production globally but hugely concentrate core technologies and servicing activities in leading metropolitan centres (Sassen, 2018). Also, innovation activity today is increasingly related to a scale of intermediates services and strictly linked with headquarters of these productions. Moreover, especially in the services sector, complementarity between inputs, speed, and complexity of information exchange in the production increase the tendency to concentrate in some places innovation activity. These zones gather wealth, innovative activities, and profitable industries, causing rising territorial inequality (Rosés and Wolf, 2021 Sassen, 2018, Viesti, 2021). In the following sections, we review, without exhaustivity, literature concerning these patterns and the role of the large metropolitan areas in such developments.

3.1 The concentration of innovative activities in urban areas

Innovative activities are highly polarised in urban hotspots. In almost all OECD countries, private R&D expenditure is higher in capital regions than in the rest of the country (OECD, 2018, p. 34). The polarisation of innovative activities is more evident analysing patents filed. In some countries, the interregional difference between the most innovative regions and the last ones in the number of filed patents is very large, as in Finland, Netherlands, and the US. In others, like Germany and Italy, the difference is very slight.

Metropolitan zones are where most inventions occur (Balland et al., 2020, Crescenzi et al., 2020, Florida et al., 2017, OECD, 2016). Between 2011-13, metropolitan areas granted 70% of all patent applications in OECD countries (OECD, 2016). This matter is more evident in East Asia and North America and less heighten in Europe where, however, metropolitan territories also account for a large part of total patents filed. Indeed, in Norway and Italy, the countries with the lowest weight of patents filed by metropolitan areas in Europe, they still account for around 40% of the total patents. Moreover, metropolitan territories specialise in the development of technologies of leading economic sectors (OECD, 2016, Sassen, 2018). In 2013, 41% of patents granted in the OECD metropolitan areas were in the ICT sector, followed by health care (15%), environment (9%), biotechnology (6%) and nanotechnology (1%) (OECD, 2016, p. 94).

Crescenzi et al. (2020) draw the geographical distribution of innovation as a global system of localised hotspots around the world, more connected among them than with the home country. Indeed, notwithstanding the spread of innovative hubs globally, particularly in Eastern countries, the diffusion of innovative activities localises in few functional and specialised areas, largely metropolitan, without relevant gains for other regions of the home country (Bottazzi and Peri, 2003). This has led the authors to speak about a "concentrated dispersion" system concerning the geography of innovation. Indeed, from 2016 to 2020, just five regions account for 35% of global patent filing and the top region for 10 % (Crescenzi et al., 2020, p. 18).

Graph 1.B in the appendix mirrors the divergent global patterns in innovation among regions and is explicative for many reasons. First, among the top forty patenters between 1990-1994, the most come from advanced countries, and among the first top ten around the world, nine come from the US and Europe, with the only exception of Southern-Kanto from Japan. If we compare this evidence with the 2010s in the second graph, the spatial shift is consistent. In the second figure, Southern-Kanto overcomes California, and Guangdong prominently becomes the second patenters around the world. Overall, the geographical distribution witnesses the massive jump of the Asian economies in terms of technology capabilities. Second, this data reflects the intense concentration of innovation among a few connected global hotspots worldwide. Indeed, the last regions have a very significant difference in patenting activity with respect to leaders, and the concentration of patents among the five core regions is very outstanding. The third worthy matter regards the declining role of the historical manufacturing hub in favour of the rise of the IT producers.

Many are the evidence of these patterns for the US (Florida et al., 2017, Glaeser, 2011). Balland et al. (2020) contend that the concentration of economic activities in large urban agglomerations increases with the complexity of economic processes. In particular, complex technological patents – measured by the number of newer technologies utilised- are hugely correlated with increasing population density and concentrates in large metropolitan agglomerations. So, cities become the coordination platforms to accumulate dispersed complex knowledge facilitating input matching and innovation productivity. The correlation increases with the complexity of the technologies. Moreover, they show that the increasing concentration of patents in large cities peaked after the third industrial revolution, with ICT development. These patterns, in turn, has led to a new spatial distribution where highly complex and digital innovations are more concentrated in cities and less complex increasing dispersed. These results align with the descriptive analysis of Forman and Goldfarb (2020), which witnessed an increasing concentration of patents among US counties from 1970 to 2010, especially in the computer and communication class.

These results contrast with the finding of Fritsch and Wyrwich (2021). They examine the concentration of patents in large metropolitan areas, with more than 1,5 million inhabitants, among a selected sample of advanced and developing countries finding no systematic evidence of increasing concentration. Indeed, the authors highlight the strong heterogeneity in the sample in terms of the share of metropolitan patents. While the concentration of patents in major metropolitan areas of some countries, such as the US and Korea, is high, other countries, such as Italy and Poland, have low concentrations. Moreover, heterogeneity appears also analysing the trends from 2000 to 2015. In some countries, the intensity of innovative activities in large agglomeration slightly increases; in others, it decreases, without suggesting a general pattern. So that, they conclude:<< the rather pronounced heterogeneity across countries suggests that the largest metropolitan areas do not necessarily host a more than proportional share of innovative activity and that the largest agglomerations did not increase in importance over the 2000 to 2015 period>> (Fritsch and Wyrwich, 2021 p. 5). However, these results may hold for the largest metropolitan area, with more than 1,5 million inhabitants, not for all types of metropolitan areas. The choice of this type of urban zones could tend to overestimate the weight of metropolitan patents for countries with large cities, such as the US, or with an intense concentration of population in one area, such as Finland or Korea, and underestimate the weight for many European countries, where cities are generally smaller, and medium-size metropolitan territories are the backbone of the urban geography (Crescenzi et al., 2020). This choice is more relevant in the case of Italy, a country that holds many small and medium-sized urban zones. However, the authors also recognised the substantial weight of large metropolitan territories in patenting activity, ranging from about 20% to 80% in the sample. According to the data of the work, for example, in Italy, just four metropolitan territories accounted for 22% of the total patents in 2015.

3.2 The concentration of economic activities in metropolitan areas

There is a positive relationship between economic growth and urbanisation (OECD/EC, 2020, p. 75). Countries with high income, indeed, has a larger share of metropolitan population. Metropolitan territories gather economic growth, technological advancements along with a positive demographic dynamic fostering overall country development (OECD/EC, 2020). Metropolitan areas -urban areas with a population greater than 500.000- in OECD countries accounted for 55% of the total OECD population, 59% of the employed, and around 60% of the total GDP in 2018 (OECD, 2020, p. 54). In Europe, they held 68% of total GDP produced and 62% of total employment in 2013 (EC, 2016, p. 58). These areas have grown faster than the rest of the country since the turn of the new millennium (OECD, 2020, p. 54). Urban territories represent the backbone of the country's economic development nowadays, concentrating the most profitable industries, technological breakthroughs, and a larger population share. However, the concentration of economic activities in these few large agglomerations is widening territorial disparities. The largest metropolitan territories grow more in GDP per capita (OECD, 2020) and population (OECD, 2018) than other urban zones, causing growing geographical polarisation within countries (Kenemy and Storper, 2020, Sassen, 2018, Viesti, 2021).

The share of metropolitan population is a crucial determinant of inter-regional disparities. According to OECD/EC (2020), between 1990-2015, regions with a wider metropolitan population in 1990 grew more in GDP per capita than country average and other regions. On the contrary, regions with a lower share of metropolitan population growth less than the country's average. This is more true for EU and OECD countries, where, in 2015, a 1% rise in GDP per capita is associated with a 0.48% increase in the share of the metropolitan population in the region (OECD/EC, 2020, p. 89). These results suggest a kind of path dependency in the trajectory of regional development. Regions with dense metropolitan areas in 1990 were more productive and created a better environment for technological productions and productivity. This, in turn, determines a comparative advantage, attracting more capital, resources and qualified workers, exacerbating inequality and structural divergence among territories.

According to Ehrlich and Overman (2020), disparities among European metropolitan areas have increased since 2005. The authors measured the coefficient of the variation-the ratio of the standard deviation to the mean- of GDP per capita for 226 European metros. The coefficient falls from 1980 to 2000, suggesting a lower level of dispersion in the regional distribution of income. After that period, however, imbalances stagnate until 2005 and then start to rise. These patterns are also evinced by a regression analysis of the GDP per capita growth rate respect to its initial level. For the period 1995-2015, they reported significant evidence of mean-reversion from the convergence period and a clear divergent trajectory for 2005-2015. According to Kenemy and Storper (2020), these findings hold accounting for consumer price differences. They adjust nominal GPD for housing costs to take into account geographical price level imbalances. Their results confirm the diverging growth among US metropolitan territories by the middle of the 1980s.

The distribution of the metropolitan population also affects intra-regional imbalances. Indeed, an equal distribution of metropolitan cities among regions may guarantee a more equal distribution of wealth. On the contrary, an unbalanced metropolitan system may enlarge inter-regional disparities. OECD/EC (2020, p. 87) compared the percentage difference in GDP per capita of leading metropolitan regions to the least ones in the respective country, with the share of the metropolitan population in the region for two groups: the first composed by high-income and low-income countries, and the second by middle-income countries. Income gap among the top and least metropolitan regions enlarged as the metropolitan population increase for both groups.

These developments have led many authors to speak about a new <<urban crisis>><(Florida, 2017). On the one hand, "Superstar Cities", large, rich urban agglomerations, part of the global network of

trade and financial transactions, specialised in high-profitable corporate services and finance, where young and talented workers flow, prosper. But, on the other hand, "lagging behind" places: medium-small cities, old manufacturing poles, and rural areas are affected by weak economic structure, high unemployment, demographic decline, and overall socio-economic performances fall. These patterns deeply enlarge territorial polarisation and geographical inequality in life and learning opportunities exacerbating structural imbalances among territories (de la Roca and Puga, 2017).
What are the roots of these developments? Structural changes have deeply affected the global value chains since the 1980s. The shift from industrial-led growth to a service-led economy driven by market-oriented facilities and the global spread of financial markets has hugely changed the geography of production. Indeed, large cities in advanced countries are today platforms for the production of leading servicing industries. Metropolitan growth, indeed, is ground on corporate and entertainment services feeding by growing companies and consumers demand (OECD/EC, 2020, p. 79, Sassen, 2018, Viesti, 2021). Complex economic activities- such as knowledge-intensive services that require multiple and instantaneous inputs- massive gain from strong agglomeration and network externalities (Balland et al., 2021). In addition, the development and use of information technologies entail physical infrastructure and material arrangements that hugely are based in large cities (Sassen, 2018). So that, large urban agglomeration become the central hotspot of the world-economy linking servicing industries localised in the cities, such as finance, legal and corporate consulting, software development, data management for firms, to the global value chains, and specialising in entertainment and consumption facilities for households.

3.3 The territorial disparities among European regions

Rosés and Wolf (2021) analyse the long-run development of European regions from 1900 to 2015. They found an intense period of sigma-convergence -the dispersion of GDP per capita over the mean- from 1950 to the second half of the 1970s. After that period, the convergence has fallen and then flattened until 2000, when started a new phase of divergence. Moreover, the estimates of beta-convergence reveal fuzzy features. They regress the growth rate of GDP per capita to its initial level in 1900. The region with a lower initial GDP per capita level should grow more than richer to achieve some level of convergence. Their findings show that a strong beta-convergence occurred in the early post-war period, but the correlation since 1980 has become very flat. According to the authors, the root of the growing divergence since 1980 in Europe and the US is the concentration of economic activity -measured throughout a Herfindahl index of GDP- due <<to strong growth in densely populated metropolitan areas>>(Rosés and Wolf, 2021, p. 42).
Iammarino et al. (2018) divided European regions into four groups according to their GDP per head respect to the EU average to study regional inequality. They witnessed for the period from 2000 to 2014 a very divergent development in population, employment and productivity of regions according to the gradient of income. The wealthier regions, hosting large cities, grow more than poorer, and the poorest group declines in many economic and demographic indicators, suggesting a strong ongoing territorial polarisation. Moreover, the weight of sectoral employment to GDP indicates structural imbalances among groups. On the one hand, economic growth localises in high-tech manufacturing production and service specialised areas, where the patenting activity is high. On the other hand, regions with routine-based productions have low patenting activity and falling employment due to the decreasing weight of the manufacturing industry in the economy. These results indicate a strong

heterogeneity in the recent regional developments in the EU, posing <<the regional question at the heart of Europe economic future>> (Iammarino et al., 2018, p. 279).
Viesti (2021, ch. 4) investigated the long period patterns of inequality of the twentieth century - measured by Theil index- for many European countries. Despite the peculiarity of each country and the historical matters that determine each specific development, he recognised some common features. Regional inequality in most European countries declines after the second world conflict until the 1970s. However, this trend has stopped around the last twenty years of the century, and since 2000, territorial disparities have enlarged again.
At the beginning of the twenty-century regional disparities were high in many countries, but they declined between the world conflicts, with the only exception of Italy. Early industrialisation initially increased regional divergences, but then, the diffusion of manufacturing productions to the continental and Mediterranean countries boosted overall growth (Viesti, 2021). After the IIWW, between 1950 and 1980, the territorial inequality among European regions declines everywhere. According to the author, the spread of technological production, strong public mission-oriented policies, and the diffusion of essential public services fostered economic growth and reduced territorial disparities. However, after the 1980s, the convergence ceased until the new century, when gaps widened in many territories.
These authors recognised as drivers of these developments the growing relevance of the metropolitan areas and their crucial role for economic development (Iammarino et al., 2018, OECD/EC, 2020, Viesti, p. 138, Rosés and Wolf, 2021, p. 42). This is due to the strong role assumed by market-oriented services and information technologies since the 1980s. The structural shift to the services economy and the vast scale application of digital and information technologies in the production process feeds the concentration of economic activities in large cities and capitals along with a decreasing weight of small and middle town and rural zones.

4. Technology and structural change as drivers of growth

Innovation is the root of economic growth. Indeed, historically, advanced economies have developed technological novelties and applied them to the production process to increase productivity, minimise the cost of production, augment output. Since the first industrial revolution, cities and regions where technological breakthroughs localised had grown much more than other places, engaging in positive development trajectories. The development process has not been even, but it has moved faster in some places, slowly in others, and it has been completely absent in still others. Material and social progress of the recent economic history affected some regions overlooking others, revealing different geographical configurations for each technological long waves of development. Each industrial revolution, rooted in a set of clustered innovations, shaped its own economic geography. Some regions and cities gathered technological advancements, wealth, and industrial sites. Others are empty of the fundamental economic structure to foster development. These patterns mirror the uneven geographical development of capitalism in the last few centuries (Harvey, 2018).
A long economic tradition tried to explain the source of innovation and its impact on society without a clear-cut conclusion. What is clear is that innovation activity is the main source of technological change, the shift from a production technique to another that ensures better outcomes. Once that the

shift from one production technique to a better one is generalised among economic sectors, far-reaching consequences occur in terms of economic structure. Technological change deeply affects the path of development of the economy, modifying the industrial structure. Indeed, once that technological change is diffused among the economy, the sectors able to use the new technologies attract employment and investment, new skills are required to the workers, profits in these industries are higher and new top firms emerge as the core source of economic growth.

In contrast, sectors with lower productivity become obsolete, wages decline, and unemployment rise, firms bust, and outmoded production processes become out of the market (Freeman, Louçã, 2001). However, technological change is a complex and socially embedded activity influenced by historical and social dynamics rather than a straightforward process. Indeed, many factors affect its outcome: institutional framework, market power, demand patterns, and labour market regulation deeply determine how innovation affects the economy (Pasinetti 1981, Pianta 2020).

In addition, technological change is not evenly spread geographically among countries, regions and city, but reshape the economic geography of its own time, generating new spatial orders. Some places have comparative advantages and economic structures able to capture better the gains of the breakthroughs and shape a virtuous cycle of growth. Others lagging behind and have not been able to catch up with technological frontiers. As well as evolutionary economics pointed out, even structural change is a path-dependent process where << previous technological or organisational endowments have a strong role in shaping subsequent capture or creation innovation>> (Crescenzi et al., p. 18, Nelson and Winter, 1982). Therefore, in each long growth cycle rooted in new innovative technologies, some places perform better than others, creating a divergent development path. It is the law of capitalistic economic development (Harvey, 2018). Instrumental in this view is the concept of National Innovation System (NIS) (Freeman, 2987, Lundvall, 2010, Nelson, 1993), the set of public and private institutions, heterogeneous individual, clusters and networks, investments and strategies, that together drive innovation of countries and regions towards distinctive pathways of specialisation. As Pianta (2020, p. 10) noted, indeed: <<The process of structural change, with countries' different abilities to contract declining industries and expand production and employment in emerging ones, plays a major role in explaining employment performances. Better outcomes are found in countries with greater activity in sectors with fast-growing (at the world level) demand and output and with greater ability to reshape their economic structures. Worse outcomes are found where a larger part of employment is in industries more exposed to the negative impact of labour-saving technological change and globalisation and where more rigidities exist in the economic structure>>. These dynamics, in turn, generate massive transformation in terms of social and work relationships and power mechanisms, shaping the long-period economic trajectory.

The analysis of the long-run growth dynamics reveals cyclical patterns of burn and boost driven by the major Industrial Revolutions enduring 50-60 years, where phases of surges alternate periods of breakdown (Freeman and Louçã, 2001). These recurrent dynamics are known as "Long Waves": periods of sustained growth of production, capital accumulation and trade lasting about 25 –30 years followed by periods of slow or stagnating growth of a similar extent. Analogous variations also affect prices and other monetary variables (Reati, 2014). Each long wave starts with a core cluster of innovations that <<transform the way of producing and living and generate specific physical systems, each related to a concrete form of work, management and use of capital>> (Louçã, 2019: 5). Indeed, every industrial revolution is rooted in a "technological paradigm" (Dosi, 1982, Freeman and Louçã, 2001, Perez, 2002), a constellation of radical and incremental innovations that change the production process structurally. Each "technological paradigm" constitutes a new spatial configuration of economic production, favouring the movement of capital and labour towards someplace. This reconfiguration fosters the development of some areas, such as occurred in the last two decades in the Silicon Valley and the leading financial centres, where wealth, innovations and advanced sectors crowded and made obsolete the industrial structure of other zones, as many old manufacturing centres today. These movements reshape the geography of wealth and production. The diffusion and the complete employment of the new technological paradigm required 30-40 years, and the contrast with the preference for routines in the society creates a process of turbulent adjustment. In the meaning of the diffusion period, institutional framework, labour market regulation, accumulation mechanism, and world power hierarchy need to change suddenly, and these adjustments generate the ground for increasing turbulence in the society.

4.1 Structural change and territorial dynamics in the first two industrial revolution

The first Industrial Revolution of the late 18th century was based on the water-powered mechanisation of the industry and the extensive innovations in the use of iron and coal for the production process that made great the British empire and spread throughout ships cotton-raw manufacturing products around the world. In this period, manufacturing cities became the most productive economic forces, and big plants in growing centres captured the increasing supply of labour deriving from agriculture. The tendency towards the spatial concentration of capital to gain from the agglomeration externalities gather in large, big cities, industrial plants, a vast mass of workers, raw materials and physical infrastructure reshaping the geography of the cities, that become the "workshop of capitalist production" (Harvey, 2018). The first industrialisation process occurred hand in hand with urbanisation and the growth of the big industrial towns. This period established a deep hierarchy among a few industrialised and crowded places, like Manchester in the UK and some cities around the world (Crescenzi et al., 2020). The concentration of the productive structure around a few industrial centres worldwide enlarges the geographical disparities among territories. Moreover, increasing investment in transportation and infrastructure to allow an easier circulation of raw materials and final commodities for trade increased the dichotomy between industrialised urban centres and rural zones.

The second industrial revolution was an intense period of economic and social transformation that occurred between the late 19th and the early 20th century. It was shaped by a large number of innovations in the electronic-mechanical branches with the extensive use of steam and oil, the golden age of the chemical industries and the diffusion of railways across the world that profoundly affected the production process and the entire society. Electric equipment, heavy chemical, and engineering industries quickly became the productivity leaders, and manufacturing production developed into the leading sector of the economy in terms of employment and productivity. The consistent cut of transportation costs reduced the "tyranny of distance" (Glaeser, 2020, p. 5). The tendency of the accumulation process to cut production costs dispersed industrial productions in many overlooked territories, spreading the population towards middle cities and suburbs (Harvey, 2018). Improvements in transportation for both people and raw materials, the spread of scientific knowledge, the diffusion of standardised production methods, the low cost of wages and houses, and new unexplored markets attract investment and industrial productions. The assembly line encouraged the mass shift of unskilled workers from agriculture to the manufacturing industry in many advanced countries, and economic growth allowed the rise of both low-skills and high-skills wages until the 1970s. The second industrialisation was a wide-ranging process affecting the geography of advanced countries deeply. Vertically integrated firms co-locate in sectoral specialised productive clusters to capture input-output externalities, gaining from easy access to customers, suppliers, and knowledge spillovers (Diodato et al., 2018, Marshall, 1920). These centrifugal forces boosted the employment toward medium and small sectoral specialised districts, where local-embedded knowledge prompted the widening industrialisation of European territories. In this phase, the governments made a considerable effort in the diffusion of essential services and core industrial productions. Alongside the direct control of enterprises in strategic economic sectors, a significant effort in industrial strategies, economic planning, and a vast plan of infrastructure constructions, were made in all western countries. These efforts also contributed to the geographical spread of production into provincial territories (Viesti, 2021). The cities were, for the most, administrative centres and the infrastructural node of the transportation system for trade and commerce. Meanwhile, innovation took place in the manufacturing industry or in national research units.

4.2 Information technologies and metropolitan growth

The last industrial revolution occurred around 1970, boosted by the diffusion of Information and Communication Technologies (ICT). The advent of the Intel microprocessor in 1972 spread the computerisation of the economy, the diffusion of sectors as Informatic, telecommunication, software, biotechnology, and financial engineering as leading innovative branches. To capture the strength of these changes, we can see how much the sectoral composition of the top ten patenters changes in the US from 1975, concentrating on Information Technologies.
Table A.1 in the appendix reports the top ten US patenters by five years for the US since 1976. According to Forman and Goldfarb (2020), between 1976 and 1981, just two of the top ten patenters in the US specialised in information technologies. In less than forty years, in 2010, seven of the ten are defined by the "Computer and Communication Technology" category, and one of the remaining three produces computer memory commodities. These changes mirror the central role of Information Technologies in the current long cycle of accumulation and the concentration of the activity of R&D in this branch. Quickly, ICTs deeply affected the entire mode of production of the economy and moved a large part of the skilled labour supply in these more productive and remunerative sectors (Pianta 2020).
Indeed, notwithstanding the global dispersal of production, the service and financial sectors gather in large cities, where also capital, income, labour, and technological breakthroughs concentrate. These patterns are changing again the geography of production, in which Global Cities today constitutes infrastructural nodes (Sassen, 2018). These urban zones can be defined as: node of global knowledge and trade networks, with a combination of economic and technological resources, leaders in the supply of financial and business services, host of headquarters of multinational enterprises, with an open and multicultural mindset in term of social and political attitudes able to influence the regional and global trajectory of development (Iammarino et al., 2018). Indeed, knowledge-intensive services have become the backbone of the growth of many leading metropolitan areas such as London and Milan, San Francisco, and New York, specialising in the supply of services such as R&D, marketing, telecommunication and computer services, scientific and technical consulting, accounting, and

financial and insurance advice (Glaeser, 2020). The service-led economy, alongside the globalisation of productions and the fragmentation of the value chains, deepened the agglomeration toward a few big and interconnected cities worldwide, strengthening the spatial polarisation of wealth, skills, and innovation activity. What does explain these matters?

The rise of cities as strategic economic places is the effect of a deep structural transformation affecting developed economies. At the roots of the new urban geography and the prominent role of the cities, there is since the mid-1980s an increasing demand for market-oriented specialised services and financial transactions that require a huge amount of physical and social arrangements, which are localised in large urban agglomerations (Sassen, 2018). The concentration of high-tech production in big cities is the result, on the one hand, of the globalisation of production, the spreading of factories, offices, and the fragmentation of the value chains that feed the demand for financial advice and specialised services. On the other hand, the increasing need for management and control functions through information technologies has contributed to a strategic role for certain major cities. The production of these intermediate services indeed involves a multiplicity of inputs that massively require the concentration of these industries in large cities making the production process partly place-bound and localised in large urban agglomerations (Glaeser, 2020, Sassen, 2018). Despite the possibility for a customer to be located everywhere, the production of these services entails a huge amount of complementarity among different producers, social connection, fast exchange of information among experts, face-to-face communication among workers, labour pooling of high-skilled and talented workers, a vast amount of physical infrastructures, and capital, that feed their concentration in few major cities. Also, from the side of household consumption and entertainment, the massive growth of service intermediation for many activities -such as buying food or flowers- accrues the concentration of these industries. In addition, time is a crucial component in the production process of these industries, where a few seconds can determine a relevant change in the result of a financial transaction or in the management of an affiliate in a foreign country. The need to foster the speed of the production feeds the concentration of these sectors in the downtown of large cities. The combination of high complexity and the speed of economic transactions has created new forces for the agglomeration of high-tech services and finance in large urban agglomerations, becoming the platforms for producing these sectors. According to Sassen (2018. p. 35), global cities in the new geography of production become the material infrastructure of the world economy, performing three core functions summarised in the following points:

(1) The function of command and coordination. Cities gained a strategic role in the current phase of the world economy due to the combination of geographic dispersal of economic activities, economic globalisation, and the rise of global financial transactions. They become the centres of command-and-control functions, where high complex managerial functions, the specialised financial and consulting services, localise to manage the dispersal of production. For this reason, headquarter complex tasks of management, top financial and services industries, gathered together in these places, gaining from the proximity of other specialised service producers.

(2) Cities are post-industrial production sites for the leading industries of this period—finance and specialised services. Global cities worldwide specialise in certain types of services and markets, becoming strategic global inputs to these industries. They are the place where complex social and physical facilities and capital gather, overcoming the enormous amount of

investment needed to realise these material infrastructures. In addition, innovative social environment, labour market pooling, and technological hyperconnection make cities a core production site for these industries.

(3) Cities are transnational marketplaces where firms and governments from all over the world can buy financial instruments and specialised services. Thus, there is not only one Global City, but each specialises in a niche of these activities, according to their history and recent development, attracting flows of a determined type of capital in a growing global division of labour. Hierarchical division of labour also occurs at the geographical level, with some cities performing this role at the regional scale.

In the next section, we will highlight two of the most prominent mechanisms that increased the relevance of cities in the world economy. The first is the rise of financial transactions and financial weight in the management of all industries. The second is the increasing demand for specialised services from all production processes, fostered by the worldwide fragmentation of production. Together these matters contribute to the concentration of these sectors in the cities.

4.2.1 The new metropolitan economy: finance and business services

The diffusion of ICT goes hand in hand with the expansion of the financial sector and the rise of market-oriented services as leading economic industries (Sassen, 2018). ICT technologies indeed revolutionise the communication concept, definitively breaking the barrier of distance.

Despite the diffusion of ICT technologies and the massive fall in transportation costs that these technologies entails, enhancing enormously the possibility of interaction without physical constraints, the third industrial revolution was a centripetal era inspired by the return to the big cities (Iammarino et al., 2018, Glaeser, 2020). Metropolitan areas have become the backbone of the country's growth, enormously concentrating market-oriented services and financial industry (Sassen, 2018). Nowadays, leading metropolitan areas are sectoral specialised financial and services producers attracting capital, technologies, and high-skilled workers.

Two processes are determinants in the concentration of leading profitable sectors in the cities nowadays, which become the strategic infrastructures of the global economy. These interconnected developments started in the mid-1980s, alongside the sharp rise of financial weight in the economies, the growth of the service sector and the spread of globalisation boosted by the development of information technologies.

First, ICT technologies enormously enhanced capital mobility, increasing both the volume and the geographical spread of global financial transactions (Sassen, 2018). Since the 1980s financial sector has grown massively, becoming a leading economic sector in many developed economies. The possibility of instantaneous and electronic financial exchanges, along with a massive increment of financial innovations and the development of new financial institutions, boosted the volume of financial profits, becoming among the most profitable economic industry (Vercelli, 2018). Financial motives also become a consistent part of the management of non-listed enterprises working on different businesses, feeding the demand for financial services worldwide through the increasing practices of inter-firm financial loans, banking lends, and a large number of mergers and acquisitions (Duménil and Lévy, 2004, Lapavitsas, 2013). The shareholder maximisation principle to enlarge the short-run value of dividends and equities turns into a managerial strategy for the US enterprises and many OECD countries (Forges Davanzati et al., 2019, Lazonick and O'Sullivan, 2000). The global spread of production also increases the volume of financial transactions through the massive growth of foreign direct investments and the rise of financial transactions between intermediaries of multinational corporations. The diffusion of a new form of financial investments with collateral of each type attached, such as raw materials, agricultural commodities, housing, and student loans, are examples of the vast amount of financial exchanges that today strongly overcome the volume of material trade (Sassen, 2018). The sharp rise of financial transactions consistently increases the geographical spread of this market, involving new local financial markets and new investors worldwide. More than a dispersion of regional financial markets, many authors witnessed an increasing integration of local financial markets into the global network of a few financial centres. In sum, the growing spatial dimension and the number of financial exchanges went hand in hand with the concentration in ownership and location of these markets around a few global places.

Indeed, the integration of local and regional financial markets into the global financial system boosts the centralisation of the financial industry in the network of leading global centres. The number of major banks of the top three countries had increased from 2009 to 2016, strengthening the power of the US, China, and Japan. The concentration in financial transactions is witnessed by the growing importance of a few leading stock markets worldwide. These reveal, then, a disproportionate concentration of worldwide capitalisation in a few cities and of national capitalisation typically in one city in each country (Sassen, 2018, p. 37), as the case of Milan in Italy suggest.

Second, the growing service intensity in the organisation of all production processes feeds the role of corporate services within advanced urban economies. The spread of economic productions worldwide has contributed to the massive growth in the demand for services by firms in all industries. The global dispersion of production sites, the offshoring of many physical productions, rather than make obsoletes the cities, increase their strategic role as command-and-control sites of the global economy, where new essential intermediate, high specialised, corporate services are produced. The fragmentation of economic productions along with the increasing complexity and volume of international transactions feed the demand for services across all geographical dimensions -global, national, or regional- that is nowadays a consistent part of the management of any material productions. Firms need to centralise the control, management, and organisation functions demanding intermediates knowledge-intensive services of all sorts. Firms use more legal, financial, advertising, consulting, accounting, transport, communications, and security services, among the others, whatever in manufacturing, wholesale distribution, entertainment, or consumer industries. Hence, today Cities are a core marketplace for services for firms, becoming essential infrastructures to organise and control the production in the global economy (Sassen, 2018).

These services are the backbone of urban economies since they facilitate adjustments to the economic cycle, develop a mechanism that organises and optimises economic exchange, facilitate the complex management of economic activities, allow the diffusion in the space of economic activity. The service production-complex gathers in the global cities, where enterprises are able to take advantage of the sectoral variety of the interactions and capture horizontal knowledge spillovers that make these places among the prominent innovation centres (Diodato et al., 2019, Duraton and Puga, 2004, Jacobs, 1970). All the production of these services, even if they can be located everywhere, disproportionally concentrates in costly and crowded cities. The growing complexity, diversity, and specialisation of the services make their production more efficient in specialised clusters. Actually, these complex productions require the proximity of multiple simultaneous inputs and feedback of other specialised services, especially in the leading and most innovative sectors of these industries (Sassen, 2018).

Moreover, despite the process of tertiarisation of the economy, many empirical works show the complementarity between advanced manufacturing productions and services. The demand of manufacturing industries for the most innovative and knowledge-intensive business services stimulates a virtuous cycle of <<growth of output, employment, and international competitiveness both within the tertiary sector and in user manufacturing industries >> (Ascani and Iammarino, 2018, p. 1587, Bogliacino et al., 2013; Evangelista et al., 2013). For these reasons, recent contributions tried to overcome the classic contraposition between vertical and sectoral specialised externalities (Marshall, 1920) and horizontal intra-sectoral knowledge spillovers (Jacobs, 1970) with the more blurred concepts of "functional specialisation"(Gervais et al., 2021). These authors contend that many global cities specialise in some corporate activities such as R&D, engineering, financial services, legal and advertising, software, and hardware assistance, which are highly complementary in the production process with a wide range of economic sectors. Economies of scale in the third industrial revolution built on functional specialised clusters, where firms innovate using related technologies involving many different sectoral inputs (Crescenzi et al., 2020). This process, in turn, boosts the overall agglomeration tendency and the concentration of high-skilled workers and innovation activities in a few global centres (O'Sullivan and Strange, 2018; Iammarino and McCann, 2018).

This contradiction between diminishing cost of interaction and tradable services and the increasing role of few top global cities shaped structural patterns of polarisation of per capita income, wages, social mobility, and technological trajectories exacerbating spatial divergence among these growing centres and lagged behind territories, overlooked by the global economy.

The complementarity between the manufacturing industry and services, particularly for knowledge-intensive service, fosters the concentration of high-tech sectors in global cities (Glaeser, 2020). This pattern of co-agglomeration strengthens the advantage position of top regions, where also international players, like multinational enterprises, accrue capital inflows and polarise regional economic structure (Ascani and Iammarino, 2018)

5. The Analysis of Italian metropolitan areas

Metropolitan areas are high-density urban territories with strong integration in economic activities, essential services, social life, cultural relations, and territorial features (art. 22, law n. 267/2000). These zones act as a strategic hub for the development of the territories, involving functional and economic integration of the municipalities that encompass. They ground on their provincial territories (law n. 65/2014), which includes 1278 municipalities, 16% of the country, accounting for 15,4% of the Italian territory. Figure 1 show the geographical settlement of Italian metropolitan areas.

Figure 1: the geographical settlement of Italian metropolitan areas

Source: Vinci (2019). Notes: The figure depicts the institutional boundaries of the 14 Italian metropolitan areas. In dark grey, the perimeters of the 20 regions.

Italian metropolitan areas are crucial zone for the development of the overall national economy, holding 36,2% of the country's population, 41 % of total value added (ISTAT, 2020), 35% of total employment in 2016, and accounting also for the large share of innovative patents applications (Start City, 2016). These data mirror the huge impact of metropolitan economies on the overall country's

development. Table A.2 in the appendix lists the Italian metropolitan areas according to the average population over the sample period and territorial macro-areas, witnessing the equal geographical distribution of these zones between Centre-North and South-Islands.
Instead, the population average depicts some sample heterogeneity, ranging from metropolitan zones with 250.000 to 4 million inhabitants. The four most populated metropolitan areas are home to more than 2 million inhabitants, and, among them, only Naples is in the South. The most populated, Rome, has a population average near to 4 million. Three big urban agglomerations of Southern and Insular Italy follow the first group, holding more than 1 million dwellers over the period. After these, a group of three middle-size Northern metropolitan cities, core places of the manufacturing productions of the last century, accommodates between 700.000 and 900.000 inhabitants. Then the smaller metropolitan cities, with a population between 500.000 and 700.000, include three southern and insular metropolitan zones. Overall, just the first three metropolitan territories, Rome, Milan and Naples, account for 17% of the country's population in 2016, underlining the crucial weight of the metropolitan territories (Istat, 2020). The creation of Italian metropolitan areas, which occurred through law number 56 in 2014, followed a long fuzzy debate. According to the constitutive law, these urban types emphasise the strong linkage between the principal city and the close commuting zones regarding economic activity, social services, and labour market pooling. In the eye of the legislators, metropolitan territories should be the key players of "the strategic development of territories" (art. 1, law 56/2014), ensuring the competitiveness of cities, enlarging networking and innovative spillovers in the territories, attracting foreign investments and advanced technological productions, but also guaranteeing social cohesion and the even geographical development (Longo and Mobilio, 2016, Vetritto, 2019).
In sum, the metropolitan territories are the places where high value-added and innovative productions, digital infrastructures, and the leading economic sectors concentrate on fostering the country's productivity (Vetritto, 2019).
To achieve these ambitious outcomes, 56/2014 law assigns innovative governance structure to metropolitan cities. The mayor of metropolitan cities is the mayor of the principal city. Along with the metropolitan mayor, two forms of collegial assembly were created to guarantee territorial governance representativeness. First, with many deliberative functions, the Metropolitan council is an indirect elective assembly where metropolitan mayors and town council members can be elected. Second, the Metropolitan Conference, composed by all metropolitan mayors, should promote territorial representativeness and guarantee the collaboration of the local authorities. According to Pioletti and Soriani (2016), the creation of these urban forms of governance in Italy is different from the other European experiences. Informal ed integrated model of metropolitan governances in other countries, such as the Netherlands, takes place over time after an intense process of networking and cooperation among big and small municipalities around strategic issues of the territories. Despite the process of formal institutionalisation, as occurred for France and Germany metropolitan territories, foreign experiences of urban metropolitan governances are not the result of the top-down process but the sum of the strategic planning and legal and material infrastructures able to foster the functional and connected governance of the territories linking together a plurality of social and economic stakeholders (Pioletti and Soriani, 2016).
The creation of Italian metropolitan areas instead seems to result from the coalescence of the old province territories. This initial deficiency created heterogeneity in the development of metropolitan areas, determining two relevant issues. The first regard the effective application of innovative

metropolitan governance. Only a virtuous minority adopted innovative strategic planning of the territories, such as Bologna, where the metropolitan conference acquired legislative power. However, many of them have not been able to implement the collegial governance inspired by the law 56/2014 conserving with slight modification the governance adopted by the old provinces (Longo and Mobilio, 2016). The second matter regards the scarce adherence of the functional dimension of metropolitan territories with their administrative local units. As Istat (2014, 2017) maintains, the functional partition of territories is fundamental to grasp the socio-economic developments of the local economies. The creation of the metropolitan cities, however, has neglected the functional boundaries of territories indicated, resulting in a fuzzy adherence between the legal-political metropolitan territory and the actual integrated area. In some cases, this has led to a political-administrative unit that boundaries and governance contain geographical areas with different socio-economic dynamics.

5.1 The territorial unit of analysis

Another issue regards the statistical analysis of Italian metropolitan areas. In this work, we follow the legislative definition of Italian metropolitan areas, considering the political-administrative local boundaries of the old provincial areas as a unit of measurement to proxy metropolitan territories. We recognise the limitation of such an approach that may underrate the functional dimension of these territories, including zones with different economic and social integration. This choice is due to the aim of the analysis. We provide evidence upon the recent development of the "effective" metropolitan territories, affected by polarisation of economic activities and growing territorial imbalances among leading cities and lagging behind zones. These elements should revive the debate on Italian urban growth, suggesting economic policies oriented to a more even geographical development and placed-based programs to support lagging behind territories. So that, the metropolitan cities, as local units, has the material and immaterial facilities to implement effective strategies and measure their impact on the local economy.

Moreover, the statistical measurement of urban zones is a matter nothing short of remarkable. Often, the administrative boundaries of the urban zones do not fit with the effective economic and social integration of these territories. Indeed, many statistical measures of the urban area consider the commuting flows to account for the overall relationship among municipalities (Istat, 2017, Dijkstra et al., 2019). This approach is useful to grasp the effective interconnections between municipalities reflecting the functional integration of the territories. This matter is particularly crucial in the classification of metropolitan territories, which by definition involve a vast urban area with large governance facilities. National and international institutions adopted various approaches to cluster cities and their commuting zones. In table A.3 in the appendix, we review the definition and the methodology of the Functional Urban Areas, elaborated by OECD-Eurostat (Dijkstra et al., 2019, OECD, 2012) and Local Labour System, individuated by Istat (2014, 2017).

On the one hand, the definition of OECD (2012), updated and harmonised with EU institution and Eurostat by Dijkstra et al. (2019), identifies 74 functional urban areas and 13 metropolitan cities in Italy. The city and their commuting zones form the Functional Urban Areas according to a people-based target of population density and commuting flow towards the core urban centre. Metropolitan regions are NUTS level 3 approximations of Functional Urban Areas with at least 250000 inhabitants. This approach tries to connect the morphology of the urban territory (population density), their

governance (local unit), and the socio-economic features (commuting flows) starting from the distribution of population in the grid (Dijkstra et al., 2019). The principal discrepancy with the Italian definition concerns the metropolitan area of Reggio Calabria, which is excluded by the OECD and Eurostat databases.
On the other hand, many analyses on the Italian urban system, such as Accetturo et al. (2019), Lamorgese and Petrella (2019), Viesti (2021), ground on the Local Labour Systems defined by Istat (2012), that differs respect OECD's definition in the methodology adopted to cluster areas. Local Labor Systems are territorial units whose boundaries are defined using the flows of daily home/work travel according to specific criteria of the demand and supply of work, regardless of the administrative articulation of the territory (Istat, 2017).
The main differences between the two approaches are the following. Functional Urban Areas are clustered starting from a population grid according to a resident density. They include only the most developed urban areas and consider exclusively the commuting inflows towards the major urban centre. Moreover, they tend to be identified according to the closer local unit, connecting morphological and functional features of the territories with their political institutions.
Local Labour System, instead, denote the overall geographical extension of the country, analysing the integration among territories throughout the reciprocal commuting flows of each municipality. In this way, they overcome the administrative boundaries focusing on the areas' socio-economic dynamics.
Our analysis proxies metropolitan cities with their province territories, creating a new dataset from many sources. There are several reasons for this choice. First, the Local Labour System accentuates too much the labour market element and, in particular, the role of the workplace. These statistical units are very useful to evince the territories' industrial structure, study the local labour market and the overall socio-economic dynamics, but do not refer to the political-administrative unit. Therefore, they are a less suitable tool for operative economic policy (Istat, 2014). Second, metropolitan cities, gathering material and immaterial infrastructures, became hubs for the broad territorial development fostering local innovation and widespread territorial entrepreneurship. So that, provincial data can better capture the overall economic performance of these territories. Moreover, principal cities often draw cultural and social services, such as health, universities, and cultural amenities, becoming strategic centres for more people than commuters. All in all, this paper aims to provide novel evidence on the ongoing structural polarisation in the recent developments of Italian metropolitan areas, encouraging a policy approach inspired by a balanced geographical urban growth. Hence, considering the economic performances of the "effective" metropolitan territories can shed light on the current disparities and suggest local-based operative policies. So that, political-administrative governance is required to implement programs and measure their effects.
Finally, excluding less developed places as Reggio Calabria, a metropolitan territory in one of the more impoverished southern regions, with strong regional relevance for economic and social matters, may bias the analysis towards a sample of leading territories unable to capture the Italian geographical deficiencies.
Notwithstanding the discrepancy in the definition of statistical units, it should be noted that differences in practice are not so wide. For example, in Viesti (2021, p. 185), among the leading Local Labour System appear twelve metropolitan territories that are also component of the 21 Italian "principal urban areas" individuated by Istat (2017). In addition, the only absence of Reggio Calabria in Eurostat and OECD datasets differs from our list of Italian metropolitan areas. Finally, Istat's report

(2020) maintains the dynamism of all metropolitan cities among urban types and their vast relevance for the country.

In table 1, we define the list of variables and the sources of the data collected to analyse the economic developments of Italian metropolitan areas, their economic structure and their innovation performances using patenting activity as a proxy. We compute the compounded annual growth rate between 2000-2018 of population, productivity, GDP per capita and technological indicators such as patent grants and applications. We also compute the average share and the growth rate of value-added for three key economic sectors: ICT Services, Financial and Insurance Services and the manufacturing industry. These sectors, suggested by the literature, are considered to show how metropolitan economies modified their economic structure in the last two decades. Indeed, we expect that top metropolitan economies have a larger share of financial, insurance and ICT services. Meanwhile, their weight in lagging metropolitan economies should be minor.

Table 1: Description of variables

name	Metadata	Source
Population rate of change	Compound annual growth rate of population 2002-2018	ISTAT- Ricostruzione intercensuaria della popolazione residente, 1991-2001, 2002-2019
Growth rate GDP per capita	Compound annual growth rate of GDP per capita	ISTAT-Conti economici territoriali- valori pro capite
Growth rate productivity	Compound annual growth rate of productivity	ISTAT-Conti economici territoriali- valori pro capite
Growth rate value-added	Compound annual growth rate of total value-added	ISTAT-Conti economici territoriali- Valore aggiunto per branca di attività (Nace Rev. 2- one digit)
Manufacturing value-added average share	Manufacturing value-added average share over the period	ISTAT-Conti economici territoriali- Valore aggiunto per branca di attività (Nace Rev, 2)
Manufacturing growth rate	Compound annual growth rate of Manufacturing value-added 2000-2018	ISTAT-Conti economici territoriali- Valore aggiunto per branca di attività (Nace Rev.2- one digit)
Financial and Insurance Services value-added share	Fin. and Insurance value-added average share over the period	ISTAT-Conti economici territoriali- Valore aggiunto per branca di attività (Nace Rev, 2)
Growth rate Financial and Insurance Services	Compound annual growth rate of Fin. and Insurance value-added 2000-2018	ISTAT-Conti economici territoriali- Valore aggiunto per branca di attività (Nace Rev.2 – one digit)
ICT Services value-added average	ICT value-added average share over the period	ISTAT-Conti economici territoriali- Valore aggiunto per branca di attività (Nace Rev, 2)
ICT Services growth rate	Compound annual growth rate of ICT value-added 2000-2018	ISTAT-Conti economici territoriali- Valore aggiunto per branca di attività (Nace Rev, 2)
Patent applications/grants ratio	Number of patent applications/grants for 100000 inhabitants	UIBM- Ufficio Italiano Brevetti e Marchi- I numeri della proprietà intellettuale
Patent grants/applications rate of change	Compound annual growth rate of patent grants/applications over the period of the number of patents for 100000 inhabitants	UIBM- Ufficio Italiano Brevetti e Marchi- I numeri della proprietà intellettuale
Mobile banking services users	mobile banking services users for one thousand inhabitants	Banca d'Italia- Base dati Statistica-Servizi di home e corporate banking: numero di utenti

Source: author's elaboration. Notes: the table describes the list of variables computed in this paper, their description and their sources.

5.2 Italian urban system: small and medium-size dispersed cities

Two historical features characterise the Italian urban system. First, the size of the cities is smaller compared to other European countries. Second, Italian economic geography is affected by historical territorial imbalances among Centre-North and South and Island macro areas. In this section, we are going to discuss the literature about the determinants of the small size of the Italian Urban system. In the next, we are presenting the evolution of the Italian urban system in light of the development waves of the country.

Notwithstanding the weight of metropolitan areas in Italy's economy, the metropolitan population is lower than the other European countries (Accetturo et al., 2019). The population living in the biggest urban agglomeration, the urban primacy, is comparable only with Germany, around 7%, but lower than Spain, France, and the UK. The difference is less pronounced considering the population living in most eight urban agglomerations, but the share of the Italian metropolitan population is still.

The small and medium size of the Italian cities, often distant from another, may affect the productivity of the urban system and the contribution to the country's growth (Frick and Rodríguez-Pose 2018, Accetturo et al., 2019, Viesti, 2021). Therefore, many analyses tried to indagate the causes of the tiny size of Italian urban zones, stressing geographical characteristics, historical and political matters.

Geographical features may explain between 30% and 50% of the size of Italian cities (Accetturo and Mocetti, 2019). Locational fundamentals may have had a decisive role in the first phase of urbanisation, concentrating population in small villages, due to the geomorphologic composition of the territory, but the weight of these factors on the urban growth, in the long run, declined (Accetturo et al., 2019). Thus, economic motives have become the principal source of population migration.

Many explanations are ground on historical contingencies. Accetturo et al. (2018) show that pirate attacks of the 19th century pushed the population to inner areas, mainly mountainous, where morphology and resources determined the growth of small centres. This happened mainly in the South, where the local economy was based on subsistence agriculture, and land endowments determined the diffusion of small centres. Pirate attacks, moreover, shrink the population of urban primacy, leading residents to move toward more impervious places. According to the counterfactual simulation exercise of the authors, without threats, in 1951, urban primacy would have been a half percentage point more. In the Centre-North, military conflicts among European regions may have had affected the development of large urban centres, smoothing the population towards smaller towns to escape from army assaults (Dincecco and Onorato, 2016).

Political fragmentation also played an important role in the size of the Italian urban system. Cervellati et al. (2018) estimate a correlation between the size of the country and the growth of cities' population, finding a positive correlation. Italian political history is characterised by strong political fragmentation. The diffusion of a multiplicity of regional states until the XIX century, often in conflict among them, curbed the expansion of their cities with respect to other countries with older unitary history determining a smaller dimension of cities. Moreover, the federal tradition of governance of the Italian state, along with strong regional cleavages, may have supported the spread of economic activities among local territories, favouring the formation of middle-urban centres (Fritsch and Wyrwich, 2021). Despite the complementarity of many of these analyses, more research is needed to understand the determinants of the smaller size of Italian cities compared with other similar countries.

5.3 The recent evolution of the Italian urban system

The recent evolution of the Italian urban system mirrors the waves of economic development of the country marked by historical imbalances among Centre-North and South and Islands macro-zones. Overall, between 1951-2011 there has been a shift of population from tiny to bigger urban zones and from non-urban to urban territories (Accetturo et al., 2018). This, however, happened more in the Centre-North, where cities enlarged, absorbing close small towns, and the demographic trend witnessed a positive dynamic supported by foreign and southern immigrant inflow (Lamorgese and Petrella, 2019).

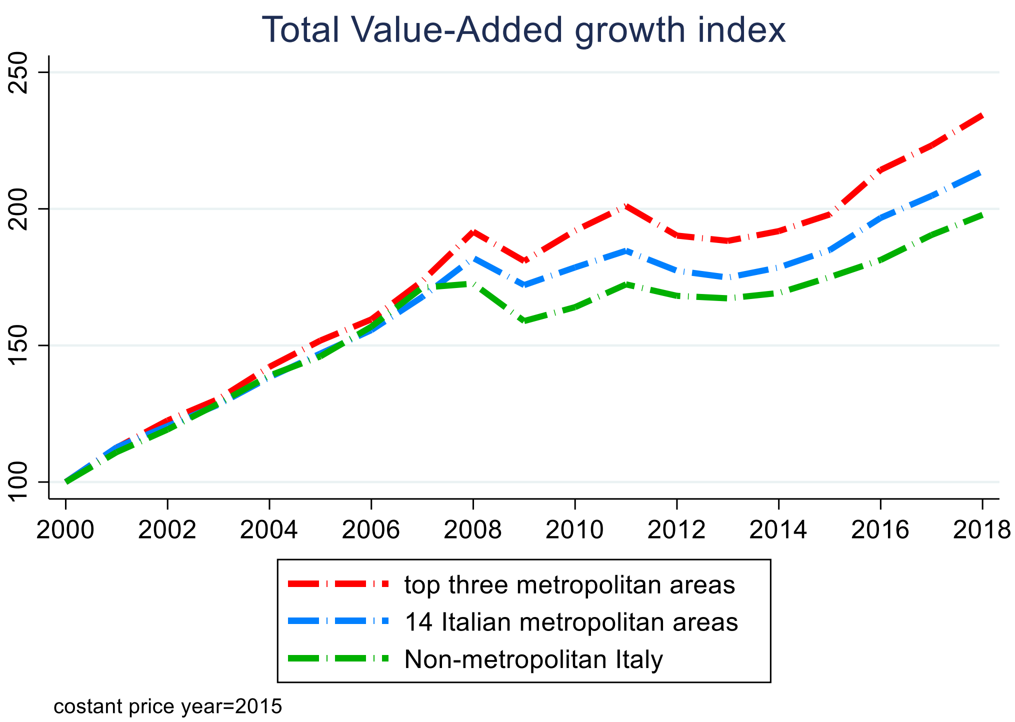
During the 1950s and 1960s, populations moved toward large industrial agglomerations and bigger cities growth more than small and intermediate centres in all the country (Accetturo and Mocetti, 2019). These flows result from a huge process of structural change in the Italian economy (Viesti, 2021). The vast spread of manufacturing industries in the central and northern regions attracted young workers from the South. These flows enlarged the population of industrial cities where large plants were localised. In the South, the massive shift from agriculture to manufacturing and public services occupations increased the population of the cities. These patterns changed the urban geography of the country, moving the population from rural to urban zones and from the southern regions to large manufacturing poles (Accetturo and Mocetti, 2019, Viesti, 2021, p 50).

Instead, from the 1970s to the turn of the century, middle-size cities attracted relatively more population than large centres. With the development of small specialised industrial clusters, the spread of industrialisation to provincial territories fostered small and medium towns growth (Becattini, 2003). The diffusion of manufacturing productions to peripherical territories supported the growth of many local economies that had not been industrialised yet in what has been called "third Italy". These experiences involved mainly the North and Centre, where geographical proximity with advanced productive structures sustained local entrepreneurship and the diffusion of specialised production networks. In the South, a weak economic structure, along with the absence of internal demand and the increasing international competition, curbed the diffusion of the industrial districts (Viesti, 2021). However, these matters occurred along with the declining weight of manufacturing employment and the advent of services and digital technologies as a source of economic growth, leading some authors to speak about a phase of "tardive industrialisation".

At the turn of the century, the increasing concentration of technologies and servicing productions in large cities changed Italian economic geography again, generating new deep imbalances between declining peripheries and large metropolitan agglomerations. From 2006 to 2018 population grew more in the larger urban zones than in the smaller ones (Viesti, 2021, p. 185). Italian metropolitan areas became the most dynamic area of the country in terms of value-added, advanced productions and population share (ISTAT, 2020). Non all metropolitan cities, however, gained from the new knowledge-economy based on market-oriented services and knowledge-intensive productions.

Figure 2 shows the polarization of economic production across the country and between metropolitan territories due to the concentration of the major advancements in value-added in the top three metropolitan areas.

Figure 2: the value-added polarisation



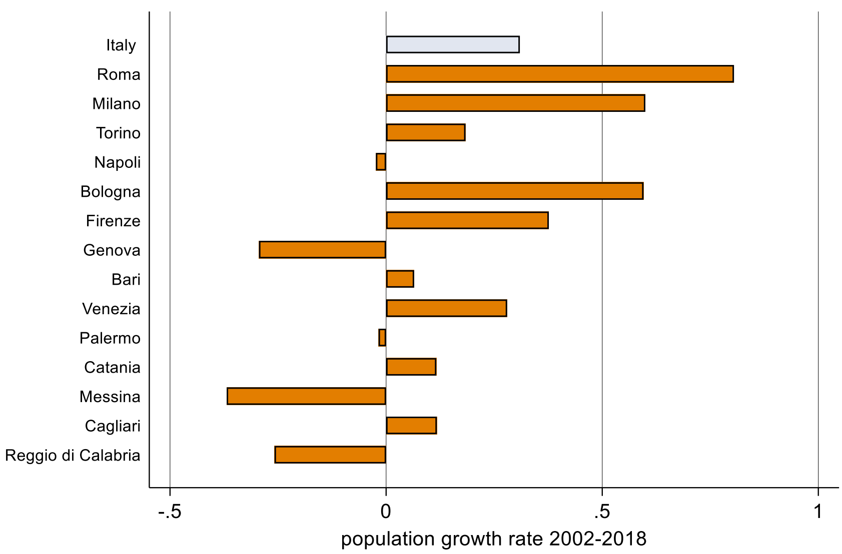
Source: author's elaboration on ISTAT data. Note: the graph depicts the growth index of total value-added. We compute the growth index dividing each year by its value in 2000, the base year, times 100. We compute this index for the top three Italian metropolitan areas- for all the period Milan, Rome and Turin-, for all the 14 Italian metropolitan areas, and for the rest of the country, the non-metropolitan Italy. For the latter, we subtract the metropolitan value-added to the country's total value-added.

We calculate the value-added growth index starting from 2000 for the top three Italian metropolitan areas, for the 14 metropolitan areas and for the non-metropolitan Italy. For each zone, we sum the value-added and calculate the growth index dividing each year by its value in 2000, the base year, times 100 at constant price. The value-added of the top three metropolitan areas- the red line in the graph- growth along with the other zones of the country until 2007, when it started to diverge, rising more than in the overall metropolitan areas and in non-metropolitan territories. Since 2007 indeed, the value-added in the top three metropolitan areas increased more than in the overall fourteen Italian metropolitan areas- the light blue line-, increasing divergence among metropolitan territories. Between 2008-2009 it decreased less than in the overall metropolitan and non-metropolitan Italy and quickly recovered to a higher level in 2010-2011. The gap across the top three metropolitan areas and the rest of metropolitan Italy slightly deepened in 2015 due to a further increase of the three leading metropolitan areas value-added and a slower growth of the overall metropolitan areas, mirroring the ongoing process of structural divergence.

The gap is even more stronger with the non-metropolitan Italy -the green line-, signed by a deep fall in 2007 and a slow recovery of its level reached only in 2015. Since 2015 it has been enlarging due to the rapid growth of the leading metropolitan zones and a weakly growth of the non-metropolitan territories. Between 2008-2015 non-metropolitan Italy value-added declined meanwhile the top three

metropolitan areas increased economic production, overcoming its level of 2008. These developments deepened the difference between the leading three metropolitan territories and the non-metropolitan Italy, affected by a huge drop and slower growth.
Differences also evince between the fourteen metropolitan areas and the non-metropolitan Italy. Metropolitan territories since 2007 grew more than non-metropolitan and enlarged the difference in 2015, triggered by a more intense increment of the former. These patterns show the country's growing territorial disparities since 2007, signed by a rapid growth of the top three metropolitan zones along with a modest increase of the overall metropolitan areas and a slower development of the non-metropolitan territories. These divergent growth trajectories accrue the geographical imbalances of the countries, augmenting the gap between economic centres and lagging peripheries. Thus, a new territorial configuration emerged featuring economic polarization within metropolitan areas and between metropolitan and non-metropolitan Italy.
Moreover, structural differences of recent growth trajectories reflect historical territorial disparities of the country. We witness a concentration of population, income, and technological productions in centre-northern metropolitan areas, while southern and insular metropolitan zones lagging-behind. These developments may exacerbate territorial inequalities polarising wealth, employment structure and life opportunities in the country. For this reason, we divided metropolitan cities into two groups according to macro-territorial localisation.
Figure 3 shows the growth rate of the population between 2002-2018. The population grew more in centre-northern metropolitan cities than in southern and insular, where in some cases dropped. Just three metropolitan areas, Roma, Milano, and Bologna, signed an increase of more than 0.5%. Centre-northern metropolitan cities, with the exception of Genova, increased population more or just below the country average. Instead, in all southern metropolitan areas, the population grew less than the national average, reflecting the concerning demographic trend affecting these territories (Viesti, 2021).

Figure 3: the population growth rate of Italian metropolitan areas between 2002-2018



Source: author's elaboration on ISTAT data. Note: the graph depicts for the period 2002-2018 the compound annual growth rate in percentage points of the fourteen Italian metropolitan areas compared to the country.

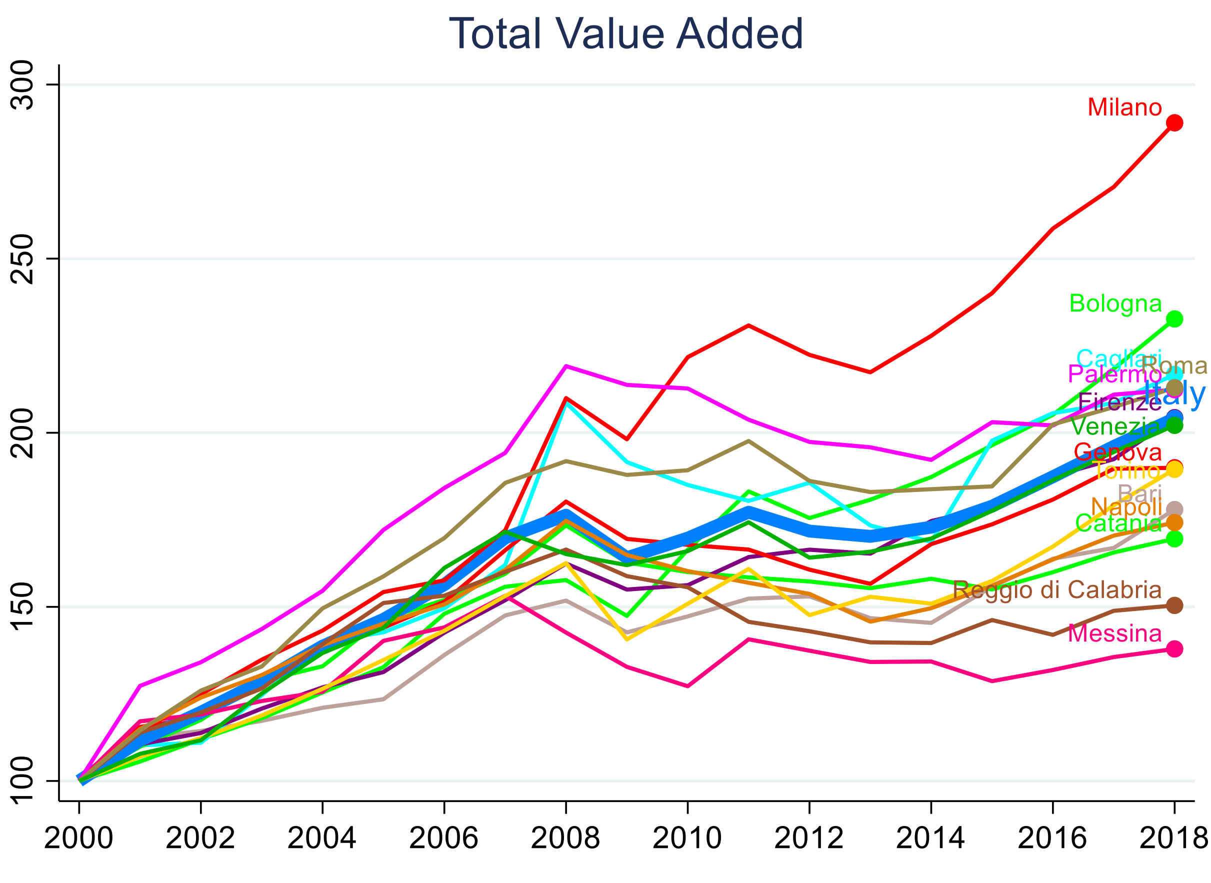
The polarisation of demography follows the GDP per capita dynamic. Figure 2.B in the appendix presents the average growth rate of GDP per capita and population for both macro-zones. In the first group, population and GDP per capita rise, driving a virtuous cycle of growth. Conversely, a lower increase of GDP per capita and declining population dynamic suggests a damaging development trajectory for the South and Islands metropolitan areas.

These results are in line with the analysis of Iammarino et al. (2018), which found a polarisation among top-income European regions, where value-added and population increase, and lagging regions, with negative demographic balance and declining economic performance. Metropolitan zones, a crucial source of the regional development in the knowledge-economy, contribute to the rising territorial polarisation, concentrating income, technologies, and advanced economic sectors. Moreover, strong heterogeneity has affected the recent development of Italian metropolitan areas. The recent diverging growth of Italian metropolitan areas seem to follow the historical macro-regional imbalances among centre-northern metropolitan zones, where population and wealth increase and southern and insular zones, affected by negative demographic balance and weaker economic structure. This trajectory may exacerbate the geographical disparities in the country, suggesting structural differences in local economies.

6. Evidence from Italian metropolitan areas

The process of structural change shaped by the third Industrial revolution- rooted in the spread of information technologies- also affected the development of Italian metropolitan areas. Their growth trajectory in the last two decades seems heterogenous, revealing a process of geographical polarisation. Territorial inequality arises between a few leading places, where income, population and technological productions concentrate, and lagging behind metropolitan zones, affected by negative demographic balance, weak economic structure and limited innovative environment, especially in the South and Islands. Figure 4 shows these developments, witnessing the polarization of economic production among Italian metropolitan areas.

Figure 4: the polarization of the value-added

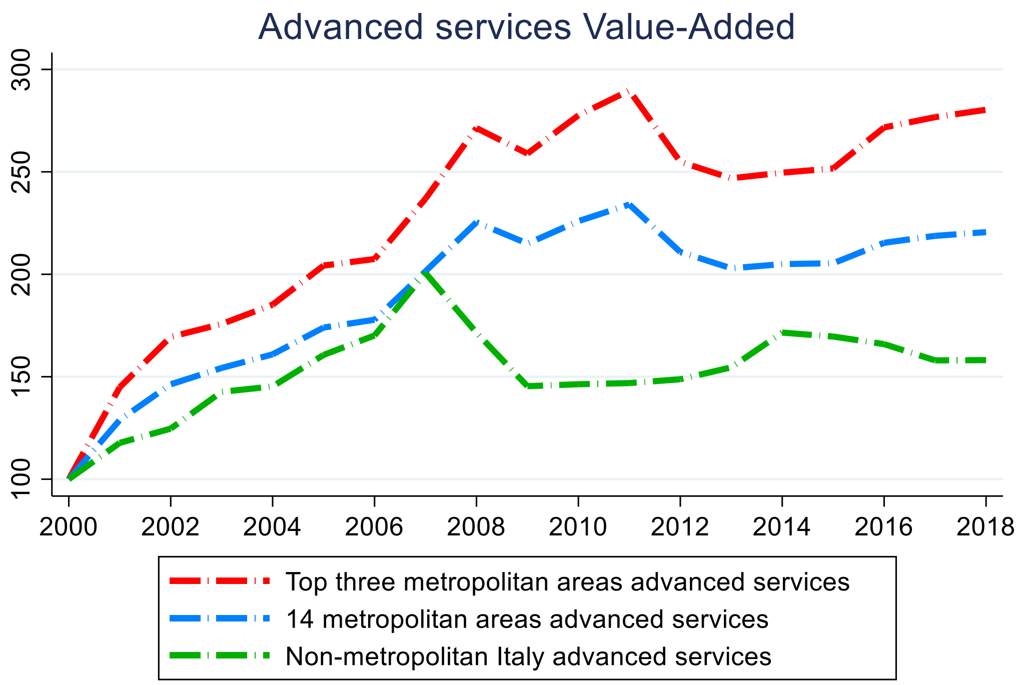


Source: author's elaboration on ISTAT data. Note: the graph depicts the growth index of total value-added of each metropolitan area and for Italy. For each metropolitan area, calculate the growth index dividing value-added of each year by its value in 2000, the base year, times 100. Prices are constant at year=2015.

We calculate the growth index of total value-added of each metropolitan area and Italy between 2000-2018. Since 2008 divergent growth has featured Italian metropolitan areas. Milan performed as the only global city in the country, disproportionately incrementing its value-added respect to the other metropolitan areas. Bologna also shows a consistent growth of its value-added; however, it never reaches the amount of value-added of the first three metropolitan areas. On the other side, many metropolitan territories, such as Messina and Reggio Calabria, declined, others, like Genova and Turin and Venice, show very modest growth since 2008, below the overall country value-added growth. These patterns witness the absence of convergence among the metropolitan zones, affected by economic polarization among the strong growth of a few territories that driven the country's growth, and a modest or stagnant development for the most, exacerbating territorial inequality across these zones.

At the root of the concentration of income and economic production in leading metropolitan zones, there is the tendency of the high-profitable advanced business services to localize in the downtown of the leading metropolitan centres to gain from the agglomeration externalities of capital, high-skilled workers, social and technological infrastructures (Sassen, 2018). This process also affects Italy. The polarization of the country in terms of advanced market-oriented services and finance feed structural divergence within metropolitan territories and between metropolitan and non-metropolitan Italy, as shown in figure 5.

Figure 5: the polarization of advanced services



Source: author's elaboration on ISTAT data. Note: the graph depicts the growth index of selected advanced service value-added. We sum the value-added of Finance and Insurance and ICT Services and calculate the growth index dividing each year by its value in 2000, the base year, times 100. We compute this index for the top three Italian metropolitan areas- for all the period Milan, Rome and Turin- , for all the 14 Italian metropolitan areas, and for the rest of the country, the non-metropolitan Italy. For the latter, we subtract the metropolitan value-added to the country's total value-added.

We calculate the growth index for selected advanced services- ICT and Financial and Insurance Services- starting from 2000 for the top three Italian metropolitan areas, for the 14 metropolitan areas and for the non-metropolitan Italy. For each zone, we sum the value-added of ICT and Financial and Insurance services and calculate the growth index dividing each year by its value in 2000, the base year, times 100 at constant price. Value-added of advanced services, the red line in the graph, in just three metropolitan areas-Milan, Turin and Rome - disproportionately raised more than in the other metropolitan areas and in the rest of the country since 2000, enlarging disparities in the territorial distribution of these highly profitable activities. Advanced service value-added in the top three metropolitan cities grew more for all the period than in the 14 Italian metropolitan areas- the light blue line- with enlarging divergence since 2016, when the distance between the two lines increased. These patterns witness the growing polarisation among the leading Italian metropolitan areas and the overall metropolitan Italy due to the concentration of these activities in a few leading places. Even more large is the gap with the rest of the country. The distance between the green line and the red line, the value-added of the non-metropolitan Italy and the three leading metropolitan zones, increased from 2000 to 2018. Particularly intense is the divergent growth after 2007, due to the fall of the green line until 2010 when started a stagnant trend. Since 2014, the gap has deepened due to the rapid growth of advanced services value-added in the top three metropolitan zones, and its decline in the non-metropolitan Italy. These developments mirror the massive polarisation of the country in terms of advanced business services as ICT and Financial and Insurance, which largely gather in just a few metropolitan areas, overlooking the other zones. The divergence between the 14 metropolitan Italy and the non-metropolitan Italy appears less intense and driven by the divergent evolution that occurred after 2008, with the consistent fall of the latter and a moderate increase of the former. After 2014 the gap is further enlarging, propelled by the decline of the advanced service value-added of the non-metropolitan Italy. This matter also witnesses the growing concentration of these activities, signing a more accentuated disparities across the three top metropolitan zones and the rest of Italy than among metropolitan and non-metropolitan zones in terms of advanced business services and finance. The huge concentration of the market-oriented services and finance in just a few top territories feeds the polarization among superstar territories, where high-technological production and knowledge-intense services take place and the other metropolitan and non-metropolitan territories, with a more traditional local economic structure and less profitable productions.

Summing up, some relevant issues emerge feeding new and old territorial inequalities.

First, the old regional imbalances among centre-northern and southern and insular metropolitan zones increased, reflecting structural differences in their local economies. The centre-northern metropolitan areas advanced more in patent application density and GDP per capita. Instead, southern and insular metropolitan cities stagnate, performing weak economic growth and scarce propensity to innovate.

These developments augment historical territorial gaps, echoing the geographical imbalances of the country. Northern metropolitan territories specialise in high-tech activities and knowledge-intensive sectors, gaining from the spread of digital technologies. In the South and Island, metropolitan economies ground on traditional productions and low-profitable activities, employing low-skilled occupations and scarce technological breakthroughs.

Table 2 depicts statistics for the metropolitan territories aggregated into macro-areas to show disparities. The difference in the value-added average share of knowledge-intensive services - such as ICT and Financial activities- among the two groups confirm these trends, underlining the lower presence of market-oriented services in southern and insular metropolitan zones. Moreover, the deep gap in the share of manufacturing value-added -about 10 per cent points- witness the geographical disparities of the process of industrialisation of the country that largely concentrates around centre-northern metropolitan zones (Viesti, 2021). Disparities among these zones increased in the last two decades, in which southern and insular metropolitan zones grew less in all technological and economic indicators selected.

Table 2: the economic performances of Italian metropolitan areas clustered in macro-areas

	patent applications growth rate	GDP per capita growth rate	productivity growth rate	Average ICT value-added	Average manufacturing value-added	Average Financial and Insurance value-added	ICT value-added growth rate	Manufacturing value-added growth	Financial and Insurance value-added
Centre-North	.005	1.74	1.33	5.37	17.01	5.63	1.20	.90	2.13
South-Islands	-.003	1.4	1.19	4.14	7.24	3.81	-.26	-.39	1.59

Source: author's elaboration. Notes: the table clusters metropolitan cities according to geographical macro-area. We computed the compound annual growth rate between 2000 and 2018 for patents application, GDP per capita productivity and value-added of three economic sectors: ICT services, Financial and Insurance services and manufacturing industry. Moreover, we compute for the same sectors the value-added average share over the sample.

Second, table 2 witnesses the general decline of the manufacturing industry in all metropolitan economies favouring the services, mirroring the structural changes of Italian metropolitan areas. Manufacturing value-added, indeed, grows less than the other sectors, and in many southern metropolitan zones, it decreases. However, the shift towards services presents lopsided geographical features. The old centre-northern manufacturing centres have performed better than other areas, increasing the weight of the service industries in their economies. In the southern and insular metropolitan zones, financial and insurance value-added increased just by 1.59%, compared to the rise of 2.38% of the centre-northern cities. The gap in ICT services is even greater, indicating the stagnant dynamic of the southern-insular metropolitan areas in one of the most advanced technological activities. These results confirm the idea of a sort of path-dependency between the precedent manufacturing structure and the spread of the high-tech servicing activities in the process of structural change of Italian metropolitan economies.

Third, structural polarisation featured the recent development of the Italian metropolitan zones. Table A.4 in the appendix shows the sectoral features of the Italian metropolitan areas. Milan is the only "Global City" (Sassen, 2018) in the country, gathering technological advances and high value-added productions. Its local economy is based on a high share of manufacturing activities, financial and ICT corporate facilities, along with dynamic innovation activity. GDP per capita and value-added growth rates are much higher than all other units in the sample, feeding the concentration of economic activity in this territory. On the opposite, Rome has losing ground in the last two decades, undertaking a concerning development trajectory. A strong specialisation in the ICT sector along with a

considerable decline in the manufacturing industry determined an unbalanced growth, affected by stagnant GDP per capita and scarce productivity gains, the worst in the sample.
There are some exceptions in the South, as shown in table 3. Some places, like Palermo and Cagliari- starting from a very low amount of the services valued-added, considerably increment the production of these services over the period.

Table 3: the sectoral economic development of Italian metropolitan areas

Metropolitan City	Financial and Insurance value-added growth rate	ICT value-added growth rate	Manufacturing value-added growth rate
Roma	1.07	3.40	-1.27
Milano	3.70	2.93	0.71
Napoli	2.05	-0.99	0.56
Torino	3.40	1.68	0.71
Bari	1.73	1.57	0.13
Palermo	4.78	0.46	-1.09
Catania	1.66	-2.39	-0.78
Firenze	2.14	0.11	0.27
Bologna	3.36	2.86	1.57
Genova	1.10	-0.35	0.85
Venezia	-0.88	0.003	1.31
Messina	0.09	-3.26	-1.30
Reggio di Calabria	0.01	-4.78	1.52
Cagliari	1.34	3.90	-0.93

Source: author's elaboration. Notes: the table depicts the sectoral dynamics of the Italian metropolitan areas. We computed the compound annual growth rate between 2000 and 2018 for three economic sectors: ICT, Financial and Insurance services and the manufacturing industry.

However, the weight of these sectors on the local economy is still not comparable to the centre-northern metropolitan areas. Even more concerning is the decline in ICT services value-added of many southern and insular metropolitan areas, which, along with weak performances in Finance and Insurance services, mirrors the growing territorial divergence in knowledge-intensive economic sectors of the country. In addition, the low patenting density in these zones indicates an economic structure driven by the spread of basic tasks and low-technological activities.
Four, uneven dynamics also arise among the centre-northern metropolitan cities due to the challenges posed by the new emerging global paradigm of the knowledge-economy as evinced by table 3. Some places, like Bologna and Turin, performed a consistent growth of ICT and financial sectors along with a sustained GDP per capita rise, undertaking a process of structural transformation driven by the local diffusion of market-oriented corporate services.
Others, like Genova and Venice, old core manufacturing areas, associate weak growth in service with a stagnant trend in innovation performances, resulting in a concerning development trajectory in light also of the consistent decrease of the residents. Overall, the heterogeneity in the development trajectories of the centre-northern Italian metropolitan areas witnesses the far-reaching consequences

of the process of technological change on the Italian metropolitan economies. In the following sections, we analyse the innovation dynamics and the economic performances of Italian metropolitan areas, focusing on key variables such as the density of patent grants for one thousand of inhabitants, GDP per capita and productivity trends, total and sectoral value-added gains. These patterns mirror the rising geographical imbalances of the recent development of these zones.

6.1 The innovation performances

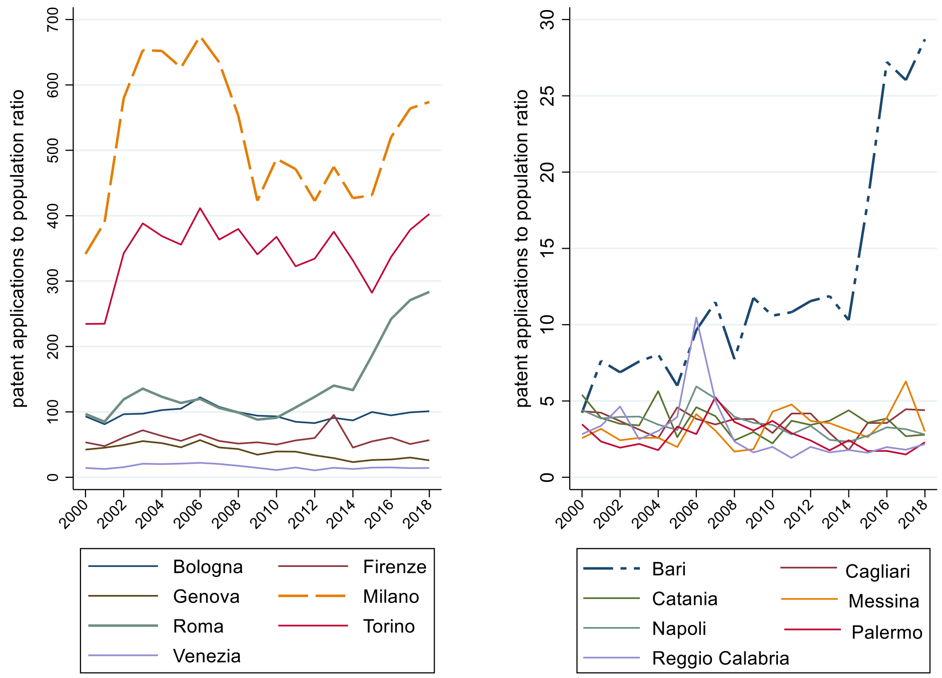
The innovation dynamics analysis of Italian metropolitan areas is conducted measuring the intensity of patent applications each year for a hundred thousand inhabitants. There are many ways to measure innovation and a long outstanding debate about the issue. We adopted this approach for two main reasons. First, recent literature stresses the ongoing increasing concentration of patents and innovation activities around leading metropolitan territories where, research centres, innovative enterprises, and high-risk capital concentrates. Metropolitan zones are, indeed, nowadays the place where the massive amount of patents and technological breakthroughs localise (Balland et al., 2021, Crescenzi et al., 2019, Florida, 2017 OECD, 2016). Second, the availability of the data. We collect the number of patent applications for Italian metropolitan areas from the statistical office of UIMB-Ufficio Italiano Marchi e Brevetti. The localization of patent data at the provincial level is abundant and allows a relatively long analysis period ranging from 2000 to 2018. Instead, many more accurate measures of innovation activities are based on temporal and short-run surveys that allow limited time spam and scarce territorial localisation.

Our index is a weighted measure of the number of patent applications with respect to the metropolitan territories' population able to compare territories of different sizes. We define the patent application to population ratios of a metropolitan territory following Fritsch and Wyrwich (2021) as:

$$InnDensity_{i,t} = 10^5 \left(\frac{h_{it}}{pop_{it}}\right)$$

In the formula, h_{it} is the number of patent applications for each of the fourteen Italian metropolitan areas i , in time t, from 2000 to 2018 and pop_{it} is the number of the population of the metropolitan territory i in each year for the same period. Therefore $InnDensity_{i,t}$, defines the patent applications to population ratio, measuring the intensity of innovation of the metropolitan territories according to a common population scale. Figure 6 plot the developments of the index between 2000-2018. We divide the figures according to the regional macro-areas of the metropolitan cities, showing the considerable imbalances in the geographical localization of innovation activities in the country. There is a massive difference in the volumes of patent application density between the two macro-regions. Southern and insular metropolitan cities have a lower patent population ratio, ranging between 0 and 5 patent requests for hundred thousand of inhabitants during all the sample period. Only the metropolitan area of Bari in this group performed a considerable increment of patent density, shifting from a 2.69 patent application to 27.11, the most significant boost among metropolitan territories. The rest of the Cities, however, achieved trivial increments, showing a stagnant trend. Instead, the right side of the graph shows the higher volume of the patent to population ratios of the centre-northern metropolitan territories, where most innovation activity is located in the country. Overall, Centre-North's innovation activity is considerably higher than the Southern and Island metropolitan territories, both at the beginning and at the end of the period.

Figure 6: the evolution of the patent application to population ratio between 2000-2018



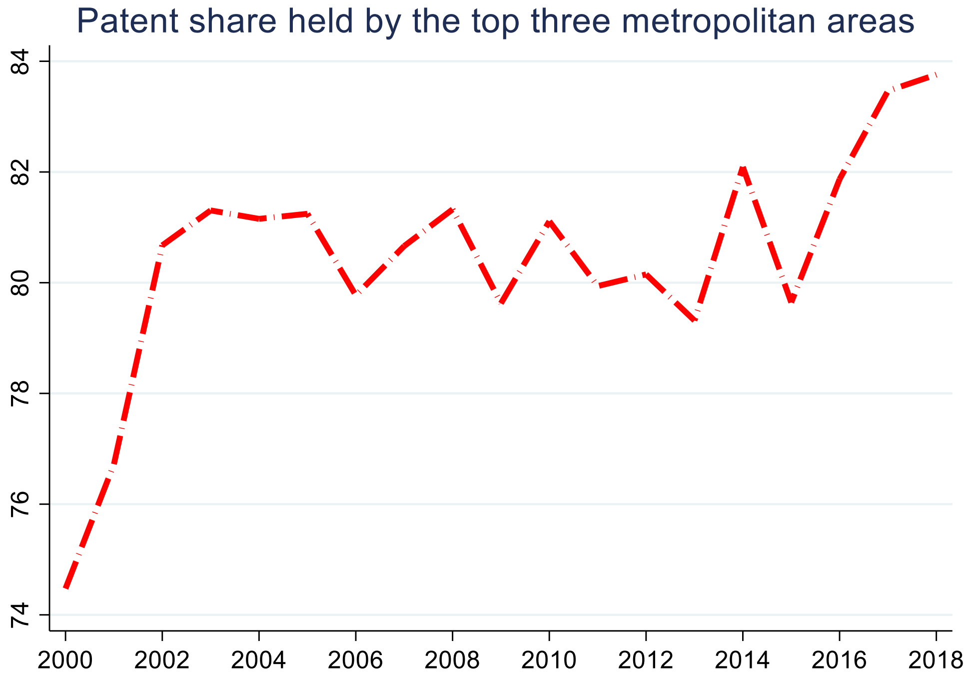
Source: own elaboration on UIMB-Ufficio Italiano Marchi e Brevetti dataset. Notes: the graph depicts the evolution of the patent to population ratio for the Italian metropolitan areas between 2000 and 2018.

Moreover, the figure suggests a process of concentration of the innovation activities among Italian metropolitan areas. Milan, alone, accounted for 43% of total patents in 2018.

Besides, the first three metropolitan cities in 2000, namely Milan, Turin and Rome, account for above 80% of the total patents according to UIMB-Ufficio Italiano Marchi e Brevetti. This percentage rose to 94,36% in 2018. Indeed, polarization also emerges among this group. Bologna follows the country's three leading most innovative areas, raising the patent application density by 7.4%. But the remaining centre-northern metropolitan cities do not follow this trend, performing stagnant or declining performances. In addition, the development of centre-northern metropolitan cities in innovative activities undertook a divergent trajectory, particularly after the great financial crisis of 2008-2010, suggesting the difficult revival of these territories in terms of innovation performances. These results mirror the geographical concentration of innovative hubs around a few territories, which also occurred among Italian metropolitan territories, where capitals, researchers, knowledge institutions and innovative firms gather (Viesti, 2021).

To test the hypothesis of the growing concentration of innovation activities, we construct a concentration index, calculating the patent quote of the leading three metropolitan areas. Figure 7 shows the share of patent applications ratio held by the top three metropolitan territories between 2000-2018.

Figure 7: the share of patent applications held by the top three metropolitan areas



Source: own elaboration on UIMB-Ufficio Italiano Marchi e Brevetti dataset. Notes: the graph depicts the share of patent applications held by the top three metropolitan areas. The top three metropolitan areas are Milan, Rome and Turin for all the period.

The share of patent applications of the top three Italian metropolitan territories increased between 2000 and 2018, mirroring the concentration of the patent to population ratio in very few metropolitan territories. The first rise occurred between 2000-2002 when the red line jumped from 74% to 81%. A second increase in the quote held by the top three metropolitan areas took place in 2015, reaching 84%. As suggested by the trend analysis, these developments mirror the polarization of patenting activity among Italian metropolitan areas.

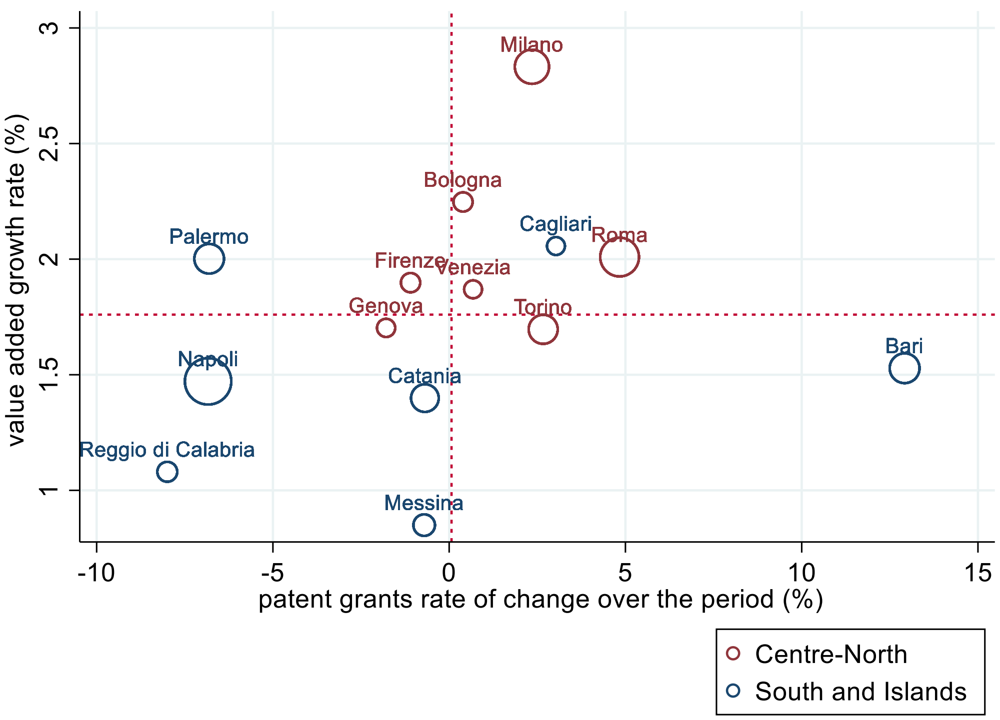
6.2 Innovation and economic developments

Value-added advancements in metropolitan cities in Italy between 2000 and 2018 show polarization, indicating divergent growth paths. Two main feature emerges from the study of the recent developments of Italian metropolitan areas. First, value-added gains concentrate in a few leading metropolitan zones in the Centre and North of the country, where also innovation activities gather. Southern and insular urban territories, starting from a lower economic activity level, have lost ground, performing weakly than the other group. These results indicate divergent growth trajectories among macro-areas, reflecting increasing territorial inequality among economic centres and new peripheries in the country (Viesti, 2021). Second, territorial heterogeneity evinces also among centre-northern metropolitan cities. Leading metropolitan cities, such as Milano and Bologna, shows strong economic dynamism sustained by advancement in patent grants. Instead, many old industrial metropolitan territories perform a more modest growth, suffering from the shift towards market-oriented service and the declining weight of industrial productions. They performed scarce increases in value-added and show stagnant or declining change in the number of patent grants localized in their metropolitan territories.

The compound annual growth rate of the number of patent grants to population ratio - our proxy to measure innovation - seems to mirror the dynamics of total value-added growth, reflecting the territorial imbalances among Italian metropolitan areas. Indeed, as figure 8 shows, metropolitan territories with consistent growth in value-added also increase territorial patent grants. This result confirms the positive relationship between economic prosperity and innovation advancements in metropolitan economies (Florida, 2017). The group of metropolitan cities that growth more than 1.76% in value-added -the mean growth rate of the sample drawn by the red dot line in the graph- also performed positively in patenting activity. On the other side, metropolitan cities with decreasing trend in the number of patent applications signed a modest growth of value-added, below the average. Few Italian metropolitan territories do not follow this pattern. The first exception regards the metropolitan area of Bari, the outliner in the graph. The considerable increase in the number of patents, the strongest among all metropolitan cities, is associated with a value-added growth rate just below the mean.

However, this trend is biased by the very low level of patenting in 2000. Indeed, even with the sharp increase in innovation activity, Bari's patent share on the total remains still below 1% in 2018. Furthermore, the gains deriving from the innovation activity are sometimes uncertain and require a long time to affect economic performances; they could not yet be visible in value-added performances. A different case regards the metropolitan territory of Palermo, where the soar in value-added of 2% is associated with a strong declining performance in innovation activity.

Figure 8: economic production and innovation activity



Source: author's elaboration on ISTAT data. I Conti Regionali Territoriali database and UIMB-Ufficio Italiano Marchi e Brevetti data.
Notes: the graph depicts the compound annual growth rate of value-added and patent grants between 2000 and 2018.

These patterns indicate a local economy based on low-tech productions and mainly supported by traditional sectors. Palermo, indeed, shows a considerable rise in the share of financial and insurance services value-added, however, specialized in basic and low innovative activities.
Figure 8, moreover, reveals a consistent territorial heterogeneity in the sample reflecting the geographical concentration of value-added gains and innovation activity among a few centre-northern metropolitan cities. The group of metropolitan territories with a positive rate of change in both patenting and total value-added is formed by centre-northern metropolitan cities, with the only exception of Cagliari. This metropolitan territory has undertaken a positive growth trajectory and advanced as the capital centre in the region. It combines a growth of more than 2% in value-added with an increase in patent grants of 3%. These findings are in line with the Icity-rank report (2018), highlighting the prominent role of Cagliari among the southern metropolitan areas and its economic dynamism.
In contrast, all the other southern and insular metropolitan cities performed a slight value-added increase along with scarce performance in patenting activity. These patterns suggest a concerning development trajectory enlarging disparities with the centre-northern ones.
The spatial concentration of economic production evinces also among centre-northern metropolitan territories, affected by heterogenous dynamics of developments between top metropolitan areas and old manufacturing poles. The firsts, such as the areas of Bologna and Milan, perform a high growth rate in patenting activity and value-added. Many other centre-northern metropolitan cities, instead, associate a modest augment of value-added with a constant or declining trend in innovation activity, like the territory of Genova and Venezia. These patterns mirror the shift they face from a manufacture-based territorial economy towards a services-integrated local economy. Genova performs a declining trend in innovation activities and the worst growth of value-added in the macro area. Venezia increases its value-added along with stagnant activity in patenting. Turin, on the opposite, associates a positive dynamic of innovation with a scarce growth in value-added. Besides a slight decline in patents applications, Firenze performed well in value-added, sustained by the smart use of the rich cultural heritage and tourism-based services (Icity-rank, 2018). The metropolitan cities of Rome, the more extensive in the sample, realized the second-biggest jump in the number of patent grants in the sample, but along with a value-added growth very slight for the size of its metropolitan territory. Overall, these trends witness the ongoing divergent growth trajectories of Italian metropolitan territories. On one side, strong macro-areas imbalances arise among the metropolitan territories. On the other side, also among the centre-north group, Milano largely overcame in economic performance all other territories. The modest economic results of the other territories witness a different growth trajectory among metropolitan cities of this macro-area, enlarging geographical inequality and economic concentration in the country.

6.3 Innovation and income dynamics

Even the distribution of wealth increments presents geographical polarization among Italian metropolitan areas. Figure 3.B in the appendix plots the trend of GDP per capita associated with patenting activity between 2000-2018. It points out the links between the technological competitiveness, demography, and income evolution of metropolitan economies, reflecting structural features. This picture, again, confirms the two issues concerning the recent developments of Italian metropolitan areas. First, centre-northern metropolitan territories growth more than southern and insular ones, which even started with a lower level of income at the beginning of the period. These developments enlarged territorial inequality among metropolitan territories generating strong geographical income imbalances. These matters are even more gravest considering the worst demographic balance of these urban zones compared to the centre-northern metropolitan cities.

Second, among the top group, some leading metropolitan territories gather the advances in demography, technological endowments, and GDP per capita. At the same time, other metropolitan cities performed a stagnant development trajectory.

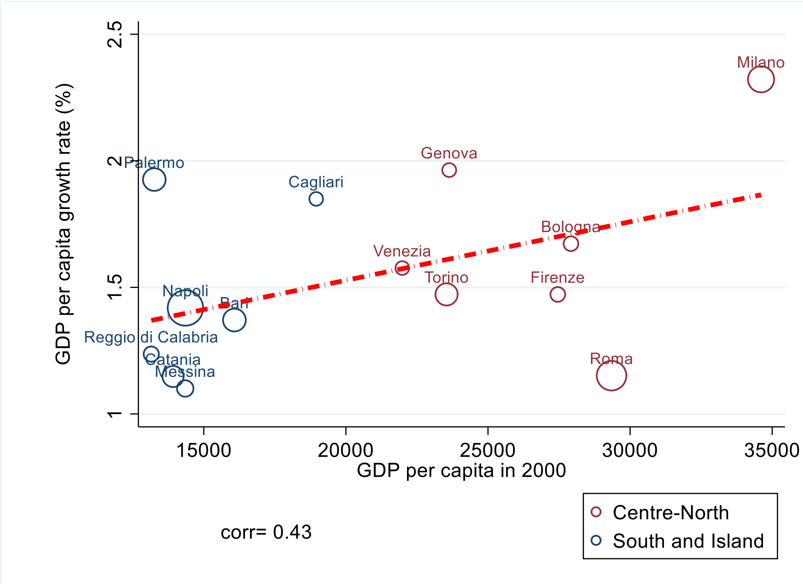
Concerning the first issue, more innovative metropolitan areas show higher growth of GDP per capita in Centre-North. In the southern and insular macro-area, lower GDP per capita increase, weak demographic balance, and declining innovation performances reflect a concerning growth path. Indeed, the growth rate of GDP per capita of Palermo and Naples of 1.92% and 1.41%, respectively, the highest in this area, followed a consistent decline in patenting activity. These features suggest an economic structure based mainly on traditional economic activities, with a scarce use of high-tech inputs and productions far from the technological frontier. Even more challenging is the position of Messina, Catania and Reggio Calabria, where the decline in patenting activity is associated with the lowest rate of growth in GDP per capita. Different patterns emerge for Cagliari and Bari, performing a modest increase in income per capita along with a rise in patent grants.

The second matter concerns the concentration of income advancements in the centre-northern metropolitan cities. Milano and Bologna gather the most growth in population, patent grants and income. These metropolitan territories, the centre of the second technological revolution based on manufacturing production, exploited the gains deriving from the new technological waves based on ICT, adapting formal and informal knowledge networks, endowments of physical and human capital and skilled employment. On the opposite, worthy is the case of Rome, performing a high increase in patent grants but the worst rise in GDP per capita. Here, some issues must be noted. First, this metropolitan area is affected by a substantial reduction in manufacturing employment, which has been a fundamental source of growth in the past. Second, the increasing specialization in ICT services exacerbated the dynamic of polarisation among wages and the spread of unpaid jobs. Third, the low GDP per capita growth is also affected by the considerable rise in population of 0.85%, the biggest one in the sample. The strong increase in GDP per capita of the metropolitan areas of Genova, instead, must be read in light of the strong reduction of the population that affected this area.

Such results suggest a divergent trajectory in the recent development of Italian metropolitan areas. Places with a higher level of GDP per capita in 2000 have grown more than the others, and territories with a lower initial level of GDP per capita performed worse. So that, we present in figure 9 a graphical inspection of this hypothesis, drawing the red line of beta convergence for Italian metropolitan areas.

We plot on the y-axis the compound annual growth rate of GDP per capita and on the x-axis its initial level in 2000. The graphical inspection seems to confirm the hypothesis of the divergence. A high level of GDP per capita in 2000 seems to be correlated for 43% to a higher GDP per capita growth rate in the last two decades. Unfortunately, the sample size of Italian metropolitan areas and the short period does not allow an econometric estimate of this process.

Figure 9: the relation between the initial level of GDP per Capita and its growth rate.

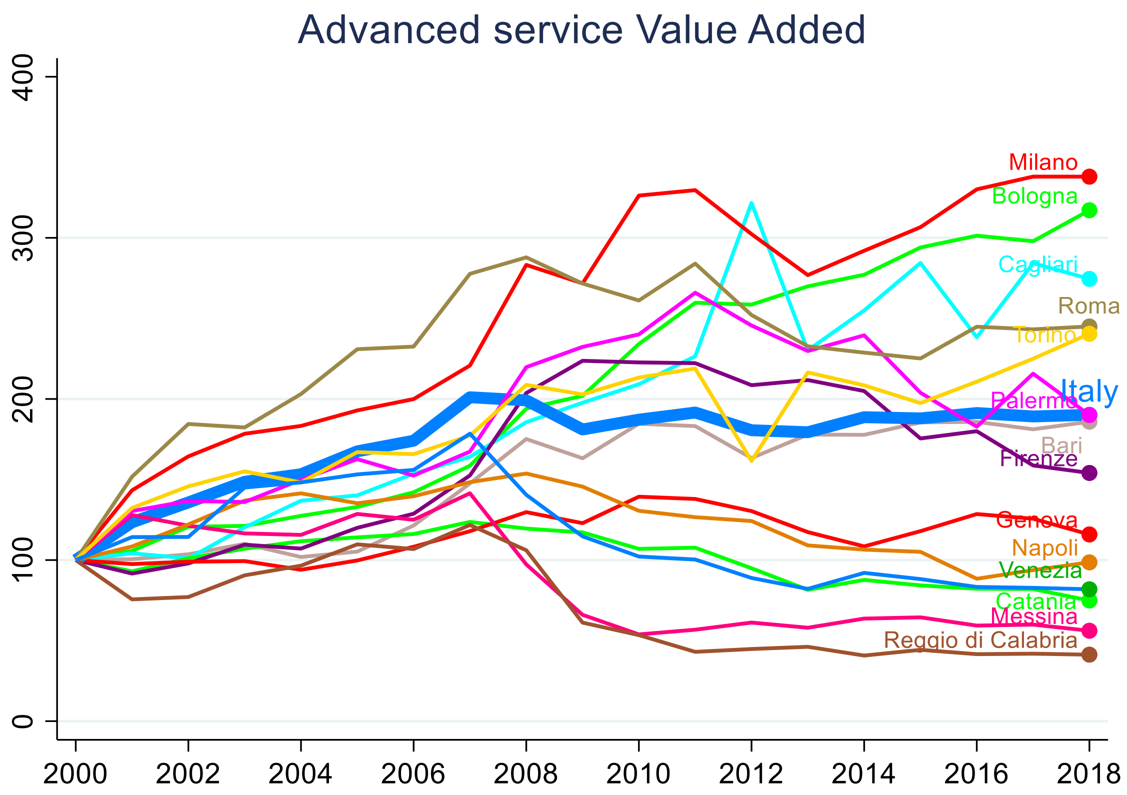


Source: author's elaboration on ISTAT data. I Conti Regionali Territoriali database and UIMB-Ufficio Italiano Marchi e Brevetti data.
Notes: the graph depicts the compound annual growth rate of GDP per capita and its initial level in 2000.

6.4 Innovation and sectoral dynamics

A deeper assessment of the sectoral dynamics is needed to analyze further the spatial distribution of the value-added and GDP per capita growth across Italian metropolitan areas. High-tech productions and knowledge-intensive services shape a virtuous cycle of growth, fostering income and innovation. In contrast, low patent grants and low manufacturing and corporate services value-added could explain a stagnant development path. We analyze the divergent growth of the advanced business services- the sum of ICT and Financial and Insurance services for each metropolitan area- in figure 10, highlighting the rising polarization of these activities across Italian metropolitan areas. Then, in figures 11 and 4.B in the appendix, we connect the average value-added share of three key economic sectors in one-digit Nace rev.2 with their growth rate. We analyse the developments of Financial and Insurance Services, ICT services and manufacturing industry, three core drivers of urban growth today (Glaeser, 2020, Harvey, 2012, Moretti, 2012, Sassen, 2018). This would help to explain how Italian metropolitan areas changed their economic structure in the last two decades. The root of the growing divergence between "superstar cities" and "lagging-behind territories" is the concentration of technologically advanced and profit-making services in the firsts, which attract capital, resources, and talents, while traditional productions feature the seconds.
The development of advanced business services across Italian metropolitan areas indicates a strong polarization, concentrating in a few leading places. Figure 10 shows the growth index for selected advanced business services, the sum of ICT and Financial and Insurance Services value-added, for each metropolitan area.

Figure 10: the polarization of the advanced corporate services



Source: author's elaboration on ISTAT data. Note: the graph depicts the growth index of selected advanced service value-added. We sum the value-added of Finance and Insurance and ICT Services and calculate the growth index dividing each year by its value in 2000, the base year, times 100. We compute this index for each Italian metropolitan area.

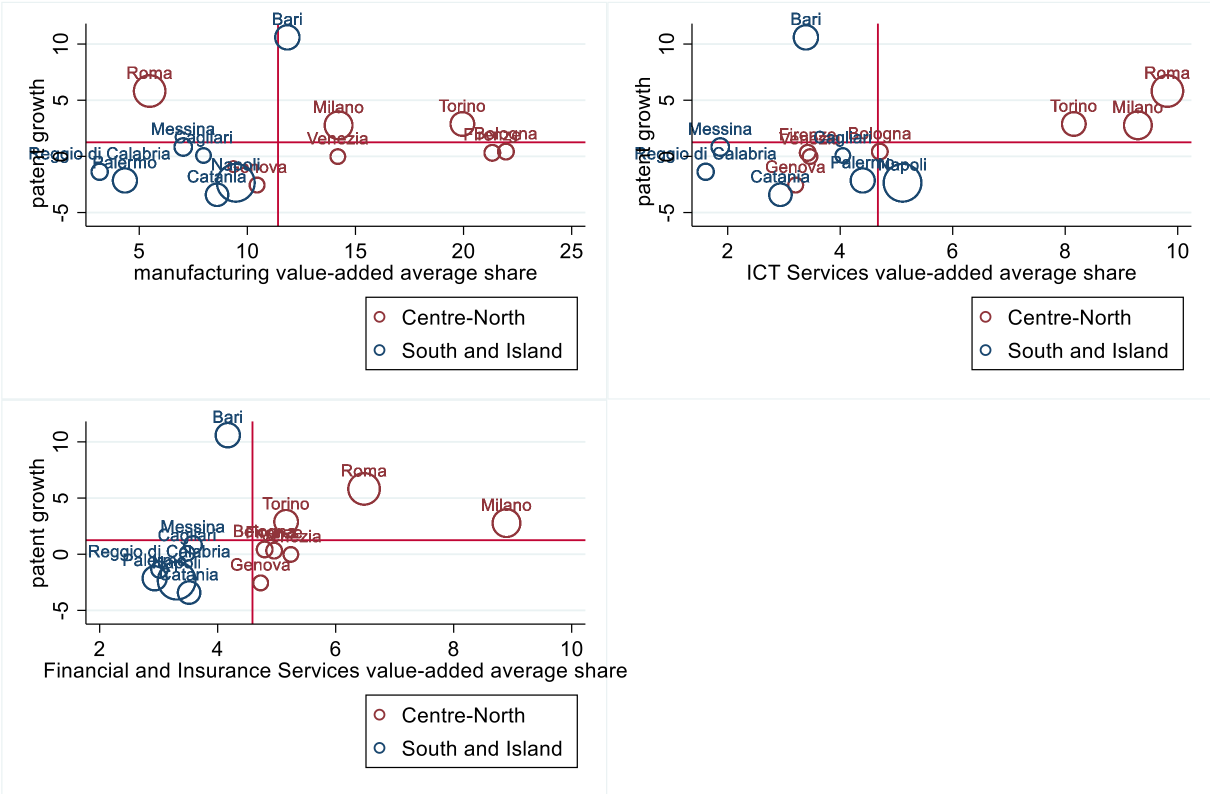
The index is calculated by dividing each year by its value in 2000, the base year, times 100 at constant price. There is a clear divergent growth across Italian metropolitan areas. A few metropolitan zones increased their performances, meanwhile, most of the metropolitan areas lag behind, often declining in the production of these activities at the roots of the urban growth nowadays (Glaeser, 2020, Sassen, 2018).

Milan, Turin, Rome and Cagliari increased the production of advanced business services between 2000-2018, growing more than the overall country. On the other side, many southern and insular metropolitan areas, such as Reggio Calabria, Messina, Catania, Naples, alongside many old manufacturing centres like Genova and Venezia, performed weakly or declined. The concentration of the advanced business services around a few zones in the country feed the divergent growth across Italian metropolitan areas, reflecting consistent differences in their local economic structure.

Looking at the more aggregated level, we recognized some relevant issues that feature the recent sectoral development of the Italian metropolitan zones.

First, hi-tech industries localize in Centre-North. In many southern and insular metropolitan areas, technological productions and patenting activity are lower. Indeed, these economies present a lower share of corporate services and manufacturing value-added, as figure 11 clearly shows.

Figure 11: the structural dynamics of Italian metropolitan areas



Source: Source: author's elaboration on ISTAT data. I Conti Regionali Territoriali database and UIMB-Ufficio Italiano Marchi e Brevetti data. Notes: the graph depicts the compound annual growth rate of patent grants and the value-added of three economic sectors: ICT services, Financial and Insurance Services and Manufacturing Industry between 2000 and 2018.

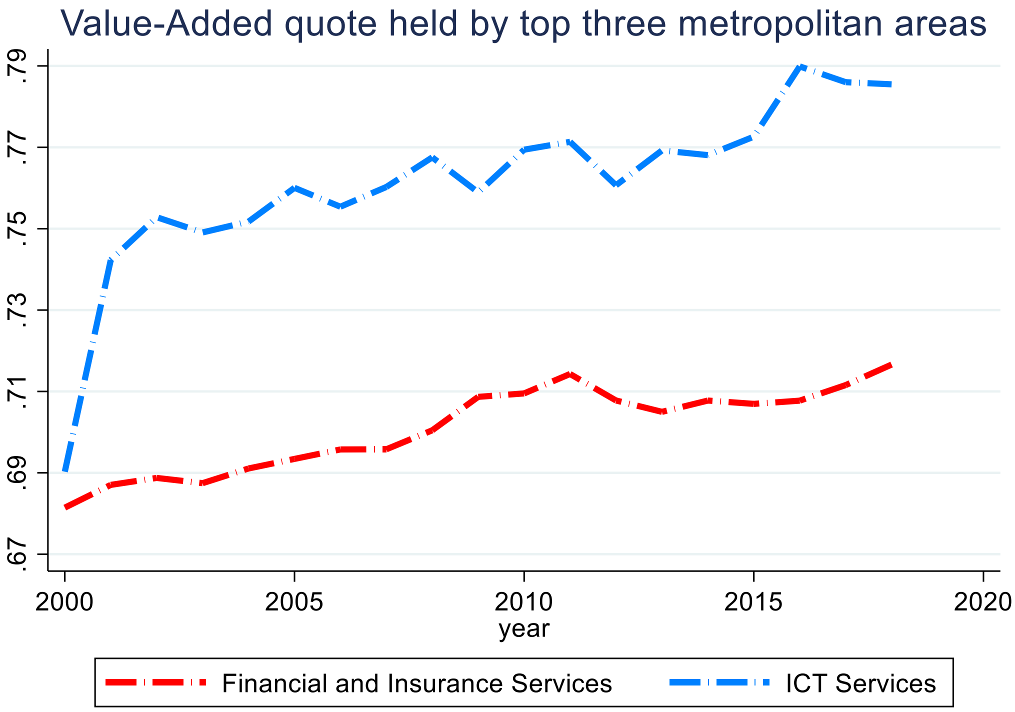
In addition, also the growth of these sectors is worse compared to the centre-northern metropolitan areas, augmenting territorial disparities as figure 4.B in the appendix witness. These patterns suggest still a consistent weight of low-tech productions and low-skills occupations in these metropolitan economies. The recent evolution of Italian metropolitan areas is affected by a growing structural divergence between macro-areas. Key high technological sectors concentrate in few centre-northern metropolitan areas, witnessing the uneven geographical development of the country.

Second, the growth of the metropolitan territories of Bari and Cagliari, the exceptions in the south and insular metropolitan zones, is fostered by a consistent rise in ICT services, along with a modest increase in financial and insurance facilities. These developments suggest a growth trajectory based on knowledge-intensive services that support higher income and higher innovation activities. Conversely, scarce value-added increases and weak innovation activity affect the development of the other southern and insular metropolitan areas, exacerbating territorial polarization.

Third, only a few of the centre-northern metropolitan cities grew in advanced services, while many other zones performed stagnant growth or decline in these sectors. Indeed, the advancements in ICT and Financial and Insurance services concentrate in a few leading territories such as Bologna, Milan and Turin, with the specialization of Roma in ICT. Other old industrial poles face the difficult shift toward a corporate integrated local economy, affected by the decreasing weight of manufacturing productions. These developments expand the lopsided geographical allocation of core economic sectors among centre-northern metropolitan territories.

Figure 12 shows the value-added share held by the top three metropolitan areas for ICT and Financial and Insurance services among Italian metropolitan territories, mirroring the growing concentration of these activities rather than their diffusion among Italian metropolitan territories. The quote of value-added held of Financial and Insurance Services increased between 2000-2018, reaching more than 70%. The concentration is even stronger for ICT Services, whose production largely localises in Rome, Milan, and Turin.

Figure 12: Index of concentration for selected services



Source: author's elaboration on ISTAT data. I Conti Regionali Territoriali database. Notes: The graph depicts the Herfindahl-Hirschman concentration index between 2000-2018 for ICT and Financial and Insurance Services. Both increase their concentration among Italian metropolitan zones.

Four, among the three economic sectors, the manufacturing industry increases less than others as pointed out by figure 4.B in the appendix, mirroring the generalized declining weight of this sector in the context of the urban economy, even more, turned on the paradigm of the "platform economy" (Sassen, 2018). However, as the distribution of the average value-added share witnessed, manufacturing production hugely concentrated in centre-northern zones, mirroring the geographical heterogeneity of the industrialization of the country, which was localised mainly in these territories (Viesti, 2021).

6.5 Factor analysis

Factor analysis is a powerful tool for reducing original data into a more compacted index, called factors, able to explain latent features of the observations. It reduces the number of variables by describing linear combinations of them, guaranteeing no information loses. Thus, factors are unobserved features that account for the original data, although in a different proportion. This statistical technique is widely used in many fields. Among others, the contribution of Río-Casasola (2021) stressed the complementarity of the use of factor and cluster analysis to group variables according to specific characteristics. Factor analysis, indeed, helps to find meaningful and simplified common factors able to explain complex features of the observations. Cluster analysis groups observations according to the score of the factors, maximizing the variance between groups and minimizing the variance within the groups. We performed a factor analysis with eight variables that are shown in table 4.

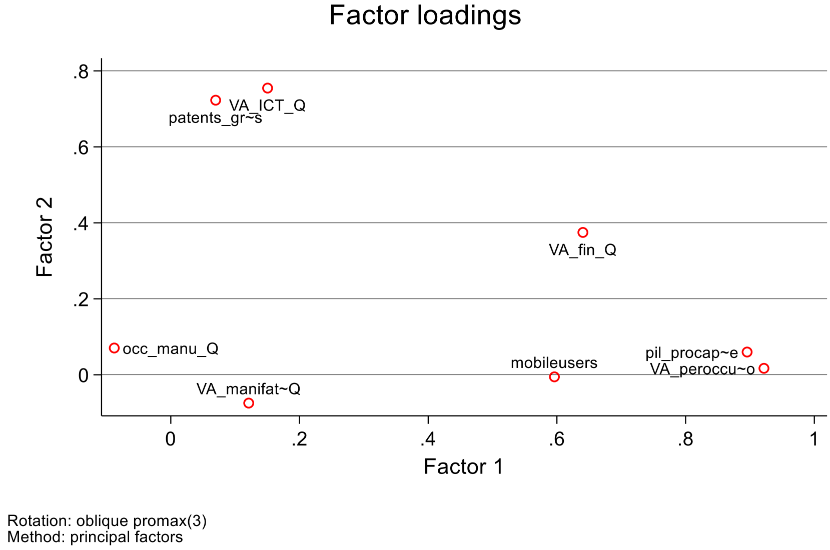
Table 4: Variables of Factor Analysis

name	Explanation
GDP per capita	GDP per capita, millions
Productivity	Value-added/total employment
Manufacturing employment share	Sectoral employment
Manufacturing Value-added share	Sectoral value-added
Financial and Insurance Value-Added share	Sectoral value-added
ICT Value-Added share	Sectoral value-added
Patents grants	Number of patent grants for 100000 inhabitants
Banking Service Users	mobile banking services users for one thousand inhabitants

Source: author's elaboration. Notes: the table list and describe the variables utilized for the Factor Analysis.

Many are the motivation for the choice of these variables. The first reason is the meaningful economic sense of these indicators. Indeed, GDP per capita is a key variable for the local economies, linking income distribution with demographic performances. Productivity and sectoral value-added of ICT Services, Financial and Insurance Services and Manufacturing industry depict structural features of the metropolitan economies, analysing the main drivers of the urban growth today. The share of manufacturing employment accounts for the labour market dynamics and is strictly linked with the historical development of these territories. A balanced territorial growth should be driven by an increase in both occupation and productivity. In contrast, growth in productivity along with a decline in occupation suggests a concerning dynamic. The number of patent grants to population ratio mirrors the technological capabilities of the metropolitan territory, accounting for the innovation performances of these zones. The number of mobile banking service users is a further proxy of the digital development of these local economies. The second motivation is econometric. These variables show moderate-high correlation in almost all the variables, more than 0.3 and 0.5, as shown in table A.5, indicating a good sample for the factor analysis. Moreover, we obtain a significative result in the Kaiser-Meyer-Olkin test for the adequacy of the sample, as shown in table A.6. All the values, indeed, are greater than 0.5, the widespread benchmark in this test. Overall, the value of 0.75 indicates the appropriateness of the model to perform factor analysis. We then performed factor analysis using Kaiser Criterion to decide the number of factors selected. As evident in figure 5.B, just two eigenvalues overcome the value of 1, the target of the Kaiser Criterion. Moreover, there is a very considerable difference between the second and the third eigenvalue, meaning that the right choice is to select the first two factors that together explain 94% of the total variance. We applied the oblique promax rotation to a better economic interpretation of the factors. In figure 13, we plot the factor loadings of each variable.

Figure 13: Factor loading on variables



Source: author's elaboration. Notes: the graph depicts the weight of the first two factors for each variable. We applied orthogonal varimax rotation to a better interpretation of the factors

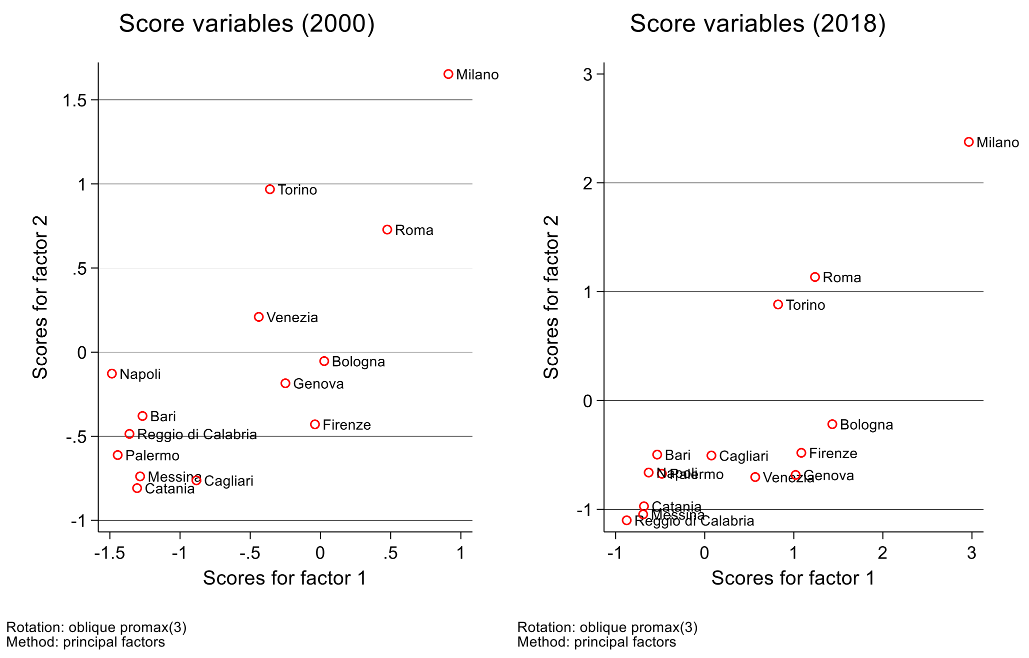
Factor 1 accounts more for GDP per capita, productivity, number of mobile banking service users, and a considerable Financial and Insurance value-added quote. Thus, it seems to be related to the economic and financial features of the metropolitan economy. Factor 2 instead, loads more on structural variables like sectoral value-added of ICT services and patent grants to population ratio, reflecting technological matters of the territories.

Much of the observations shift between 2000-2018 is due to factor 2 intense modification that consistently enlarged the score range in 2018. In particular upper bound increased due to the jump of Milan, which peaks the highest value of more than 2 points. Southern and insular metropolitan zones instead have the lowest value in both the years, performing trivial advancements, except the tiny improvements of Cagliari and Bari. But, even the other centre-northern metropolitan areas performed weakly, increasing the polarisation scores across observations. Overall, these results suggest an increasing territorial divergence in the technological structure of the Italian metropolitan areas, feeding by the considerable advancements of Milan and the stagnant performances of almost all other metropolitan zones.

Increasing polarization evinces from the score changes between the two periods in Factor 1, mirroring disparities in economic and financial performances among metropolitan zones. Southern and insular metropolitan zones do not increase their score consistently, except for the jump of Cagliari above 0. Milan performed better than all the sample also in Factor 1, reaching the highest score of 3 points. Meanwhile, Rome, the second-highest score in 2000, is overcome by Bologna in 2018, witnessing the decline of this metropolitan city. Overall, in both periods, the graph evinces the territorial macro-areas imbalances of the country, where centre-northern metropolitan zones - starting from higher scores- performed better than southern ones but achieved slight advancements. The strong growth of

Milan, in addition, feeds the concentration of economic and technological activities.

Figure 14: observation scores for selected years



Source: author's elaboration. Notes: the graph plot the factor scores of Italian metropolitan areas in 2000 and 2018.

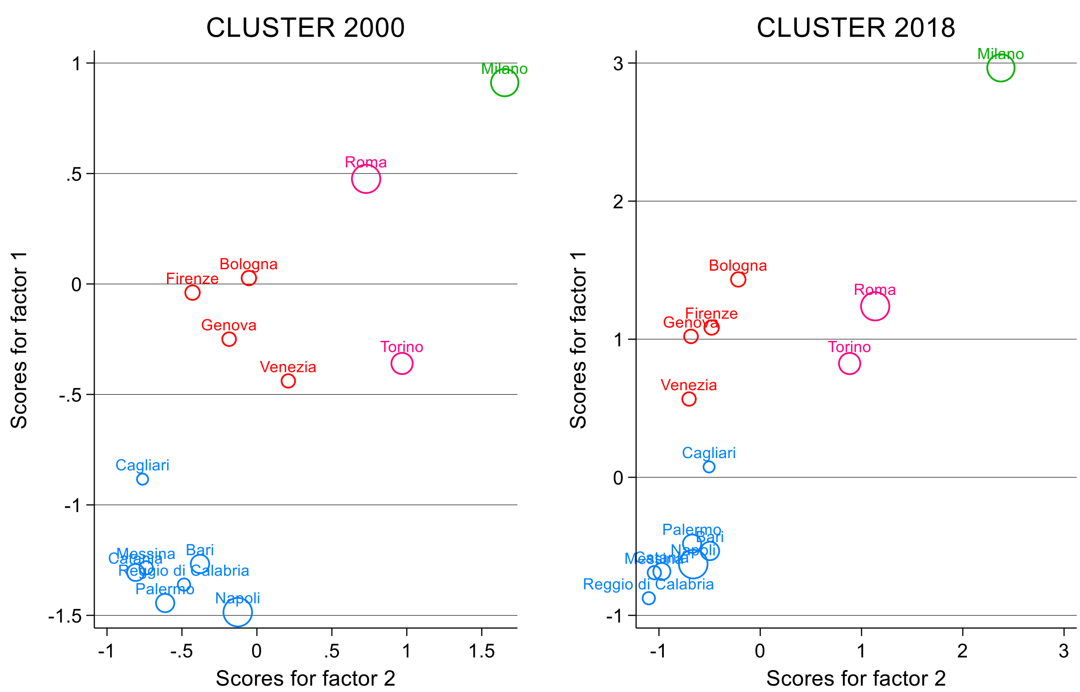
There are two interesting exceptions. First, Turin is in the middle of both the plots, with a high value of Factor 2 with respect to the other centre-northern metropolitan areas but performing a modest growth. Cagliari, instead, signed the highest score advancements across southern and insular zones in both factors scores, whereas it remains far from the top metropolitan areas.

6.6 Cluster Analysis

We then conducted two cluster analyses based on factors between 2000-2018 to shed light on the development of metropolitan areas across the period. Different results from the clustering algorithm may indicate changes in the structural characteristics of Italian metropolitan areas. Less heterogeneity among groups in 2018 may mirror a process of convergence across metropolitan territories. On the opposite, equal groups resulting from the clustering process between 2000 and 2018 may indicate not consistently modification in the growth trajectories of Italian metropolitan areas, reinforcing their structural differences in the last two decades.
Cluster analysis is a powerful tool for finding groups in data (Kaufman and Rousseeuw, 1990) and is widely used to group cities according to some socio-economic, demographic, and morphologic features (Akande et al., 2019, Ingrams et al., 2020, Piekut et al., 2012). Indeed, according to Everitt et al. (2011), the cities classification in clusters based on some specific features is one of the most prominent uses of this method. Whatever the procedure used, this analysis aims to group observations according to some characteristics minimising the within-group variance and generating clusters as different as possible between them.
To implement cluster analysis of Italian metropolitan areas, we adopted a K-means algorithm- an unsupervised learning procedure - very diffused among clustering partition methods. In the K-means

procedure, the researcher specifies the number of clusters to be created before the analysis. An iterative process assigns each observation to the group with the closest mean. Then for each cluster generated, a new group mean is calculated. These steps continue until no observations change groups, and there is no possibility of associating an observation to a more similar group.
The decision of the first number of clusters can affect the result and the replicability of the analysis. It may produce different results for each selected starting point. We then employed a random starting seed as initial cluster averages to partially overcome this issue.
To decide the number of clusters, we plot in figure 6.B in the appendix the total within variance of each cluster solution as a function of the number of groups. Following the procedure suggested by Makles (2012, p.1), we: "search for a kink in the curve generated from the within sum of squares (WSS) for all cluster solutions". This procedure is commonly known as the "elbow method", and it is very diffused to select cluster numbers in an iterative process like K-mean. The solution required that the point with the strongest shift in the inclination, a bend, or a knee, can be considered as the one that minimises intra-cluster variation. In other words, it is the point where adding a new cluster do not increase the heterogeneity between the clusters. We then decided to select four groups for both the clustering process as suggested by figure 6.B in the appendix, which is the point with very low within sum of squared for both the periods. Four clusters are indeed the best solution for both years, ensuring comparable results.
The cluster algorithm output is depicted in figure 15.

Figure 15: the output of the clustering algorithm

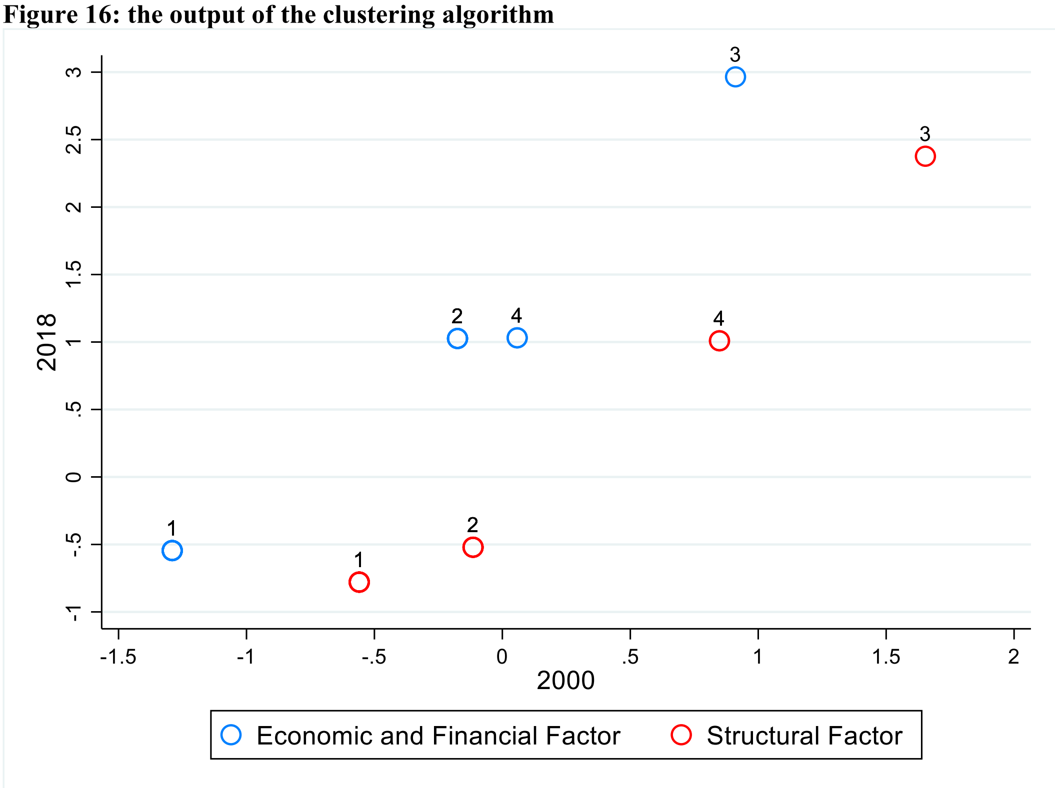


Source: author's elaboration. Notes: the graph plots the result of the clustering process using the K-mean algorithm in 2000 and 2018. Groups formed by K-mean algorithm are the same.

No modification occurred in the cluster formation, suggesting no consistent changes in the development path of these territories, as the list of the member of each cluster in table A.6 in the appendix suggest. The block of southern and insular metropolitan areas, the pink bubble in the figure, is the same between 2000-2018, mirroring irrelevant changes in the structural features of these territories. Cluster 2 include centre-northern metropolitan areas of Bologna, Florence, Venezia and Genova, featuring a higher level of income and Factor 1 performances. The third cluster, the metropolitan area of Milan, the green bubble, generates its own cluster in both periods, confirming its different growth trajectory as the only Global City in the country. Fourth cluster groups metropolitan areas of Turin and Rome, characterized by a high factor 2 score. Overall, this exercise testifies the absence of convergence among Italian metropolitan territories in which polarization increases due to the strong growth of Milan and the modest growth of all others.

We plot in figure 16 the average score of each clustering solution for both factors in 2000 and 2018. Overall, the score variance among groups is greater in 2018 than in 2000, as summarized by table A.7 in the appendix, suggesting divergent growth trajectories across metropolitan territories. These results are due to Milan's massive shift, which jumps in both factors and the immobilism of the others. Cluster one, the worst for both the indicators, expands its gap between 2000-2018 in factor 1 from all other groups. This development evinces the growing imbalances in income and financial matters among Italian metropolitan areas, especially for southern and insular metropolitan areas that developed very slowly. Cluster two and four that group centre-northern metropolitan territories achieves the same average score value for factor 1 in 2018, even starting with a slightly different position. However, both clusters hugely amplify the distance with Milan, which triplicates its score, reaching a difference of 1.96 points in 2018. These results mirror the growing polarization among the Italian metropolitan areas due to the growth of one global city in income and technological performances while the other metropolitan territories lagging behind.

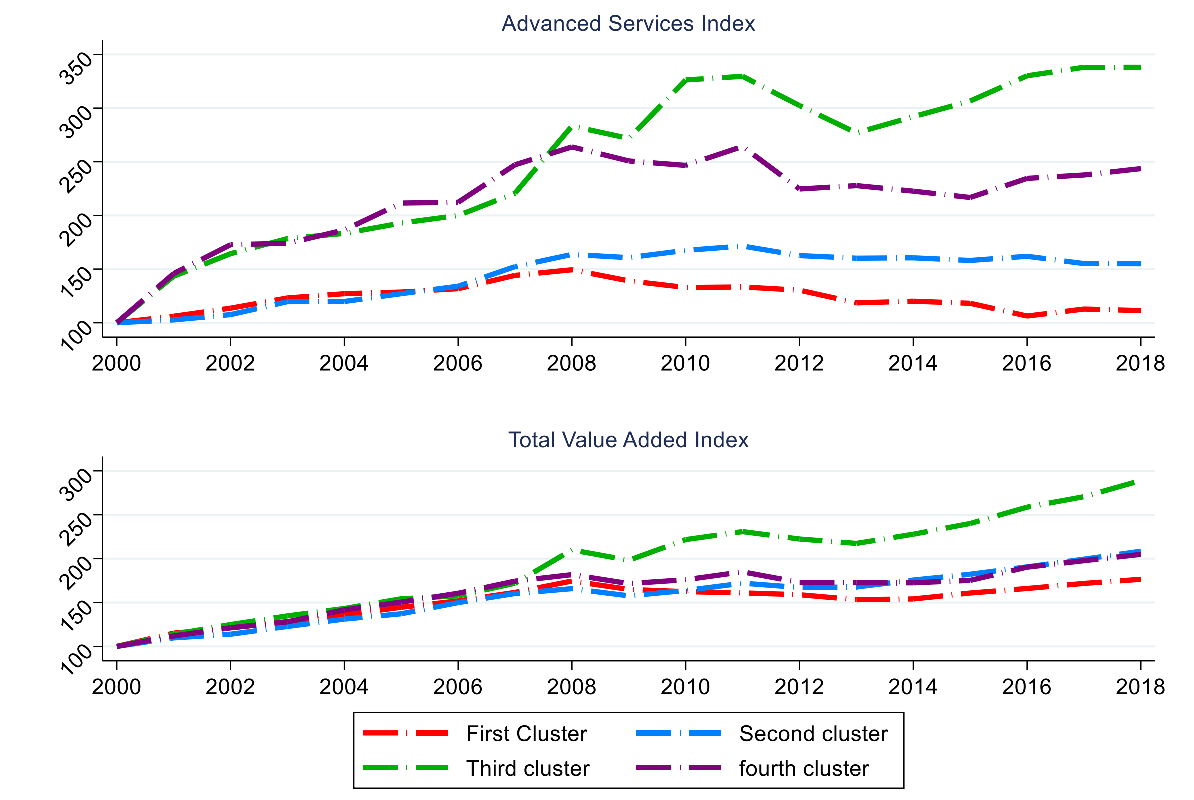
Figure 16: the output of the clustering algorithm



Source: author's elaboration. Notes: the graph depicts the cluster average of each group for both factors in 2000 and 2018. Distance between clusters increased in 2018, mirroring growing polarisation among metropolitan cities

Factor 2 show very similar patterns, witnessing the polarization in term of technological activities and ICT services. The first two clusters deepen the gap with the third and fourth groups, reflecting the concentration of patenting activity and ICT services in just a few metropolitan territories. These results mirror the stagnation of many Italian metropolitan areas in terms of innovation and ICT services. In addition, also between top performers, there is increasing heterogeneity. Cluster three, Milan, reaches the highest increases augmenting its distance from cluster forth, which performed only a very tiny increase since 2000, affected by the immobilism of Turin and the decline of Rome.
Cluster method allowed to summarize the developments of the last two decades of the Italian metropolitan areas, grouping them according to economic and structural indicators. Milan, cluster three, shows a positive development path regarding income, productivity, high-tech corporate services, and patent grants. Cluster fourth, formed by the metropolitan areas of Rome and Turin, performed modestly in economic indicators and stagnated in technological factors, witnessing these territories' scarce growth. Cluster two that contains the other centre-northern metropolitan areas, increased the score slightly in economic indicator but augmented the gap with the leading territories in factor 2. Finally, cluster 1, holding southern and insular metropolitan areas, have the worst performance in both years. They modestly increased the economic score, but less than all other groups, and worsened in factor 2. Figure 17 illustrates these trends by creating growth rate indexes for advanced business services and total value-added for each cluster.

Figure 17: polarization among clusters



Source: author's elaboration on ISTAT data. Note: the graph depicts the growth index of selected business advanced services- the sum of Finance and Insurance and ICT Services – and for the total value-added. We calculate the growth index dividing each year by its value in 2000, the base year, times 100 for each cluster.

During 2000-2018 imbalances increased among Italian metropolitan territories due to the increasing polarization of technological and economic endowments in a few zones. Economic polarization evinces in both the indexes highlighting divergent metropolitan growth in technological services and total value-added growth. Milan grows more than other zones, while centre-northern metropolitan territories stagnate, enlarging territorial polarization. Southern and insular metropolitan areas lag behind, exacerbating territorial inequalities.

7. Conclusion

Large cities are a core driver of technological innovation and economic growth. The process of structural change shaped by the third Industrial revolution- rooted in the spread of information technologies- boosted the weight of finance and corporate service in all production processes, redrawing the current economic geography. The dispersal of economic production, the massive rise of global financial transactions and the concentration of physical and social arrangements in a few metropolitan areas changed the territorial configuration of the world economy. As a result, uneven geographical development arises between ‘’Superstars Cities’’ and ‘’places that do not matter’’. The firsts are hotspots of the economic production and trade, material infrastructures of the global economy, where wealth, capital, advanced technological sectors, and high-skilled workers gather. The seconds are territories affected by deindustrialization, low productivity, weak economic structure and negative demographic balance, facing declining trajectories. This has led many authors to speak about a “new urban crisis” in which few global cities gather economic and social prosperity, meanwhile peripheric metropolitan zones fall, increasing impoverishment and social discontent. As Glaeser contends: “cities should be judged on whatever they are turning poor children into rich adults, and many apparently are failing in this fundamental task” (Glaeser, 2020, p. 13).

This paper investigates the developments of Italian metropolitan areas between 2000-2018, building on insights from economic geography and innovation studies. We witness a concentration of wealth, economic production, technological industries, and innovation activities even among Italian metropolitan territories that may worsen the country’s territorial inequality. Divergences arise between one leading place, Milan, where income, population and technological productions concentrate, and lagging-behind metropolitan zones, mainly in South and Island of the country, declining territories overlooked by the world economy. Moreover, centre-northern old manufacturing metropolitan areas are losing ground, signed by a stagnant development.

We evinced an increasing process of structural polarisation among Italian metropolitan economies analysing the growth rate of GDP per capita, productivity, total and sectoral value-added linked with the dynamic of the patent to population ratio. Centre-northern metropolitan cities, which started from a higher level of population, GDP per capita, productivity, patenting activity, increased their gap with the southern and insular metropolitan areas between 2000-2018. Furthermore, differences in knowledge-intensive services value-added - such as ICT and Financial and Insurance activities- among the two groups mirrors the lower presence of hi-tech sectors in southern and insular metropolitan zones. These results stress the historical territorial imbalances of the economic development of the country.

Moreover, polarization dynamics also arise among the centre-northern metropolitan areas due to the challenges posed by the new emerging global paradigm of the knowledge-economy. Milan is the only “global city” in the country, while the other centre-northern zones lagging behind. At a more disaggregated level, some places are increasing the weight of ICT and Financial and Insurance services in their metropolitan economies, fostering a growth path based on advanced corporate services and technological manufacturing productions, like Bologna, undertaking a process of structural transformation driven by the local diffusion of market-oriented corporate services. Some metropolitan economies instead, like Genova and Venice, old core manufacturing areas, associate weak growth in service with a stagnant trend in innovation performances, resulting in a worsening development trajectory in light also of the consistent decrease of the residents. Turin performed a slow growth in the last two decades, enlarging the gap with Milan. We also provide evidence of a growing divide between Milan and Rome, which has losing ground in most fields, affected by industrial decline. This picture mirrors the heterogeneity in the development trajectories of these zones witnessing the far-reaching consequences of the process of technological change affecting Italian metropolitan economies.

Polarisation also evinces in terms of innovation activities. The study on the patent dynamics reveals a stable or increasing concentration of the number of patents to population ratio among Italian metropolitan areas. Again, issues of the structural imbalances among macro-areas emerged, with centre-northern metropolitan areas performing better. But, overall, patenting activity, enormously concentrates in just three metropolitan territories with an increasing trend, mirroring the massive localization of innovative activities around a few hi-tech hotspots.

We then performed factor analysis using many economic indicators- such as GDP per capita and productivity-, structural variables -like the sectoral value-added share of Financial and Insurance Services, ICT Services, and value-added and employment share of manufacturing Industry to grasp the economic and structural development of Italian metropolitan areas. Moreover, we proxied digital performances with the number of patents and the number of mobile banking service users weighted by population.

Factor analysis helped to reduce complex data in more suitable factors regarding structural, technological and economic features of these territories. We then implemented a cluster analysis based on these factors, a proportional linear combination of original variables. Two are the results of this exercise.

First, the equal clustering output between 2000 and 2018 suggests no consistent modifications in the development path of these territories. Clusters are formed for both the years by the same metropolitan areas, grouped according to average factor score similarity. No signs of convergence occurred across Italian metropolitan areas during the last two decades. In particular, southern and insular zones performed worse than others in both years. The centre-northern metropolitan zones signed a slight growth, but very far from the consistent jump of Milan, the other cluster. Overall, lagging-behind metropolitan areas grow less than the leading ones, increasing territorial polarization. In the case of factor 2, linked with the quote of ICT Service and patent granted weighted to population, all groups increased their score less than the cluster formed by Milan decrease their scores, expanding territorial divergence in technological endowments.

Second, for 2018, we witness more variance between group average factor scores, mirroring growing polarization. The growth of the metropolitan area of Milan takes place alongside a substantial immobilism of the other Italian metropolitan areas, feeding the concentration of income and high-tech economic activities. The decline of Rome and Turin, alongside a modest growth of the other centre-northern metropolitan areas in factor 1 scores- related to economic performances- diminishes the distance between these two middle groups. But, both increased the gap with the leading and the lowest group. These patterns are even more evident considering factor 2 related to ICT Service and patent granted, which declines or stagnate for all groups except for the cluster formed by Milan.

The results suggest the need for a new approach to urban planning inspired by placed-based policies to foster the growth of the lagging-behind territories. The growing mobility of capital, along with the rapid concentration of high-skilled workers in a few zones, massively foster inequality among territories. The concentration of technological and economic endowments in a few places augment the disparities in life opportunities and socio-economic performances. These patterns may exacerbate political division and social discontent. The work has some limitations. Due to the sample size, it has not been possible to apply more sophisticated econometric tools to better understand the development process. Moreover, a deep analysis of the technological class of patents is required to accurately assess the technological structure of territories. Finally, a broader analysis of sectoral dynamics is needed due to the strong specialization of many Italian metropolitan areas in specific economic activities - such as Tourism- that should be taken into account in future works.

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APPENDIX A: Tables

Table A.1: the top ten leader firms for patent applications in the US since 1975

1976-80	**1981-85**	**1986-90**	**1991-95**	**1996-00**	**2001-05**	**2006-10**
GE	GE	**GE**	**IBM**	**IBM**	**IBM**	**IBM**
AT&T	**IBM**	**GM**	**Motorola**	**Micron**	**HP**	**Microsoft**
IBM	**AT&T**	**Kodak**	GE	**Lucent**	**Microsoft**	**Qualcomm**
Westinghouse	Westinghouse	**IBM**	**Kodak**	**Intel**	**Intel**	GE
RCA	Dow Chemical	Dow Chemical	**GM**	**HP**	Micron	**AT&T**
USA/Sec. Navy	DuPont	DuPont	**AT&T**	**Motorola**	GE	**Intel**
DuPont	**GM**	**AT&T**	**Xerox**	**GE**	Texas I	**HP**
GM	Mobil	**Motorola**	**Texas I**	Kodak	**Cisco**	Honeywell
Dow Chemical	**RCA**	Westinghouse	3M	**AMD**	Honeywell	**Apple**
Phillips Petro.	Allied Chemical	Allied Signal	DuPont	Xerox	**Broadcom**	Micron

Source: Forman, C., & Goldfarb, A. (2020). The table highlights the IT producers among the top ten leader firms for patent applications in the US since 1976 by five-year average.

Table A.2: The list of Italian metropolitan areas

Metropolitan Area	Population (mm)	Macro area	Freq.
Roma	3998064	North and Center	19
Milano	3109687	North and Center	19
Napoli	3070139	South and Island	19
Torino	2237526	North and Center	19
Bari	1259716	South and Island	19
Palermo	1244234	South and Island	19
Catania	1078977	South and Island	19
Firenze	975448	North and Center	19
Bologna	968138	North and Center	19
Genova	863834	North and Center	19
Venezia	838317	North and Center	19
Messina	648753	South and Island	19
Reggio Calabria	553748	South and Island	19
Cagliari	447340	South and Island	19

Source: author's elaboration. Notes: The table lists the Italian metropolitan areas according to their macro-area and average population over the sample period. The population refers to the resident number at the end of each year.

Table A.3: the functional approach to the definition of urban zones

Statistical Units	**Local Labour System (LLS),** ISTAT (2015, 2017):	**Functional Urban Areas (FUA).** OECD-Eurostat (Dijkstra et al., 2019, EC, OECD, 2012)
Definition.	Local Labour systems are territorial units whose boundaries are defined using the flows of daily home/work travel according to specific criteria of the demand and supply of work, regardless of the administrative articulation of the territory (Istat, 2015).	Functional Urban Areas are people-based clusters of urban zones based on population density grid and commuting flow towards the urban centre. This approach tries to connect the morphology of the urban territory (population density), the governance (local unit, municipalities, or statistical unit), and the socio-economic features of the zones (commuting flows), starting from the distribution of population density.
Method:	Local Labor Systems ground on contiguous municipalities delimited throughout the entire country. They are formed by analysing the grid of commuting flows between municipalities so that, the resident population works and exercises most of their social and economic relations within the local system. The local Labour System must follow some principles (Istat 2014, p. 21): 1. Self-containment of commuting flows. The share of movements outside the border must be limited; the most of daily flows must occur within the local labour system. 2. Integrated flows of commuters between the municipalities. The number of reciprocal commuting flows in the local system must be elevated, satisfying a pre-selected target parameter. 3. Continuity in the time of the flows.	Functional Urban Areas are integrated urban zones formed by a city and their commuting zones. Metropolitan regions are NUTS level 3 approximations of functional urban areas with at least 250 000 inhabitants. Functional Urban Areas are composed by: The city. A space covered by high population density with a minimum size of population. The definition of cities accounts only for the agglomeration of people in space using a consistent threshold of density and total population Commuting zones. A lower density area surrounding the city but closely linked to the latter from an economic and functional point of view. It is combined by multiple local units integrated with the city's labour market.
Identification process	ISTAT (2014) uses an algorithm of regionalisation to cluster municipalities according to parameters and trade-off rules about the size, the self-containment and the integration of LLS. The algorithm is based on several components. 1) the grid of the municipalities and the commuting matrix 2)A self-containment function based on the reciprocal commuting inflows and outflows between municipalities	The individuation of the Functional Urban Areas requires the following elements (Dijkstra et al., 2019): 1)identification of the urban centre: a set of contiguous, high density (1,500 residents per square kilometre) grid cells with a population of at last 50,000 in the adjacent cells. 2) City identification: one or more local units with at least 50% of their residents inside an urban centre.

	3) a set of parameters that identify pre-established thresholds relating to the size and the self-containment measure to define an LLS (Istat, 2014, p. 29). 4) a validity condition that establishes the criteria that must be satisfied to have a potential LLS. 5) a standardised cohesion measure that allows clustering each municipality into the most integrated LLS on the base of the reciprocal flows. 6) iterative procedure assigns each location to a cluster, through the measure of cohesion (%), until all clusters satisfy the condition of validity (4)	3) Delimitate commuting zone: a set of contiguous local units that have at least 15% of their employed residents in the urban centre 4) A functional urban area is the combination of the city with its commuting zone. 5) Metropolitan regions are FUA of at least 250 000 inhabitants.
differences	Functional Urban Areas definition takes into account the functional, administrative and morphological components of the urban territories starting from the population density. It includes only the most developed urban areas and considers exclusively the commuting inflows towards the major urban centre. The count of urban core begins with a population grid and clusters cells according to a target of density. Local Labour System instead, starting from the commuting matrix, denote the overall geographical extension of the country, analysing the integration among territories throughout the reciprocal commuting inflows and outflows of each municipality, without reference to population density. Local Labour System boundaries fit well to grasp local labour market dynamics, the territorial network of production and industrial structure, mirroring the overall socio-economic features of these zones. However, the Local Labour System does not account for local political-administrative governance, resulting in less suitable to operative policy implementation. The new harmonised definition of Functional Urban Area, try to connect socio-economic features to political-administrative entities. So that, it will become a key tool to territorial planning, local-based policy and their measurement.	

Source: author's elaboration. Notes: the table review the definition and the principal differences among the Functional Urban Areas, a statistical unit elaborated by OECD-EC (2012, Dijkstra et al., 2019) and the Local Labour System, developed by Istat (2011,2014, 2017).

Table A.4: The structural features of Italian metropolitan areas

Metropolitan City	Average share of Financial and Insurance value-added	Average share of ICT services value-added	Average share Manufacturing value-added mean
Roma	6.41	9.81	5.48
Milano	8.89	9.29	14.22
Napoli	3.30	5.10	9.46
Torino	5.16	8.15	19.94
Bari	4.17	3.39	11.85
Palermo	2.93	4.40	4.33
Catania	3.51	2.93	8.59
Firenze	4.95	3.42	21.33
Bologna	4.79	4.70	21.95
Genova	4.72	3.20	10.45
Venezia	5.24	3.46	14.18
Messina	3.58	1.86	7.03
Reggio di Calabria	3.01	1.60	3.17
Cagliari	3.48	4.04	7.97

Source: author's elaboration. Notes: the table depicts sectoral features of the Italian metropolitan areas. We calculated the average value-added share over the sample for three economic sectors: ICT, Financial and Insurance Services, and the manufacturing industry.

A.5: Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GDP per capita	1.000							
(2) VA Productivity	0.945	1.000						
(3) Manufacturing employment share	0.392	0.286	1.000					
(4) Manufacturing Value-added share	0.484	0.367	0.970	1.000				
(5) Financial and Insurance Value-Added share	0.859	0.826	0.277	0.328	1.000			
(6) ICT Value-Added	0.637	0.612	0.208	0.204	0.682	1.000		
(7) Patent grants	0.657	0.616	0.368	0.366	0.701	0.719	1.000	
(8) Mobile banking Service Users	0.726	0.764	0.227	0.280	0.570	0.380	0.552	1.000

Source: author's elaboration. Notes: the table depicts the correlation among the variables utilized for the Factor Analysis.

Table A.6: Adequacy test for the sample

Variables	Kaiser-Meyer-Olkin measure of sampling adequacy
GDP per capita	0.748
Productivity	0.827
Manufacturing employment share	0.546
Manufacturing Value-added share	0.551
Financial and Insurance Value-Added share	0.877
ICT Value-Added	0.789
Patents grants	0.833
Banking Service Users	0.806
Overall	0.751

Source: author's elaboration. Notes: the table depicts the measure of adequacy of the sample according to the Kaiser-Meyer-Olkin test.

Table A.6: The list of the clusters in 2000/2018

Metropolitan area	Cluster
Cagliari	1
Bari	1
Reggio di Calabria	1
Messina	1
Napoli	1
Catania	1
Palermo	1
Genova	2
Venezia	2
Bologna	2
Firenze	2
Milano	3
Roma	4
Torino	4

Source: author's elaboration. Notes: the table depicts the list of metropolitan areas according to the result of the K-mean algorithm.

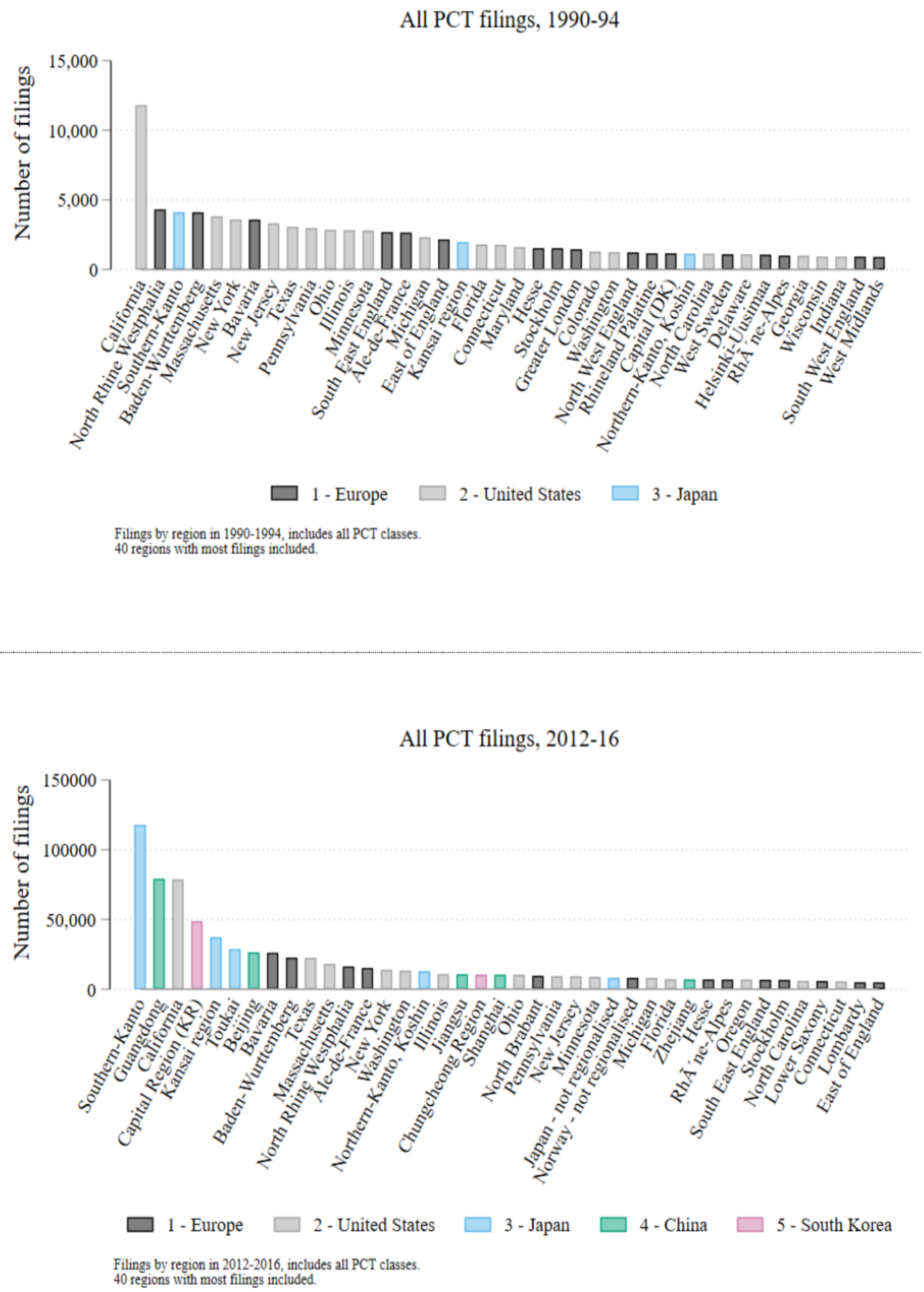
Table A.7: Factor average scores by clusters

Clusters	Factor 1 (2018)	Factor 1 (2000)	Factor 2 (2018)	Factor 2 (2000)
1	-.545	-1.29	-0.779	-.559
2	1.026	-.175	-0.521	-.115
3	2.965	.911	2.377	1.653
4	1.031	.058	1.009	.849

Source: author's elaboration. Notes: the table depicts the average score of each cluster in 2000 and 2018.

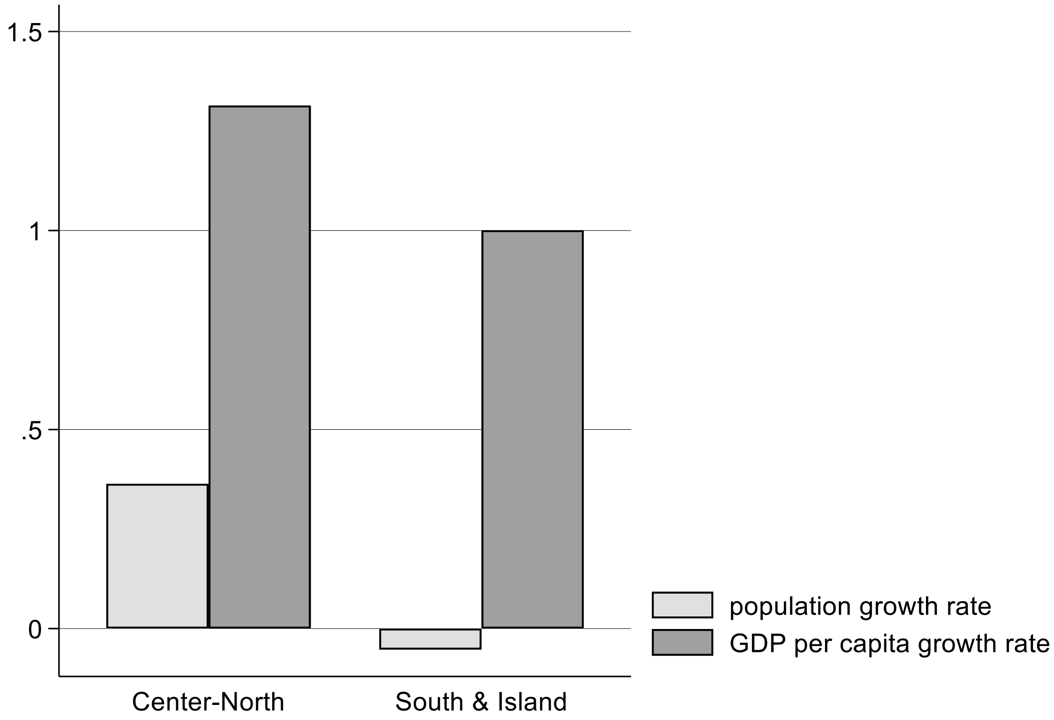
APPENDIX B: Figures

Figure 1.B: Global Innovative Hotspots



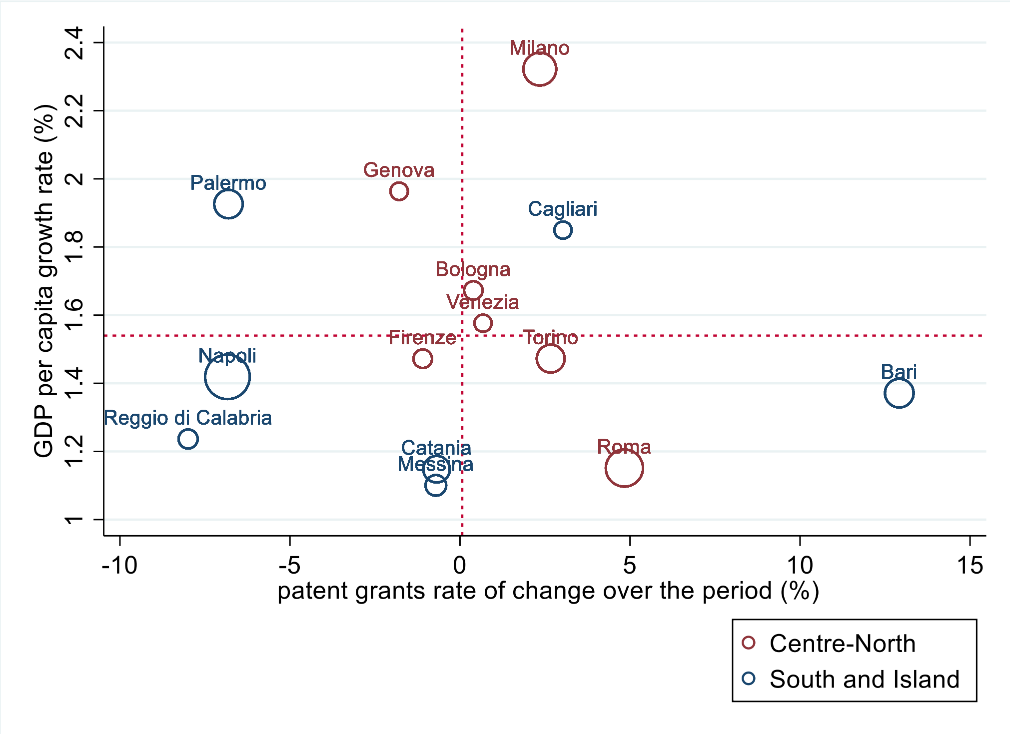
Source: Crescenzi et al, 2020, p. 25. Note: The first graph shows the number of filings by regions between 1990-1994 for all PCT classes, the forty regions with the most patents are included. The second shows the number of filings by regions between 2012-2016 for all PCT classes, the forty regions with the most patents are included.

Figure 2.B: Growth rate of GDP per capita and population of Italian metropolitan areas grouped in macro-regions



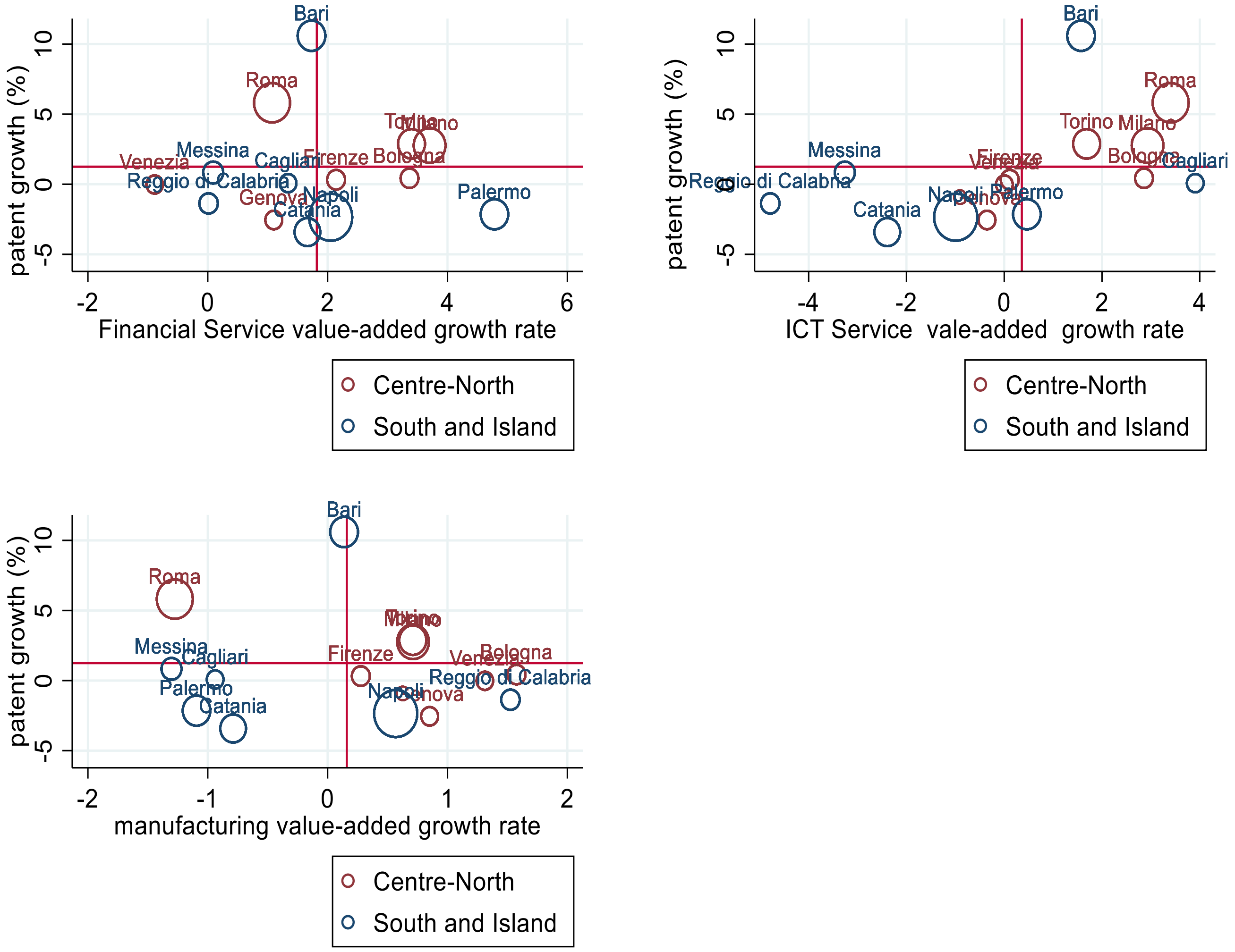
Source: Source: author's elaboration on ISTAT data. I Conti Regionali Territoriali database. Note: the graph depicts the compound annual growth rate in percentage points for the Italian metropolitan areas grouped in macro-regions. The growth rate is the average value among the growth rate of ache metropolitan areas for 2002-2018.

Figure 3.B: Income and innovation activity



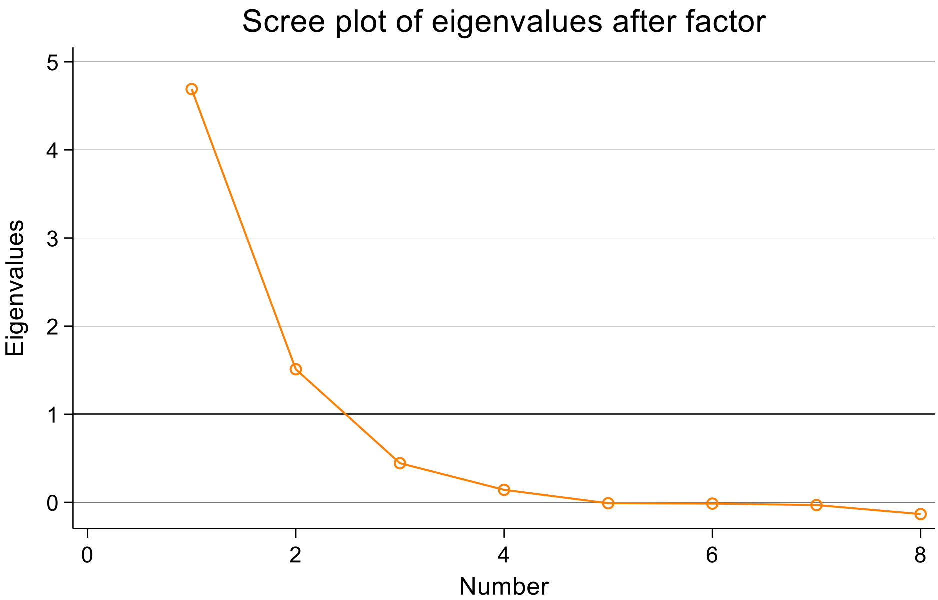
Source: Source: author's elaboration on ISTAT data. I Conti Regionali Territoriali database and UIMB-Ufficio Italiano Marchi e Brevetti data. Notes: the graph depicts the compound annual growth rate of GDP per capita and patent grants between 2000 and 2018.

Figure 4.B: the structural dynamics



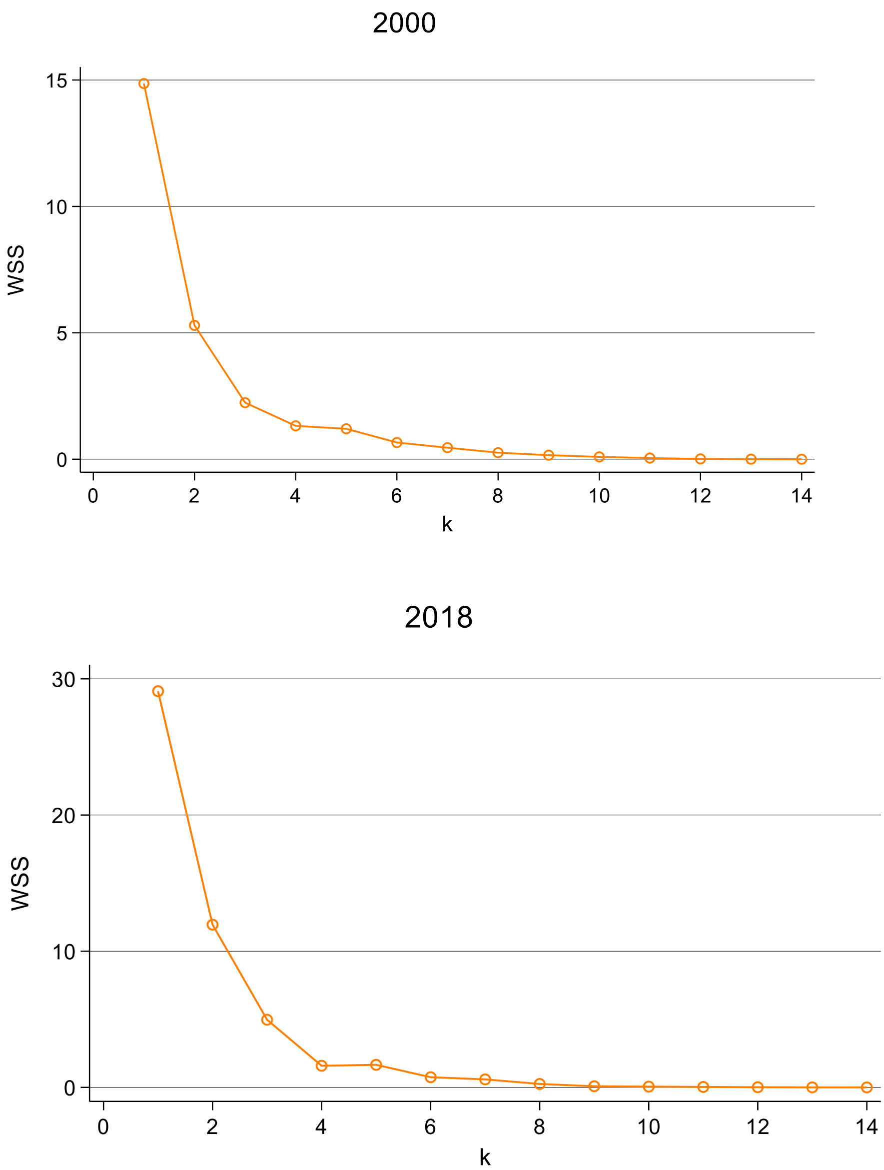
Source: Source: author's elaboration on ISTAT data. I Conti Regionali Territoriali database and UIMB-Ufficio Italiano Marchi e Brevetti data. Notes: the graph depicts the compound annual growth rate of patent grants and the average share of value-added for three economic sectors: ICT services, Financial and Insurance Services and Manufacturing Industry between 2000 and 2018.

Figure 5.B: Scree plot of eigenvalues



Source: author's elaboration. Notes: the graph depicts the Kaiser method to select the number of factors. It plots the value of eigenvalues according to the number of factors.

Figure 6.B: the " Elbow method" to select the number of clusters



Source: author's elaboration. Notes: the graph plot the total within variance of each cluster solution as a function of the number of groups. This is a widespread procedure to select the number of clusters.